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WP5 - Cost-effective and User-Friendly Services for Building Users and Occupants

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D5.1 Services for building's occupants

1.0

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Abstract:

This document presents the energy and non-energy services visualized in an informative and intuitive user dashboard, for the building occupants that participate in the PHOENIX project. At first the Comfort, Convenience and Well-being related services are presented, followed by the Predictive Maintenance and automatic SRI calculation and EPC evaluation methodologies. Finally, the visualization dashboard for the building occupants is presented followed by the most important scenarios in the form of mock-ups representing the different features of the dashboard web app. All different energy and non-energy services make a reference on the social enablers and barriers that are possibly relevant to each case.

Keywords:

Visualization Dashboard, Building Occupant, Non-Energy Services, Energy Services, SRI, EPC, Predictive Maintenance

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Revision History

The following table describes the main changes done in the document since created.

Revision	Date	Description	Author (Organization)
0.1	15/06/2021	ToC draft	Dimitra Georgakaki (Ubitech)
0.2	05/07/2021	Comfort, Convenience and Well-being related services	Kostas Tsatsakis
0.3	09/07/2021	User Information and Dashboard	Dimitra Georgakaki (Ubitech)
0.4	20/07/2021	Predictive maintenance, EPC, SRI	Alfonso Ramallo (UMU)
0.5	22/07/2021	Summary, Introduction, Conclusions	Dimitra Georgakaki (Ubitech)
0.6	30/07/2021	Final version	Dimitra Georgakaki (Ubitech)
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Executive Summary

EU's ambition for reduction of the CO_2 emissions is directly linked to the smart building transformation initiative, the introduction of novel energy and non-energy services addressed to building occupants and energy authorities and the more active participation of all energy related beneficiaries, to smart energy contracts.

The Phoenix Smartness Hub or the Phoenix Platform, that will be used to support such building transformations, establishes a direct connection between the data recorded from a number of IoT sensors and the energy services delivered to the Phoenix main beneficiaries, which in the scope of deliverable 5.1 are the building occupants (owners or tenants) and the building managers.

In more detail, non-energy services related to the comfort, health and well-being of the building occupant are designed at this stage to be further implemented, and integrated in the platform, allowing the end user to optimally control his indoor environment, either manually after receiving appropriate recommendations from the platform or automatically by allowing the platform to perform decisions based on prior information.

On the other hand, the building/facility managers are more interested in the building energy performance, the building smartness indicators, opportunities to replace legacy equipment with smart equipment and any aspects of predictive maintenance regarding to the building equipment. So, services related to predictive maintenance, SRI and EPC evaluation are also designed and integrated into the Phoenix Smartness Hub.

Finally, presenting all the above as well as other user and smart grid related energy services in an informative and easy to use dashboard, is of utmost importance for the success of such smart energy programs, as the active and fruitful user interaction and engagement will continually optimize the whole user-platform system.

Disclaimer

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Acronyms

Abbreviation	Description
DoA	Description of Action
SRI	Smart Readiness Indicator
KPI	Key Performance Indicator
DHW	Domestic Hot Water
IAQ	Internal Air Quality
EPA	Environmental Protection Agency
VOC	Volatile Organic Compound
TLV	Threshold Limit Value
TWA	Time Weighted Average
STEL	Short Term Exposure Limit
JRC	Joint Research Centre
SOTA	State of the Art
DSS	Decision Support System
HVAC	Heating Ventilation Air Condition
EPC	Energy Performance Certificate
HBI	Human Building Interaction
UI	User Interface
ESCOs	Energy Service Company
DR	Demand Response
UC	Use Case
PDM	Predictive Maintenance
MC	Monitoring and Control
PMV	Predicted Mean Vote
PPD	Predicted Percentage Dissatisfied

1. Introduction and Objectives

This deliverable (D5.1) is the first version of the services for building occupants that participate in the Phoenix Smartness Hub. These services are all designed and implemented under the scope of WP5 of the DoA. More specifically section 2 of D5.1 is mapped to task 5.2, comfort, convenience and wellbeing related services, section 3 is mapped to task 5.3, predictive maintenance, and automatic SRI calculation and EPC evaluation and finally section 4 corresponds to task 5.1, user information and dashboard. Each of the respective sections follows a similar structure. First a general introduction is given followed by a state-of-the-art analysis that explains the current status of the explained topic. Then the design specifications and requirements (input from deliverable 2.3) regarding each group of services is presented, in a first attempt to analyse the functionality and the provided services from a user perspective.

Starting from the non-energy services of section 2, the following objectives are targeted:

- Development of services centered on maximizing the wellbeing of users and occupants. Consideration of internal environments with respect to health according to thermal, acoustic, visual and other facets.

- A level of personalization is required at the implementation and testing for situations that could affect users and occupant's health such as fuel poverty, overheating or abnormal situations.

The non-energy services are divided into three groups following the SRI categorization: health & wellbeing, convenience and comfort. The comfort service is related to the thermal and visual comfort of the end-user and is subjected to personal preferences of the indoor temperature and luminance. The health and wellbeing service is directly related to the indoor air quality and the luminance profile of the dwelling. Finally, the convenience is related to the smartness and level of automation of the dwelling and is increased as the automated system gets optimized and takes decisions that are in accordance with the occupants' comfort levels. These services described in section 2 are directly related to task 2.3 (and thus D2.3), where the requirements and architecture design have been established, and task 5.2 where the actual implementation of the Comfort, Convenience and Wellbeing Engine is covered. The visualization of the services is presented in the Building Occupants Visualization Dashboard, carried out in task 5.1.

Section 3 describes services relevant more to building managers. The main objectives we are trying to achieve here are:

- Development of predictive maintenance algorithms for building's systems and appliances.

- Implementation of mechanism for EPC evaluation and SRI calculation.

From an SRI perspective, these services are covered under the maintenance and fault prediction domain. The monitoring of selected devices measurements and the early detection of outliers can alert the relevant stakeholders so that they can act promptly when faults are detected. The design of the Predictive Maintenance Engine and the SRI/ EPC Evaluation Engine is covered in task 2.3 (and thus D2.3). The implementation of the engines that will offer the services described in section 3, is covered in task 5.3. The visualization results are shown in the Building Occupants Visualization Dashboard, carried out in task 5.1.

Finally, section 4 presents the Building Occupants Visualization Dashboard, and analyses in the form of mock-ups the main functionalities and how the user interacts with it. The main objective here is:

- Detail study of preferences on Human Building Interaction (HBI). Development of interaction innovation intuitive enough for the elderly, the vulnerable and other special groups.

Once more the design of the dashboard is analytically described in task 2.3 (and thus D2.3) and the implementation is delivered in task 5.1. Finally, the integration of all the above will be carried out at a later step of the Phoenix project, under task 5.4, Integration, Testing and Refinement and the results will be presented at another deliverable of WP5.

2. Comfort, Convenience and Well-being related services

2.1. Introduction

As stated in the DoA the scope of the work in T5.2 is to design added value non-energy services to building occupants as also promoted by the Smart Readiness Indicator specifications. As stated in the architecture document the role of this service bundle is to first enable identification of poor indoor conditions in buildings that may cause comfort or health issues to the building occupants. Furthermore, the component incorporates smart services that will enable either automated control of the building devices to ensure comfort, health and well-being conditions or context based personalized notifications and messages to building occupants related to the comfort and well-being conditions in premises (while keeping the energy usage as low as possible to meet the requirements).

In order to properly design the PHOENIX non-energy services software bundle, there are different steps to be considered:

a) A review of the literature in the field of comfort, convenience and health in building environment also considering the SRI regulation about the provision of non-energy services
b) A review of project requirements with focus on social related requirements analysis as performed in D2.2. Through this analysis, individually defined factors may be extracted to denote the user-driven weighting of importance of the opportunity costs for rescheduling or postponing certain loads' use.

Then, the design of the application will take place in this document, highlighting the key functionalities to be incorporated in the solution at the development phase.

2.2. State of the art analysis

As stated in the introduction, the scope of this section is to provide a brief review of the market and the regulation with focus on the provision of non-energy services. An early analysis was reported in D2.1 while in this document more details about the specific focus topic (non-energy services) is provided.

Starting with the SRI regulation review, there are 3 main impact categories specified as part of the analysis performed under T5.2, namely:

- Comfort: This impact category refers to the impacts of services on occupant's comfort. Comfort refers to conscious and unconscious perception of the physical environment, including **thermal comfort, acoustic comfort** and **visual performance** (e.g., provision of sufficient lighting levels without glare).
- Convenience: This impact category refers to the impacts of services on convenience for occupants, i.e., the extent to which services "make life easier" for the occupant, e.g**. TBS requiring fewer manual interactions.**
- Well-being and health: This impact category refers to the impacts of services on the well-being and health of occupants. For instance, smarter controls can deliver an **improved indoor air quality** compared to traditional controls, thus raising occupants' well-being, with a commensurate impact on their health.

By specifying the key impact criteria to be considered in the analysis, the scope of the review is to define assessment criteria for the evaluation of the non -energy services. The analysis performed in this section is threefold. At first, we specify the assessment criteria defined in SRI. On the other hand, and considering the scope on this domain is rather extended, a non-exhaustive list of comfort, health and convenience KPIs defined in the literature are presented. Again, the analysis is split into two parts: the definition of assessment criteria and indicators related to short term impact (micro - level analysis) and the macro level definition of the impact of smart building technologies. While the focus is about the former (as the overall evaluation is performed to specific demo sites), the long-term impact of smart building technologies in health and well-being is briefly presented in this review.

Starting with SRI analysis, the focus is at the review of the different domains (smart building technologies) towards the selection of services (such as improved indoor air quality control, ability to better manage thermal comfort, maximizing the use of natural daylight while improving lighting regulation) that increase the impact of comfort, convenience and health. The non-exhaustive list of SRI services that have a high impact (level 2-3 at the scale of 0-3 as defined in SRI specifications) on comfort, convenience and health are presented in the following table:

Table 1. Impact criteria of comfort, convenience, and health services

Domain	Service	Comfort	Convenience	Health & wellbeing
Heating/Cooling	Individual room control with occupancy detection	2	3	2
	Control of heating system based on local predictions (e.g., through model predictive control)	3	3	1
	Advanced central automatic control with intermittent operation and/or room temperature feedback control	2	3	2
DHW	Automatic control based on information about context conditions (electricity prices, local generation etc..)	0	2	0
Ventilation	Local Demand Control based on air quality sensors (CO2, VOC, etc..)	3	3	3
	Modulate or bypass heat recovery based on multiple room temperature sensors or predictive control	2	2	2
	H,x- directed control: minimize the amount of mechanical cooling. Calculation is performed based on temperatures and humidity	3	2	1
	Real time monitoring & historical information of IAQ available to occupants + warning about occupant actions (e.g., window opening)	0	0	3
Lighting	Automatic occupancy-based lights control (manual on / dimmed or auto off)	2	2	0
	Automatic dimming including scene-based light control (during time intervals,	3	3	3

	dynamic and adapted lighting scenes are set, for example, in terms of illuminance level, different correlated colour temperature (CCT)			
DE	Predictive blind control (e.g., based on weather forecast)	3	3	3
	Centralized coordination of operable windows, e.g., to control free natural night cooling	2	2	1
Storage	Automated management of (building-level) electricity consumption and supply, with potential to continue limited off-grid operation (island mode)	0	3	0
MC	With central indication of detected faults and alarms for all relevant TBS, including diagnosing functions	0	3	3
	Central or remote reporting of real-time energy use per energy carrier, combining TBS of all main domains in one interface	0	3	0
	Scheduled override of DSM control and reactivation with optimized control	0	3	0

Some key remarks about the list of services as specified in SRI are reported:

- The services related only to convenience (DHW, Storage, MC) are related with energy-services oriented functionalities to be considered by other tools delivered in the project (e.g., self-consumption, flexibility services, predictive maintenance)
- Starting with heating systems, advanced central automatic control with intermittent operation and/or room temperature feedback control or taking into account occupancy presence can contribute to comfort and convenience levels of users.
- The same applies for ventilation systems where the focus is also on IAQ monitoring and impact of outdoor air exchange to indoor air conditions.
- For lighting systems, occupancy-based control or context-based control is defined as an added value in terms of comfort, health and convenience

- Windows opening/closing should be combined with outdoor environmental conditions to address both visual and thermal comfort needs of occupants

From the aforementioned analysis the focus towards the provision of non -energy services should be about smart systems that are associated with visual and thermal comfort needs of occupants (heating/cooling and lighting), considering also smart systems (ventilation control and windows opening/close) that impact also the health conditions in premises.

Along with the review of SRI, the evaluation of the literature about non-energy KPIs that quantify the impact of smart building devices is performed. The analysis starts with comfort related indicators (thermal and visual) that are briefly presented.

Starting with thermal comfort evaluation, ASHRAE Standard 55 is the document that defines the KPIs with focus on PMV and PPD. In addition to these KPIs, adaptive comfort models are incorporated in the standard. At EU level the most recent standard is the EN 16789-1 (which updated the well know EN 15251) where thermal comfort KPIs are defined. We have to point out that relevant KPIs are defined by certification bodies: LEED, WELL etc…. In the context of PHOENIX project, the idea is to incorporate adaptive comfort models at the evaluation of the comfort level of the users.

Considering visual comfort evaluation, it encompasses a variety of aspects, such as aesthetic quality, lighting ambiance and view [1]:

- Light quality
- Luminosity
- Absence of glare

As stated in [2] and the EN 16789-1 standard, specific metrics are related to health aspects, as also highlighted in the SRI methodology. Within the context of PHOENIX project and taking into account the hardware limitations, the focus will be on the KPIs related to the luminosity level and the impact of artificial vs. natural. In addition to comfort related parameters, health related parameters need to be considered in the analysis. Focusing on specific IAQ values that are monitored from smart systems, there is the existing regulation that clearly specifies the calculation methodology and the boundary values. An overview of this information is available in [3].

The threshold values as specified in the EPA regulation for the most common IAQ values monitored in the residential building environment along with the calculation formulas are:

- PM2.5: PM2.5, in particular, are particles which are 2.5 μm or less in diameter. Their threshold limit value is **25 μg/m3, based on 24-hour data**.

- CO_2: Human health effects can be observed at levels over 7,000 ppm. Therefore, the occupational limits set are 5,000 ppm TLV-TWA* and 30,000 ppm TLV-STEL**.
- NO_2: Due to the adverse effects associated with nitrogen dioxide (NO_2), the EPA strengthened its health guidelines and set a 1-hour standard at the level of 100 ppb.
- tVOC: As it combines the values from different VOCs. Note that its threshold limit value is 0.1 ppm TLV-TWA* and 0.3 ppm TLV-STEL**.

*TLV-TWA: Threshold Limit Value - Time Weighted Average (usually 8 hours)
**TLV-STEL: Threshold Limit Value - Short Term Exposure Limit (usually 15 minutes)

Related to health issues and IAQ conditions, there is a high reference in the COVID-19 era. This is clearly depicted also in EU reporting where there is a clear linkage of air quality conditions with COVID-19 [4]. Also, all major health bodies define IAQ related measures and processes in order to reduce the potential for airborne transmission of COVID-19 in building environment [5-9].

In [10] the positive connection between air pollutants (PM2.5 and NO_2) and COVID-19 contagion urges to level the air quality index. From the viewpoint of engineering controls, ventilation can help dilute contaminants and reduce infection risk. As suggested, air should not be recirculated, and thus hygiene ventilation can be done using 100% fresh air with efficient energy consumption for sustainability [11]. Even at commercial level, there are solutions that combine metrics from sensors in order to identify the risk of potential for airborne transmission of COVID-19 [12-14].

It is evident from aforementioned analysis that employing preventive measures to mitigate air pollution can reduce exposure rate of COVID-19 and thus the design of non-energy services should target also this new situation. Along with the definition of the KPIs, there is a need to link of the KPIs with control actions to be delivered in ventilation systems (for non-residential buildings). In [15], a presentation of these control strategies is provided.

Considering long term impact there exist some literature that estimates the impact of smart building systems and services in non-energy related aspects. While this long-term impact analysis is out of the scope of PHOENIX project, the review of the work is provided as reference. JRC [16] reports1 a synthesis of co-benefit impacts from many studies but the most significant is the so-called COMBI study [17] (Calculating and

[1] *https://publications.jrc.ec.europa.eu/repository/handle/JRC120683*

Operationalising the Multiple Benefits of Energy Efficiency in Europe2), which compiled an assessment of health and wellbeing impacts from all 28 EU countries and derived monetized benefits for: asthma (DALY), excess winter mortality, indoor air pollution, mortality - ozone, mortality -PM2.5, reduced congestion amongst others. The JRC study compiles and synthesizes the data on the impacts and monetised values of the following:

- reduced winter mortality attributable to lower ozone and PM2.5
- reduced winter morbidity attributable to lower indoor air pollution (units of 1000 YOLL), lower asthma (units of DALY), lower PM2.5 (units of YOLL)
- reduced diseases arising from thermal discomfort
- learning and productivity benefits due to better concentration, savings/higher productivity due to avoided "sick building syndrome" whose value can then be assessed in terms of active days gained (indoor exposure) and workforce performance (mn workdays).

As an illustration of the type of impacts that are reported, in the next figure we show the probability of negative health issues across the EU-28.

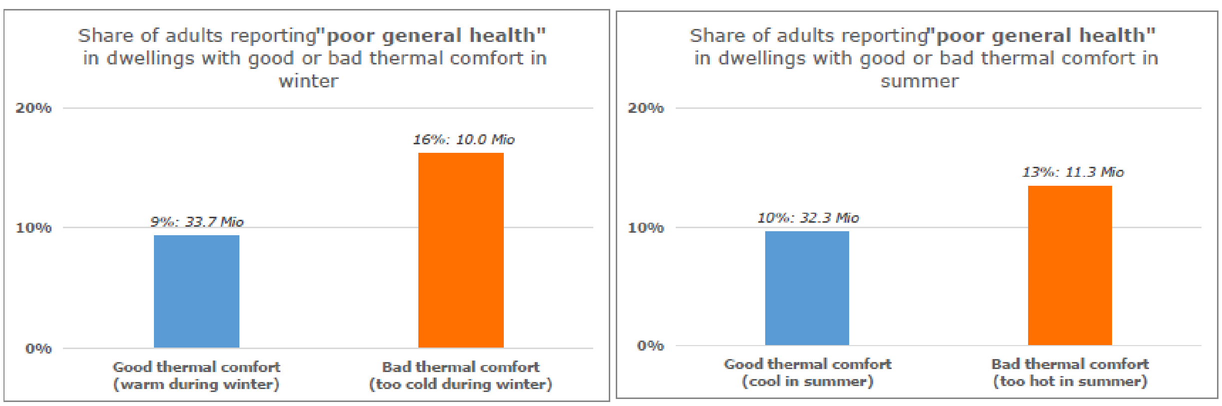


Figure 1. The probability of negative health issues across the EU-28.

Overall, around 22 million Europeans (ca. 4.4%) suffer from bad thermal comfort in winter or summer that impact the general health conditions.

Furthermore, a survey from 2015 and 2016 [18] examined several characteristics of a healthy home and the importance for healthy living. In this context, participants were asked to score health categories from 1 to 7 (1 being "not important" and 7 being "very important"). The results of this survey indicate:

- sleeping well received a score of 6.4

[2] *https://combi-project.eu/benefits/*

- ventilation for fresh air scored 6.1
- plenty of daylight received a score of 5.9.

In this context, smart building technologies can help occupants to achieve the characteristics of healthy homes, by increasing the level of controllability/automatization with the use of indoor environmental quality sensors (to regulate temperature, humidity, ventilation, lighting and CO2) and maintain healthy indoor climate conditions and thermal comfort level.

2.3. Requirements overview based on social barriers and enablers

The scope of this section is to briefly present the list of business and social requirements that are associated with the design and provision of non-energy services in PHOENIX project. This list of requirements (individually defined factors to denote the user-driven weighting of importance for rescheduling or postponing certain loads' use) together with the state-of-the-art analysis as reported above will pave the way for the design of the component in the following section.

From a business viewpoint as reported in D2.1, the requirements remain at a high level, presented in the following table:

Table 2. User requirements regarding comfort, health and well-being

Req_ID	Description
1	PHOENIX may provide to building occupants the option for scheduling the operation of devices
2	PHOENIX may provide to building occupants the option for semi automation - automation with user interaction
3	PHOENIX should provide to building occupants the option to override automated control actions
4	PHOENIX should provide to building occupants updates of energy and environmental information in real time
5	PHOENIX should provide to building occupants updates of energy and environmental information at daily level
6	PHOENIX should provide to building occupants updates of energy and environmental information at week level
7	PHOENIX should provide to building occupants updates of energy and environmental information at month level

8	PHOENIX should provide services to building occupants to ensure comfort preservation
9	PHOENIX should provide services to building occupants to promote the establishment of a health environment
10	PHOENIX should provide services to building occupants to promote the establishment of a convenient environment
11	PHOENIX should provide to building occupants information about IAQ conditions in premises

Therefore, the focus on the analysis is at the review of social enablers and barriers in D2.2 in order to introduce design requirements for the implementation. A non-exhaustive list of requirements is derived from this social analysis:

- Lack of knowledge of how to use smart building equipment is a key barrier for demonstration of the different service types. The age and computer literacy level are dominant parameters affecting the knowledge about the different systems and thus the provision of services should take into account this parameter
- Convenience is an important enabler for the majority of participants, who value the simplification of procedures and actions offered by smart building technology highly. Those with higher incomes and those between 16-50 years old are much more appreciative of the convenience smart technology offers
- Privacy is considered an important barrier for over 60% of respondents, signifying that well planned resourcing is needed to reinforce consumers' trust and that information flows need to maintain a certain level of consents. Particularly people aged between 16-50 appear to be more concerned about their privacy being compromised than those aged over 50
- Indoor comfort is a strong enabler for building upgrade for the majority of building occupants. Priority on comfort rather any other type of service
- Equipment's usefulness tends to be a very important enabler, mostly for the users. The type of equipment used affects the perception about the different services. Particularly the active work force of society perceives usefulness as a very important enabler
- Reliability is a strong enabler, especially for the non-users, whereas smart technology is considered unreliable by the 40% of the users. Hence, it is mandatory for the service to be reliable
- Time savings is an important enabler for the active work force group, aged between 16-50, mandating for the provision of convenience services
- The improvement of life's quality tends to be a very important enabler for the majority of building occupants especially in the COVID era. People over 50 are not as appreciative of the quality-of-life

aspects as those between 16-50, which is natural considering the latter value apart from health, other quality of life dimensions like mental and social well-being and comfort.

- Concept knowledge & understanding: Service control is a very important factor for building's smartification only for the users. The users should always have an understanding about the actions to be performed by a service. Those with low computer literacy level and people aged over 50 have more difficulty in grasping the concept of smart technology and its workings, as opposed to those aged between 16-50 years' old.
- Tendency to try new products Strong enabler for new smart technologies for users and neutral for non-users; the provision of appealing services is an added value feature of any new service. Amongst people who tend to change their lifestyles to try new products, there is a share of respondents who identify themselves as early adopters of smart technology, willing to take the opportunity and first bring the innovation to the market. This group of people, who are mostly those of higher income or with some sort of professional affinity to smart technology, are willing to enjoy more sophisticated services.

By taking into account this list of factors, the design principles of the PHOENIX Non-Energy Services Engine are presented in the following section.

2.4. Non-Energy Services Engine Design Specifications

A high-level presentation of the Non-Energy Services Engine was presented in D2.3 specifying the list of features to be supported by the tool.

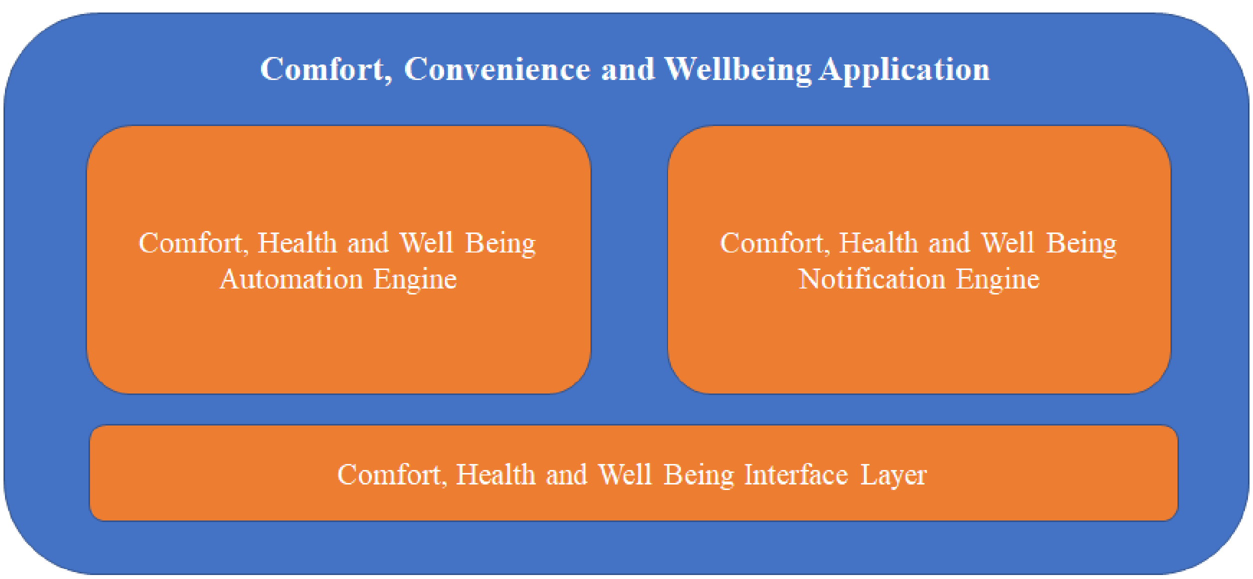


Figure 2. Comfort, Convenience and Wellbeing Engine Overview

More specifically:

- **Comfort, Health and Well Being Interface Layer:** The role of this module is to act as the wrapper of the application in order to ensure information exchange with external components.
- **Comfort, Health and Well Being Notification Engine:** The role of this DSS module is to correlate building contextual conditions along with the extracted comfort profiles and user settings in order to generate the appropriate notifications associated with the indoor conditions in premises.
- **Comfort, Health and Well Being Automation Engine:** The role of this DSS module is to correlate building contextual conditions along with the extracted comfort profiles and user settings in order to automatize the operation of controllable devices (focus on HVAC, Lights etc.) on the way to ensure the establishment of a comfortable, health and well-conditioned environment.

The design details of each of the modules that consist of the solution are provided below:

Comfort, Health and Well Being Interface Layer

There are two main functionalities to be considered by this component, briefly presented in this section.

Integration with 3rd party systems

Starting with the interface layer, the specifications for this module strongly rely on the availability of data and analytics services. This is the part of integration with external systems in order to retrieve data from the building environment (as specified in D2.3 and technical specifications definition) and the results of user analytics as specified in WP4. Related to the latter and considering the functionality of the user profiling component as specified in D4.1 we have analytics results about:

- Occupancy Scheduling: providing information about the level of occupancy at a specific zone, taking into account time related parameters
- Comfort Profiling: providing information about the comfort boundaries of the users under different environmental conditions: temperature, humidity, luminance etc…

Comfort, Health and Well Being Level Assessment.

As stated in the SoTA section, SRI evaluation remains at a rather static and high level. Therefore, considering the list of KPIs as presented in the state-of-the-art analysis, the role of this engine is to perform a real-life evaluation of comfort, health and well-being flowing the different strategies implemented by this component. In more details KPI values are calculated for:

- Thermal comfort: Current comfort status and the average thermal comfort status for the last XX days also considering data availability
- Visual comfort: Current comfort status and the average visual comfort status for the last XX days also considering data availability (luminance level)
- IAQ status: Current comfort status and the average comfort level considering the specifications for each metric as reported in state-of-the-art analysis
- Automation level: Considering the number of automated and manual actions triggered in order to evaluate the automation level of the building.

Comfort, Health and Well Being Recommendation Engine

As a next step, the details of the Comfort, Health and Well Being Recommendation Engine are provided. A data driven approach is adopted for the implementation to enable timely, context- aware, quantified, meaningful, accurate and personalized feedback provision in order to maximize comfort and well-being conditions in premises. More specifically, the features of the recommendation approach (via a tailor-made and personalized recommendation engine) should include:

- Timely and Context-Aware: triggers and meaningful feedback for timely need-to-act will be offered close to relevant events and necessary actions, taking into account real-time conditions like environmental conditions from sensors (luminance, temperature & humidity)
- Non-intrusive: feedback modality, frequency and context will be configurable to ensure discreteness
- Personalized: feedback will be customized to occupant characteristics and relevant energy behaviours, comfort preferences and contextual requirements. Feedback from the end users is also considered in order to ensure personalization at the different notifications triggered to the users.

The high-level overview of the recommendation engine is presented in the following figure.

Figure 3 Non-Energy Services Recommendation Engine

More specifically, the enhanced recommendation model should take into account:

- **User parameters**: user norms /groups defined in the project
- **Context conditions:** Real time context information values: environmental conditions, device status etc…
- **Model parameters** incorporated in the analysis:
  - business strategies and priorities: health first, comfort first etc.
  - non-functional aspects are examined as trigger points for the recommendation's engine, namely: *level of participation, level of triggering etc…*

Overall, the recommendation engine process layer is characterized by the following hierarchical structure towards triggering best fitted recommendations:

User* receiving a *message* under specific *context condition* and on the basis of *model priorities

It is evident that a multi-dimensional framework is specified for the recommendation engine. The main focus in the project is about the semantic rule annotation of the aforementioned model parameters; towards triggering best fitted recommendations (defined following consultation with the demo partners) to the users based on contextual and operational conditions. A non -exhaustive list of recommendations to be incorporated in the 1st version of the application is presented in Annex I.

Comfort, Health and Well Being Automation Engine

Complementary to the recommendation Engine, the Comfort, Health and Well Being Automation Engine is also defined as a data driven decision support system to maximize comfort and wellbeing conditions in building premises. Again, contextual conditions from the building environment (environmental conditions, user profiles and device settings) are specified as the input parameters for the DSS systems. By taking into account impact criteria such as the goal objective (comfort vs health), the level of automation (frequency of triggers) and the feedback from the end users (by rating the automation actions performed by the system), the DSS system adapts its operation in order to perform the appropriate control strategies. A high-level overview of the DSS system is presented in the following figure.

More specifically, the enhanced automation engine should take into account:

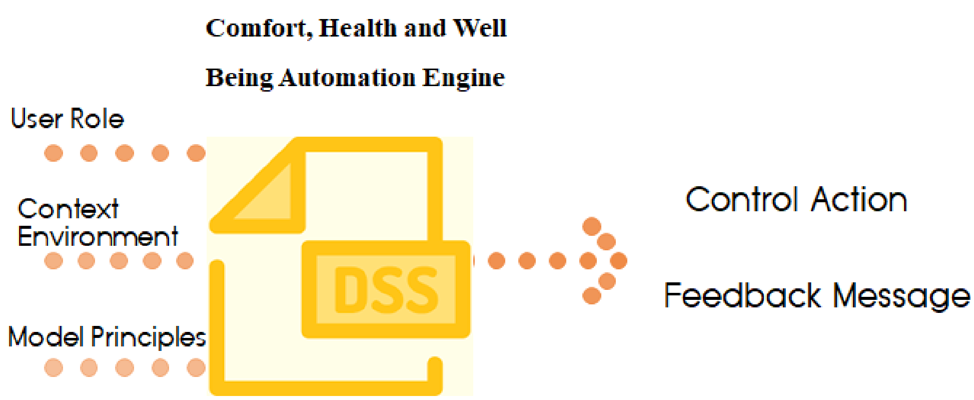


Figure 4 Non-Energy Services Automation Engine

- **User parameters**: user norms /groups defined in the project
- **Context conditions:** Real time context information values: environmental conditions, device status, device controllability etc…
- **Model parameters** incorporated in the analysis:
    - business strategies and priorities: health first, comfort first etc.
    - non-functional aspects are examined as trigger points for the recommendation's engine, namely: *level of triggering, level of automation acceptance, etc…*

We have to point out that again the different parameters and criteria incorporated in the engine are defined following consultation with the demo partners, setting that way the knowledge base for the PHOENIX DSS system.

A non - exhaustive list of triggering parameters to be incorporated in the 1st version of the automation application is presented in Annex I.

Note: While the engine is modular enough to support a fully flexible implementation, pilot site specificities will *set constrains during the demonstration period. Pilot specificities will be reported in the 2nd version of this deliverable. In this version, we highlight some key demo specific requirements as specified (reported also in D7.2)*

- *The occupants of the Greek pilot will have the pleasure to feel more comfortable in terms of lighting and temperature conditions due to automatic shading systems while getting notified of the air quality (CO2 concentration).*
- *The UMU pilot has a great deal of sensing capacity within the living spaces. These sensors measure variables such as temperature, relative humidity, luminosity and HVAC parameters. With this, we aim at developing mechanisms of monitoring and control that will increase the comfort of the building users. In addition to that we will identify ways of increasing productivity thanks to better indoor conditions.*
- *ARDEN: Temperature sensors will allow for improved control and better matching of temperature levels with the requirements of building occupants. This will prevent overheating and energy waste and also underheating. In the residential pilots, the use of heating zone controls can relax the fear of leaving the heating on or using energy unnecessarily to heat up an empty room. The more control a person has over their energy usage, the more comfortable the building becomes.*

LTU: This objective is concerned with aspects of people's everyday living. The occupants of the demo site might feel more comfortable in terms of temperature and air quality conditions due to sensor-based improved temperature control. Sensors will be installed in common areas, and in some selected apartments based on consent from the occupants.

3. Predictive Maintenance and automatic SRI calculation and EPC evaluation

3.1. Introduction

The new model of smart buildings will increase on technical complexity, including on their installations of more sensors and actuators that add up to other systems that were already becoming more complex. This is the case for example of mechanical ventilation systems, getting more and more popular (and mandatory) in some buildings, building energy management systems or security (alarms) installations.

For this increase on the number of devices to simplify and not add an extra load to building managers and building owners, it is necessary that the platforms such as the one developed at PHOENIX help on the maintenance of the building. It has been foreseen that one of the important ways of doing so will be by the implementation of predictive maintenance.

The large amount of data that will come from sensors on smart buildings will allow to have an idea of the operation of devices and systems and it will show potential failures if the correct algorithms are in place. The PHOENIX platform will receive the data from the sensors and the dashboard will have a profile defined for maintenance-related roles, persons that are in charge on controlling the operation of installations.

These have been considered on the group of services for occupants as this are services that do not go beyond the building envelope as they do when they are design for grid interaction (as an example). Deliverables 5.2 and successive will have a more explicit definition of the services for occupants and building users that will be developed on project PHOENIX, but on this document an overview of the environment in which they are developed and how the services design is tackled will be described.

Special attention will be placed on EPC and SRI automatic calculations as they are at the moment important pillars of the building assessment on European regulation.

3.2. State of the art analysis

Predictive maintenance has been seen as a field with great potential on the European Union. On a situation in which the producers and manufacturers offshore are becoming highly competitive, measures that increase productivity, reduce failure and minimise the cost are not only desirable, but necessary.

According to industry Europe [19], Predictive Maintenance (PdM) is going to make a turn in Europe, although predictive maintenance has been seen in origin a tool for industry, the more complex systems in building will benefit rather soon from the technologies developed in this front for industry. Key benefits foreseen in this publication from PdM could be:

- Optimisation of operational expenses
- Material cost savings
- Reduction in manufacturing expenses
- Lean production to decrease inventory overhead
- Sophisticated data-driven analytics, insights, and decisions
- Faster time-to-market through artificial intelligence technologies

Adding to those, one could also expect that the increase satisfaction of users because the predictive maintenance decreases the interruption of availability of services will be a benefit and a driver for adopting this.

We can see, that although the built environment is very different to the industrial environment, benefits such as “optimisation of operational expenses” or “Sophisticated data-driven analytics, insights and decisions” could well be extrapolated to the building operation. In fact, we could find equivalents on building operation that could be replaced by those on industry, but that would be highly beneficial. One of them is the replacement of equipment, such as those forming the conditioning system, the ventilation or the domestic hot water.

Predictive maintenance has also been seen as a potential advantage by the Business Innovation Observatory [20]. It is outlined on that document how predictive maintenance is the next natural step to status-based maintenance, and how the predictive maintenance based on IoT technologies can detect abnormalities in real time, and with that reduce the cost of maintenance.

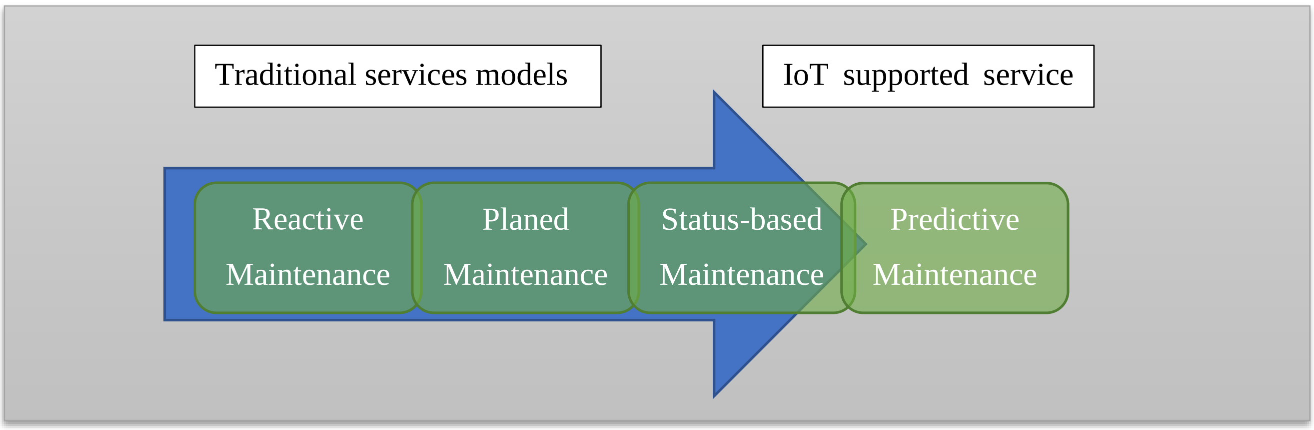


Figure 5 represents how the new IoT paradigm can offer predictive maintenance. Source Reply, from [20].

Figure 5 represents how the new IoT paradigm can offer predictive maintenance. Source Reply, from [20].

With respect to the standard of evaluation of the services in the new paradigm of smart buildings that is the Smart Readiness Indicator (SRI). On the SRI, there exist a domain for Maintenance and fault detection. This domain reflects how the smart services will contribute to the good operation of the building and reflect the development of the predictive maintenance. Predictive maintenance has a weighting factor of 16.7% which is a large percentage (the second largest after energy flexibility and storage) of the weights to calculate the overall SRI. This gives an impression of the importance of this domain. Figure 6 shows the different weights on the SRI calculation.

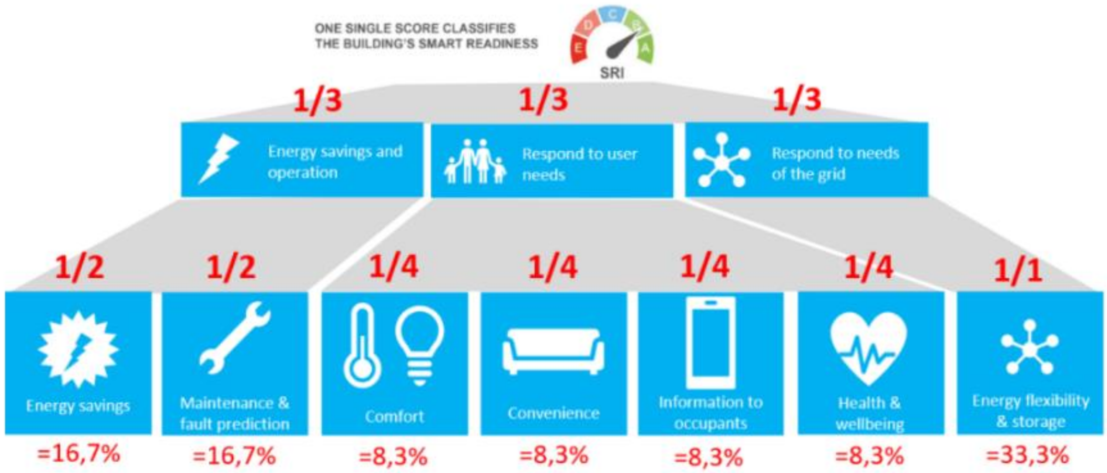


Figure 6. Maintenance and fault prediction is one of the domains in which the smart services are evaluated. Predictive maintenance is the core of this domain.

The services that allow scoring high values on the maintenance and fault detection field are those that permit to monitor the operation of the machines. In that sense, some of the domains are more important than others. In the following table we show the services that allow to sum three or more points to the domain of maintenance and fault prediction. Table 3 shows how only a centralized monitoring and control system of the heating the cooling and the overall building allows to have the highest score on Maintenance and fault prediction.

Table 3: Highest scoring services of the SRI on Maintenance and fault prediction.

Domain	Level	Service	Impact on M&FP
Heating	level 4	Central or remote reporting of performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	3
Cooling	level 4	Central or remote reporting of	3

		performance evaluation including forecasting and/or benchmarking; also including predictive management and fault detection	
Monitoring and Control	level 3	Central or remote reporting of realtime energy use per energy carrier, combining TBS of all domains in one interface	3

3.3. Requirements overview based on social barriers and enablers.

After the work developed on WP2, it is possible to know the requirements that will be found for developing the services proposed on this section, those relative to PdM. With respect to the occupants's requirements, the ones that are relevant to PdM, and automatic assessment can be seen as the ones on Table 3.

Table 4: Requirement of services related to PdM and automatic assessment.

ID	Description
1	PHOENIX should provide to building occupants comparative information about past performance
2	PHOENIX should provide to building occupants information about local generation and the level of self-consumption
3	PHOENIX should provide to building occupants information about energy waste per device type
4	PHOENIX should support the dynamic calculation of SRI score

5	PHOENIX should provide to building occupants the option for remote control of smart devices
6	PHOENIX may provide to building occupants the option for scheduling the operation of devices
7	PHOENIX may provide to building occupants the option for semi automation - automation with user interaction
8	PHOENIX should provide to building occupants the option to override automated control actions

As can be seen on the table, there is a certain weight on obtaining good remote control of the devices. This has been pointed out by occupant's preferences and outlines how the necessity of accessible devices for maintenance is a priority.

Also as a result of WP2, it was possible to identify social enablers and barriers relative to PdM and automatic assessment. On that respect, the following is a summary on what can be considered barriers on services of this field.

Barriers

- It has been seen that privacy is a concern for the incorporation of smart services, this is the case for BMSs what an important part of the PdM of buildings. In that sense, 63% of those that use smart system consider privacy a concern for the transformation towards smart buildings.

- Another important barrier that was seen on the incorporation of smart systems and that will have an impact on the field of PdM and automatic assessment is the lack of perceived control on the technology. This is particularly true on existing building in which the blue-collar professionals are used to their equipment and a potential "smartization" can be seen as a lack of control of the devices. This barrier is also educational; as new training will need to be given in some cases for the professionals to accept the new technologies.

Enablers

- With respect to the enablers that can be identified on a scenario of integrating new services for PdM and automatic assessment, one of the most appealing enablers will be the monetary savings. As it was seen on the state of the art, the implementation of PdM can lead to substantial savings as the components are used to their full life, and replacement is done before a failure can cascade down to other equipment. This is seen by building mangers that in general see the monetary saving as a motivational argument.

- With respect to concept valuation, it was seen on the surveys done on WP2 that the lower maintenance cost is seen as appealing by the users and that the upgrades give them an impression os valorisation of the building due to this. This positive response is given by smart-services users and non-users.

- Social norms and lead user. This is particularly true for maintenance of commercial buildings. More and more standards are appearing that show that a given building is distinctive in a certain manner. This has happened with the energy efficiency, and programs such as LEED or BREAM were a way of offer a better product for contractors. This could go the same way in terms of smart controls for buildings. The norm of other building together with the competition with early adopters is seen as a motivation to integrate smart services for PdM and automatic assessment.

3.4. PHOENIX Predictive maintenance and automatic assessment methodologies

The developments carried out to create the services on PdM and automatic assessment have been focused on two different approaches.

1) The Predictive maintenance and the Energy Performance certificate has been conceived to be created using time series data of the building. In that sense, the data coming from devices that is received by the context broker allows to do forecasting of the series as well of inverse modelling what will respectively offer the possibility of providing predictive maintenance and energy performance evaluation.

2) A more complex approach will be taken for the automatic calculation of the SRI. In this sense, the modelling of the entities representing data will be taken into consideration to automatically calculate the SRI. In that sense, a dedicated engine will check the entities that have been signed up on the context broker, and with them, it will be possible to know levels of a given domain within the SRI evaluation. This information will be then passed to the scoring unit, developed currently by SAGOE (See Del 4.1) that will give the ultimate score. Figure 7 shows how the components of a building once classified in the correct way can be identifiers of services on the SRI.

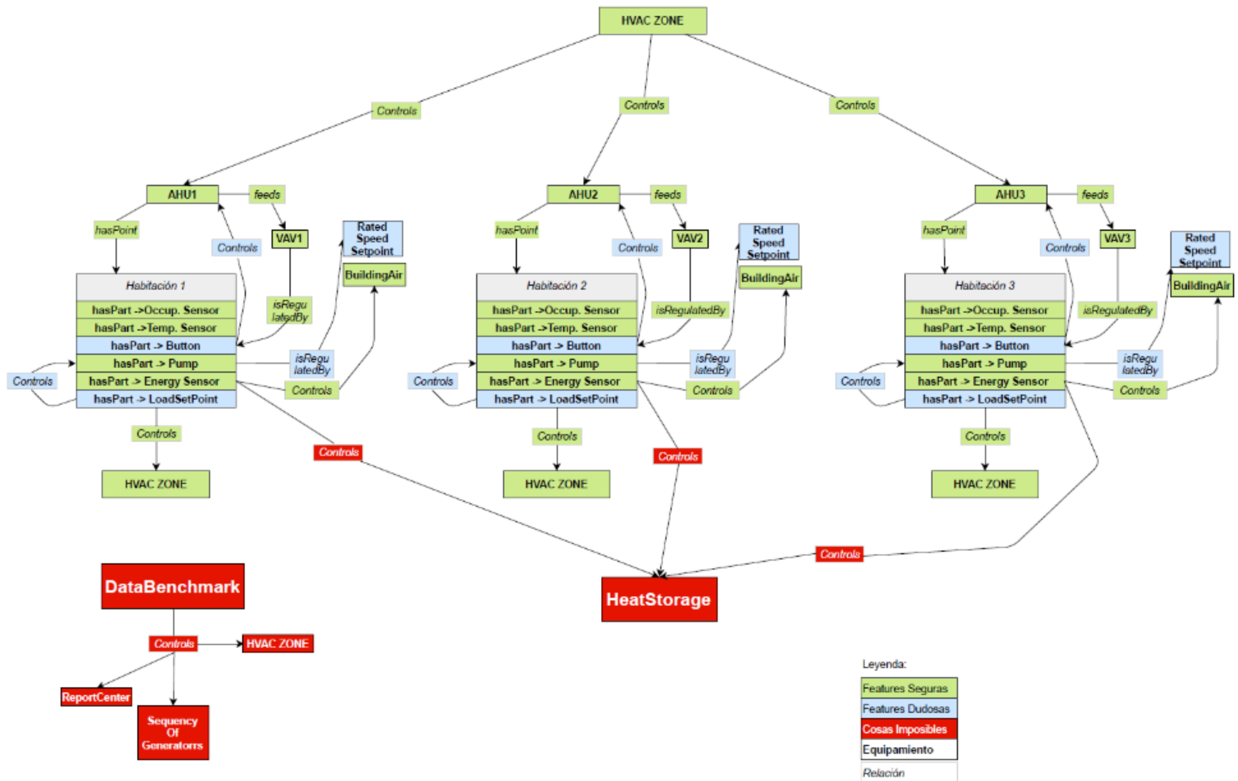


Figure 7. Components of a building that once modelled using an ontology will be indicators of smartness levels on the SRI.

Once the components of the building can be identified because they have been signed up on the context broker as data providers, the framework of the automatic calculation of the SRI will make the calculations of the different domains and will use the correct weights depending on the building at hand (type) and the location (weather zone). This will give an SRI evaluation matrix that could be shown on the PHOENIX platform.

From Del 4.1 a more general vision of the automatic SRI calculation can be seen in figure 8. The building assessment (step 1) is represented by the top yellow part. The following steps are represented by the three circles in the middle, but the amount of information that needs to be introduced by the human on the higher layer will be reduced to a minimum once the engine can read the entities from the context broker and imply the level of smartness that them represent.

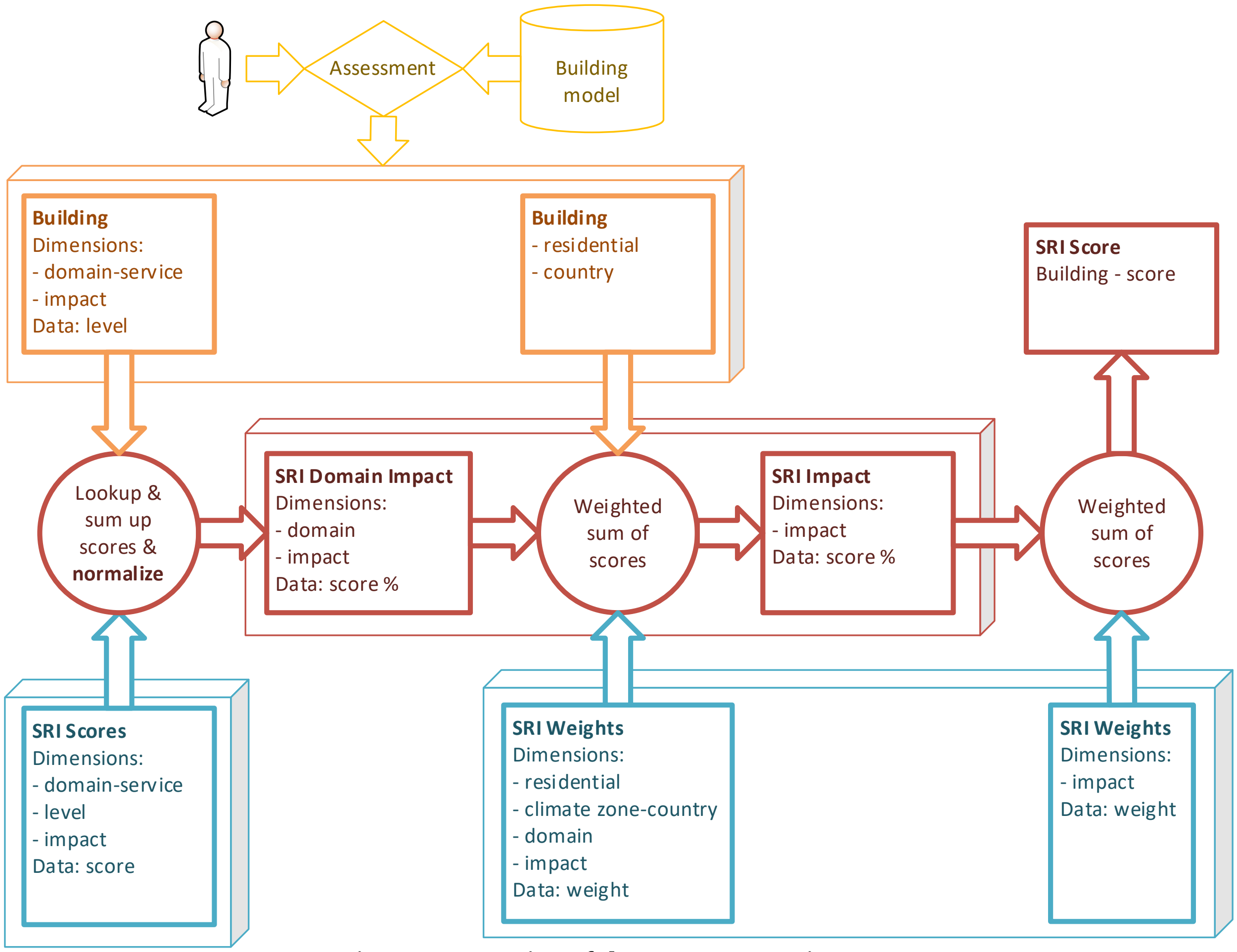


Figure 8 - Overview of the SRI Computation Process.

4. User Information and Dashboard

4.1. Introduction

The human-building experience and interaction (HBI) are handled in task 5.1, where an intuitive and informative end-user dashboard is designed and delivered. By end-user in this task, we mean the residential and commercial building occupants (both owners and inhabitants) that can act either as energy consumers in the Phoenix project or have a more hybrid role as energy prosumers. The aim is for every building occupant/participant in the Phoenix project to be able to have complete awareness and control on the smart dwelling where he/she lives/or works through a series of UI features that concentrate on the seven domains of the SRI [21] namely energy savings, maintenance and fault prediction, comfort, convenience, information to occupant, health and well-being and energy demand flexibility. Each of these domains are described by one or more energy or non-energy services that are implemented in tasks 5.1, 5.2 and 5.3 as specified in the doA of the project.

Because of the fact that the amount of information that can be demonstrated in the user dashboard is pretty extensive, a requirements analysis has been conducted after having examined a user questionnaire survey, circulated to the building occupants anonymously in order to use their feedback as a prioritization list on what is needed to be included in the dashboard. To achieve this, barriers and enablers from each demo country have been utilised to drive the requirements analysis and mark down what can be done and what not.

Also, the individual user settings and preferences as well as customizations on the amount of displayable information according to the computer literacy level of the occupant, play a central role in the dashboard objectives, so input from task 4.3 is highly relevant in the context of this dashboard.

Finally, it is worth noting down that the dashboard will also be used to demonstrate the synergic grid interaction and automatic energy saving, from tasks 6.2 and 6.3 respectively. The establishment of a smart contract between ESCOs/facility managers and consumers/prosumers and thus the depiction of the contractual parameters and the billing strategy will also be a part of the dashboard (implemented in task 6.1 as described in the doA).

4.2. State-of-the art analysis

There is an exhaustive list in the current literature about the design and implementation of dashboards in the energy sector, responsible to deliver a meaningful picture of building energy data and bring to the table the best possible human building interaction (HBI). According to [22], a key factor to evaluate when conducting a human computer interface (HCI) problem (in our case HBI) is the user experience which remains a highly subjective issue. The key characteristics of usability are presented below:

- User effectiveness is the overall ability of the user to accomplish a certain task in the dashboard.
- User efficiency refers to the speed and accuracy of completion of this task.
- User tolerance is the ability to minimize the number of errors, in the process of task completion.
- Ease of use is the ability of the user to learn and use the dashboard.
- User engagement refers to weather the dashboard is pleasing and satisfying in a way that a certain number of person-hours per month is dedicated to it.

As the adoption of smart equipment in the residential sector becomes more and more apparent, monitoring of the residential energy use and trying to make intelligent decisions about it, is becoming a significant factor in lowering the contribution to carbon emissions, besides the strategies already implemented in the commercial sector. Overall, the occupants of a dwelling are mainly interested in tracking energy consumption and comfort at building or zone level, to identify potential energy savings opportunities [23].

In an effort to predict the building energy consumption, a significant mismatch has been reported in literature between the predicted and the actual energy consumption values. The occupant preferences and overall behaviour in most cases are not taken into account, despite the fact that changes in human behaviour can result in improving the energy efficiency and thus the energy and cost savings. The interaction of the occupant with the building is difficult to be quantified but several approaches exist that take into account the manual control actions of the user over the smart assets of the dwelling, the thermal, visual and air quality user comfort [24] and the users' feedback during their interaction with the energy dashboard. For example, Holopainen et al. [25] suggested that the reduction of excess heating and cooling by means of control methods (implicitly through the depiction of user recommendations or explicitly through automated control actions), may also result in increasing the users' satisfaction, as they feel that they have more control over their environment. So in that example, a positive feedback could be recorded in the dashboard through the respective user interface. On the other hand, [26] if control is not provided as an option in the dashboard, or if the control is not effective enough or if there is a negative impact on the comfort, health and well-being of the user, then a discomfort event will be recorded along with the respective negative feedback on the dashboard.

There exist three main methodologies to use so as to influence and drive changes in building occupant behaviours: eco-feedback, social interaction and gamification. Eco-feedback [22] provides information regarding historical and current energy metrics, which has been proven to lead to significant reductions in energy consumption and energy waste. A web-based (or mobile app) energy dashboard is used as an interface between the occupant and eco-feedback and can not only include monitoring metrics, but also comparative information, as well as short-term and long-term suggestions for improving energy efficiency, promote comfort and/or encourage the user to participate actively into grid demand response events. The social interaction methodology relies on the fact that a user is influenced by his social network, so information regarding comparisons over similar peers or clusters of consumers/prosumers, can highly lead to energy use reductions. This can be combined with the eco-feedback method and for example provide an advanced system that connects co-workers over organizational networks, when applied in the commercial sector. Finally, the gamification strategy leverages a more personal and interactive experience, where a game can change the user behaviour through observational learning [22] and a series of rewards is triggered in case the desired energy behaviours are recorded.

In conclusion, the design and implementation of a user energy dashboard is not an easy task, and all the aforementioned points must be very carefully examined and combined with the social barriers and enablers of users according to the respective legislation of each country.

4.3. Requirements' overview based on social barriers and enablers

The high-level Phoenix project objective dedicated to prosumers and consumers is "Prosumers to enjoy the value and benefit of innovative energy and non-energy services by increasing the smartness of their building premises". A list of use cases has been extracted (D2.1) and here a reference is made on those use cases that directly affect the building occupants (UC02 is not related to building occupants):

- UC01: Adapt & Play integration of domestic appliances, legacy equipment and building systems. The results of the measurements from smart appliances, equipment and BMS will be continuously monitored in the user dashboard, both real-time as well as historically.

- UC03: Services for building occupants to maximize their energy efficiency and increase overall building performance. Monitoring and analytics of the energy consumption, energy waste, EPC and other metrics will be depicted in the dashboard (energy savings SRI domain).

- UC04: Provision of Comfort, Convenience and Wellbeing services to building occupants. Comfort, convenience, and health & wellbeing SRI domains are calculated and thus depicted in the dashboard, taking into account average values at daily, weekly and monthly level over thermal, visual and IAQ comfort levels.

- UC05: Portfolio flexibility analysis and configuration to optimize grid operation. The availability of flexible smart assets of the dwelling and their characteristics related to DR events will be monitored in the dashboard.

- UC06: Flexible billing services and smart contracts for the retailer customers. Information regarding smart contract parameters (between a customer and a retailer) as well as personalized billing services will also be available in the dashboard.

- UC07: Advanced energy services to promote self-consumption optimization. Results on energy generation and energy storage, and optimizations on self-consumption in the case of prosumers, will also be made available in the dashboard.

From the use cases definition and the questionnaire surveys provided to the Phoenix pilot customers (residentials/commercial building occupants participating in early project activities), a list of specific building occupants' requirements has been extracted as demonstrated in the table below:

Table 5. User dashboard requirements

Req. ID	Description	Relevant UC
01	PHOENIX should provide services to building occupants to promote energy savings	_03
02	PHOENIX should provide services to building occupants to ensure comfort preservation	_04
03	PHOENIX should provide services to building occupants to promote the establishment of a health environment	_04
04	PHOENIX should provide services to building occupants to promote the establishment of a convenient environment	_04

05	PHOENIX should provide services to building occupants to enable participation in smart energy programmes	_05, _06
06	PHOENIX should provide services to building occupants to ensure prompt remuneration for the provided services	_05, _06
07	PHOENIX should provide services to building occupants to increase awareness about energy efficiency and smart programs	_03
08	PHOENIX should provide services to building occupants that will minimize end user's interaction- limited disturbance	_03, _05, _06, _07
09	PHOENIX should provide information to building occupants about total energy consumption	_01, _03
10	PHOENIX should provide information to building occupants about CO2 impact	_01, _03
11	PHOENIX should provide information to building occupants about historical consumption	_01, _03
12	PHOENIX should provide information to building occupants about comfort levels and environmental conditions	_01, _04
13	PHOENIX should provide information to building occupants about energy savings and waste	_01, _03
14	PHOENIX should provide information to building occupants about consumption of similar peers	_01, _03
15	PHOENIX should provide to building occupants comparative information about past performance	_01, _03
16	PHOENIX should provide to building occupants information about IAQ conditions in premises	_01, _04
17	PHOENIX should provide to building occupants information about local generation and the level of self-consumption	_01, _07
18	PHOENIX should provide to building occupants information about total energy waste	_01, _03
19	PHOENIX should provide to building occupants information about energy waste per device type	_01, _03
20	PHOENIX should support the dynamic calculation of SRI score	_01, _03
21	PHOENIX should provide to building occupants the option for remote control of smart devices	_01
22	PHOENIX may provide to building occupants the option for scheduling the operation of devices	_01, _03, _04
23	PHOENIX may provide to building occupants the option for semi automation - automation with user interaction	_01, _03, _04
24	PHOENIX should provide to building occupants the option to override automated control actions	_01, _03, _04
25	PHOENIX should provide to building occupants updates of energy and environmental information in real time	_01, _03, _04
26	PHOENIX should provide to building occupants updates of energy and environmental information at daily level	_01, _03, _04
27	PHOENIX should provide to building occupants updates of energy and environmental information at week level	_01, _03, _04
28	PHOENIX should provide to building occupants updates of energy and environmental information at month level	_01, _03, _04
29	PHOENIX should provide to building occupants updates of building performance KPIs in real time	_01, _03
30	PHOENIX should provide to building occupants updates of building performance KPIs at week level	_01, _03
31	PHOENIX should provide to building occupants updates of building performance KPIs at month level	_01, _03

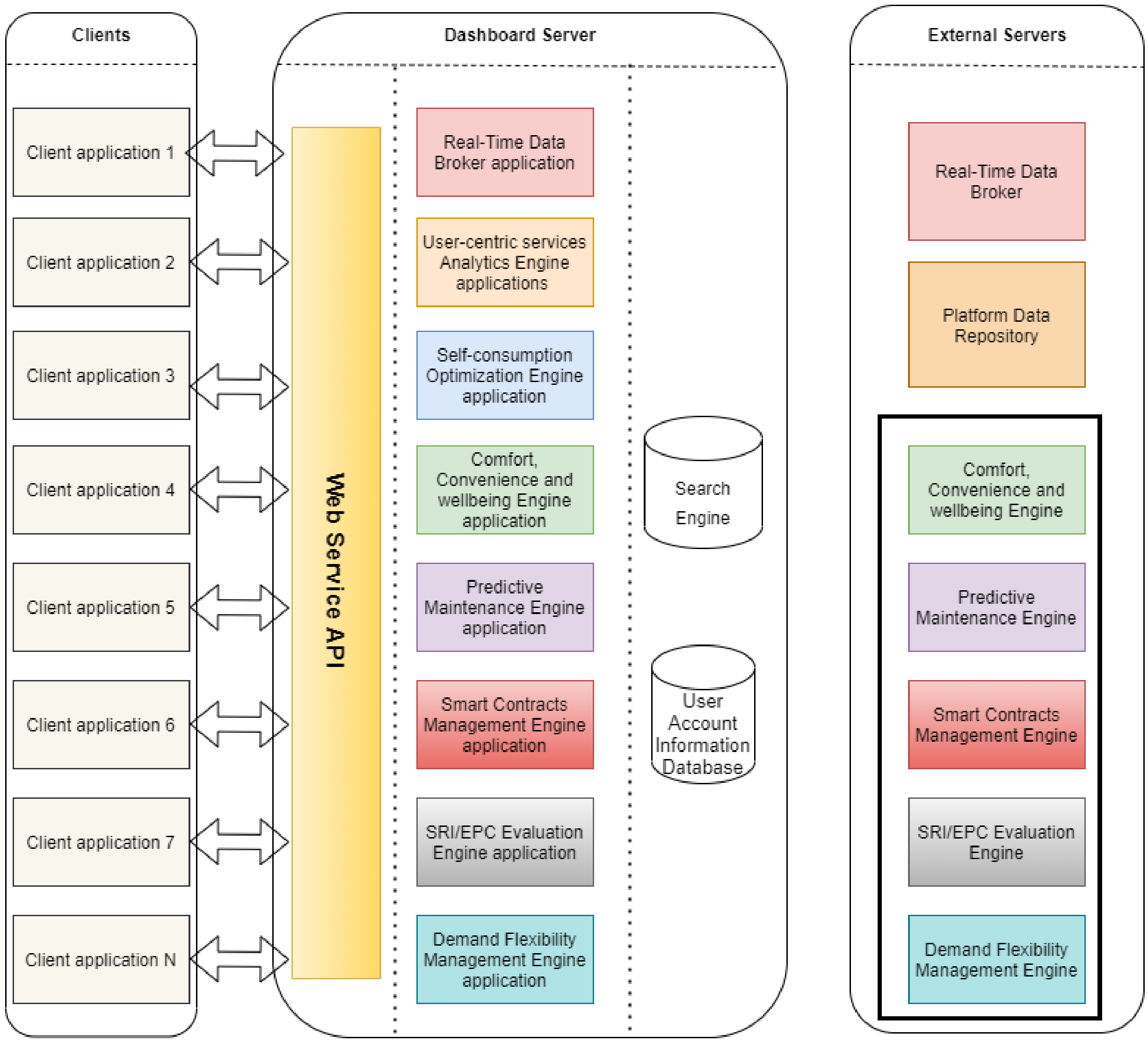
It is worth mentioning that the above requirements and their feasibility should be directly linked to the social barriers and enablers extracted in D2.2:

- Privacy concerns: Over 63% of the people who are currently involved with smart systems state that privacy is a major concern, that also affects the user dashboard implementation. For instance, information on energy use, on occupants' movements around the dwelling, personal preferences and customizations driven from a small set of questions when the user first registers in the dashboard, are all personal information that raise the concern about how this kind of data can be exploited in a harmful way. For that reason, an informed consent form will be shown and agreed before the dashboard user makes his first login.
- Lack of perceived control on the technology: For the non-users of smart systems, especially people over 65 years old and those who are not technology savvy, there is a lack of knowledge on how to use the smart equipment and therefore how to interact with the respective web or mobile app. For that purpose and specifically for that target group, a simpler screen will be made available called "at a glance" that will provide an easy-to-understand summary of how the smart home is performing and what can be changed in case of a discomfort event or an energy waste event.
- Monetary savings: The majority of occupants (more than 70%), consider that cost savings are a significant factor regarding being involved in the use of smart systems. For that purpose, a clear picture on cost savings as well as billing information will always be made available in the dashboard.
- Energy conservation: On the energy savings perspective, again more than the 70% of the people that participated in the user survey, are also interested in increasing the energy savings. For that purpose, useful tips will be made available in the dashboard that will promote the "correct" energy use behaviour always respecting the comfort boundaries of the occupant. Information on past energy use, comparative graphs and comparisons with similar peers are also available through the respective dashboard pages.
- Perceived attributes and qualities: In this category there exist five distinct aspects, convenience, usefulness, reliability, time savings and quality life improvement. The dashboard provides a reliable and useful interface for the occupant to participate in the Phoenix smart energy platform. The more user engagement, the more improvement on the way the user perceives his environment and thus quality of life improvement.
- Enabling customer control: The dashboard gives the occupant the sense of control of the smart home by promoting both manual and automated control actions on the various smart assets. This also improves the overall user experience, as the user feels confident and comfortable to interfere with his living conditions and change accordingly his behaviour. The more customization on the dashboard the more customer participation in it.
- Social norms and lead user combined with tendency to change: As we all know, the social networks have

a great power on people's decisions and actions. So, in the case of the occupant dashboard, social peer pressure can act as a big enabler for the adoption, use and active participation in it. This inevitably brings the people that are currently non-users (such as people over 51 years old) a perspective to change towards the direction of engaged dashboard users.

4.4. Dashboard design specifications and basic workflows

After having analysed the requirements of the building occupants, it is time to proceed to the architecture of the user dashboard and the report of the most important workflows while the users interact with it. Figure 9, presents the overall dashboard architecture, the web applications, and the interaction with external servers:



* The applications of the dashboard server can acess all the real-time information stored in the Real-time Data Broker

** The Engines of external Servers can interact with the Real-time Data Broker and the Platform Data Repository

*** Search Engine is a replica of the Platform Data Repository
**** User Account Information Database holds user information

Figure 9. The design of the web-based user dashboard

The following workflow scenarios are extracted from figure 9:

<u>Predictive maintenance scenario:</u>

The building occupant provides his user settings in the visualization dashboard. The predictive maintenance engine provides maintenance alerts through the dashboard to the end user. This will be done via the specific monitoring of key devices for maintenance. The dashboard on maintenance mode will reflect things like the energy use of fans on air handling units, what represents the need for replacing the filters, the temperature of DHW tanks that can represent a leak on the system, or other data streams that the building manager can consider crucial for maintenance. Forecasting of those time series using seasonal algorithms such as ARIMA will be used for the early detection of outliers and therefore critical situations. A set of alarms could be configured to give visibility to these events so building managers can act.

<u>SRI/EPC evaluation scenario</u>:

The SRI/EPC indicators are returned to the dashboard by the SRI/EPC evaluation engine. For this, and considering the central importance that the SRI will have on PHOENIX project, the dashboard will show the matrix of complete evaluation of the SRI, and the link to the components that make that level of smartness realisable. In the same way, the dashboard section for EPC automatic evaluation will allow to select for whole building power meters, and temperature streams that will give an indication of the total performance of the building and therefore a proxy of the EPC evaluation.

<u>Demand flexibility management scenario</u>:

The demand flexibility KPIs are presented in the visualization dashboard. For demand flexibility it will be important from the building site to be able to analyse, evaluate and quantify how much flexibility they can offer to the grid. For this, it will be important to select heavy consumers of the building and their nominal power, so they can evaluate and calculate by how much they can sell "negawatts"[3] or displacements on the demand to the grid or the current aggregator. In the case of small building such as dwellings this dashboard will also include information about the situation of the grid in the present and in the day ahead, so they can plan their own demand modification to get the benefits on price or CO_2 emissions.

<u>Smart contracts management scenario</u>:

A retailer or aggregator introduces a contract offer with specific parameters into the visualization dashboard according to the USEF standard and the occupant is able to visualize it, study it and either accept or reject terms. There is also the possibility of an offer negotiation process to get initiated between the dashboard and the smart contracts management engine so as a counteroffer can be made available to the occupant. For this aspect of the dashboard a connection to the USEF framework will be developed that using a translator from XML to JSON provides information to the context broker about the transactions that took place for that given

[3] *Sometimes refered as the capacity of teh users of decreasing their power on demand.*

building. With that, a record of the interactions between the grid and the building will be kept.

Comfort, convenience and well-being scenario:

The building occupant provides his user settings and control actions in the visualization dashboard. The comfort, convenience and well-being engine provides the notifications to the dashboard either in the form of recommendations to the user to change his energy behaviour and perform a manual action like changing the temperature thermostat or in the form of informative notifications regarding the automated control actions taken by the engine itself.

User-centric analytics scenario:

Descriptive and predictive analytics regarding raw sensor data, user energy (consumption, waste, generation etc.) and non-energy services (comfort profiles), need to always be made available to the dashboard for the end-user. Most of the results will be depicted in the form of graphs where the user can select a per day/week/month basis, select a specific timeframe, zoom in and out of the graph.

Self-consumption optimization scenario:

The self-consumption optimization engine is responsible to provide energy savings optimization (towards the energy utility operators as well as the building occupants) through the day-ahead forecasting of energy generation, energy storage and energy consumption at building level, so all relevant information regarding energy generation, energy storage and energy self-consumed is depicted in the dashboard.

Real time data broker scenario:

All real time metrics of the Phoenix platform coming from sensors, external data sources, components of the Phoenix platform etc. are made available to the visualization dashboard by directly interacting with the real time data broker.

4.5. Mock-ups for the visualization of energy/non-energy services

In this subsection of the deliverable, the mock-ups of the visualization dashboard are presented, giving a quick way to get some meaningful visuals of the web application to be implemented. At a later stage of the Phoenix project, the mock-ups of the corresponding mobile version of the dashboard will also be included. The mock-up methodology also served well in presenting alpha versions of the dashboard to the relevant stakeholders and receiving quick feedback for future optimizations regarding not only the functionality but also the user experience (different segments of information targeted to different prosumer/consumer groups, changes in graphs to highlight aspects of interest, changes in the colours of the UI design, as colours can set the mood, tone and concept of the whole dashboard etc.)

The home page of the visualization dashboard is shown in figure 10. "*About PHOENIX"*, offers a summary of the scope of the project with a more specific reference on the occupants' dashboard scope. A "*learn more"* button is used and directs the users to the official Phoenix project site, in case they want to read any other details regarding the project. A YouTube video is also available for a very quick presentation of the dashboard and of course the relevant "Log in" and "Register" options for the users.

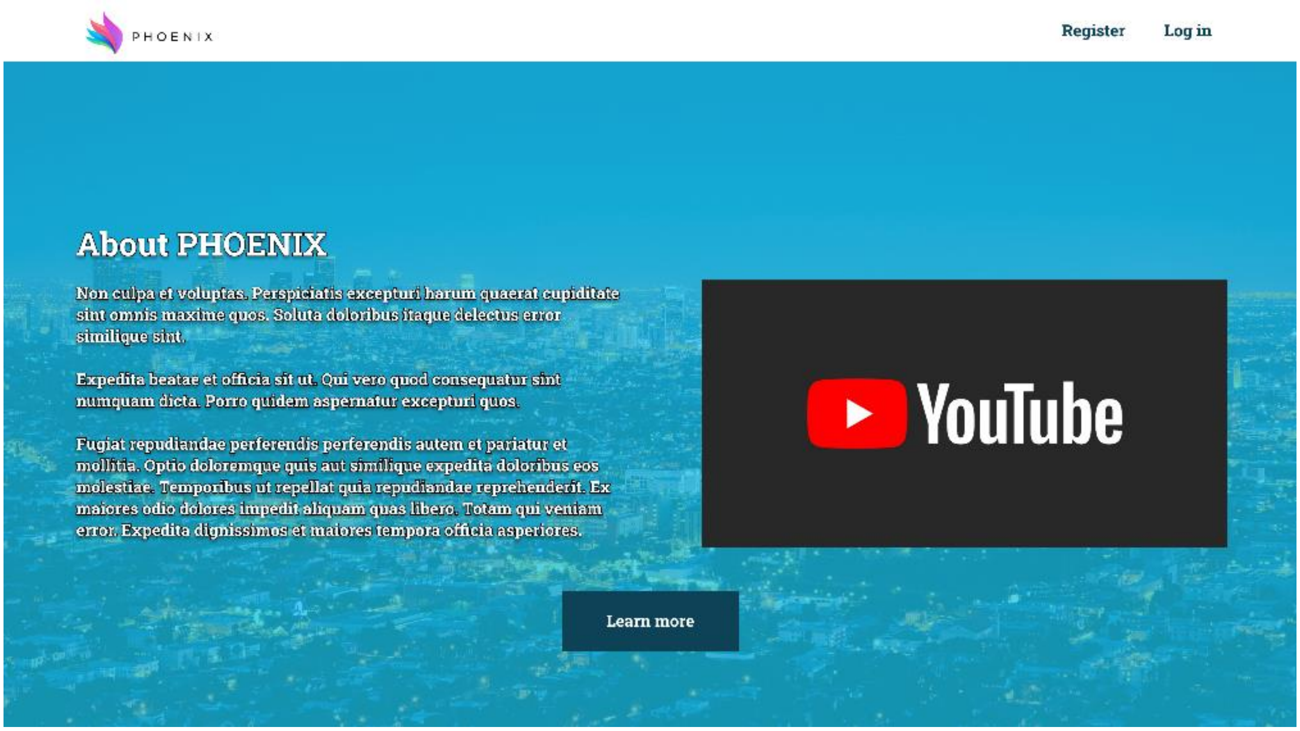
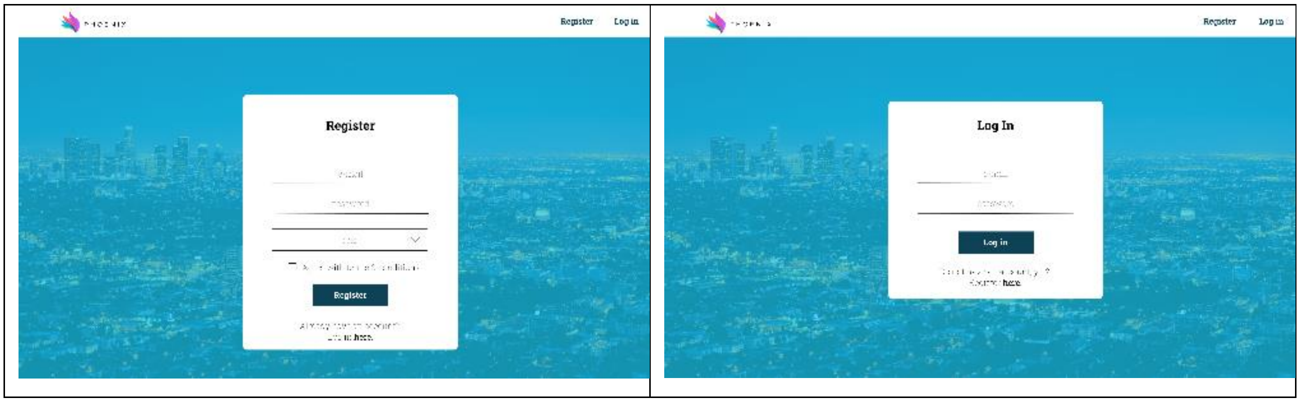


Figure 10. The home page of Phoenix dashboard.

Figures 11a and 11b show the register and login screens. It should be noted that the user in order to complete the registration process, needs to provide his consent through the button "Agree with terms and conditions", because at a later step and during the user profile creation, some user questions may contain GDPR information. The register screen will also support a "role" button, in case different roles will receive different levels of information.



Figures 11. a) The Register screen, b) the Login screen.

After successfully completing the small user questionnaire, the user is redirected to the “At a glance” page, which offers a quick dashboard for those users who are not so much tech savvy to go through all the available pages and functionalities offered by the app. The minimal dashboard is divided in: general information, smart readiness scores, energy consumption, energy generation, energy certificate and notifications. It is worth noting that each user is directly linked with a default building view (LaNave in this case) and he/she can modify this in his/her account settings. In more detail:

- General information: It contains the current values of temperature, humidity, level of CO2 and illuminance as well as if these values represent comfort or discomfort states.
- Smart readiness scores: It contains the SRI score of the building and the respective scores from each SRI domain.
- Energy consumption: It contains the total building energy consumption, the difference since last month, the total CO2 emissions and the difference since last month.
- Energy generation: It contains the total energy generation, the difference since last month, the total energy self-consumed and the difference since last month.
- Energy certificate: It contains the EPC score of the building and the EPC certificate can be downloaded.
- Notifications: It contains the notifications of the maintenance alerts and the recommendations for comfort preservation.

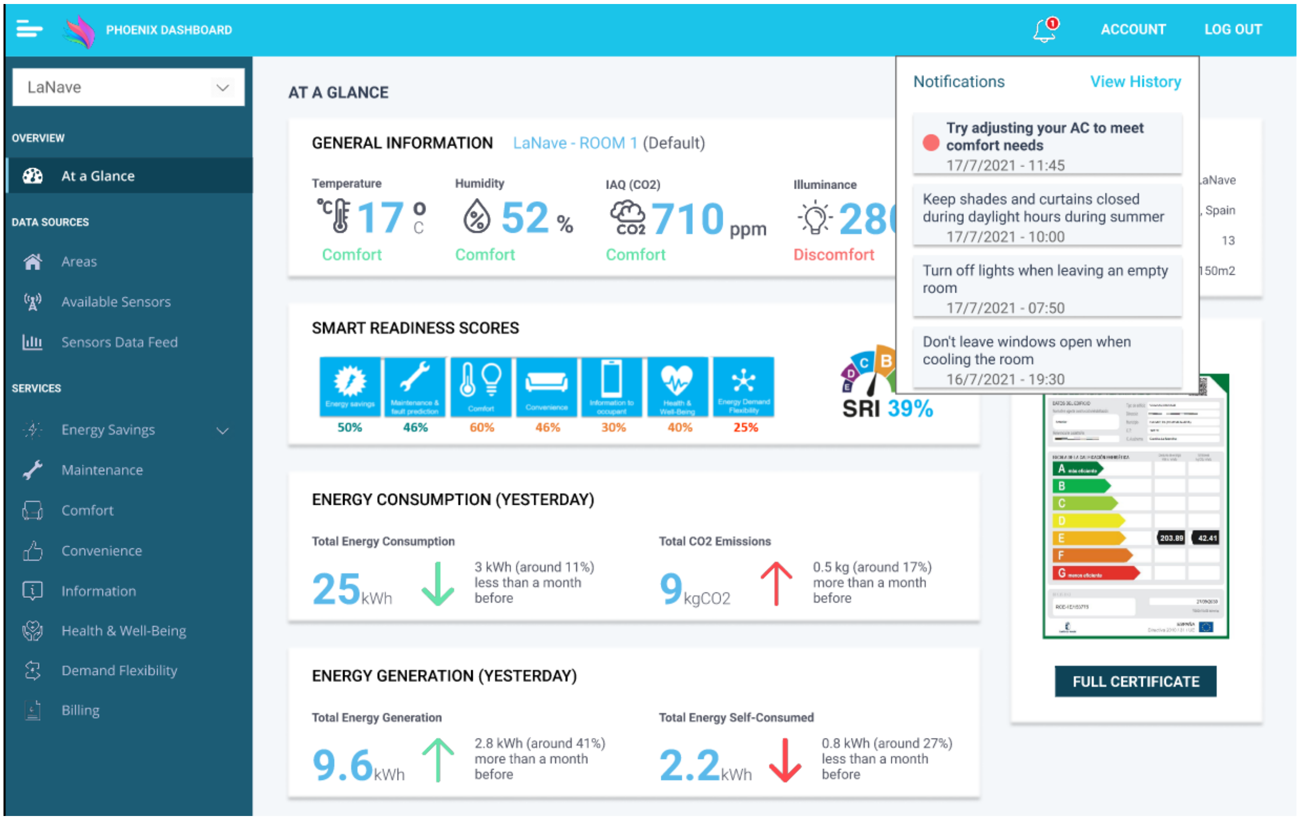


Figure 12. At a glance page.

Moving on to the Data sources group of pages, we have "Areas", "Available Sensors" and "Sensors Data Feed", let us now analyse each one of them. Figure 13 presents the page "areas", where the available rooms/zones of LaNave building are shown. Each area contains information on the occupational state, users registered, the choice to add/edit/remove an area and the choice to see the sensors under this specific area.

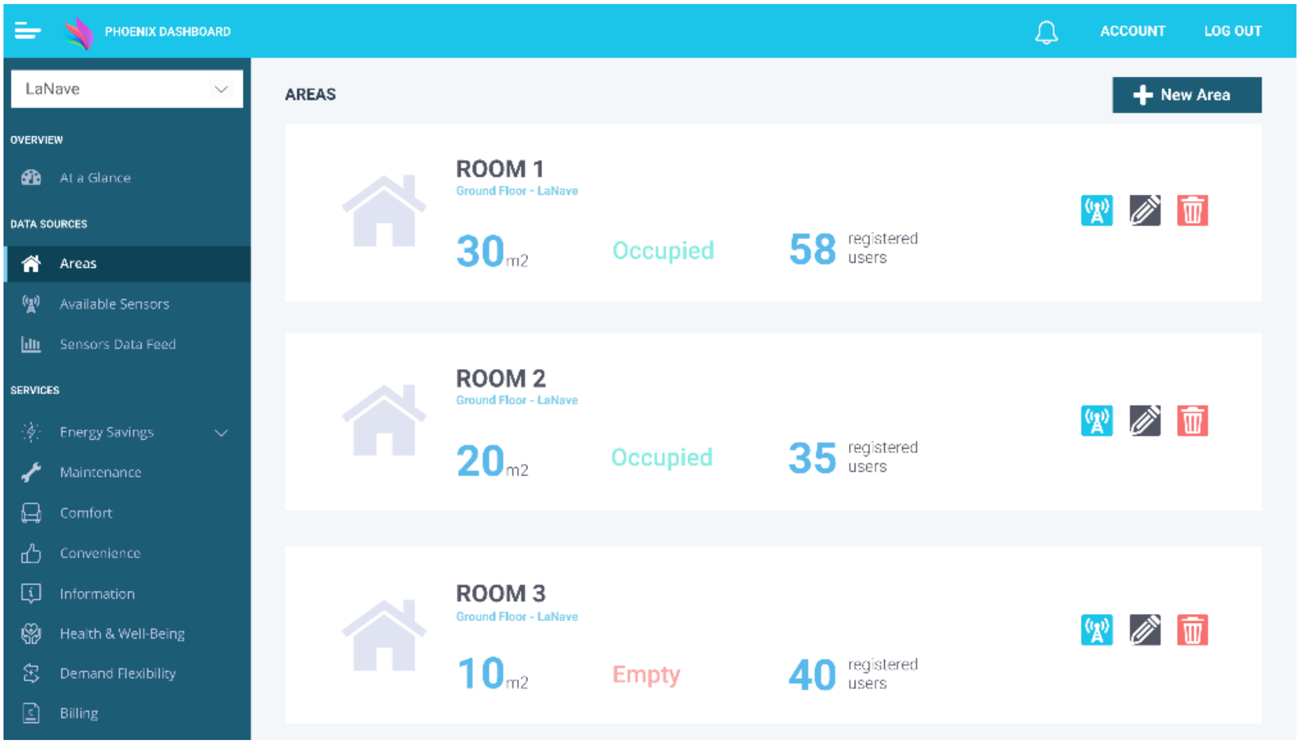


Figure 13. How to define the areas in the dashboard.

Figure 14 presents the available sensors of the “default room/zone” (where the user is registered). The user has the option also to see available sensors from any room/zone he wishes. Options to check the available data stream of the specific sensor measurements, add/edit/remove a sensor and finally in case of a controllable asset such as for example lighting control, options to manually control, schedule, or fully automate the action of switching on/off the lights.

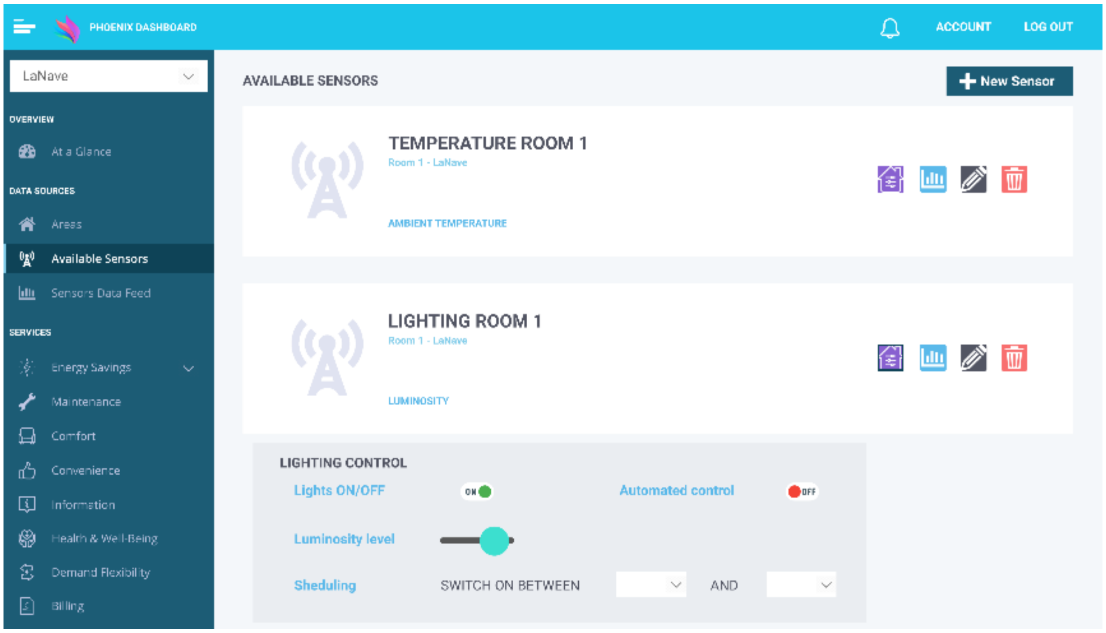


Figure 14. Available sensors and how to add/edit them.

Finally, figure 15 presents the chosen sensor data feed at an hourly level (can be modified), choice to see historical snapshots on older data feeds and filters for room/sensor type/time range as more options for customizations on the data feeds.

Figure 15. An example sensor feed.

Moving on to the services group, which hosts the 7 SRI domains, “Energy Savings”, “Maintenance”, “Comfort”, “Convenience”, “Information to Occupant”, “Health and Well-being”, “Demand Flexibility as well as “Billing” information. Under the “Energy Savings” page, we have the “Energy Consumption”, “Self-consumption”, “Energy Savings”, and “Energy waste” sub-pages. As indicative examples from this category, we will demonstrate the functionality from Energy Consumption and Self-Consumption.

Figure 16a. demonstrates a summary on energy consumption of the past 12 months (total energy consumption, total CO_2 emissions), a graph on the historical consumption of the past 12 months and a comparative graph on the energy consumption behaviour of similar peers. Of course, the scope can be enhanced, and this kind of information can also be made available at a zone level, this will be analysed at a future deliverable. Figure 16b. shows s self-consumption report and an informative graph that combines the PV generation, the consumption from the grid and the self-consumption.

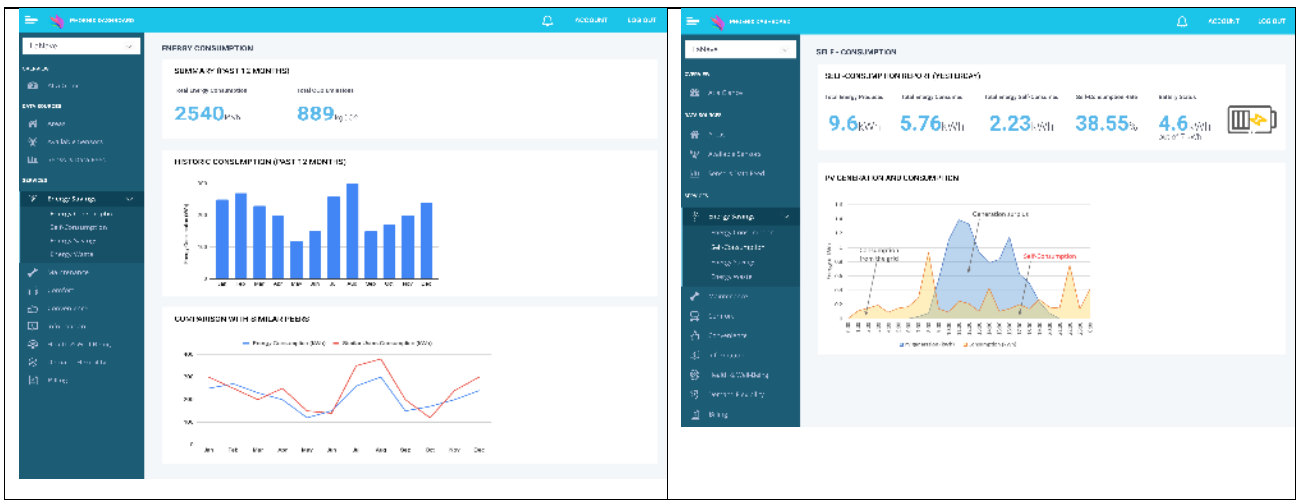


Figure 16. a) Information on building energy consumption, b) information on generation and self-consumption.

The “comfort” page is related to the thermal and visual comfort status of the user. There exist current indications on thermal and visual comfort statuses as well as the average comfort/discomfort status over the last 15 days (this can be modifiable). The user may choose to see the comfort status at a specific room/zone.

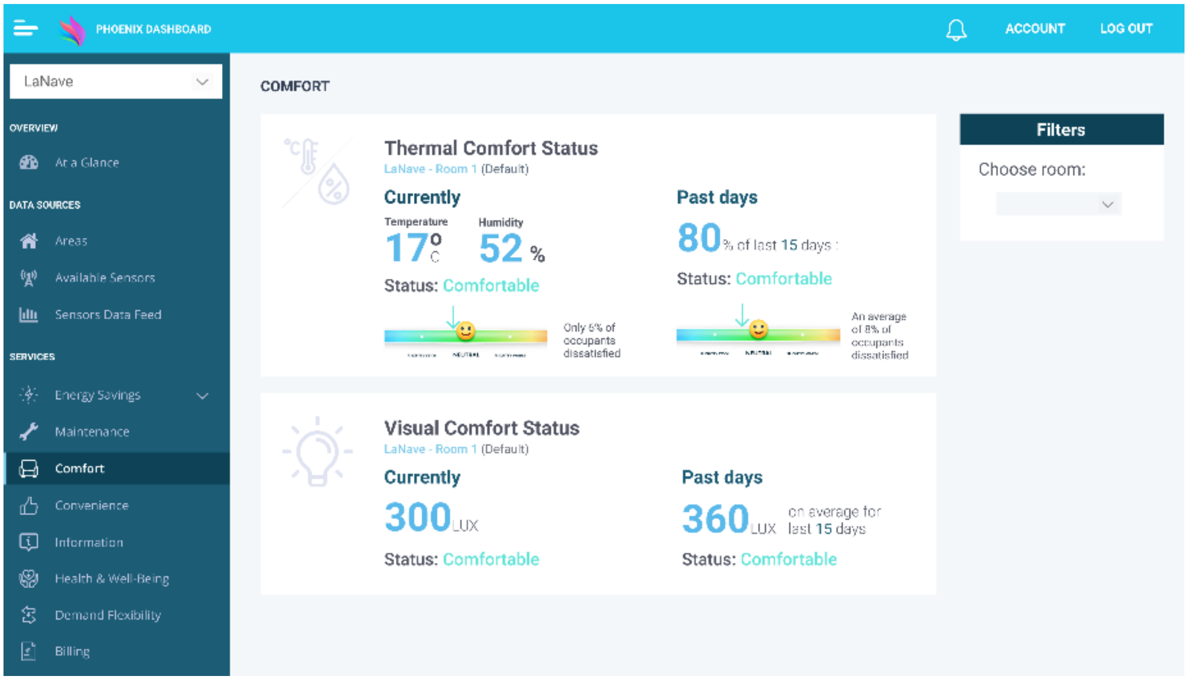


Figure 17. The user comfort status.

On the convenience perspective, the automation level thus the smartness level, contribute to the overall feeling of the user that he has control over his environment and feels safe and confident in it. Some statistics over the manual and system actions are made available, over the last day and the last month (these are customizable).

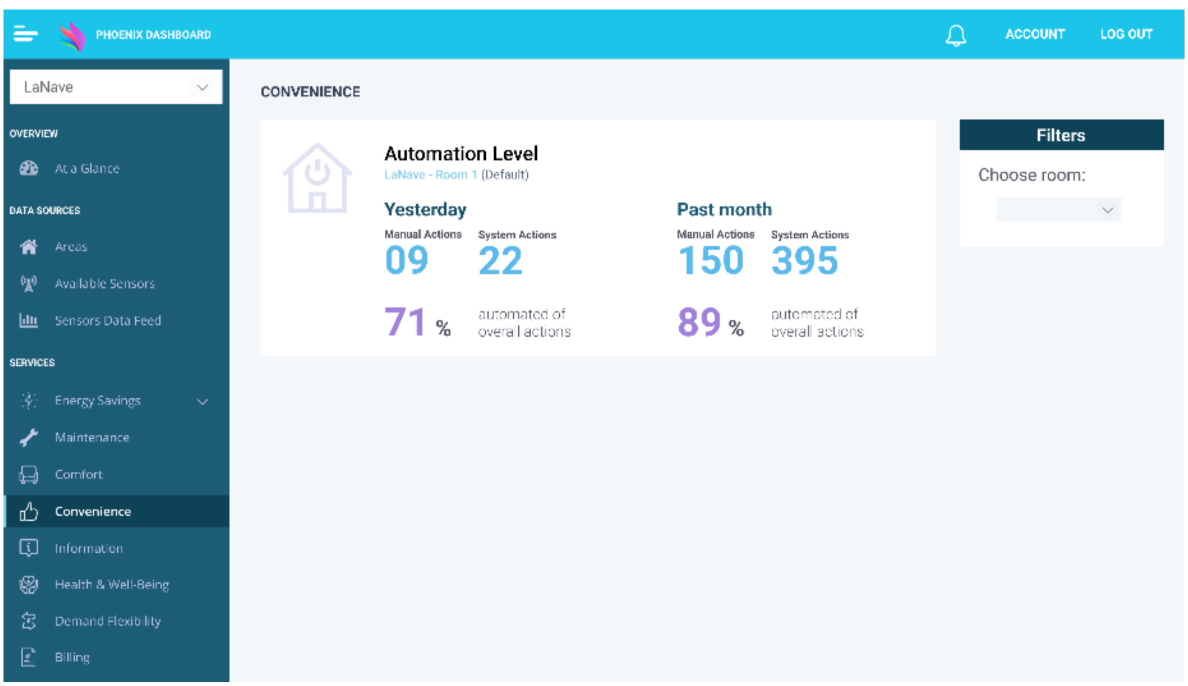


Figure 18. The user convenience level.

The “health” tab is about the indoor air quality (the CO2 levels) and the current comfort status of the user as well as the average comfort status over the past days, e.g., 15 days. The user may choose to see the comfort status at a specific room/zone.

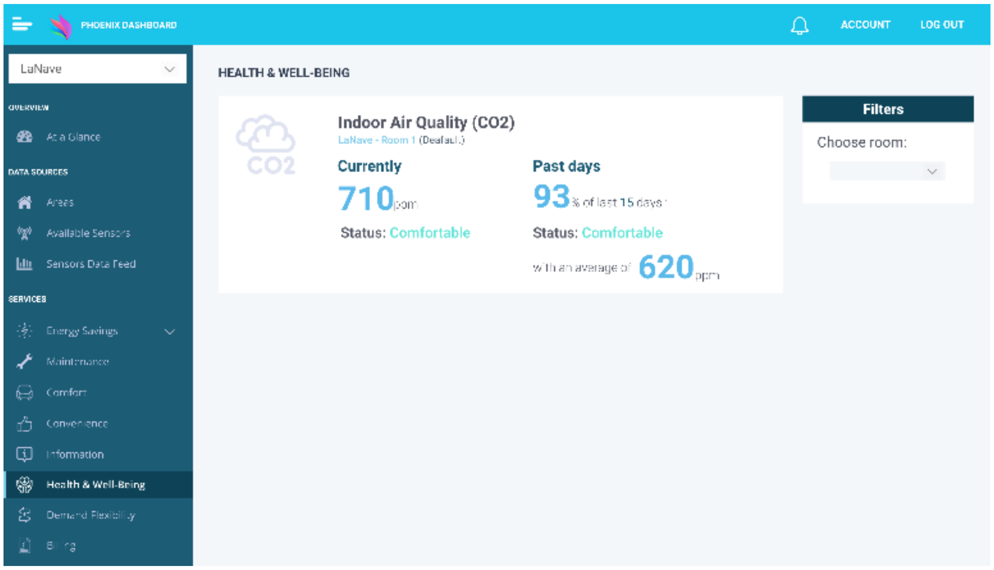


Figure 19. The user health depends on the indoor air quality.

The “information to occupants” tab contains a notifications history for the user and the level of granularity or some statistics on those notifications could also be a part of this page, but will be considered in a future version of the deliverable.

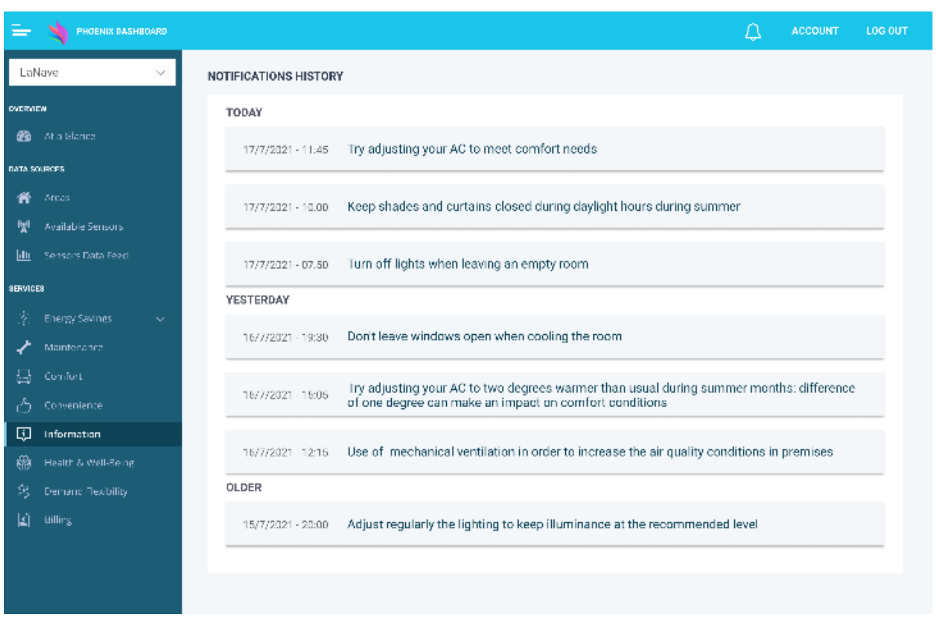


Figure 20. Notifications and recommendations

5. Conclusions

The portfolio of ICT solutions that Phoenix offers, aims to increase the smartness of legacy systems and appliances in existing buildings which will in their turn increase the SRI and energy efficiency of the building/dwelling. These improvements will consequently translate into new human-centric services for building users and an optimization on the execution of grid operations and data sharing between various energy stakeholders.

In this work, an initial attempt has been made to approach the description of these new human-centric smart services, addressed to building occupants and building managers that participate in the Phoenix smartness hub project. Overall D5.1 aims to cover Key Objective KO4 from the GA: "Provide cost-effective services for building end-users to maximize the energy efficiency and overall performance". The human-building-interaction technologies developed in WP5 will facilitate the users engagement and awareness about their energy behaviour and optimize the user experience through useful recommendations towards the end-users as well as triggers of automated actions through the Phoenix DSS.

In more detail, the first steps towards the design, specification and interactions between the components that deliver the user services in the PHOENIX architecture have been grounded. Overall, the cornerstone of all the user related services is the user dashboard, which provides interaction with various applications depending on the business case or more specifically on the SRI domain that PHOENIX project aims to target. In this deliverable, the focus has been given on services relevant to the comfort, convenience and well-being engine, the predictive maintenance engine and the SRI/EPC evaluation engine.

This work is also highly linked to the work delivered under task 4.3, the user-centric services analytics engine, as this engine is responsible for all aggregated, historical and forecasted energy analytics that will be depicted in the user visualization dashboard. Other business applications mainly targeted to energy utilities will also be integrated in the dashboard under the scope of deliverables of WP6. The mock-ups presented in this deliverable will help to achieve the final integration of all the user and grid services in the PHOENIX platform.

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[24] K. Tsatsakis et al., "An enhanced human-centric performance framework towards promoting behavioural energy efficiency in buildings", ASHRAE 2017, Athens.

7. Annex

7.1. Annex 1

In this section, the indicative list of recommendations and automation strategies for non-energy services as defined by the demo partners at the very early phase of the project are presented. More specifically:

- Recommendation's specs provide the message structure, message type, goal objective, target device, triggering parameters (contextual conditions) and the success criteria
- Automation strategies provide the automation structure, goal objective, target device, triggering parameters (contextual conditions) and the success criteria

We have to point out that this is a preliminary list and updates will apply as the project evolves.

ID	Message	Goal of message	Customer Feedback	Appliance targeted	Trigger	Success definition
1	Clean or replace Air Conditioning filters regularly, to create a health environment	Health	Recommendation	Cooling	IAQ conditions monitoring	Read message or high rating by customer
2	Keep shades and curtains closed during daylight hours during summer.	Comfort	Recommendation	DE	Temperature level	Read message or high rating by customer
3	Do not leave windows open when cooling the room	Comfort	Recommendation	DE	Temperature level	Read message or high rating by customer
4	Use of natural or mechanical ventilation in order to increase the air quality conditions in premises	Health	Recommendation	Ventilation	IAQ conditions monitoring	Read message or high rating by customer
5	Use appropriate clothing to reduce the need for cooling.	Comfort	Recommendation	Cooling	Temperature level	Read message or high rating by customer
6	Open / close windows and doors where relevant to reduce the need for cooling and to provide a comfort environment	Comfort	Recommendation	DE	Temperature level	Read message or high rating by customer
7	Open / close windows and doors where relevant to provide a healthy environment for your family and friends.	Health	Recommendation	DE	IAQ conditions monitoring	Read message or high rating by customer
8	Try adjusting your AC to two degrees warmer than usual during summer months: difference of one degree can make an impact on comfort conditions	Comfort	Recommendation	Cooling	Temperature level	Read message or high rating by customer
9	Long weekend or holidays and no one at home? The XXX device can be turned off	Convenience	Recommendation	All	Occupancy Schedule	Read message or high rating by customer

10	Do not block air vents with drapes and furniture to look after indoor air quality	Health	Recommendation	Ventilation	IAQ conditions monitoring	Read message or high rating by customer
11	Set thermostat lower in winter when leaving the house.	Convenience	Recommendation	Heaters	Occupancy Schedule	Read message or high rating by customer
12	Keeping your heating on constantly on a low heat could increase your comfort levels than switching it on and off for big blasts of heat.	Comfort	Recommendation	Heaters	Temperature level	Read message or high rating by customer
13	Do not leave windows open when heating the room to meet your comfort needs	Comfort	Recommendation	Heaters	Temperature level	Read message or high rating by customer
14	Use appropriate clothing to reduce the need for heating	Comfort	Recommendation	Heaters	Temperature level	Read message or high rating by customer
15	Try adjusting your thermostat a degree or two lower to meet your comfort needs	Comfort	Recommendation	Heaters	Temperature level	Read message or high rating by customer
16	Turn off lights when leaving an empty room.	Convenience	Recommendation	Lights	Occupancy Schedule	Read message or high rating by customer
17	Regularly adjust the lighting to keep illuminance at the recommended level.	Comfort	Recommendation	Lights	Luminance monitoring	Read message or high rating by customer
18	Regularly adjust the lighting to keep illuminance at the recommended level and provide a healthy environment.	Health	Recommendation	Lights	Luminance Level monitoring	Read message or high rating by customer
19	Adjusting the curtains and blinds not only according to the daylight but also season can help you to keep the illuminance without turning lights on. This also provides a healthy environment	Health	Recommendation	Lights	Luminance Level monitoring	Read message or high rating by customer

	for your family and friends.					
20	Your current thermal comfort status is xxx	Comfort	Information	Information	Other	Read message or high rating by customer
21	Your current visual comfort status is xxx	Comfort	Information	Information	Other	Read message or high rating by customer
22	Your current IAQ status is xxx	Health	Information	Information	IAQ conditions monitoring	Read message or high rating by customer
23	Set thermostat higher/ turn off thermostat in summer when leaving the house.	Convenience	Recommendation	Cooling	Occupancy Schedule	Read message or high rating by customer
24	Keep shades and curtains open during daylight hours	Comfort	Recommendation	DE	Luminance monitoring	Read message or high rating by customer

Table A.1 Indicative list of recommendations for non-energy services

ID	Automation Strategy	Goal of automation	Appliance targeted	Trigger	Success definition
1	Regularly adjust the lighting to keep illuminance at the recommended level.	Comfort	Lights	Luminance monitoring	high rating by customer

2	Keep shades and curtains closed during daylight hours during summer.	Comfort	DE	Temperature level	high rating by customer
3	Try adjusting your AC to meet comfort needs	Comfort	Cooling	Temperature level	high rating by customer
4	Try adjusting your thermostat to meet comfort needs	Comfort	Heaters	Temperature level	high rating by customer
5	Set thermostat lower in winter when leaving the house.	Convenience	Heaters	Occupancy Schedule	high rating by customer
6	Turn off lights when leaving an empty room.	Convenience	Lights	Occupancy Schedule	high rating by customer
7	Turn off thermostat in summer when leaving the house.	Convenience	Cooling	Occupancy Schedule	high rating by customer
8	Use of mechanical ventilation in order to increase the air quality conditions in premises	Health	Ventilation	IAQ conditions monitoring	high rating by customer
9	Regularly adjust the lighting to keep illuminance at the recommended level and provide a healthy environment.	Health	Lights	Luminance Level monitoring	high rating by customer

10	Adjusting the curtains and blinds not only according to the daylight but also season can help you to keep the illuminance without turning lights on.	Health	Lights	Luminance Level monitoring	high rating by customer

Table A.2 Indicative list of automation strategies for non-energy services