MOBISTYLE

MOBISTYLE
MOtivating end-users Behavioral change by combined ICT based modular Information on energy use, indoor environment, health and lifeSTYLE

Contract No.: 723032

Report: Applicable platform and database for software and information interoperability

Work Package: Work package 4, Task 4.2
Deliverable: D 4.2

Status: Public

Prepared for:
European Commission
EASME
Project Advisor: Mr Pau Rey-García

Prepared by:
Rosamaria Olivadese, DEMO Consultants BV
September 30th, 2017

This project has received funding from the European Union's H2020 framework programme for research and innovation under grant agreement no 723032. The sole responsibility for the content lies with the authors. It does not necessarily reflect the opinion of the European Communities. The European Commission is not responsible to any use that may be made of the information contained therein.

H2020-EE07-2016-IA

Contents

List of acronyms and abbreviations

ICT: Information and Communications Technologies

IoT: Internet of Things

BMS: Building Management System

BIM: Building Information Modelling

KPI: Key Performance Parameter

API: Application Programming Interface

RESTful API: REpresentional State Transfer API

Definitions

MOBISTYLE system: in this deliverable, MOBISTYLE system refers to the overall process, starting from the sensors to providing feedback to users. The terms 'systems' and 'process' are used, in this deliverable, as synonyms.

MOBISTYLE platform: in this deliverable the term MOBISTYLE platform refers only to the part of the overall system where data are collected and processed. The MOBISTYLE platform is in charge to gather data from the sensors, store them and process the data in order to be used by the analytical tools and in order to be visualized in the dashboard. The description of the MOBISTYLE platform is the main goal of this deliverable.

Publishable executive summary

This deliverable (D4.2) describes the overall MOBISTYLE process and the general architecture of the MOBISTYLE platform.
Information provided in this deliverable is the starting point for further implementation of the platform and for the implementation and testing of the MOBISTYLE system in the demonstration cases.

The MOBISTYLE platform, here described, is the result of the contribution mainly of two ICT partners within the consortium, DEMO and Holonix. The input and collaboration of the different ICT partners have been fundamental for the understanding and clarification of the MOBISTYLE system first, and of the MOBISTYLE platform in the second stage. The role and tasks of the different partners have been also clarified.

The MOBISTYLE platform is an enhanced and extended version of two existing platforms, RE Suite developed by DEMO and i-Like developed by Holonix. Specific needs and scope of MOBISTYLE are addressed in the integrated and updated tools.
In particular, in reference to RE Suite developed by DEMO, the integration of data coming from very different sources - buildings, smart appliances, and occupants – both during data collection and processing, has been designed and implemented in the upgraded tool.
The core of this deliverable is the development plan of the MOBISTYLE platform in particular in reference to the database description that will be implemented afterward to enable the baseline monitoring phase in the demonstration cases.

The basic platform is currently operational and described in deliverable D5.1, due to M12. However, the final platform, as described in this report, with all the interfaces to satisfy the interoperability requirements and the integration between different software tools and mobile applications will be provided in M42.

1. Introduction

The building sector is one of the greatest energy consumers, accounting around 40% of the total energy use [1]. For this reason, the design of energy efficient buildings and improvements in the energy performance of the existing building stock is of vital importance [2]. However, working on the building itself and its components and installations is not enough to reduce the energy consumption. Users have a great impact on the behavior of the building and of energy consumption.

In this context, the goal of MOBISTYLE is to raise consumer awareness and motivate behavioral change by providing attractive personalized combined knowledge services on energy use, indoor environment, health, and lifestyle, by Information and Communication Technologies (ICT) tools. Providing more understandable information on energy, health and lifestyle will motivate end-users to change their behavior towards optimized energy use and provide confidence in choosing the right thing. It will offer consumers more and lasting incentives that only information on energy use.

In WP 4 Practical ICT tools will be developed, including:

- robust and cost-effective sensing technologies that can be deployed with a minimal setup in small and large-scale installation spaces;
- an integration platform with modular configuration for data and software interoperability, inter-connecting sensor networks that aim to improve the range and type of energy-efficient behaviors;
- a set of software applications for mobile devices and wearables, to enable energy-efficient behaviors of the end-users.

The main aspects of ICT tool development that will be covered by MOBISTYLE are:

- embedding strategies of emotional, corporeal seduction for stimulating of end-users, without significantly increasing cognitive load in the tools;
- including mobile technologies, grounded in conceptual narrative frameworks, to encourage end-users to feel an emerging need to delve further and become curious about energy, health and the resulting lifestyle;
- integrating narrative techniques from choreography, music, and serious gaming.

The first deliverable of WP4, D4.2, is the presented report “Development of an ICT platform, databases, and interfaces”. This report aims to describe ICT tools - comprising a platform, a database, and the necessary interfaces - to facilitate the integration and interoperability between different types of software tools and mobile apps for measurement, assessment, monitoring and simulation of building condition, energy performance and user behaviors. This document wants to describe the overall MOBISTYLE process for providing feedback and raising awareness to the end user, starting from the data collection – coming from sensors – about energy use, indoor environmental quality and health. Moreover, a detail analysis and study of the MOBISTYLE platform is provided.

In chapter 2, a description of the MOBISTYLE process is provided in order to give a general overview of the story behind the platform, how this should work and its components.

Chapter 3 contains an analysis of platforms already present on the market to understand which lesson can be learned from them, what can be used and what can be further implemented or developed within MOBISTYLE. Moreover, a more detailed and technical description of the components of the platform is given.

Chapter 4 describes the first step for the design of the platform, the definition of the databases and their relations with the platform. Starting with the definition of the requirements, the platform design is developed and described. It follows the description of the proof of concept and a preliminary verification of the data from the demonstration cases. Starting from month 13, after this delivery, the database should be able to collect data from the sensors installed in the demo cases and be connected to the platform to visualize the data, as part of the baseline monitoring phase. In the next steps, databases and platform will be implemented as well as the overall MOBISTYLE platform.

In chapter 5 the characteristics of the sensors and their hardware are described. This is the starting point of the next phase (task 4.1) in which sensors chosen specifically for the MOBISTYLE project will be installed in the demonstration cases to support data collection and analysis.

Chapter 6 describes conclusions for this part of the research.

2. Global concept of MOBISTYLE

The overall aim of MOBISTYLE is to raise consumer awareness and motivate behavioral change by providing attractive personalized and combined knowledge services on energy use, indoor environment, health, and lifestyle, by ICT solutions. Providing more understandable information on energy, health, and lifestyle will motivate end-users to change their behavior towards optimized energy use and provide confidence in choosing the right thing. It will offer consumers more and lasting incentives than only information on energy use.

To achieve this goal, a platform is built, where data from various devices can be collected, analyzed and presented to the consumer. By analyzing these data, the platform will allow developers to create various applications that will raise consumers' awareness about energy use. Through these applications, the end-user will be able to receive feedback about the energy use in the building and from smart appliances and through serious gaming the consumer will be involved in the process of improving and change his behavior for a better lifestyle and comfort.

In the MOBISTYLE system, there are three main steps, as shown in Fig.1. First, data are collected from the environment via sensors from the building, from the appliances and from wearables. The data are transmitted, stored and processed in the MOBISTYLE platform. Finally, in the third phase, the analyzed data are disclosed to the user through applications, and serious gaming applications, on their mobile phone, computer or tablet. The user is, in this way, aware of the situation about energy consumption and behaves consequently, changing his habit to improve his own health and comfort conditions. This change of behavior will result in an increase of energy performance, notified by the sensors. It is important to underline that the arrow that from the feedback to users goes back to the sensors – in the image below – is a validation loop. The input to the sensors is not changed after the whole MOBISTYLE flow is completed. The sensors will collect always the same kind of data and ideally the collected data will show a reduction of the energy use.

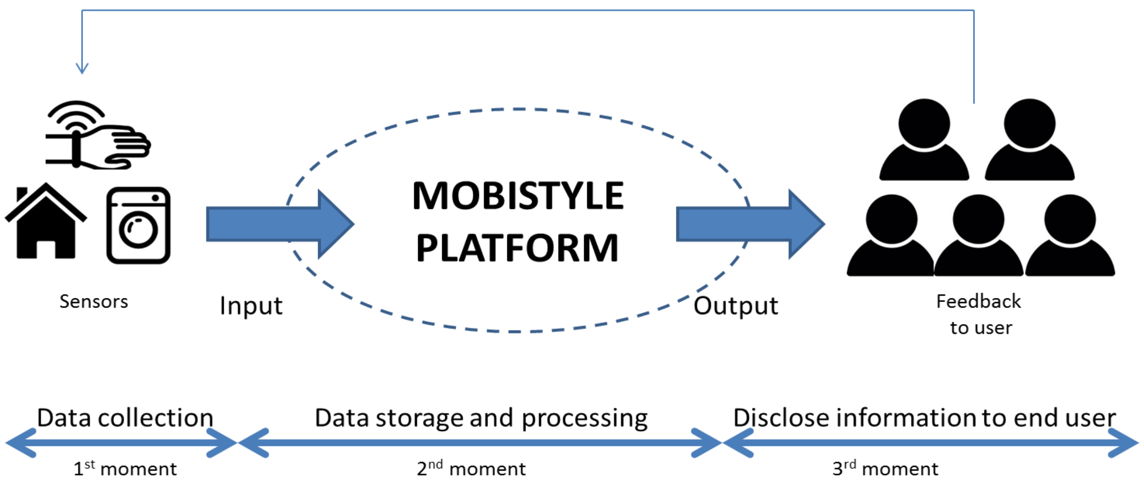

Fig. 1 - MOBISTYLE process

The first step in the MOBISTYLE system is data collection. Data are collected through the use of sensors from three main sources: the building, the occupants and smart appliances installed in the building. The building has sensors that will collect data about inner temperature, humidity, amount of carbon dioxide, usage of electricity, usage of energy, occupancy, etc. The occupants will provide information, through the use of wearables, about their personal condition, heartbeat, temperature, time of rest, time of activity, so their behavior. Finally, the smart appliances will transmit data, through sensors embedded in them, about their usage, if full or partially full, etc. Each sensor has its own Identity Number.

In this phase, it is important the concept of Internet of things. In fact, the tools used to gather data are smart devices that are embedded with software, sensors, network connectivity and are able to collect and exchange data and be connected with each other.

Internet of Things (IoT) is defined as objects with computing devices in them that are able to connect to each other and exchange data using the internet [3].
IoT has been a rapidly growing and evolving technical field over the past years, with no signs of that growth halting in the near future. Its potential is going to affect not only people's way of living but also of working. According to predictions from the European Commission, there will be 50 to 100 billion IoT-enabled devices connected to the Internet in 2020 [4]. This is happening because the broadband internet is becoming widely available at affordable costs. Moreover always more devices are designed with Wi-Fi connection and sensors built in [5].
A large portion of these devices is made up from various types of sensors that can measure buildings, roads or building occupants. When sensors are installed in buildings, the owners and occupants are able to receive real-time information regarding the building and its environment.

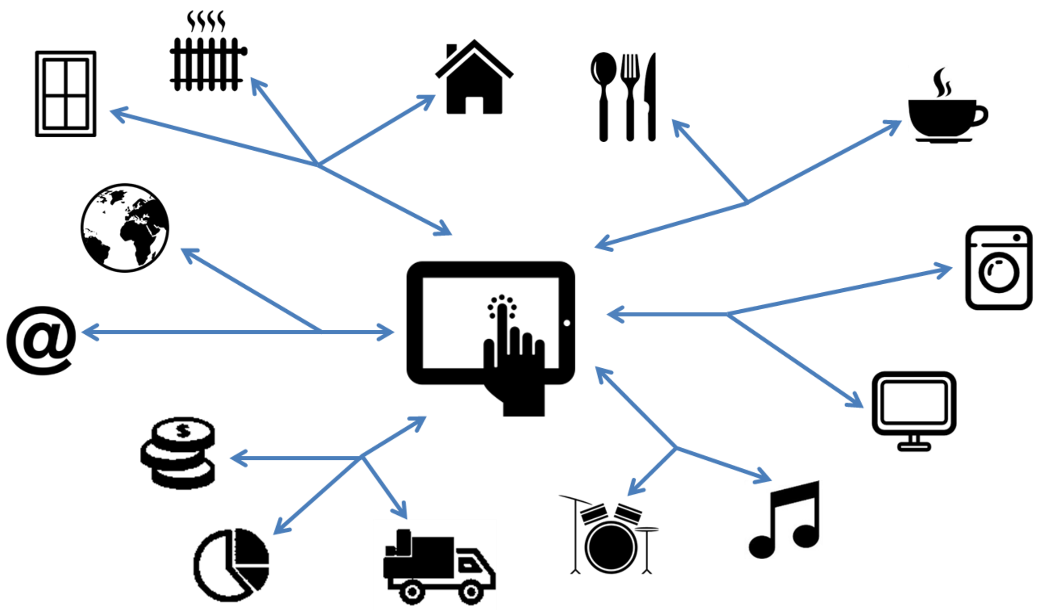

Fig. 2 - Internet of Things

In the second moment, 'data storage and processing', all the sensors send their data to a database connected to the platform. Inside the database two types of data can be stored separately: row data (ex. Sensor1234: value 1, value 2, value 3, etc.) from the building, from the occupants and from the smart appliances, and user data that are really the Identity Number (ID) of the sensors (their reference number, their location, etc.).

The database will be connected to a platform that will process, analyze and convert the data into understandable data for the user. The platform itself will not run any data analysis about energy comfort and health. The role of the platform is to store, collect, process and visualize the data. The platform plays a bridge role between two main elements of the overall system. On one hand, the platform will communicate with external analytical tools that will run the analysis of the data regarding energy, comfort and health. On the other hand, the platform will provide the output for an open application platform that will contain dashboards and serious gaming applications as well as other possible widgets, useful to increase awareness of the consumers on energy use, indoor environmental quality and health.

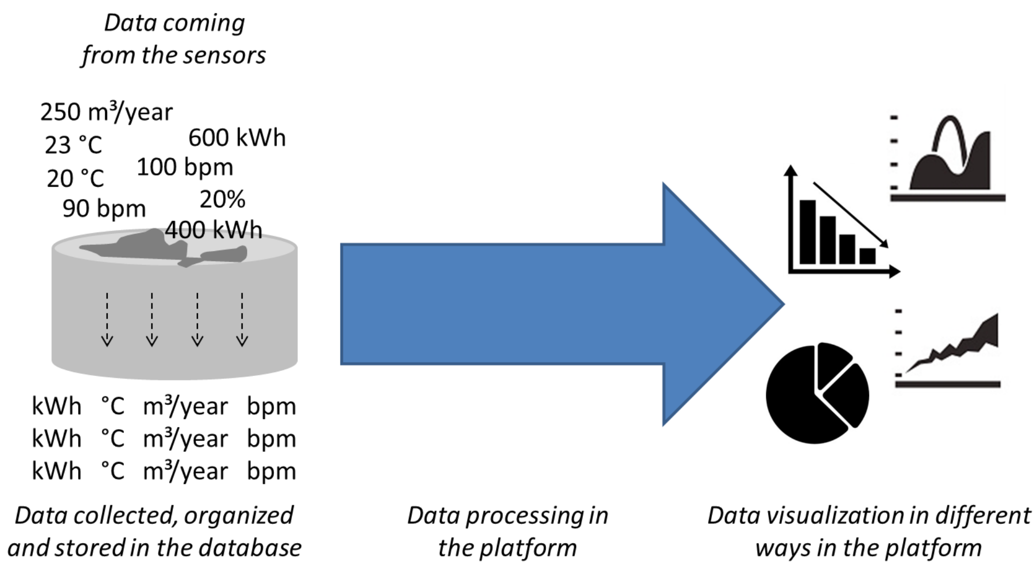

Fig. 3 - Database and platform

The analytical tools are software used by the experts to run the analysis of the data, regarding energy use, comfort and health. The output of the analysis of data is the computed values of the Key Performance Indicators (KPI) and are visualized in the platform itself. KPI are parameters that allow evaluating the success of a particular activity, in our case to evaluate the energy consumption, the inner environmental quality and health. For example, KPIs for buildings' energy use are primary energy consumption, emission of carbon dioxide, electricity consumption, costs for electricity consumption.

The last phase of the overall MOBISTYLE system is the disclosure of information to the end user. The user will be aware of the actual condition of the building and his behavior about energy use, comfort, and health through two main tools: a dashboard and serious gaming applications.

The dashboard will visualize two kinds of data: real time data and the computed values of the KPI. The real time dashboard will visualize the data with respect to time. The KPI dashboard will visualize the facts, the historical post-processed data, information in reference to a certain date and time. It is just one average value result of the analysis of the real time data. The real time data show, on the contrary, the overall trend in time of a certain parameter for example, the indoor temperature. These dashboards can be also "gamified", in the sense that data are shown in a more interesting and enjoyable way in order to improve user engagement.

The values of the KPIs are not necessarily the only output coming from the analytical tools. In the next phases of the research project, other types of feedback strategies will be used in order to translate in a more understandable way for the user these results.

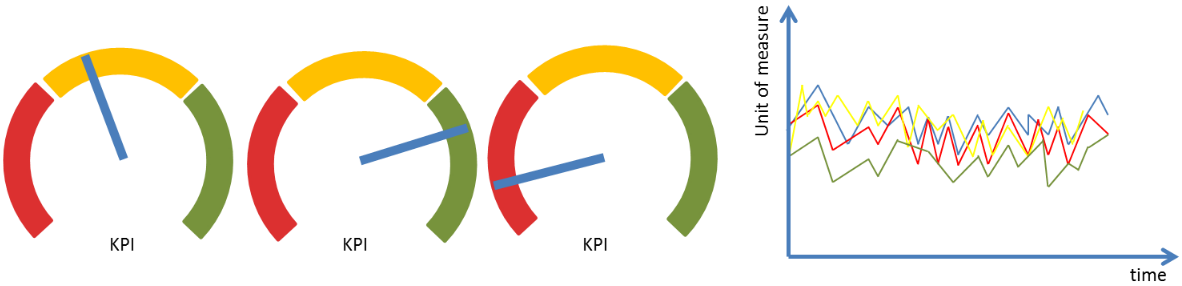

Fig. 4 - KPIs dashboard and real-time dashboard

Feedback to users will also be provided through gamification and serious gaming. Through the involvement of the user in games, available on their smartphone, the user will be informed about the current use and conditions of the building and, according to this, the consumer will be encouraged to accommodate and change his / her behavior for a better use of the energy, a better comfort, and a better health condition.

The last component, still under discussion, is the overall idea of the open application platform. Here, tools for software development, widget and applications should be available for third parties who are interested in using the MOBISTYLE results for educational purposes or are interested in joining MOBISTYLE to develop more applications.

3. Review of the state of art

3.1. Lesson learned from existing solutions

To understand how it is possible to develop the MOBISTYLE platform, useful aspects of existing solutions have been analyzed. The aim of this chapter is to understand the application, opportunities and the limits of each platform considered, keeping in mind what can be useful for the development of the MOBISTYLE platform. The choice of which platform to analyze has been done according to the following considerations:

- the choice of which platform to analyze has been reduced to the ones known by the partners, also for business exploitation. Some platform has been developed by the consortium partners (RE Suite and i-Like). Other platforms have been used within other European Research Projects and Dutch National Research Projects;
- some platforms (IoT platforms), are commonly used and are available for everyone to use, and here are briefly described the most common ones.

For each platform a brief description of its main characteristics has been done; advantages and disadvantages of the platform itself have been highlighted and considerations in relation to MOBISTYLE have been made.

The goal of this chapter is to understand which are the different options available now that can be used or implemented within the MOBISTYLE project and which is the lesson that can be learned by those experience for the development of the MOBISTYLE platform.

Cloud platforms (Amazon IoT, Azure IoT)

Description: Cloud computing is a form of internet-based computing that provides shared computers processing resources and data to computers and other devices. It enables flexible resources provisions.
Many cloud providers offer Platform-as-a-Service solutions for the development of the cloud application. Always more providers are starting to offer IoT-specific services since the cloud computing is able to satisfy IoT needs of storing, processing and visualizing.
Big developers of cloud solutions, such as Amazon, Microsoft, Google, have developed their own cloud standards and formats, most of the time incompatible with each other and make difficult the integration between IoT and cloud [6].

Amazon has a developed a series of services, Amazon Web Services, that are part of a cloud computing platform. To build the applications, they provide a lot of services to compute, process and visualize data. Amazon IoT connects the devices to a database in a secure way through encryption [6].

Azure is a product of Microsoft that consists of an integrated cloud system that ICT developers can build, deploy and manage through Microsoft's global network of data-centers. Applications designed by the professionals can run on different frameworks and can be written in different programming languages thanks to open source technologies. Security and privacy protocols are built in the Azure platform at every development phase from initial planning to launch. Thanks to website creation wizard, Azure Web Sites can be used to create a completely new website or to implement one of the pre-configured available [6, 7].

As the previous two brands, also Google Cloud Platform consists of a series of different services that can be combined, built deployed and managed by the developer. One of its main features is the scalability and the security built-in. Devices can be easily connected and the platform collects the data and visualizes them. Data are stored in the Cloud Storage and the visualization of the data is done by another Google service within Google IoT, Google Charts [6, 8].

Advantages: in general cloud platforms can connect to different devices by using a few protocols via the internet. Moreover, these IoT platforms manage everything for the consumer – connections, data filtering, data storage and data access.

Disadvantages: these platforms are usable through subscription.

Considerations in relation to MOBISTYLE: IoT platforms are an interesting solution for MOBISTYLE especially because they can manage the whole process of data collection and data management and processing. One issue might be that not all sensors can be connected directly to these IoT platforms since they might use different and not compatible protocols.

Enginency solution by ICM

Description: ICM has developed, within the European Research Project Enginency (H2020-2015-1, Grant Agreement No. 720661) [9] an info-data collector able to gather info from a wireless network and integrate the readings into a Building Management System (BMS). The starting point for this development is very similar to the MOBISTYLE process. In the case of Enginency, the goal is to acquire and process data coming from sensors installed in a building in order to get an accuracy model of the building behavior. The system developed by ICM is able to deal with other protocols and systems, and is not limited to one single option. Moreover, it is capable of integrating several systems and collecting data from all of them, in one single info-point collector and in a clear way for the user.

The monitoring network provides measurements about indoor environment – temperature, humidity, brightness –, electrical, thermal energy consumption, water and gas consumption, air quality and ventilation – flux and volume –, outdoor information – temperature, humidity, wind speed and direction, solar radiation and positioning, brightness, atmospheric pressure –.

The sensors are connected via wireless by using a radio standard ZigBee system. In order to connect the sensor network to the BMS system, there is the need of a gateway, since the ZigBee protocol is not one of the systems implemented in the BMS. The gateway will gather all the measurements of the ZigBee sensors and will translate this information to the MODBUS protocol that the BMS uses.

In the end, the BMS system is a data server; all the information is accessible through the internet via the web server.

Advantages: the Enginency solution provided by ICM is customizable; the existing sensor network can be implemented with new sensors network in order to get as much data as possible and of the widest range.

Disadvantages: the Enginency solution has, for the moment, a quiet technical interface, not easily understandable for the end user.

Considerations in relation to MOBISTYLE: the Enginency solution is interesting for MOBISTYLE if we consider the possibility to use it in the first phase of the MOBISTYLE system, data collection. As BMS it can be used in the demonstration cases as collector to get data from the building sensors and not from the smart appliances and the occupants.

Moreover, only building sensors data are gathered, while in MOBISTYLE project data come from three different sources: the building, the smart appliances, and the occupants. If a collector unit will be installed in the demonstration cases of MOBISTYLE, this should be able to connect and collect the data from these three sources.

On a more technical level, within MOBISTYLE the intention is to use internet connection instead of radio connection (ZigBee) in order to be able to connect more sensors – that have an internet connection – and to maintain a simple and compatible system.

RE Suite

Description: RE Suite, developed by DEMO Consultants, is born as a tool package for real estate management that allows to collect, structure, analyze and share real estate information. It is a complete software package, modular in design so that it can be implemented in a modular system. Re Suite supports the entire cycle of real estate development and information management. The tool provides continuous insight into real estate information so that the asset manager is better in control of the real estate portfolio.

The structure of RE Suite contains three main elements: RE Foundation, RE Applications, and Cockpit.
RE Foundation consists of data model, links to other external sources, Enterprise Resource Planning (ERP) and administrative systems. RE Foundation has, as an extension, RE Service. RE Service run automatically at a certain time to get data from another system. Together RE Service and RE Foundation are the basic fundamental structure of RE Suite. RE Foundation is the one responsible for the interaction with the external system while RE Suite Client – that contains RE Application and RE Cockpit – are not involved in any exchange of data happening in the environment. RE Applications, contains applications for property management, as RE Maintenance, RE Energy. RE Maintenance results in a long-term maintenance planning, indicating risks and costs of building maintenance and monitoring quality levels of real estate; RE Energy indicates the energy level and the building's energy performance. The third component, Cockpit, contains generic modules that can be implemented and used separately from the applications. An example is RE Dashboard. RE Dashboard provides information about Key Performance Indicators for property control, asset management, and performance-based contracting. This tool displays the collected data allowing their analysis and

comparison. RE Dashboard is independent from applications in the RE Suite package and can be applied for any kind of data.

Advantages: one of the advantages of RE Suite is its architecture in modules so that it can be adapted to the different needs. Being a complete tool set that collect, structure, analyze and disclose to the end user information, there is no need to refer to any other software or tool for any of the phases from data collection to visualization.

Disadvantages: RE Suite is not an analytical tool. It cannot perform any kind of calculation regarding energy performance. Calculations need to be performed by other tools and then imported in RE Suite for the visualization. RE Suite can provide the information to the analytical tools.

Considerations in relation to MOBISTYLE: RE Suite is a very good starting point for the MOBISTYLE platform since it can collect, process and visualize data. Its modularity allows scaling its architecture in order to be able to store and process data coming not only from the building but also from smart appliances and from the occupants. The fact that RE Suite is not an analytical tool per se, can be overtaken by setting the compatibility formats in order to export the data and import the results of the calculations run by the analytical tools that will be used within MOBISTYLE.

i-Like

Description: Holonix i-LiKe solution is an innovative platform designed and built in its origin for manufacturers and users of industrial machines, to allow both monitoring and analyzing performances of the machines. The solution is smart, as it allows both old-technology and up-to-date technology companies to become smarter. For the first, the solution creates remote control using a specific HW created by Holonix and called KISS; for the other, the solution allows access to the native PLC of the machine "smartifying" it. In both cases, the solution allows connection to the cloud, getting data available for additional value added services. From a business point of view, the solution is thought to be sold to companies that use the machine, as well as to the machines producers. They will be both aware of the collected information about the machine, getting data about usage, maintenance, stops, KPIs, etc.

The i-Like platform is an IoT interface to categorize and manage sensors and users. It does not cover the big data persistence layer in the IoT stack but instead leverages on the uppermost layers of it (i.e. application and data format). It provides to end users a tool to visualize meaningful sensor data (raw or processed) using a web application and manages the security and permissions aspects. In MOBISTYLE the I-Like platform will be the end user tool to receive information about the sensor ecosystem and to trigger the behavioral changes in the users using notifications based on the sensorized entities related to them.

Advantages: i-LiKe solution allows the manufacturer and the user to stay connected, logging machine operating parameters and usage data, maximizing their perceived value, recording KPIs, ensuring ever greater competitiveness and enhancing customer loyalty. The solution is composed of 4 modules:

- Monitoring: in Real Time of machine (cycle times, activities, alarms in case of malfunction, downtime, and anomalies).
- Maintenance: optimization of planning and scheduling of maintenance activities; reduction of failures and down time to time; viewing the history of interventions and analysis of data; maximizing reliability and plant availability.
- Analysis: viewing KPIs and alarm history; access to the machine usage statistics and reports.
- Fleet Management: interface for geolocation of machines installed.

Disadvantages: the end user of i-Like is always a technician, able to read the data visualized by the platform. As it is now, i-Like is not of interest for a generic consumer that is not a technician or a professional in the certain field considered.

Considerations in relation to MOBISTYLE: the i-Like solution is developed by consortium partner Holonix. Its structure in modules gives the possibility to implement it according to the needs of the project. For this reason, also the implementation of the visualization of certain parameters, if and how to give suggestions to the end-user in order to induce a change of behavior, can be done without changing the whole core and basic architecture of the platform. i-Like is an interesting starting point for the development of the MOBISTYLE platform.

WebEasy

Description: WebEasy is a Building Management System with lots of functionalities regarding the regulation of the indoor environmental quality, monitoring energy usage, security, health, and hygiene. WebEasy develops software and hardware for accessing, controlling and monitoring installations in the building [10].
The WebEasy system is developed on the basis of the Niagara Framework, a new development that offers the solution of integrating smart devices, automation systems, and enterprise applications.
It is easy to set up and settings and control strategies can be customized from a standard web browser. Moreover, the internet offers the possibility to contact anytime from any place the WebEasy installations, so that the remote control is easy and be done via PC, smartphone or tablet.

WebEasy has developed a comprehensive application library for various building-based installations. Customization is possible for each installation, while the software is composed of a standard library.

Advantages: WebEasy is a BMS solution "all in one" so that it can be used in any kind of project, regardless of the size. There are only one hardware, one control platform and one visualization method for all the applications regarding climate control, space management and supply automation and security.

Disadvantages: WebEasy is a tool designed for technicians and building managers. The visualization of the data collection is not adapted for general users of the building. Moreover, it does not provide any feedback to the user of the platform on how to improve or solve potential issues or to plan maintenance.

Considerations in relation to MOBISTYLE: WebEasy is interesting for MOBISTYLE if we consider the possibility to use it in the first phase of the MOBISTYLE system, data collection. As BMS it can be used in the demonstration cases as collector to get data from the building sensors and not from the smart appliances and the occupants.

Conclusions: in this chapter, four interesting and very different kind of platforms have been described. All of them have some potential within the project MOBISTYLE.

Webeasy and the Enginency solution are BMS. Currently, these systems allow the collection of building and indoor environmental data. An interesting implementation of these solutions within MOBISTYLE might be the possibility, for these systems, to collect not only data coming from the building sensors but also data coming from smart appliances and wearables. In this way, these systems can be used as collector in each building in the first phase of data collection, to which the MOBISTYLE platform can connect to gather all the data, process and visualize them.
To achieve this goal of having one management system as collector, also IoT platforms can be used. But, it can be difficult to connect each sensor to the IoT platforms described, if not done by experts. Hence, at the moment it seems easier to rely on third parties for the installation of the sensors in each demonstration case, their data management, and storage. This means that probably, the MOBISTYLE platform will need to connect in each demo case to more than one system in order to gather all the data.

For the development of the MOBISTYLE platform itself, RE Suite and i-Like will be used. This choice is given by the fact that are designed by two partners of the MOBISTYLE consortium that can implement, adapt, modify the architecture and the interface of the platforms according to the needs of the projects. The connection between the two platforms for the exchange of data will be, hence, easy to define and establish. RE Suite will be responsible for the data collection, storage, and processing. It will provide the data to the analytical tools and to i-Like that will be instead in charge of the visualization of the data in a way to be interesting for the consumer. Each platform will be implemented to satisfy all the requirements of MOBISTYLE, from the database to their interface with the end user.

3.2. Overview of MOBISTYLE ICT platform

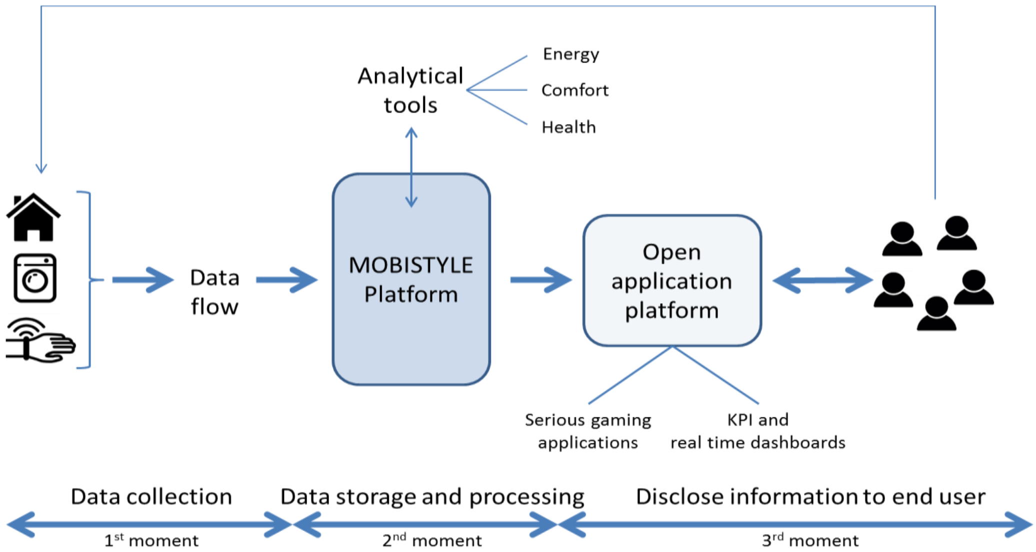

Fig. 5 - General scheme for MOBISTYLE System

The aim of MOBISTYLE is to raise consumer awareness regarding energy use, indoor environment, health, and lifestyle. This awareness will support and motivate end-users to act consciously toward energy use, energy efficiency, and health.

To achieve this goal, information and data about energy use and behavior need to be available to the end-user in an easy and understandable way. So, ICT tools are provided to translate the collected data and elaborate them in order to be shared with the consumer.

As described in chapter 2, the MOBISTYLE system consists of three main moments: data collection, data storage, and processing, disclosing information to end user. In this chapter each phase will be described more in detail, analyzing also the different components of the overall system and platform involved. In particular, for each moment, the following elements will be described:

- Phase 1, data collection: sensors, gateway
- Phase 2, data storage and processing: database, platform, analytical tools
- Phase 3, disclosing information to end user: open application and serious gaming.

Phase 1, data collection: Sensors
(See blue rectangle in Fig.15)

The starting point in the MOBISTYLE system is the sources to allow data collection. Buildings, occupants and smart appliances installed in the buildings themselves are equipped with sensors that measure the parameters listed below:

- heating usage;
- electricity usage;
- domestic hot water consumption;
- operative temperature;

- relative humidity;
- amount of CO_2 in the building;
- occupancy;
- window opening;
- ventilation adjustments;
- thermostat adjustment;
- personal health and wellbeing.

These parameters refer to energy usage, inner environmental quality, and health conditions. These parameters are also defined the KPIs, described in detail in the report from WP3 (Building Assessment Sessions Outcomes after the 1st Specific Workshop in Amsterdam, 14-15 February 2017). These parameters are fundamental to choose the right type of sensors to be installed in the demonstration cases in the monitoring phase, as part of WP6 and the next deliverable for WP4 (D4.1).

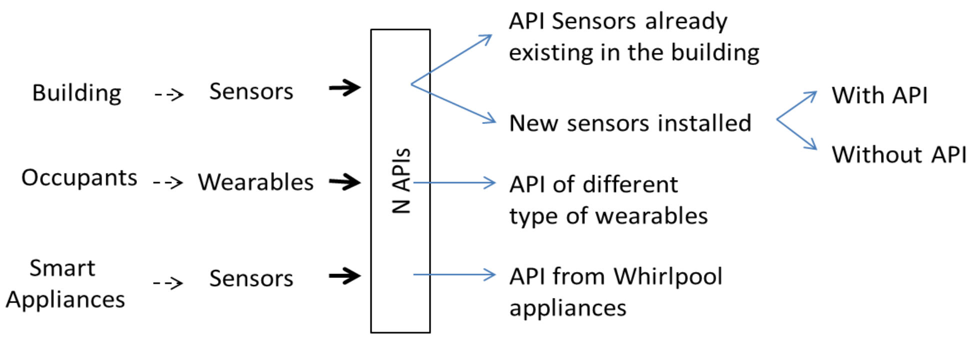

Fig. 6 - Sensors

As shown in the image above, (Fig.6), there are three main groups of sensors depending on the source: sensors installed in the building, sensors worn by the occupants, smart appliances. However, the sensors can be divided into two main categories: the ones that have already Application Programming Interfaces (API) codes provided by the manufacturer and the ones that do not have API codes.

Three scenarios are available for the sensors and their API connections (Fig.7):

- Option 1a: the sensors possess their own API so that the manufacturer system queries data through the API and the internet. This is the pull mechanism, in the sense that the supplier system pulls the data from the sensors.
- Option 1b: the sensors do not have an API but the sensors push their data to the supplier's system. So the API is on the supplier's system side, opposite with respect to option 1. This is the push system.
- Option 2: the sensor does not have an API; this means that the software developer – i.e. DEMO Consultants, within the MOBISTYLE consortium – needs to write both the API and the code to communicate with the API. In this option, data are directly stored in the MOBISTYLE database.

- Option 3: the sensors send data to a BMS or collector. Here data are not only collected but also temporarily stored; at this point, the system of the supplier, through an API, queries the data - via the internet – from the BMS system.

Which software to use will depend on the choice of the sensors and will be implemented in the next deliverable D4.1.

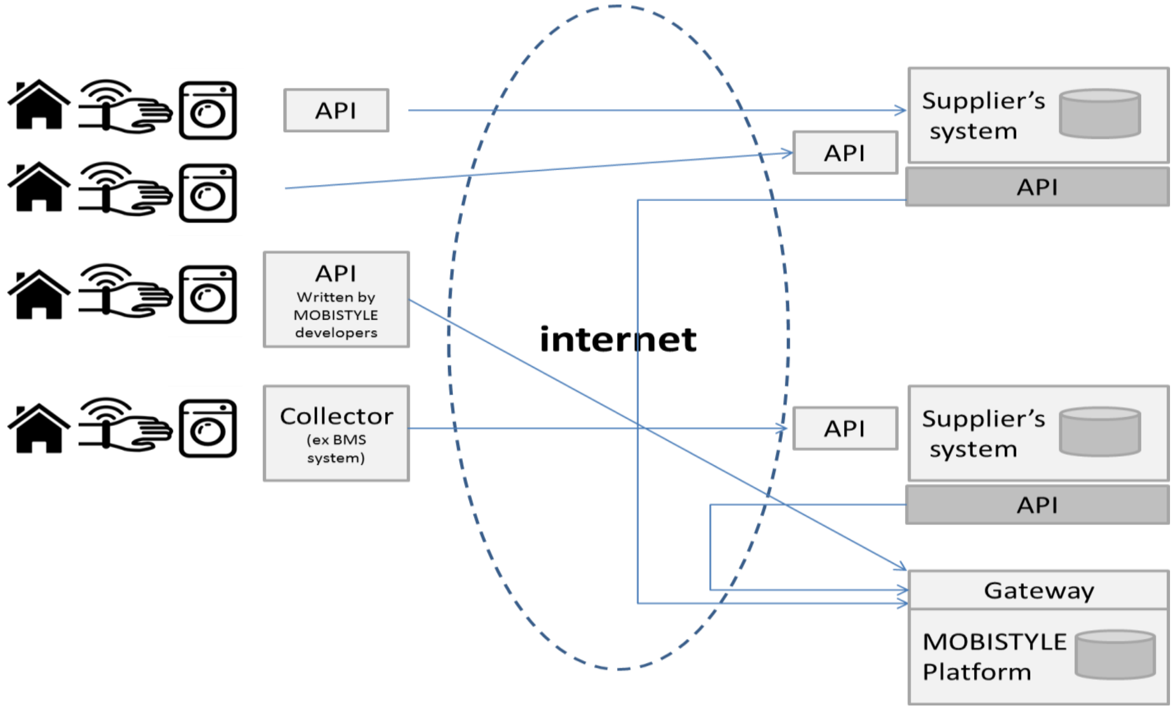

Fig. 7 - Data collection: from sensors to gateway

Sensors that have already an API code are an optimal solution for the overall design of the platform because of time issue and for the general complexity of the system. In fact, the APIs are made available by the manufacturer and it is easily possible to connect to the system of the supplier. However, privacy issue can be raised, since information about user data – such as location, values of the data collected, and so on – can be available on the internet and are totally accessible from the manufacturer that can decide how to use that information.

On the other hand, the option of having sensors without API code can be an advantage in respect to privacy that can be solved by embedding in the API privacy and safety codifications. However, design wise, this solution can take more time and the design process can be difficult because specifications about the sensors are needed from the manufacturer, but are not always available. Moreover, in most cases, and especially if many sensors are installed, it is important to install a collector in the building, where to collect and temporarily store the data. This collector can be a physical element or a platform, like the BMS. The disadvantage of having a physical element is that, if the collector is malfunctioning, the experts need to go on site to check and repair the collector. If all the data go directly to the system of the supplier, the management of the overall system is easier since the developer just have to connect his platform to the API of the supplier in order to query the data.

In any case, since everything goes through the internet, an interface between the MOBISTYLE platform and the internet and the other platforms form the sensors' supplier is needed. This is the gateway.

Phase 1, data collection: Gateway
(See blue rectangle in Fig.15)

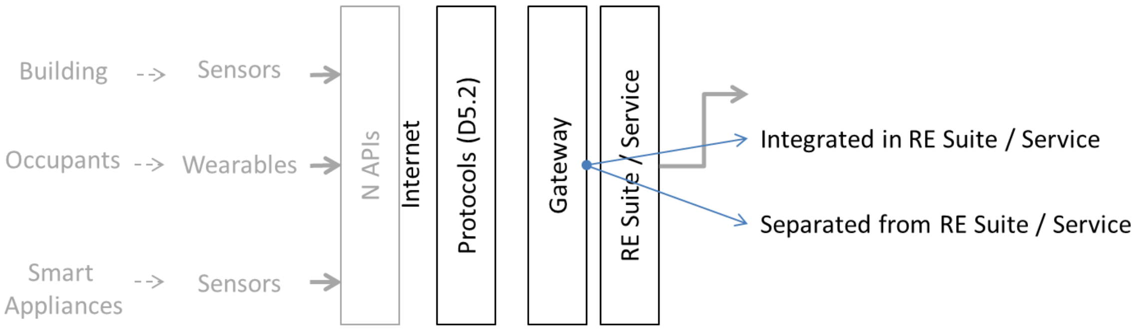

Fig. 8 - Gateway

The gateway is the interface to the internet for the MOBISTYLE platform. A gateway is necessary whenever data are flowing from one point to another via the internet. If data are collected, stored and processed in the building itself or not via the internet, a gateway is not needed.
In the gateway, all the software adapters and codes to query data from the sensors and the suppliers' database are created and configured.

Each connection will be secured to ensure data privacy and integrity. Two different kinds of safety protocols are needed: an access security protocol (SSL, HTTPS, etc.) and a privacy protocol. Privacy protocols are located before the gateway while safety protocols are located after the gateway. However, here more discussion and further study are needed. The protocols will be developed and described in the next deliverable of WP5, D5.2 (M24).

There are two options available for the location of the gateway. The final choice will be further explained in chapter 4 of this deliverable.

- The gateway and its functionalities are integrated into the platform (Fig.9).
  In this situation, all codifications to connect to the API of the sensors' suppliers are embedded in the gateway. This also means that, imagining that other platforms want to access the data, these platforms need to know the API of the sensors' supplier in order to query the proper data. Since the gateway is embedded in the platform, there is no need of an API between the platform and the gateway themselves. This solution is very advantageous to control the data flow and avoid having an extra step of connecting to another system as buffer/filter. The disadvantage is that the gateway needs to be able to connect to all the different suppliers' systems, so the developers need to know the API of each supplier.

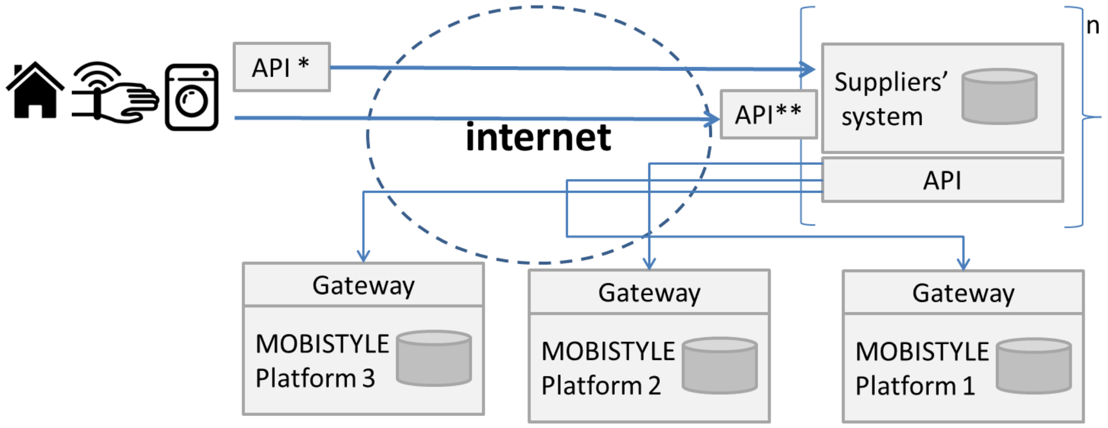

Fig. 9 - Gateway integrated into the platform
the pull system, ** the push system,
n refers to the number of suppliers' system, based on the different brand of sensors used

- The gateway and its functionalities are not integrated into the platform (Fig.10).
  In this situation, the gateway is completely separated from the MOBISTYLE platform. This means that all the platforms that want to get data from the sensors need query data connecting first to the gateway that is connected to the sensors and to the sensors' supplier system. Here the gateway is provided with API so that the external platforms can connect to it and query data. This solution is advantageous in case more platforms need to get information about energy usage, indoor environmental quality, and health. The platforms need only to connect to one gateway to query all the data.

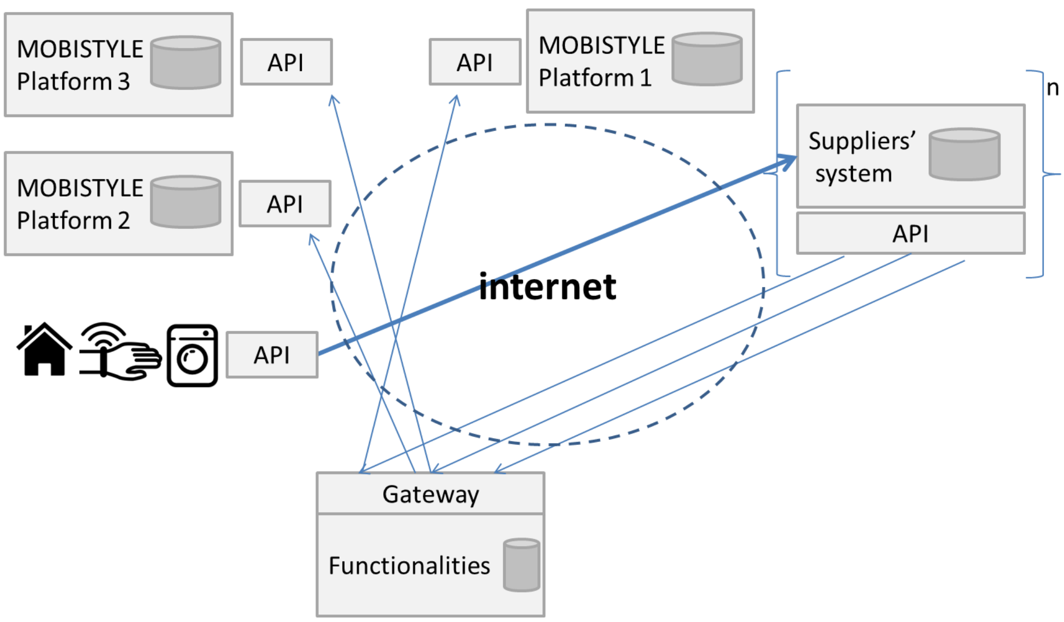

Fig. 10 - Gateway separated from the platform, push system
n refers to the number of suppliers' system, based on the different brand of sensors used

Phase 2, data storage and processing: Database
(See orange rectangle in Fig.15)

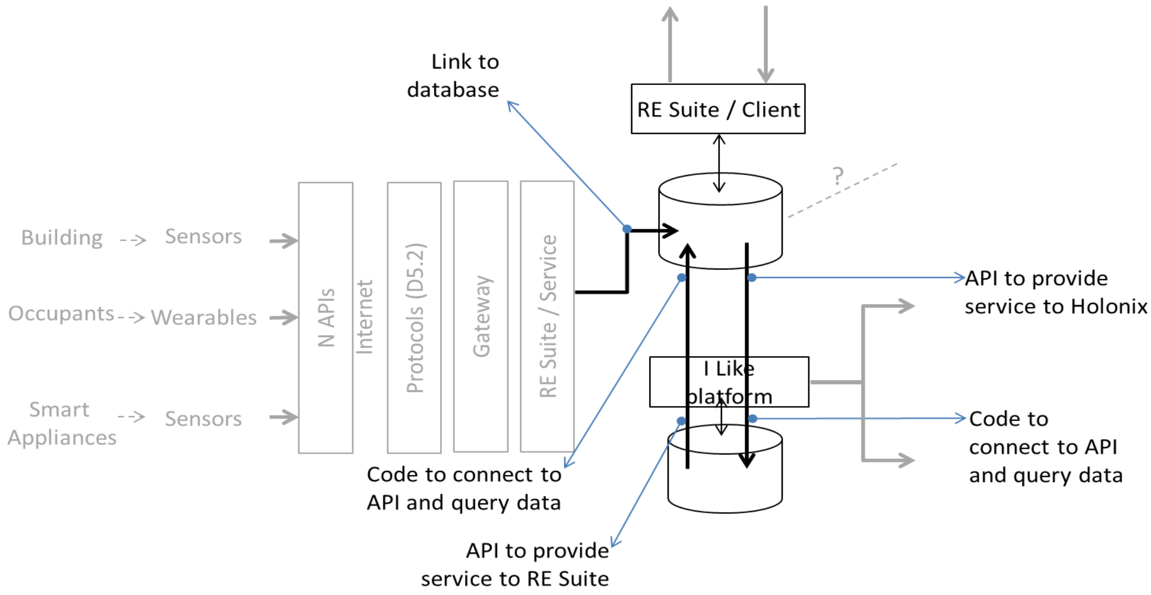

Fig. 11 - MOBISTYLE database and platform

Once data are collected and sent to the supplier's system, the MOBISTYLE platform query data from the manufacturers via the gateway. In the MOBISTYLE project, there are software developer partners that can implement and extend their existing systems to satisfy the needs of the MOBISTYLE project. These are DEMO and Holonix.

The platform will query all raw data collected in the suppliers' databases. This means that before storing data in the MOBISTYLE database, the data need to be partially processed in order to be then organized and stored correctly in the database.

There is not only one database to store all data, but a series of different database with different specifications and features will be used according to which kind of data needs to be stored.
The types of data are the following:

- raw data value;
- type of data, unit of measure;
- location data;
- timestamp;
- user profile data.

As described in chapter 3.1, the platform RE Suite, developed by DEMO, is a real estate management tool able to collect, structure, analyze and share real estate information. RE Suite is composed of two main components: RE Service and RE Client. RE Service is, as shown in Fig. 11, the basic structure, which contains the gateway and preprocesses data before storing them in the database.

The database of RE Suite will store all data coming from the building, from the wearables, and from the smart appliances.

The i-Like database will be in charge of storing user information and credentials. Every personal information will be stored with modern cryptography algorithms. The sensors will be aggregated in a virtual structure, conveniently called “sensorized entity”, to define the ecosystem to which they belong (e.g. a classroom, an apartment, etc.). Every “sensorized entity” will be mapped to the MOBISTYLE users currently using it, with permissions to read the data which will expire when the user no longer has access to it or after a fixed time. Doing so, the same “sensorized entity” can be accessed to different users and vice versa. Every personal information will be stored with modern cryptography algorithms. No one other than the i-Like platform can access directly to the database, a RESTFul API is the only way for third-party applications to retrieve the data. The i-Like platform currently uses a MySQL database.

The key for the development of the overall MOBISTYLE platform, and then of the whole system that brings to providing feedback to the end users, is the link between the databases of RE Suite and i-Like. As also shown in Fig.11, RE Suite will query user data from I-Like database connecting to the API from I-Like. These data will be processed and temporarily stored in RE Suite and, together with the other data coming from the sensors, they will be the input for the analytical tools.
On the other hand, the i-Like database will query two kinds of data from the RE Suite: raw data and KPI values, result of the calculation of the analytical tools.

The communication between i-Like platform and RE Suite will be transparent to the user. The i-Like machine will automatically retrieve all the data regarding a specific “sensorized entity” as soon as the user requests it using the RESTFul APIs. The endpoints for the status of the “sensorized entity” or the historical data are configurable and can be reused for entities of the same type (e.g. two apartments of the same hotel). The configuration is flexible enough to even specify the JSON path where to read the status of the “sensorized entity”, in this way also the structure of the message coming from RE Suite can be very different between cases. In the same way, the dashboard can be configured to read a specific attribute of the JSON message, showing only its valuable information. No hardcoded attributes or fixed structure is needed in order to show the sensors data.

Phase 2, data storage and processing: Platform
(See orange rectangle in Fig.15)

The MOBISTYLE platform is the core of the whole system. It composed by RE Suite and i-Like. RE Suite is a platform used by the experts for the evaluation of the status of a building. i-Like is used by the consumer and shows real-time and historical data. As described before, the connection of the two platforms and their database is fundamental in order to allow the overall flow from sensors to users.

RE Suite and I-Like play two different roles in the MOBISTYLE project. RE Suite store all sensors data and communicate with the analytical tools. No calculations happen in RE Suite. The communication between RE Suite and the analytical tools will probably be solved through the definition of an import -export function. RE Suite is able to export post-processed data in the format needed by the analytical tools. In turn, the analytical tools import the document provided by RE Suite and export the results of the calculations in a format compatible with RE Suite, which will import, process and store these values.

On the contrary, i-Like is responsible for the visualization of the data. Here is where the consumer logs in to access his / her profile to visualize data about energy consumption of the building, indoor environmental quality and health. These data are related to the user and its location. To trigger behavioral change, one of the options is to visualize the information about the sensor ecosystem and notifications based on the "sensorized entities" in a gamified way. The conversation about this possibility is going between the different ICT partners, especially Highskillz and Holonix, to understand the best strategy to achieve this objective.
Moreover, the i-Like platform will be the link to the open application platform.

Phase 2, data storage and processing: Analytical tools
(See green rectangle in Fig.15)

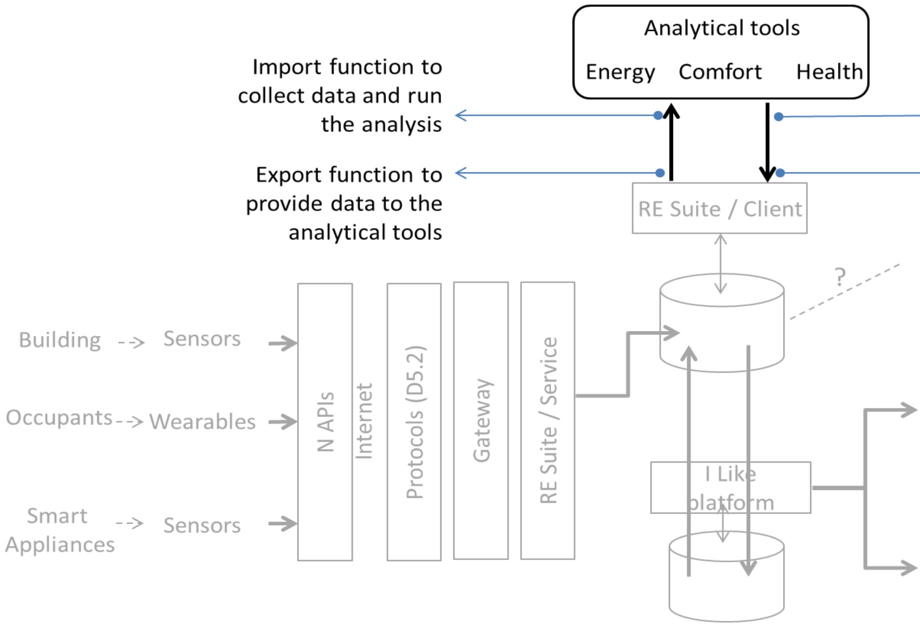

Fig. 12 - Analytical tools

The analytical tools will use the processed data from RE Suite as input for the analysis regarding energy, comfort, and health, in order to define the KPIs. As previously described, a compatible import-export function in the analytical tools and in RE Suite will allow the transfer of data and results of the calculations from one tool to the other and vice versa. The results of the calculations are the Key Performance Parameters (KPIs), described in WP3. To perform energy analysis, csv files format are needed.

The KPIs will be visualized via an extension of the Real Time Dashboard provided by i-Like. The KPI values will be imported by RE Suite and sent to i-Like for their visualization. Here comes back the importance of the API connections between RE Suite and i-Like. Also, since the KPI will be used for providing feedback to users, and the open application platform – linked to i-Like - will allow the creation of serious gaming applications, it becomes logical to have everything related to end users coming from and visualized in the i-Like platform. More information on the visualization of the Dashboard is provided in deliverable D5.1 in WP5.

Phase 3, disclosing information to end user: Gamification and Serious Gaming *(See yellow rectangle in Fig.15)*

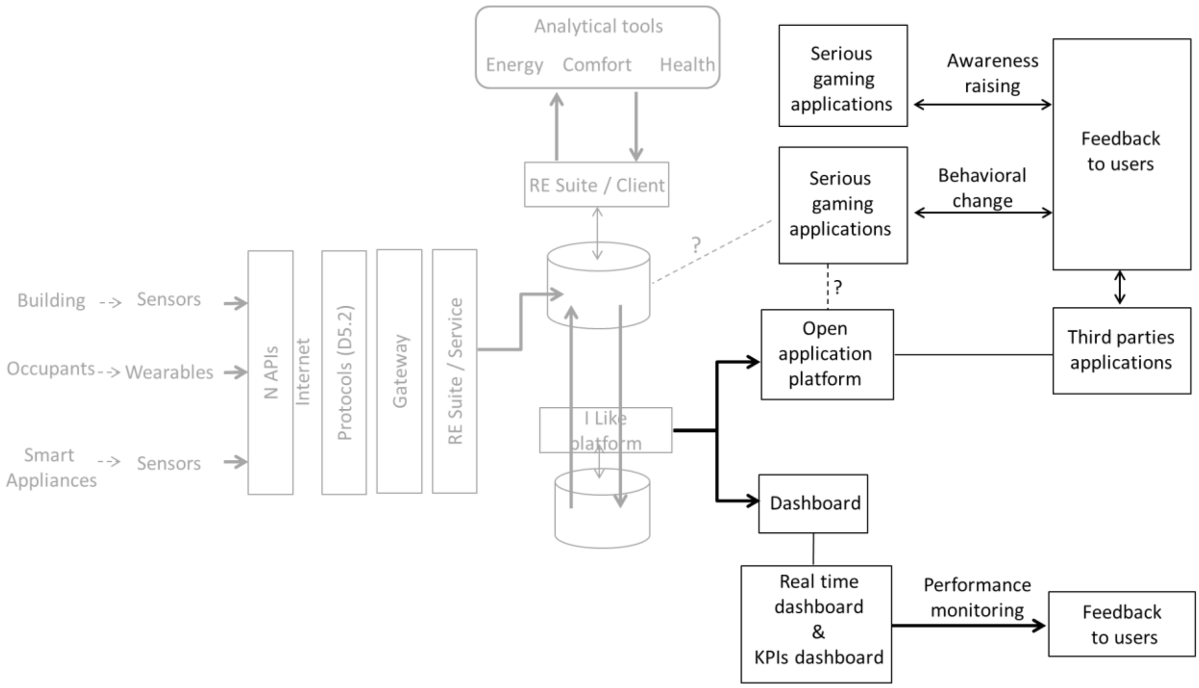

Fig. 13 - Disclosing information to end user

The last step of the MOBISTYLE is the disclosure of information to the end user. In this last phase all data collected, processed, and analyzed are translated in a comprehensible language for the consumer. Through this, the end user will be made aware of energy use and inner comfort in the building he/she uses, and about his/her personal wellbeing. Moreover, the user will be involved in the tentative of changing his/her behavior for a better good: more energy saving, more comfort, more health.
To achieve this, that is the main goal of MOBISTYLE, the information is disclosed to the user in two ways, via a dashboard and via serious gaming applications.

As described previously, the dashboard visualizes two kinds of data, real time data and the KPI values. The real time data show the trend of the parameters like temperature, humidity, etc. The KPIs represent instead an average value. The dashboard can be gamified, in order to provide more interesting and enjoyable information to improve users' engagement. The conversation about this point is still ongoing between the two ICT responsible partners Holonix and Highskillz and will be presented in the upcoming deliverables.

Serious gaming applications will be developed and they are the second method to give feedback to users. Two types of serious gaming applications are going to be developed: one for educational purposes to raise awareness and one to trigger behavioral change. The first one will be self-standing, not connected to the MOBISTYLE platform. There is no for real-time data, neither for user data. Historical data might be used as a reference. The environment and the gaming will be simulated in order to educate people and raise their awareness.

Regarding the second application, currently, it is still not clear whether the open application platform to foster behavioral change will be connected to the open application platform or will gather the data directly from the RE Suite database.

The application to raise awareness will be mainly self-standing, it simulates the environment and it will not need real time data, neither maybe historic data

The last point regards the open application platform. For now, this has been considered as detached from the main infrastructure of MOBISTYLE and vehicle of exploitation for the investigation of new business models. Further discussion will be done on this topic in preparation of next deliverables of WP4 and WP5.

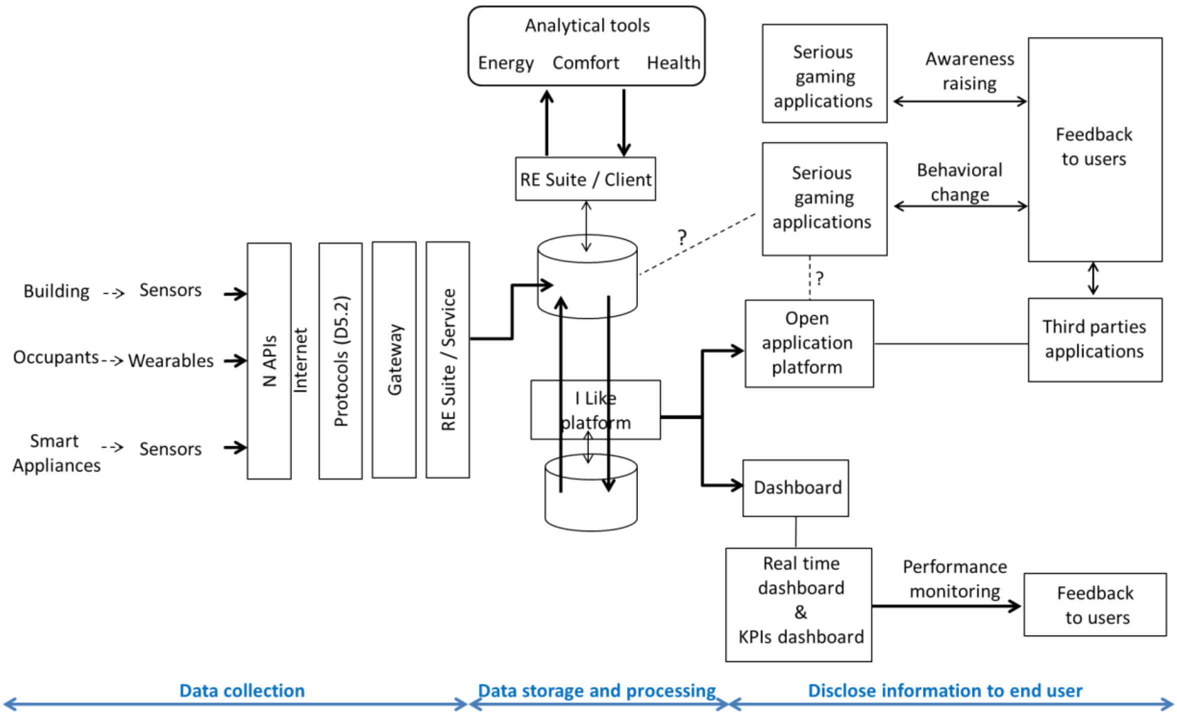

Fig. 14 - MOBISTYLE System

In the following image (Fig.15) it is possible to see the correspondences of each part described above and the competences of each member of the MOBISTYLE consortium.

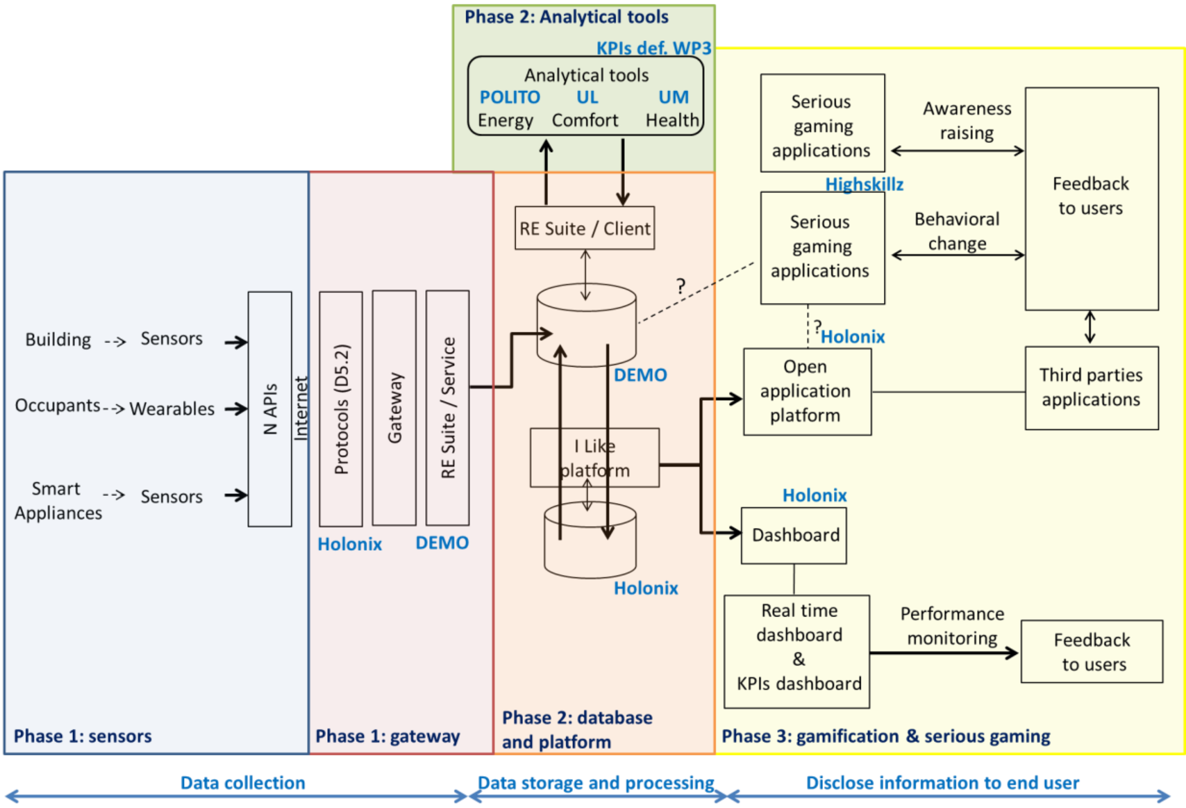

Fig. 15 - MOBISTYLE system and tasks
Blue: pp. 17-20 – Red: pp. 20-21 – Orange: pp. 22-24 – Green: pp. 24-25 – Yellow: pp. 25-26

4. Development of the MOBISTYLE IT Platform

In chapter 2, the overall idea behind MOBISTYLE and its general architecture have been described. Then, in chapter 3.2, the characteristics of each component, in each phase of the MOBISTYLE process have been illustrated. The goal of this report is the description of platform and database for software and information interoperability.

In this chapter 4 the requirements of the platform and database, the development plan together with the proof of concept will be delineated.

Moreover, further recommendations for improvement and development of solutions are presented in deliverable D2.3. These are general and case-specific suggestions from the sociologists and anthropologists to help the ICT developers in designing the best and most suitable applications to communicate energy, comfort, and health-related information to the end users.

Tasks and scopes for each component of the MOBISTYLE system are described as shown in Fig.16.

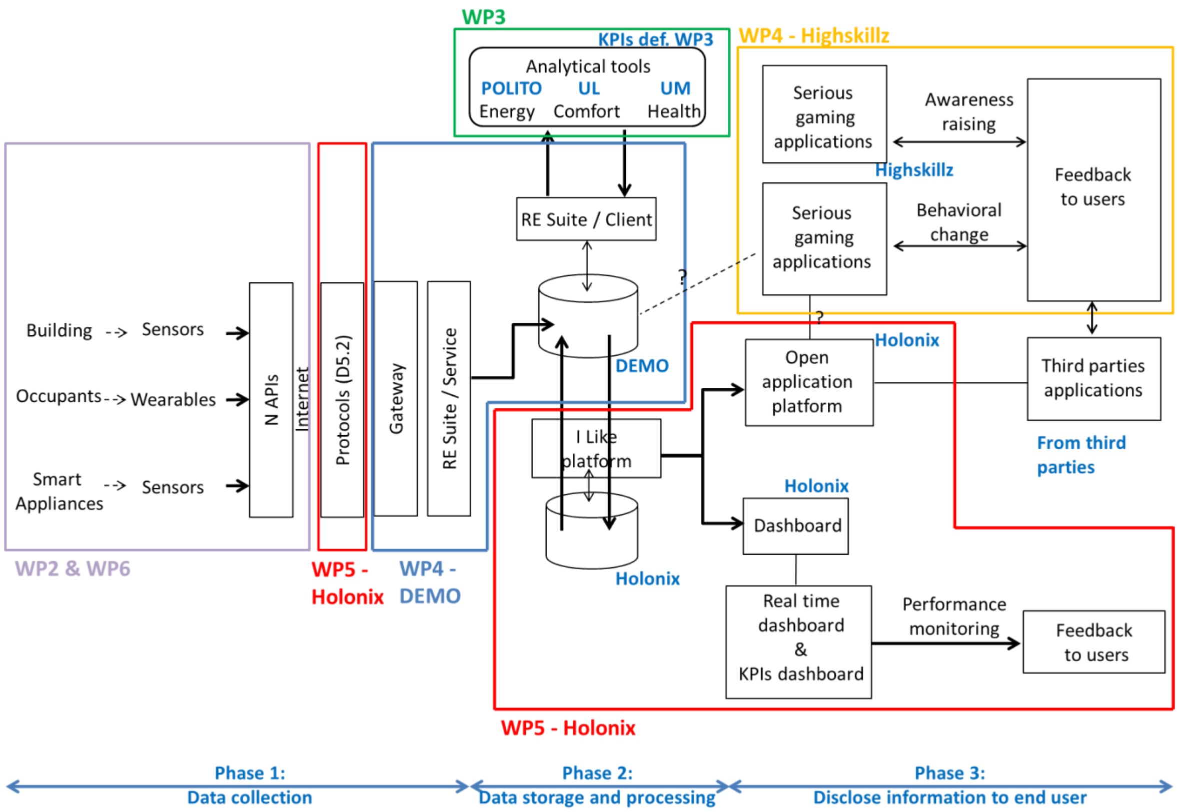

Fig. 16 - Tasks' division with focus on ICT tasks (WP4 - WP5)

4.1. Concept requirements for the MOBISTYLE platform

In general, the MOBISTYLE platform needs to be:

- Flexible;
- Configurable;
- Secure;
- Scalable.

Flexibility is a feature that allows the platform to adapt to the different situation with an easy implementation. For example, in case more sensors are added to the network to gather a new kind of data, the MOBISTYLE system should be able to connect to those sensors with few, and not substantial, changes of its characteristics. For this reason, it is important that all the information coming from the sensors and from the databases of the manufacturer goes through the gateway, in order not to add unnecessary complexity to the system.

The MOBISTYLE platform needs to have a user-friendly configuration and interface. In fact, building owners or manager needs to configure the system with information about the installed sensors and needs to be able to visualize the data and to change general settings for data collection. All this is provided by RE Suite. In this same context, the I-Like platform will be accessed by the end-user, so that its interface will need to be user-friendly and customizable, without too technical information.

The MOBISTYLE platform will process a large amount data. It is fundamental to properly secure every part of the system. Layers of encryption and authentication between the components need to be designed. The credentials will be stored as a secure hash in the database in order to prevent passwords leaking. Moreover, it is important that also the devices running the platform software are protected against unauthorized access. The design of protocols for privacy and safety will be described in deliverable D5.2 (M24).

Finally, MOBISTYLE platform needs to be scalable. Currently, the MOBISTYLE platform is applied only to five demonstration cases but, ideally, in the future, the MOBISTYLE platform will be used by many buildings, occupants and smart appliances. Big amount of data will be collected and stored and they will need to be retrieved. So the platform will need to be able to adapt itself to gather more data and to perform properly in terms of data collection and processing. In general, a system is considered scalable if it is capable of increasing its total output under an increased load when resources (typically hardware) are added.

4.2. Use cases

For the definition of the requirements, the starting point is the description of the use case. A use case is a methodology used in system analysis to identify, clarify and organize system requirements. It consists of a list of actions defining the interactions between an actor and a system to achieve a certain goal. From these schemes, it is possible to determine the functional, technical and interoperability requirements of the system, in this case of the MOBISTYLE platform.

Three main users have been identified for the definition of the use cases: the building occupants, the technical manager and the experts for the calculations with the analytical tools. In the presented use cases, it is possible to understand how each user interfaces with the MOBISTYLE platform. The following situations are described in the use cases:

- actors: building occupants and technical manager – wearable monitoring of users;
- actors: building occupants and technical manager – environmental monitoring;
- actors: experts – calculation of energy performance, comfort and health.

The use cases here described are a done in collaboration with the consortium partner Holonix.

4.2.1 Actors: building occupants and technical manager – wearable monitoring of users

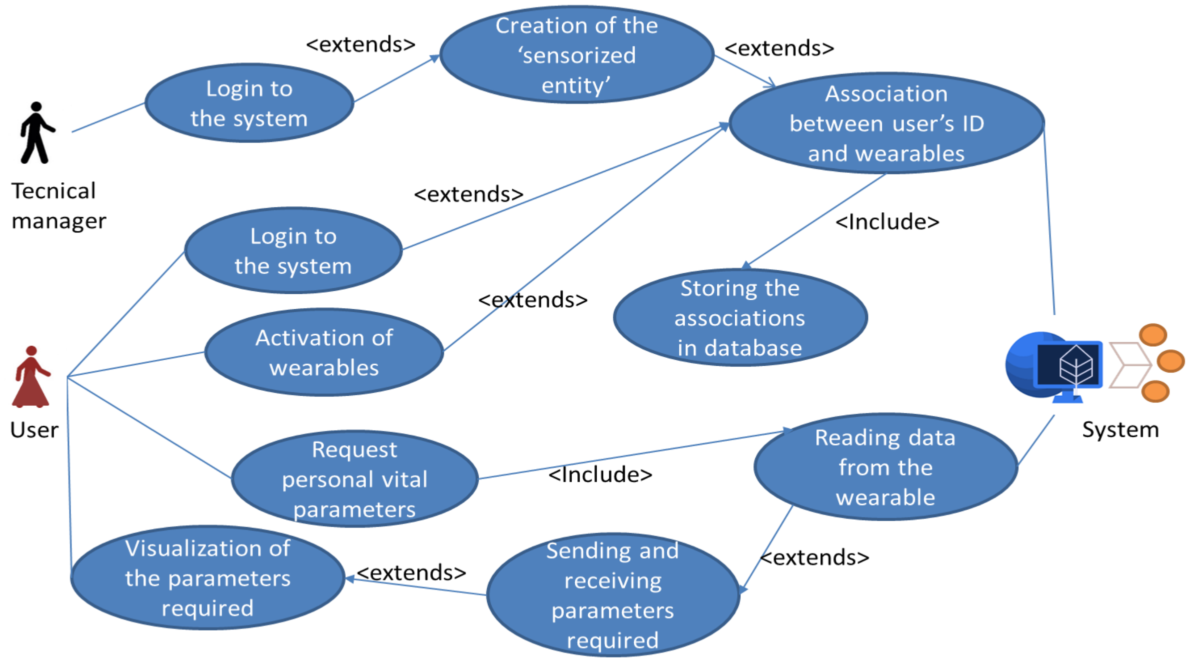

Fig. 17 - Use case: Wearable monitoring of users

The actors involved in this use case are the technical manager and the building occupants. This use case shows which actions the user will make to visualize his / her personal vital parameters gathered from the wearable.

The user will login in the system and will also activate the wearable. The technical manager will login in the system – MOBISTYLE platform – and will create the "sensorized entity", i.e. the wearable. Then, the manager will associate the user's ID to the wearable so that every time that the user login in the system, the system itself is able to connect the information of the user and the data gathered.

In this example, the user requires to visualize his / personal vital parameters in reference to a certain period in time. Data are collected by the sensor embedded in the wearable and processed by the MOBISTYLE platform, together with the historical data. The requested data then visualized on the user's mobile, laptop or tablet.

4.2.2 Actors: building occupants and technical manager – environmental monitoring

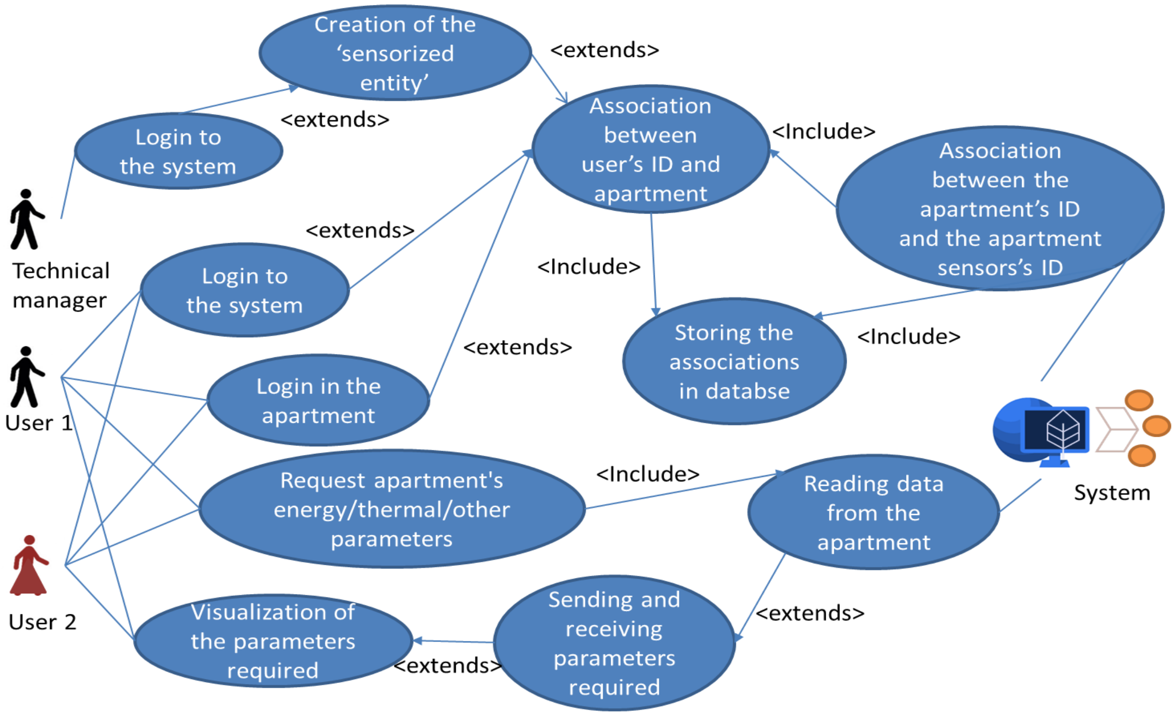

Fig. 18 - Use case: Environmental monitoring

The actors involved in this use case are the technical manager and the building occupants. This use case shows which actions the users will make to visualize parameters regarding energy consumption and comfort in an apartment.

The user will login in the system and in the apartment. The technical manager is, in this case, the administrator of the residential building. The technical manager will at first login in the MOBISTYLE platform to create the "sensorized entities", here the different apartments. Then, the manager will associate the user's ID to the apartment and he will also associate the apartment's ID with the apartment sensors' ID. The two associations will be stored in the database. From this moment a connection between the sensors, the apartment and the users will be established so that it will be possible to retrieve the correct data from the MOBISTYLE platform when the user will request the visualization of certain parameters in time. As in the previous case, the user will request the visualization of specific data from his/her mobile, laptop, or tablet that will be retrieved by the MOBISTYLE platform.

4.2.3 Actors: experts – calculation of energy performance, comfort and health

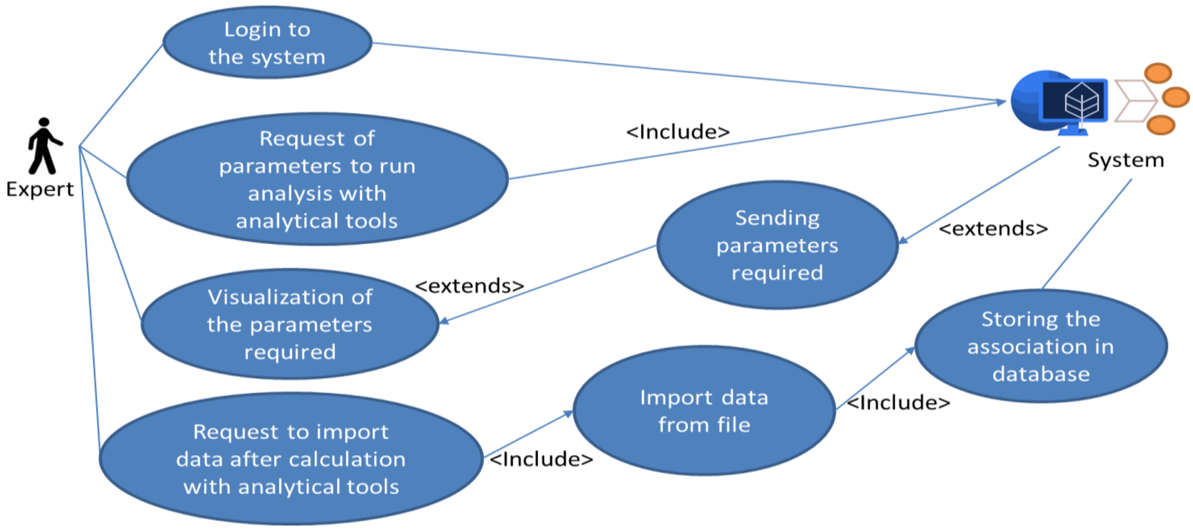

Fig. 19 - Use case: Calculation of energy performance, comfort, and health

The actor involved in this use case is the expert. This use case shows which actions the expert will make to request data to the platform in order to be able to perform the calculations with the analytical tools and, then, to import the results in the platform to be available for giving feedback to user through the visualization of real-time and KPI dashboards and through serious gaming applications.

The expert will login in the system and will request to gather and export parameters to perform analysis about energy consumption, comfort and health. As in the cases shown above, the data will be gathered the MOBISTYLE platform and they will be visualized by the expert in the required format by using the RE Suite part of the platform.

After having performed the analysis with another tool – external to the platform – the expert will need to import the results of the calculations in the platform in order to provide feedback to the user. The expert will log in again and will send a request to import the data output. Data will be imported and stored in the database of the MOBISTYLE platform. Moreover, for the expert, it will be possible to visualize a techical dashboard within RE Suite.

4.3. List of requirements

The list of requirements is divided into three main categories:

- Functional requirements:
  define a function of a system or its components. A function is described as a set of inputs, behavior, and outputs;
- Technical requirements:
  refer to the technical aspects that a system must fulfill;
- Interoperability requirements:
  define how technical systems or components are shared and connected to each other.

Functional requirements

Functional requirements of MOBISTYLE platform are the following:

Requirements	Technical managers	Occupants	Experts
Access via laptop	V	V	V
Via tablet	V	V	
Via mobile		V	
Registration to the MOBISTYLE platform	V	V	V
Landing page	V	V	V
Login with credentials	V	V	V
Visualization of “sensorized entities” - All	V		V
- Just the ones to with the user is associated		V	
Visualization of information, characteristics, drawings, images, how many sensors are installed and so on	V	V	V
Possibility to add, modify, delete the “sensorized entity”	V		
Possibility to add, modify, delete sensors’ specifications	V		
Possibility to choose which “sensorized entity” to consider	V	V	V
Possibility to choose, for each “sensorized entity”, which parameters to collect and in which period of time to run the technical calculations.			V
Associate the “sensorized entity” with the sensors	V		
Associate the “sensorized entity” with the occupants	V		
Create, modify, delete the account of the occupants and the experts	V		

Click on the sensor's icon on a plan or image in order to visualize the characteristics of the sensor	V	V	
Click on the sensor's icon for the visualization of real-time data	V	V	V
Access to all kind of data, from the building sensors, from the occupants wearable and from the smart appliances as well as user data	V		V
Visualization of KPI dashboard being able to choose what to visualize, for example, energy performance or also comfort and health	V	V	
Visualization of historical data with the possibility to choose which period to visualize(current month, last month, specific period)	V	V	
Possibility to compare data of different periods (historical data and KPIs)	V	V	
Possibility to export graphics of the dashboards and data in different formats	V		V
Possibility to create a report for each "sensorized entity" in different formats	V		
Possibility to import results from the technical analysis			V

Tab. 1 – List of functional requirements and users

Technical requirements

The MOBISTYLE platform is composed of two existing platforms, RE Suite developed by DEMO and i-Like developed by Holonix. For the two platforms, technical requirements are defined separately, in order to facilitate also the further development.

Technical requirements of RE Suite are specified below per system component:

1. RE Suite Service
    a. The RE Suite Service should be able to interrogate the web services that are generally provided by the manufacturers of the sensors. These are either SOAP

(Simple Object Access Protocol) or RESTful (REpresentional State Transfer) web services.

   b. The RE Suite Service should be able to run according to pre-configured schedules for the collection and storage of sensor data. The frequency may differ per sensor or category of sensors (building sensors, occupants' sensors, occupants sensors, smart appliances sensors).
   c. The RE Suite Service should apply secure connections via SSL (Secure Sockets Layer) with authentication (username and password).
   d. RE Suite service needs to process data to be compatible with the analytical tools.
   e. The RE Suite should be able to store the collected data into a NoSQL server (MongoDB, Couch, …).
   f. The RE Suite Service should be able to enrich the sensor data with building information and user profiles by interrogating the Holonix Web Service.
   g. The support for new devices should be easy to implement in RE Suite Service.
2. Database
   a. The database should be able to process and store a large amount of (sensor) data.
   b. The database should be able to handle complex data structures.
   c. The database should be able to process queries over large datasets in an efficient way.
3. RE Suite Client
   a. The RE Suite Client should be accessible via web.
   b. The RE Suite Client access should be provided with authentication and authorization control.
   c. The RE Suite Client should be able to interface with the NoSQL server in order to access the collected sensor data.
   d. The RE Suite Client should be able to provide an export file containing sensor data and building information for analysis in CSV / Excel format.
   e. The RE Suite Client should take care of the anonymization of the exported data.
   f. The RE Suite Client should be able to import the analysis results in Excel format.
   g. The imported analysis data is stored in the NoSQL database so that it can be interrogated by the I-Like platform via a web service for KPI dashboard visualization.
4. RE Suite Web Service
   a. The RE Suite Web Service should be able to provide KPI data (from the analysis result) to the I-Like platform.
   b. The RE Suite Web Service should be able to access the NoSQL database and provide the data in JSON format.
   c. The RE Suite Web Service should be a RESTful Web Service.

Technical requirements for i-Like are as follows:

1. i-Like Service
   a. The i-Like service should be able to interrogate the RE Suite WebAPI in order to retrieve the sensor data.

   b. The i-Like service should retrieve the data from RE Suite in polling for the real-time dashboard updates.
   c. The i-Like service must use secure authentication methods and credential storage.
   d. The i-Like service should assure that the information about a specific user is not seen or available to other users in the platform.
   e. Every user can be linked with specific sensor data, meaning the i-Like service is in charge of creating and managing data mapping.
   f. The i-Like service should analyze specific user data in order to create notifications for the user behavioral changes.
   g. Being the consumer tool, i-Like service should implement user experience functions, such as password change, password retrieval, account removal, etc.
2. Database
   a. The database should be relational and capable of manage from small to medium amount of data with complex relationships very quickly.
   b. The database should be able to handle complex data structures.
3. i-Like Client
   a. The i-Like client should be accessible via web.
   b. The i-Like client should have a registration page in order to register to MOBISTYLE.
   c. The i-Like client has to communicate with the RESTful APIs of the i-Like service.
   d. The i-Like client should provide an easy to use and intuitive GUI to allow users to interact with the MOBISTYLE platform.
   e. The i-Like client should provide an easy to use and configurable dashboard to visualize the data, real-time and historical.
   f. The i-Like client should inform the user about his behavior and status, and provide an easy tool to visualize the notifications.
   g. The i-Like client should provide to the technical managers an interface for the creation of the “sensorized entities” and the user association to those entities (nevertheless the ability to revoke the user access to the entities).
4. i-Like Web Service
   a. The i-Like Web Service should be able to provide user data to the RE Suite platform.
   b. The i-Like Web Service should be able to access the relational database and provide the data in JSON format.
   c. The i-Like Web Service should be a RESTful Web Service.

Interoperability requirements

Interoperability requirements are related to three different parts of the MOBISTYLE platform, as shown in the image below:

- The first part of interoperability requirements is related to the link between RE Suite and i-Like, that will be developed through collaboration between DEMO and Holonix.
- The second part of interoperability requirements is related to the connection between the MOBISTYLE platform and in particular RE Suite and the analytical tools; this connection will be developed by DEMO in collaboration with the partners of WP3 (POLITO, UM, IRI UL).

- The third part of interoperability requirements is related to the connection between the MOBISTYLE platform and in particular i-Like and the open application platform for the definition of the application and serious gaming application to provide feedback to users; this connection will be developed by Holonix in collaboration with Highskillz.

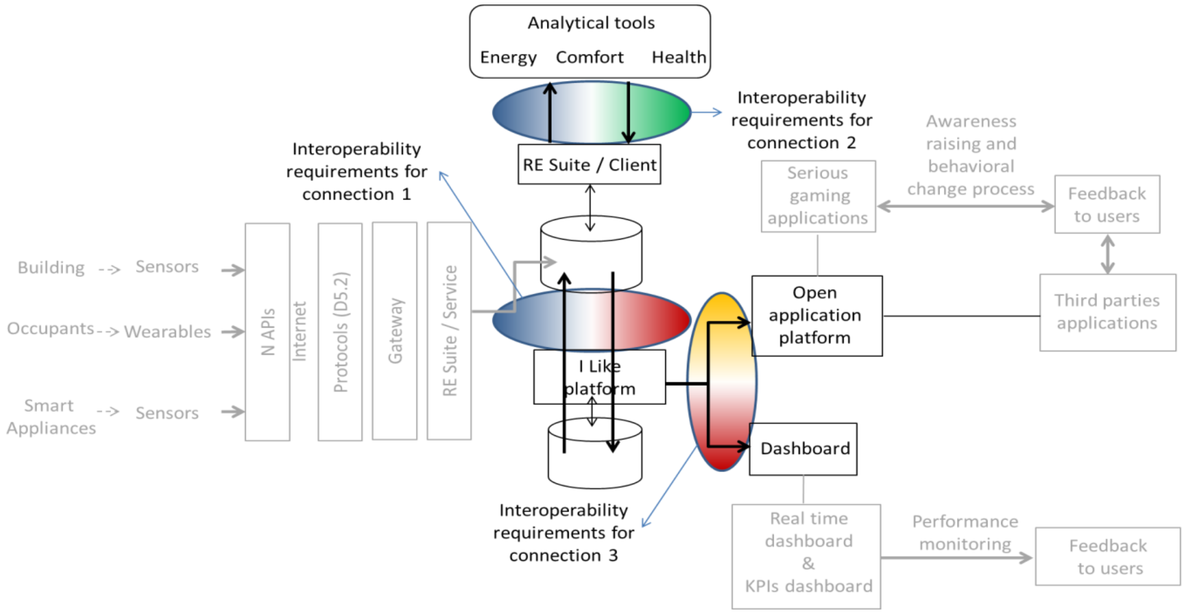

Fig. 20 – Interoperability requirements for the indicated links
Blue = DEMO, Red = Holonix, Yellow = Highskillz, Green = WP3

Interoperability requirements for RE Suite are as follow:

- The platform and the sensors need to be connected to the internet to allow data exchange and access data.
- RE Suite needs to be able to connect to different platforms for data exchange, in this case, i-Like.
- RE Suite needs to have an import-export platform for data exchange with the analytical tools.
- RE Suite needs to be accessible via login credentials to the experts and managers in order to configure the data collection.
- Possibility to extract information from BIM models, when available, as input for the expert to perform the technical analysis.

Interoperability requirements for i-Like are as follows:

- the platform needs to be connected to the internet.
- the i-Like platform needs to be connected to RE Suite in order to retrieve the sensors data.
- the i-Like platform and dashboard are connected via WebAPI as is.
- the i-Like platform and RE Suite need to be connected via machine to machine API Keys to be transparent to the users.

- the i-Like platform and Highskillz solution need to be connected via machine to machine API Keys to be transparent to the users.
- All the interoperability connections need to be via RESTful APIs.

4.4. Development plan

The software development is conducted according to the well-known Waterfall method. This methodology consists of a set of process steps that are executed in a sequential order as is shown in the image below.

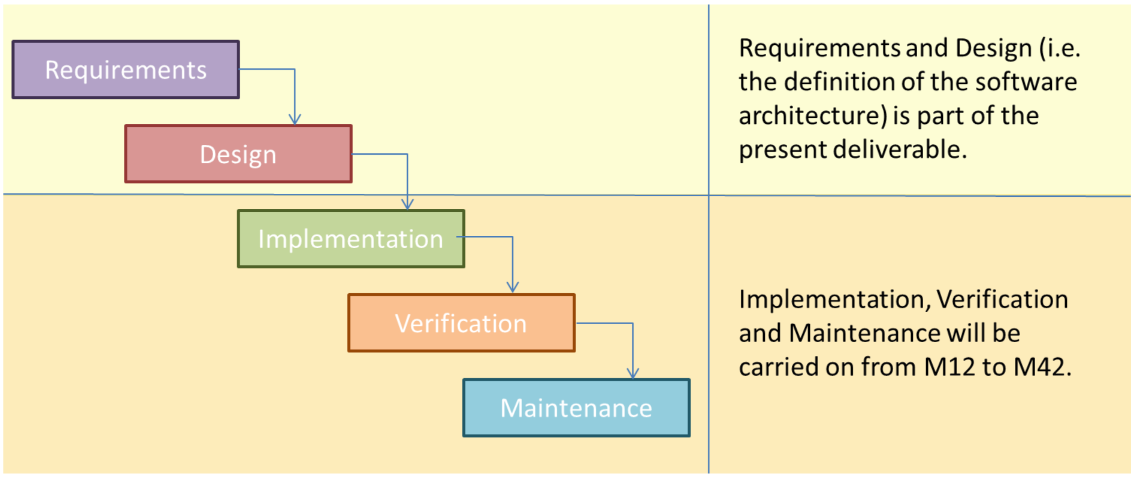

Fig. 21 - Waterfall method for software development

Requirements

The requirements are divided in functional, technical and interoperability requirements. These are described in section 4.3.

Design

The design for the software to be created consists of a technical specification of the software parts that need to be developed or enhanced. In addition, UML diagrams are created as concise design documentation presenting the static software model and dynamic behavior of the model.

Implementation

During the implementation phase, the required software will be developed and installed. For the Mobistyle platform this comprises:

Re Suite

1. RE Suite service
    - The RE Suite Service will be developed as an executable console application that can be started via a Windows Task scheduler. The task scheduler will start RE Suite Service at a minimum interval. The frequency for the different devices is configured in the RE Suite Database and read by the RE Suite Service. The Service relates the frequency of data collection for the devices with the minimum interval (n times minimum interval).

- The RE Suite Service will be installed in the web server part of the SaaS environment.
- The programming code of RE Suite Service is set up in a modular object-oriented way by defining base and subclasses. Then, a new type of device is added and the logic, which is specific for this new device, is implemented in a new subclass.
- RE Suite Service will include the gateway in order to simplify the overall system and have a better control of data flow and avoid having an extra step of connecting to another system as a filter. The implementation of the gateway in RE Suite Service will be further developed and described in D4.1 (M24), also because strictly connected with the choice of the sensors to be installed in demonstration case and their APIs.
- The RE Suite Service needs to be extended with functionality to interrogate the I-Like Web Service.

2. Database
   - A NoSQL server will be configured and provided with a database instance named MOBISTYLE. Currently, RE Suite Client, Service and Web Service do not support the connection to a NoSQL database. This will be developed.
   - The document specifications will be implemented so that the NoSQL server is able to store the data according to the structure as specified. NoSQL database, like MongoDB, guarantees high performance and storage of a large amount of data.
   - Connectivity with the RE Suite Service, RE Suite Client, and RE Suite Web Service will be provided.
3. RE Suite client
   - The export/import functions for data analysis/result will be developed within the Administration part of the RE Suite client.
   - An OU (Organizational Unit) will be created on the DEMO SaaS server.
   - The RE Suite Client software will be installed on the DEMO SaaS server within the newly created OU.
   - RE Suite Client will anonymize the data before export for the analysis. This will be done according to safety protocols set up by Holonix in WP5, D5.2.
   - RE Suite Client has a login page.
4. RE Suite Web service

   The RESTful Web Service will be developed and installed on the Web server part of the SaaS environment. A secure connection is established by configuring SLL with username and password. The web service will be made accessible via the internet in order to allow interrogation by the ILike platform.

i-Like

1. i-Like Service
   - A Java Spring MVC web application will be deployed on a company managed server (for development and scope of the project).
   - A shared Apache Tomcat web container will be configured and deployed on the server.

- Most of the already available modules and functions will be license activated for the scope of the project.
- The missing modules such as the notification module and rent/entity association module will be developed and integrated into the i-Like platform.
- Every new WebAPI will be available as soon as it's implemented and integrated into the i-Like platform.
- A brand new installation of the platform will be dedicated to the MOBISTYLE project.

2. Database
    - A shared MySQL instance will be running on the server.
    - Tools and procedures will be available when migration will occur.
3. I-Like Client
    - A dedicated HTTP Apache server will be configured and deployed.
    - When the test and development phase ends, certificates and keys will be installed and configured on the server, allowing for HTTPS communications.
    - An AngularJS, HTML5, CSS3 client application will be deployed and configured on the Apache server.
4. I-Like Web Service
    - The web services, being part of the i-Like service, will be active and available as soon as the web application is deployed with authentication.

Verification

During the verification phase the software is tested as individual components but also the whole system is subjected to test.

RE Suite

1. RE Suite Service
    - Test the scheduling of the service for the applied sensors within the demo case
    - Test the connectivity with the applied web services.
    - Test the storage of the collected sensor data in the NoSQL database.
    - Test the connectivity with the I Like platform for enriching the sensor data with building information and user profiles.
2. Database
    - Test the NoSQL database connectivity.
    - Test the storage of the sensor data by scripting documents and executing them on the database.
    - Check the connectivity of the NoSQL database from the RE Suite Service and Web Service of the SaaS environment.
3. RE Suite Client
    - Test the login procedure an authorization for the RE Suite Client platform.
    - Test the export function that creates a CSV/Excel file with the sensor data enriched with building information.
    - Test the import function that processes the result sheet of the data analysis.

i-Like

1. i-Like Service
    - Test the web services.
    - Test the polling and connectivity with RE Suite.
    - Test the user data reachability.
    - Test notification creation.
    - Benchmark with massive connections.
2. Database
    - Test data integrity.
    - Benchmark with heavy query load.
3. i-Like Client
    - Test user navigation.
    - Test user interaction.
    - Test with multiple user devices and browsers.
    - Benchmark with massive connections.
4. i-Like Web Service
    - Test data structure and authentication.

Maintenance

During the maintenance phase, the software is in production and issues/questions might be raised by the users of the MOBISTYLE platform. A MOBISTYLE issue tracker will be set up to register and process the user issues/questions during the maintenance phase (in this case the demonstration phase).

4.5. Proof of concept

In the following pages some mock-ups are presented how the platform should look like to the different users. Fig.22 and Fig.23 show the interface of RE Suite for the experts that will login in the MOBISTYLE platform and will be redirected to the RE Suite page. In the images, it is shown the sequence to export data, and the expert dashboard visualization after the results of the technical analysis are re-imported in RE Suite. Moreover, UML user diagrams for import-export functions are here represented (Fig.24, Fig.25).

The other images (Fig.26, Fig.27, Fig.28) show the interface for the end user from the I-Like platform. For example, each user can visualize the “sensorized entities” to which he is connected, he can visualize the user profile details.

It was not possible to perform a preliminary verification of data for the demo cases since data are not still available. This will be explained in the upcoming deliverables.

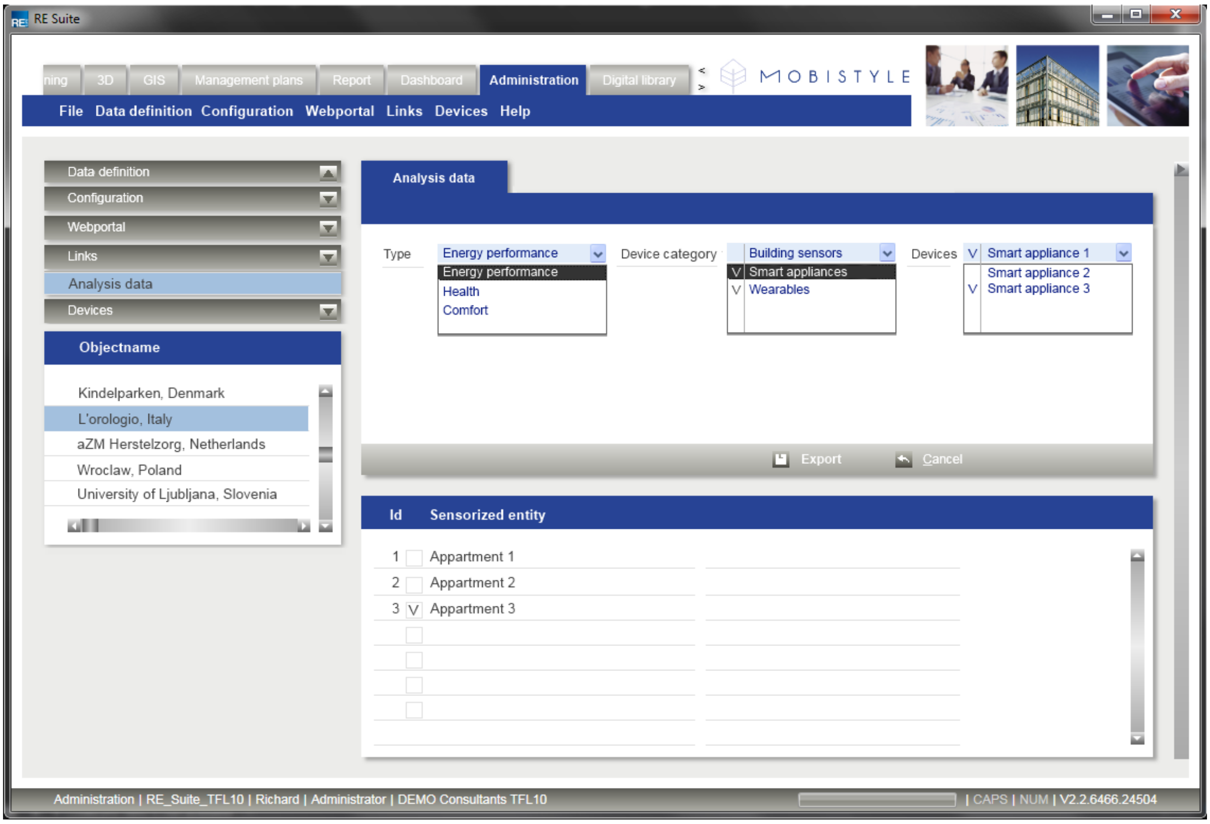

Fig. 22 – Export process for the experts

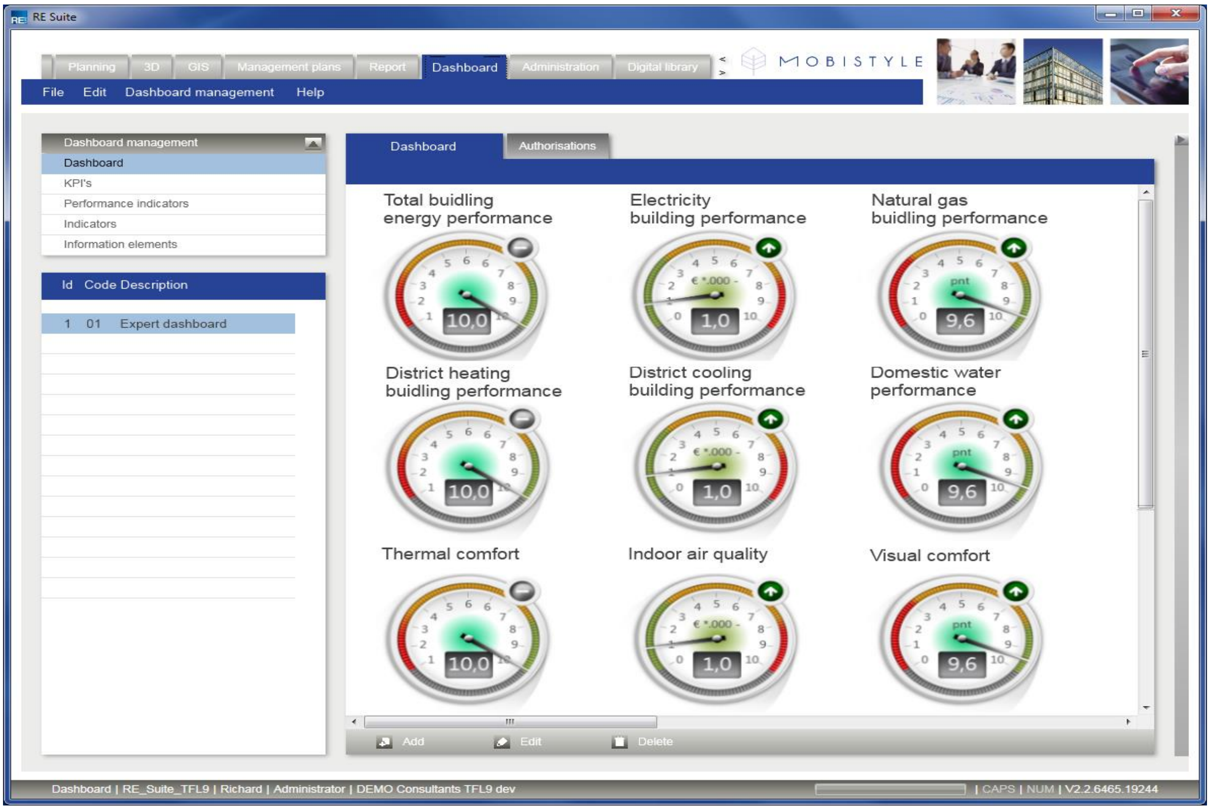

Fig. 23 – Visualization of the expert's dashboard

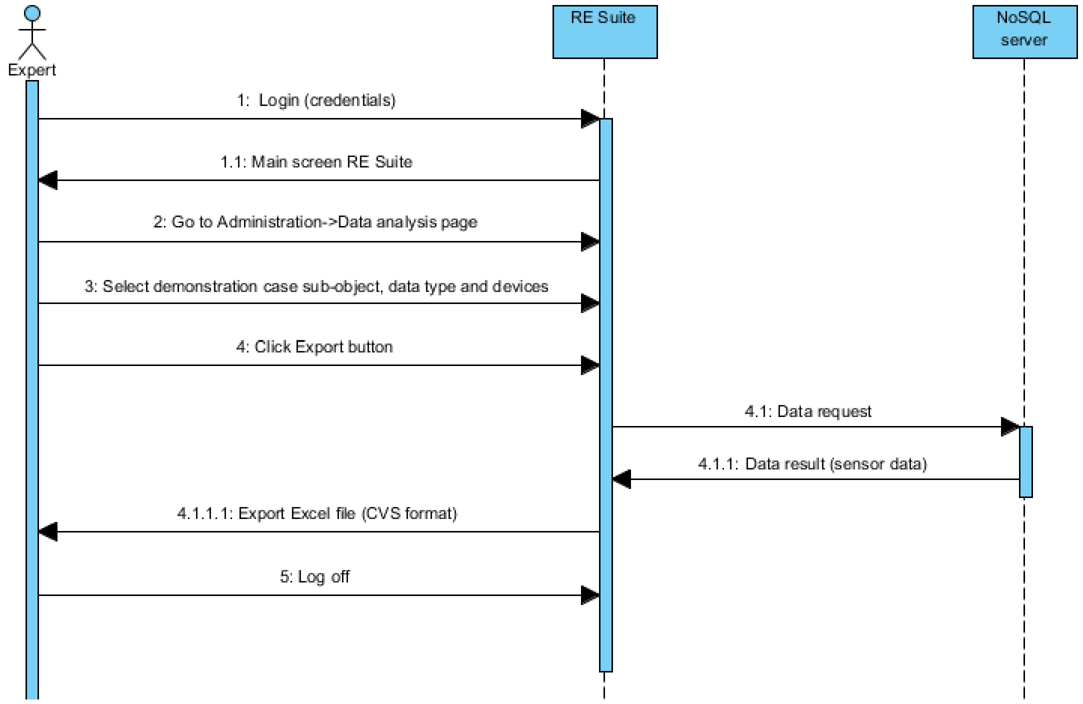

Fig. 24 – UML user diagram to export data

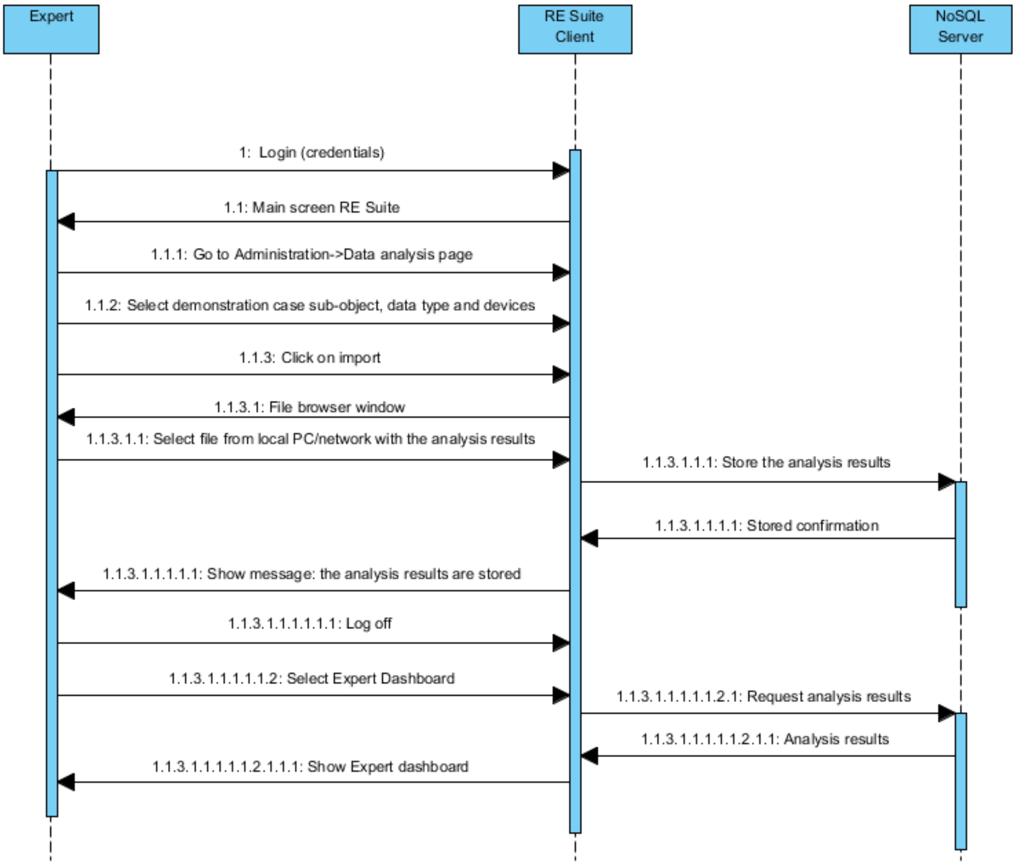

Fig. 25 – UML user diagram to import data

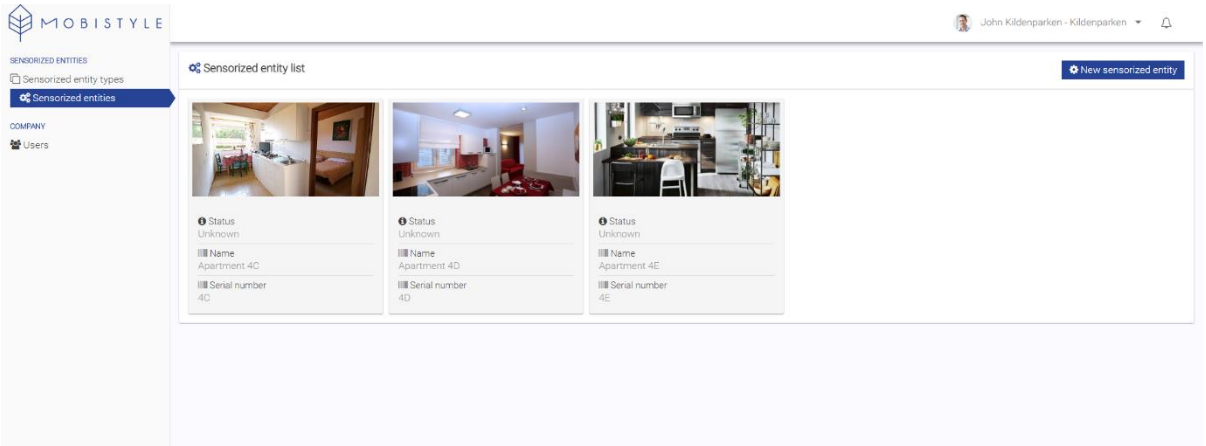

Fig. 26 – Sensorized entities for user

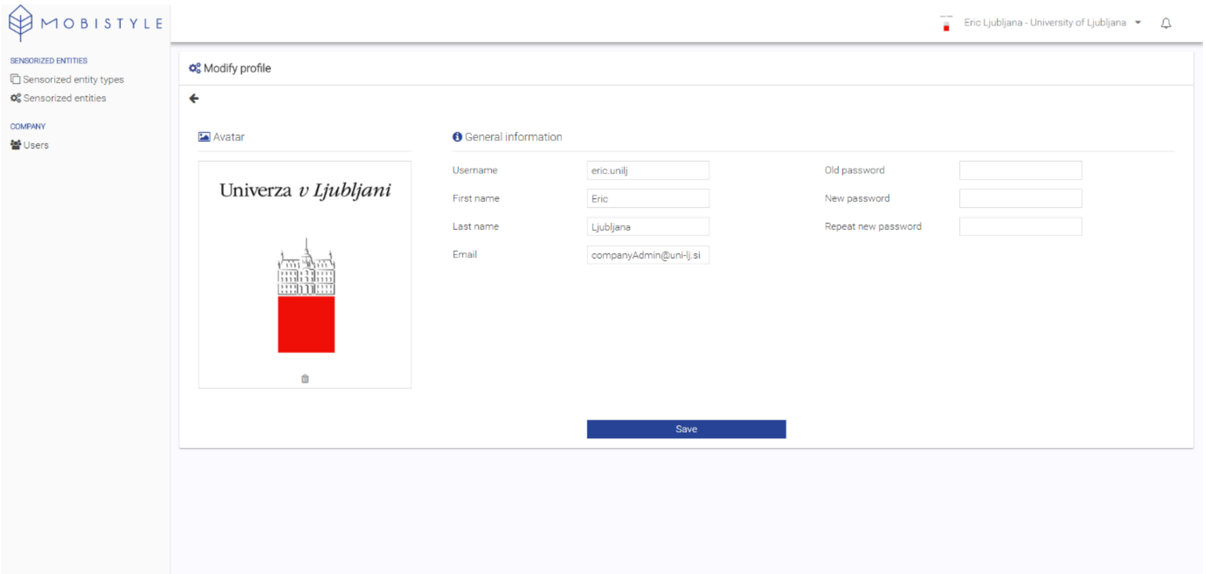

Fig. 27 - User profile

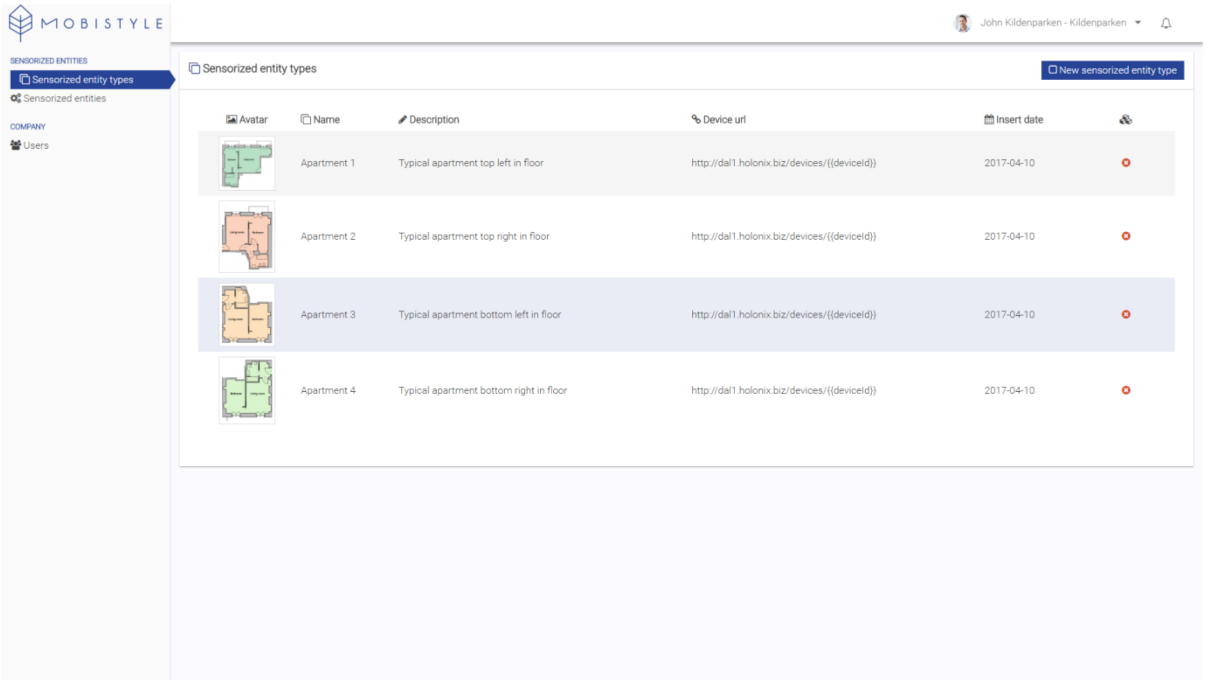

Fig. 28 - Example of sensorized entity types for Kildeparken apartments

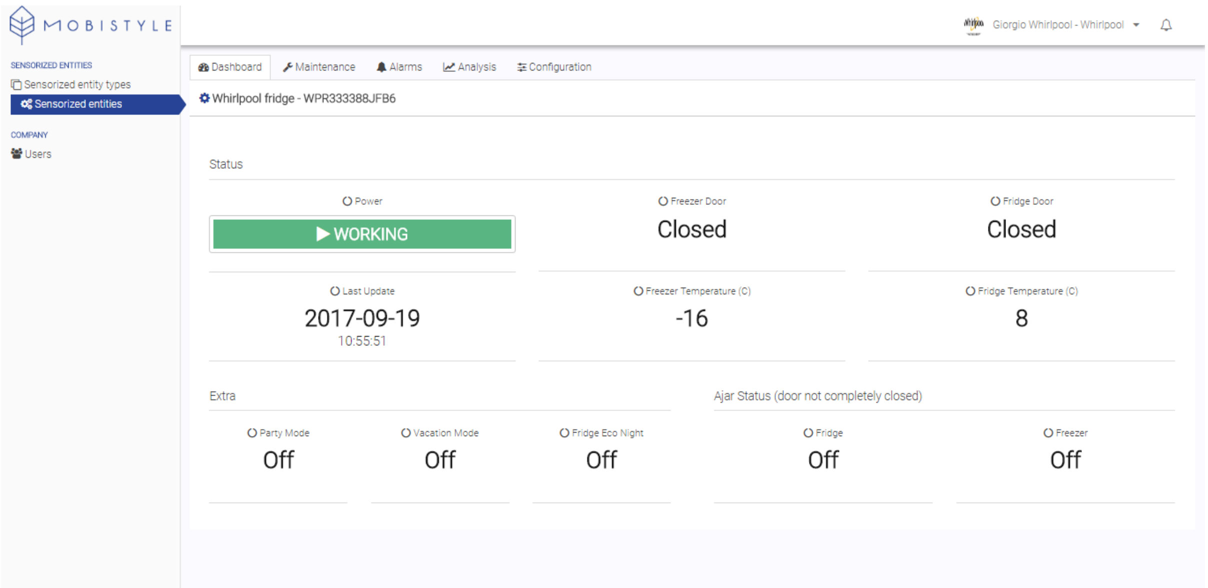

Fig. 29 - Example of real-time dashboard for sensorized entity serial number WPR333388JFB6 (as per D5.1 by Holonix due to 30/09/2017)

5. Further development and interfaces

Chapter 5 represents the starting point for the preparation of the upcoming deliverable D4.1 (M24) regarding applicable hardware and software solution for sensing technologies. This deliverable will be focused on developing sensing technologies and monitoring of user behavior. According to the KPIs defined in WP3 and the output of the investigation of the demonstration cases in WP6, specific sensors to answer MOBISTYLE's needs will be installed in the building together with the choice of which smart appliances to use and which wearable. In this occasion (D4.1) will be also describe how the sensors will communicate with the MOBISTYLE platform and in particular the configuration of RE Service and the gateway.

Information shared in this section of the report D4.2 are an implementation of what explained in deliverable D2.1 – Inventory of supplied data that gives an overview of measuring equipment available on the market where sensors' technologies are analyzed and evaluated against several performance factors such as usefulness of the parameter that the sensor monitors, cost effectiveness, measuring range, accuracy, response time, type of communication of the devices, resolution, applicability, availability.

In this deliverable D4.2, the first part of chapter 5 will recall and implement information regarding the classification of the sensors (chapter 5.1), while in the second part (5.2) a description of different sensor hardware available on the market is presented. This is done to facilitate WP6 in the choice of the sensors to be installed in the demonstration cases for the monitoring phase.

5.1. Sensors classification

In order to reach the desired final result of the MOBISTYLE project, various types of measurements need to be performed by the sensor networks that are to be installed in buildings. This section will first choose the kind of data to be collected within three categories (building energy performance, indoor environmental quality and building occupants). After that, some characteristics on which to compare sensor devices are defined.

5.1.1. Sensor categories

Ahmad et al. (2016) describes two sensor categories that correspond with the aims of the MOBISTYLE project: building energy performance and the indoor environmental quality [11]. Moreover, MOBISTYLE aims to measure health and body parameters of the building occupants. The following sections describe these three categories and their different measurable parameters.

- Sensors for Building Energy Performance;
- Sensors for Indoor Environmental Quality;
- Sensors for Building Occupants.

Sensors for Building Energy Performance

The energy usage of a building can be measured by monitoring the flow of several elements into the building. Fugate et al. (2011) state that the following sources should be monitored [12]:

- electricity meters;

- natural gas meters;
- domestic water usage.

Energy usage can be monitored on various levels, such as building or apartment level, room level and plug level. These levels offer an increasing amount of detail about the source of the energy consumption. Building level offers no such information; it only monitors the total consumption of the building. By installing more sensors or meters closer to appliances, it will be possible to identify the source of high energy usage.

About gas usage, it is most commonly measured by the gas meter of a building, which keeps track of the total gas usage of that building. Unlike electricity usage, it is not feasible to measure the usage at different points inside the building, although, modern smart thermostats may provide useful data related to the running time of central heating systems.

Sensors for Indoor Environmental Quality

The quality of the indoor (thermal) environment can be measured considering the following basic parameters [13]:

- air temperature;
- air velocity;
- air humidity;
- air quality.

The air temperature is an important factor when evaluating topics like the comfort of the users of the building, the performance of the heating / cooling systems and the quality of the insulation. Air temperature will vary throughout a building, one sensor would not be sufficient. It would be wise to measure the temperature in various places, on each floor or in each room.

When measuring the air velocity, ISO 7730 states that both the mean air velocity and the standard deviation should be considered [14]. The mean air velocity provides information about the ventilation and heat transfer on the body. A high standard deviation in the air velocity can help to identify drafts, which can cause a human response to discomfort.

A third parameter to consider is the air humidity. This is often measured in terms of relative humidity, the ratio of the prevailing amount of water vapor to the saturated amount of water vapor in the air [13]. A high relative humidity can be, at certain temperatures, the cause of discomfort due to the inhalation of humid and warm air and high skin humidity [15].

Aside from these physical parameters, also subjective parameters can be considered, for example, clothing and metabolic rate. These two parameters show a lot about the perceived comfort of building users, but cannot be easily measured by typical sensors. In order to evaluate these parameters, they either have to be estimated based on existing models or assessed by the person itself.

Sensors for Building Occupants

Monitoring the health of an occupant is drastically different from measuring the parameters stated previously, as this cannot be measured with a static sensor in the building. Health tracking has to be done on a device (almost) directly attached to the body, such as smartphones and other small wearables. Currently, wearable technology is still relatively new and has limited functionality. Common features found on these devices are:

- heart rate sensors;
- step counter;
- activity level;
- sleep analysis.

It would not be feasible to let occupants wear multiple wearables during the day, and sometimes night, in order to measure all these parameters. Because of this, it is important to use one or maybe two wearables that can cover as many of these parameters as possible.

5.1.2. Sensor characteristics

In order to choose the most suitable sensor hardware, several characteristics which can be used to compare available solutions have been defined [11, 13]. These are the following:

- accuracy;
- range;
- communication protocol;
- cost;
- availability.

Accuracy and range give information about the specifications of the sensing technology used, for example, a temperature sensor accuracy of ±0.1°C and a range of -100°C to 500°C and a power usage meter with an accuracy of ±0.001 kWh.

To allow the software platform to connect to the hardware, it needs to have public software or network APIs for the platform to hook into. If the device has no such interface, it cannot be accessed by the platform and would, therefore, be unusable. Examples of popular types of connectivity are: RESTful API (on local network or cloud-based), MQTT and Bluetooth.

According to the aims of the MOBISTYLE project, the sensors to be installed should be non-intrusive and low-cost. Therefore, it is essential to keep the cost of a sensor in mind. Sensor costs can be split up into two categories: equipment cost and maintenance cost [11]. Deciding whether the initial price is justified often depends on the amount of functionality available; a single device containing many different sensors would be more suitable than multiple single-sensor devices. The installation cost can vary depending on several factors. A wired device requires more work to install compared to wireless devices. Also, the installation of new `smart' energy or gas ow meters is more expensive than devices that can monitor existing meters.

5.2. Sensor hardware

Based on the classification of parameters and sensor characteristics in the previous section, it is now possible to compare various smart devices which are to be used in the proof of concept. The selected hardware should come from a variety of vendors with different data access protocols or data models in order to prove the flexibility of the system. Equipment cost should be kept as low as possible by, for example, selecting devices that can measure multiple parameters.

In the following sections, several devices and technologies that can be used to measure building energy performance, indoor environmental quality or building occupants will be presented. For each category, one device will be selected. This device will be the most suitable to use during the validation process.

5.2.1. Building Energy Performance

Optical Pulse Sensor

The first type of energy metering, on building level, has to be done on or around the main energy meter of the building. Many older energy meters are equipped with an LED light that ashes a certain amount of times for each kWh of energy used, often around 2000 times. These ashes can be detected by an optical pulse sensor attached to the energy meter. This device can convert a number of registered ashes to a certain amount of energy consumed (kWh). This solution offers an easy way to monitor a wide range of energy meters installed throughout Europe without modifying the actual meter itself. Gas meters often do not have such a light installed, so this sensor cannot be applied to gas usage monitoring.

Smart Meter

Most European countries are in the process of installing `smart meters' to automatically gather energy and gas consumption in order to improve the billing process.

Current Transformer

Another approach, which can be implemented in many buildings worldwide, uses a current transformer (CT) sensor. Based on the intensity of the magnetic field created by a single AC wire, this sensor can determine the current owing through it. The CT sensor, however, is only able to measure the total power (watts) being used at a specific point in time. This means that a total usage in kWh is hard to calculate and can only be estimated. This is not necessarily a bad thing, by observing the change in amount of watts used over time it is still possible to determine factors like peak and valleys caused by using appliances that consume a lot of power. A CT sensor can easily be clipped onto a wire, it does not need to be secured in any other way, nor does it require any change to the existing installation. These sensors are sold for approximately €15 for the 30A model, and while adding a small micro controller to connect it would increase the overall cost slightly, it is still an affordable solution.

Smart Plug

In order to get more detailed information about the source of energy consumption, it is possible to use a smart plug. These plugs are connected to the building's Wi-Fi network and support switching the power on or off and viewing data like voltage, current, and total energy consumption. There is a limited amount of vendors creating these plugs (TP-Link, D-Link, Belkin), but they are available throughout Europe. Each smart plug costs approximately €40 to €50, which means that installing these in every socket in a building can become quite expensive.

Device	Accuracy	Range	Update Freq.	Output	Energy	Gas	Availability
Optical Pulse Sensor	±0.5 – 2 Wh	N/A	0.5 – 2 m/s	Pulse count	Y	Y	Global
Smart meter DSMR	±1 Wh	N/A	10 s	kWh/m^3	Y	Y	Netherlands
CT Sensor	N/A	5/30/200 A	Near instant	W	Y	N	Global
TP-Link Smart Plug	N/A	15 A	N/A	A and V	Y	N	Global

Tab. 2 – Summary of Building Energy Performance measurement hardware

The findings above (see table #) show that there are devices available to measure power consumption at different levels. In the proof of concept setup, it will not be possible to have a regular energy meter available. Because of this, it is not possible to use the optical sensor or extract data from a smart meter. So, the options available are the CT sensor and smart plugs. The CT sensor is cheap and easy to install by clipping it onto an AC wire, whereas the smart plugs are more expensive but still easy to install. To keep the equipment costs of the proof of concept as low as possible, a CT sensor will be attached to a power strip. This provides a cheap and portable solution which makes demonstration easy.

5.2.2. Indoor Environmental Quality

Netatmo Weather Station

Contrary to what the name might suggest, this weather station has an indoor module that monitors the temperature, humidity, air quality, CO_2 level and sound level. It is also possible to connect multiple indoor modules to monitor in several places throughout the building. The device offers a RESTful API to retrieve the latest measurements. The basic version with an indoor and outdoor module is available for €169 and it is easy to install.

Sensorist

The Danish company Sensorist offers a solution where several wireless battery-powered sensors can connect to a base station. Available sensors can measure temperature, humidity, and CO_2 levels. These sensors can be installed both inside and outside and can also be accessed via a RESTful API. A basic version with just temperature and humidity sensors costs €185 and a CO_2 probe is an additional €262.

INAP Sensor

One of DEMO's partner companies in Slovenia is currently developing and producing a portable device containing various sensors usable for IEQ monitoring. The latest prototype has sensors for temperature, humidity, pressure, air quality, sound and light (color) levels. It can be powered by either a battery pack or wall plug. It can be installed in various different locations, both inside and outside with little effort. Because the product is still in the prototyping stage, some details about the product are still unavailable. INAP is aiming for a price of around €100, but this is subject to change. INAP will be adding an API to access data to the device, but details about this are currently not available either.

Qivivo Smart Thermostat

Another available solution for monitoring the indoor environmental quality is the Smart Thermostat. New Smart Thermostats available on the market today, like the Qivivo Smart Thermostat (or NEST Thermostat) are equipped with temperature and humidity sensors. These sensors are mainly used to regulate the heating and cooling systems installed in buildings, but this data is often also available for third-party developers to use. The Qivivo thermostat is available for €150 but needs to be installed properly by a professional which will increase the price. After installation, the thermostat and sensor data is available in various apps and via a RESTful API online. Because this thermostat controls the heating and cooling systems from a central point in the building, it is not possible to add additional sensors to monitor other rooms.

Fibaro (Z-Wave)

The Fibaro ecosystem is a home automation platform that is able to connect to various sensors using the Z-Wave wireless protocol architecture. Z-Wave allows for reliable transmission of short data messages on the 868 MHz radio band (in Europe) [16]. Currently, there is a wide range of sensors, actors, and gateways available for the Fibaro system, such as motion sensors, door sensors, smoke sensors and a universal binary sensor to which any binary or DS18B20 temperature sensor can be connected [17]. The Fibaro platform offers a RESTful API, but its main function is to control actors connected to the system. Because of this, retrieving indoor environmental quality sensor data only seems to be possible for temperature sensors. A starter kit, including the Fibaro gateway, starts at approximately €260. A full setup is quite expensive since each sensor costs approximately €30-60.

Custom Hardware

In recent years, small sensors and microcontrollers with Wi-Fi or mobile connectivity have become available for purchase at affordable prices. This has allowed many people to build their own sensor networks easily, without relying on products like the ones mentioned above. Building custom hardware allows full control over things such as used sensors, communication protocols, power supply and measuring frequency. It is important to note that, while the hardware can be obtained at a low price, a lot of work and investments still need to be put into designing software, printed circuit boards (PCB) and cases before they can be used in a production environment.

Device	Temperature	Humidity	Air velocity	Air quality	Sound	Protocol	Price	Update Frequency
Netatmo	Y	Y	Y	CO_2	Y	REST	€150	5m
Sensorist	Y	Y	N	CO_2	N	REST	€450	15m

INAP Sensor	Y	Y	N	CO_2	Y	N/A	€100	N/A
Qivivo	Y	Y	N	N	N	REST	€150+	N/A
Fibaro	Y	Y	Y	CO_2	Y	REST	€450+	N/A
Custom	?	?	?	?	?	?	Low	Fast

Tab. 3 – Summary of Indoor Environmental Quality measurement hardware

Internet connected equipment to monitor the indoor environmental quality in residential buildings is only offered by a small amount of vendors, which provides a limited amount of options that fit this research's needs. As an alternative to the readily available devices, many of the sensors used can be obtained for a low price to allow for the development of a custom hardware solution (see table 2).

Both Netatmo and Sensorist currently offer the right products to measure the indoor environmental quality. They have a variety of sensors available and offer an online RESTful interface to access data. Building custom hardware requires a lot of development time and investments while giving full control over the specifications in return. This investment seems unnecessary when other vendors offer ready-made solutions that suit this research's needs. When comparing Netatmo's product to the Sensorist solution, it is clear that the first offers a wider variety of sensors at a significantly lower price. Because of this, the Netatmo system will be connected to the proof of concept for demonstration.

5.2.3. Building Occupants

Zen Watch 3

One of the best and affordable (€250) smartwatches based on the Android Wear platform is currently the Zen Watch 3 by Asus (Faulkner, 2017). Primarily, this device functions as a watch with features such as notification viewing, making phone calls and various other speech commands. Because this device runs on the Android Wear software developed by Google and has an accelerometer, it is able to connect to the Google Fit service. This service analyzes data from the accelerometer and location history in order to determine step count and body activity (walking, running, working out). Additional applications can be installed to track sleep cycles and food consumption [18].

Apple Watch

As a response to the popularity of smart watches and Google taking over this market, Apple has made their own smart watch called the Apple Watch [19]. These watches are equipped with the same features as Android Wear, but they come with a heart rate sensor in every model. Unlike the ZenWatch, these watches are only compatible with other Apple devices. The cheapest model Apple Watch starts at €340 and can go up to €1500 for the luxury models made from more expensive materials. Fitness and health data can be retrieved with the HealthKit API offered by Apple via an app installed on the watch. There is no web-based API offered by Apple because fitness data is only stored on the watch itself.

Fitbit AltaHR

The American company Fitbit offers a wide range of wearable fitness bands or activity trackers, which are primarily focused on measuring the user's body activity throughout the day and night [20]. These bands come with a variety of features like step/calorie/distance counting, sleep tracking, continuous heart rate tracking and exercise recognition. New models even have displays to show stats, the current time and phone notifications, making the device function a lot like a smart watch. These bands are often a lot cheaper than available smart watches, with the latest Fitbit model costing €150. Measurements done by the Fitbit bands are available via an online RESTful API for third-party applications to use.

MOX Activity Monitor

A company originating from one of the partners in the MOBISTYLE consortium, Maastricht Instruments has developed a smart activity monitoring device [21]. It is claimed to be a comfortable and reliable wearable that is able to measure movement during daily activities. The two available models either allow for a Bluetooth or USB connection in order to extract data. The output data can either be the number of activities per minute or raw data which can be analyzed later on. The MOX Activity Monitor is not yet available for public sale, only for research and demonstration purposes.

Device	Steps	Activity	Heart rate	Sleep	Price	Platform	Protocol	Availability
Zen Watch 3	Y	Y	Y	Y	€250	Android iOS	REST	Global
Apple Watch	Y	Y	N	Y	€340+	Android iOS	On Device	Global
FitBit AltaHR	Y	Y	N	Y	€150	Android iOS	REST	Global
MOX Activity Monitor	Y	Y	N	N	N/A	Any	Bluetooth/USB	Not for sale

Tab. 4 – Summary of Building Occupant measurement hardware

Because of the recent surge in popularity of wearable devices, researches recently performed show that almost 50% of their interviewed users own one or more wearable devices [22]. People use these devices to measure their daily activity level and other health-related parameters, as these devices make such measurements incredibly easy. Most of these devices are either smartwatches or fitness bands, which contain various sensors measuring body parameters.

Other, more medical, equipment could also measure these parameters, but they often do not satisfy the MOBISTYLE requirement of being low cost and non-intrusive. For example, a classic blood pressure monitor is too obtrusive to be worn all day by a user. A wearable device can also function as a watch, glasses or even clothing so that they do not interfere with daily activities and can be useful in many other ways (see table 3).

Fitness bands like the Fitbit AltaHR offer a complete solution for measuring various body parameters. Smart watches available on the market can provide the same functionality, but sometimes require additional apps to be installed. Moreover, they start at a significantly higher price than Fitbit's latest band. Because of this, and the availability of an easy to access RESTful API on the Fitbit devices, the AltaHR will be used in the proof of concept for the presented research.

6. Conclusion

Deliverable D4.2 aims to clarify and support the platform architecture idea.

The MOBISTYLE platform is the combination of two existing software application platforms developed by two partners of the consortium, RE Suite by DEMO Consultants and I-Like by Holonix. Thanks to the combination and connection of these two software application platforms it will be possible to store raw data collected from the sensors – in RE Suite database – and the profile data – in I-Like database. Through RE Suite it will be possible to store, process and visualize data. The experts will interface with this platform in order to get all the data needed to run the technical calculation about energy, comfort, and health. End users will connect, through a login function, to the I-Like platform to visualize processed data and KPI values. Hence, I-Like will be responsible for the interaction of the MOBISTYLE system with the end user for providing feedback to users. The i-Like platform will be also the connection to the open application platform for the realization of serious gaming applications, another way to provide feedback to users.

Moreover, when necessary for the experts and when the BIM model of the building is available, RE Suite – as part of the MOBISTYLE platform- can facilitate the extraction of information from BIM as input for the expert for the technical analysis.

To support this system functional, technical and interoperability requirements of the platform have been defined. With the architecture and the development plan described in this deliverable, the integration and interoperability between different types of software tools are possible, connecting data coming from different sensors. As shown in the diagram of the architecture of the MOBISTYLE system, the platform satisfies interoperability requirements being able to connect to tools for measuring, assessing, monitoring and simulating of building condition, energy performance, and user behavior.

Another point that can be considered for the future development of the MOBISTYLE platform is its characteristic of being extensible. Currently, the system is meant to be flexible, scalable, user-friendly and configurable. The concept of extensibility of a platform refers to the possibility to measure the ability to extend a system and the level of effort required to implement the extension. An extensible system is the one whose internal structure and data flow are minimally or not at all affected by new or modified functionality. This can be an interesting feature for the future development of the platform so that it would be possible to add new functionality or modify the existing functionality minimizing the impact to the existing system functions.

After M12 the research activity will continue making the database available to start the monitoring phase in October. In the meantime the preparation for the first deliverable D4.1 will start. Sensors will be chosen for each demonstration case as well as how the sensors will be connected to the platform for data storing will be further designed and implemented.

References

[1] D. Clements-Croome. Creating the Productive Workplace, E&FN Spon, Taylor &Francis Group, London/New York, 2nd edition, 2006.

[2] L. Jagemar and D. Olsson. The EPBD and Continuous Commissioning. CIT Energy Management AB. Göteborg, October 2007.

[3] http://dictionary.cambridge.org/dictionary/english/

[4] H. Sundmaeker, P. Guillemin, P. Friess, S. Woelfflé. Vision and challenges for realising the internet of things. (2010) Cluster of European Research Projects on the Internet of Things, European Commision.

[5] https://www.forbes.com/sites/jacobmorgan/2014/05/13/simple-explanation-internet-things-that-anyone-can-understand/#c58b0331d091

[6] T. Pflanzner, A. Kertesz, A survey of IoT cloud providers. (2016) 39th International Convention on Information and Communication Technology, Electronics and Microelectronics (MIPRO), Croatian Society for Information and Communication Technology, Electronics and Microelectronics – MIPRO, pp. 730-735.

[7] https://azure.microsoft.com/en-us/

[8] https://cloud.google.com/

[9] Enginency, A Holistic System for Building Inspection and Energy Efficiency Management, Project Number 720661, Call H2020-FTIPilot-2015-1, Grant Agreement No. 720661

[10] https://www.webeasy.nl/, within the project TKI TRECO-office: toward Real Energy performance and COntrol by predicting, monitoring, comparing and controlling for Offices and Public Buildings,

[11] M. W. Ahmad, M. Mourshed, D. Mundow, M. Sisinni, Y. Rezgui, Building energy metering and environmental monitoring – A state-of-art review and directions for future research. (2016) Energy and Buildings, vol. 120, pp.85-102

[12] D. Fugate, P. Fuhr, T. Kuruganti, Instrumentation systems for commercial building energy efficiency. (2011) Future of Instrumentation International Workshop (FIIW), pp. 21-24

[13] K. Parsons, Human Thermal Environments: The Effects of Hot, Moderate, and Cold Environments on Human Health, Comfort, and Performance. CRC Press, Taylor & Francis Group, Boca Raton, 3rd edition, 2002

[14] ISO 7730:2005, Ergonomics of the thermal environment -- Analytical determination and interpretation of thermal comfort using calculation of the PMV and PPD indices and local thermal comfort criteria. International Organization for Standardization

[15] J. Toftum, A. S. Jørgensen, P. O. Fanger, Upper limits of air humidity for preventing warm respiratory discomfort. (1998) Energy and Buildings, vol.28, n.1, pp. 15-23

[16] C. Gomez, J. Paradells, Wireless home automation networks: A survey of architectures and technologies. (2010), IEEE Communications magazine, vol. 48, n. 6, pp. 92-101

[17] Fibaro (2017), Fibaro binary sensors, http://manuals.fibaro.com/binary-sensor/, accessed 2017-07-26

[18] Asus (2017), Asus ZenWatch 3 (WI503Q), https://www.asus.com/ZenWatch/ASUS-ZenWatch-3-WI503Q/, accessed 2017-07-26

[19] Apple (2017), Apple Watch Series 2, https://www.apple.com/apple-watch-series-2/, accessed 2017-07-26

[20] Fitbit (2017), Fitbit Alta HR, https://www.fitbit.com/altahr, accessed 2017-07-26

[21] Maastricht Instruments (2015), Mox physical activity monitor, http://www.maastrichtinstruments.nl/portfolio/mox-physical-activity-monitor/, accessed 2017-07-26

[22] Business Insider (2016), Wearable devices can become more popular if they solve this one problem, http://www.businessinsider.com/wearable-devices-can-become-more-popular-if-they-solve-this-one-problem-2016-5?international=true&r=US&IR=T, accessed 2017-07-26

[23] C. Lubbers (2017), Design a software platform for the collection and storage of smart-sensor data in buildings, Technische Informatica Rotterdam University of Applied Sciences, supervisor Dr. Rizal Sebastian at DEMO Consultants BV (Delft, The Netherlands), graduation assignment, June 2017