(FP7 614100)

D2.1.2 Requirement and Lessons Learned Report

27 February 2015 – Version 1.0

Published by the IMPReSS Consortium

Dissemination Level: Public

Project co-funded by the European Commission within the 7th Framework Programme and the Conselho Nacional de Desenvolvimento Científico e Tecnológico
Objective ICT-2013.10.2 EU-Brazil research and development Cooperation

Document control page

Document file: D2.1.2 Requirement and Lessons Learned Report_v1.0.docx
Document version: 1.0
Document owner: Trine F. Sørensen (IN-JET)

Work package: WP2 Requirement Engineering and SDP Architecture
Task: Task 2.2 SDP requirement analysis and engineering
Deliverable type: R

Document status: ☒ approved by the document owner for internal review
☒ approved for submission to the EC

Document history:

Version	Author(s)	Date	Summary of changes made
0.1	Trine F. Sørensen (IN-JET)	31-10-2014	ToC
0.2	Trine F. Sørensen (IN-JET)	17-02-2015	Initial version ready for internal review
0.3	Trine F. Sørensen (IN-JET)	26-02-2015	Requirement status updated
1.0	Trine F. Sørensen (IN-JET)	27-02-2015	Comments from internal review incorporated. Final version ready for submission to EC

Internal review history:

Reviewed by	Date	Summary of comments
Thiago Rocha	23-02-2015	Accepted with minor comments
Ferry Pramudianto	27-02-2015	Accepted with minor comments

Index:

1. Executive summary

This deliverable is follow-up of the deliverable *D2.1.1 Initial Requirement Report*. The deliverable presents the results of the Lessons Learned process as carried out in this first cycle of the project and an updated and current list of System Development Platform (SDP) and Pilot Application requirements reflecting the end of the first iteration of the IMPReSS project. It also gives a brief overview of the requirement engineering methodology.

A total of 30 Lessons Learned across the project's work packages have been identified during the first iteration of the project.

Three Lessons Learned have resulted in the creation of three new SDP requirements:

- IMP-32 IMPReSS platform should schedule/manage resource access based on application criticality.
- IMP-38 Sensors integrated into Impress platform shall provide data both generating events periodically and responding to direct requests from other platform components.
- IMP-41 RAI shall provide a tool that help developer while creating new device managers.

One of the Lessons Learned (in WP2) was that it was deemed useful to elicit and document a list of pilot application level requirements , i.e. the requirements related to the applications that will be developed and implemented at the two IMPReSS pilot sites in Brazil: Teatro Amazonas and Federal University of Pernambuco. These requirements focus on the perspective of the Final Recipient User, i.e. the end-user who will use the application. We thus operate with two parallel sets of requirements that are or course deeply interlinked: System Development Platform (SDP) requirements and Pilot Application requirements. This approach has strengthened the user-centric focus adopted by the project. The remaining Lessons Learned are mainly related to approaches to improve the development work processes.

The second part of this deliverable focuses on the requirements: SDP sets of requirements are managed by the online tool JIRA where they follow a predefined workflow implemented to ensure the quality of the requirements and their proper management. The requirement workflow follows unique steps (or statuses) and all requirements must go through all the steps in the workflow.

IMPReSS SDP Requirement Status

A total of 41 requirements have been identified for the IMPReSS SDP. Since the submission of the initial list of SDP requirements in *D2.1.1 Initial Requirement Report*, ten new requirements have been created (IMP-32 - IMP-41). The current status is that two SDP requirements have been validated, seven have been implemented, thirteen are part of the specification, seven have been passed through the quality check and six recently created SDP requirements are still open. Six requirements did not pass the Quality Check because they were either duplicates, out of scope, or non-sense in relation to the project visions and objectives. The figure below illustrates the status of the SDP requirements in M18:

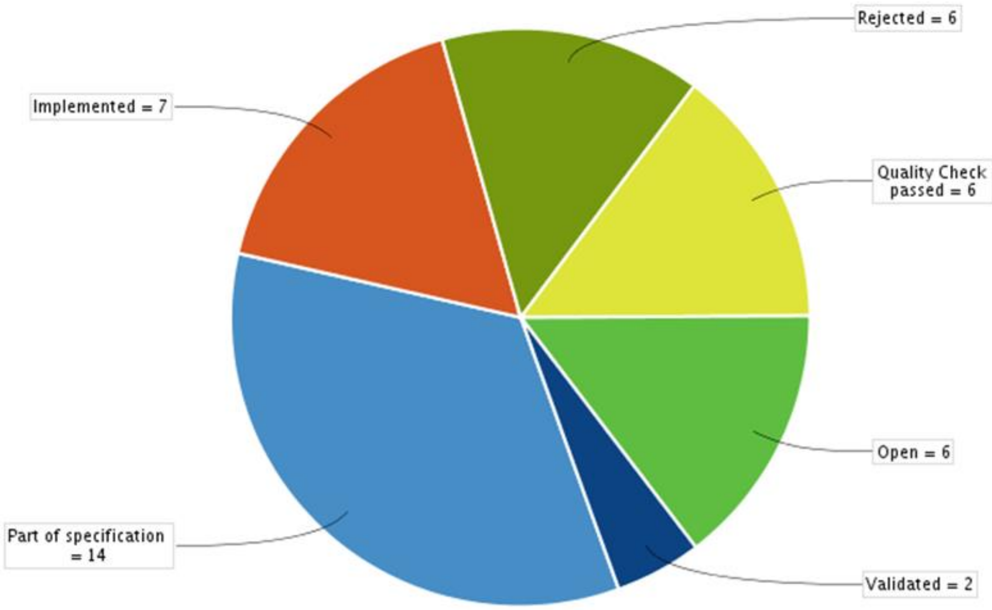

Figure 1: Current status of IMPReSS SDP requirements (M18)

IMPReSS Pilot Application Requirement Status

A total of 58 Pilot Application requirements were initially elicited based on the pilot scenarios and use cases identified in *D2.1.1 Initial Requirement Report* and on a workshop session with the project consortium in Copenhagen. The initial list of the Pilot Application requirements are documented in a working document *WD2.1.2 Pilot Application End-User Requirements*.

All requirements have been passed through the Quality Check out of which 39 requirements passed. A total of 19 requirements were rejected which is a relatively high number; however, this is due to the fact that the requirements for each pilot site were elicited separately and the later quality check then identified - as expected - a number of similar requirements thereby resulting in their rejection as duplicates.

The current status in M18 is that thirteen Pilot Application requirements have been made part of specification, fourteen have been implemented and twelve have been validated, see Figure 2 below:

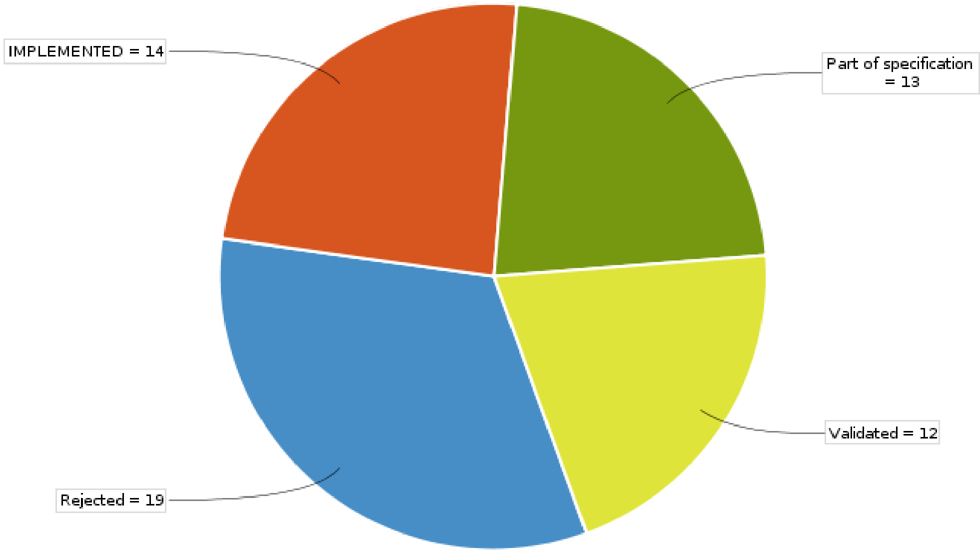

Figure 2: Current status of Pilot Application level requirements (M18)

To address the recommendations from the first review, the Pilot Application requirements will be updated taking into account use cases that are able to stress the SDP. The final list of SDP and Pilot Application requirements and their validation results will be documented in *D8.5 Platform Analysis and Feedback Report* due M30.

2. Introduction

The elicitation and analysis of user requirements is an important procedure which will ensure that the IMPReSS SDP meets the users' needs and requirements. In the IMPReSS project, the elicitation of user requirements is done through careful analysis of the scenarios and use cases which have been defined by the two IMPReSS pilots. These scenarios and use cases are described in the deliverable *D2.1.1 Initial Requirement Report* where they have been analysed by the IMPReSS developers in order to facilitate the development of technical use cases and extraction of requirements.

At a consortium meeting in Manaus in March 2014, it was decided that it was also necessary to focus more specifically on the pilot application level requirements, i.e. on end-user requirements[1], for the demonstrators in conjunction with the work in and results from WP8 Platform Evaluation and Application Development. This would help to ensure that the pilots' needs and requirements are fully incorporated into the development of the IMPReSS SDP platform. The pilot application level requirements have been documented in the working document *WD2.1.2 Pilot Application End-User Requirements*.

2.1 Purpose, context and scope of this deliverable

The deliverable gives an overview of the refined set of requirements that will be used within the remaining iterative step according to the user-centred design approach and methodology adopted in the project. It takes into account all requirements that have been defined *in D2.1.1 Initial Requirement Report* and in working document *WD2.1.2 Pilot Application End-User Requirements*. It also takes into account any new requirements that have been created after the publication of *D2.1.1 Initial Requirement Report* including any as a result of the Lessons Learned.

The purpose of this deliverable is also to present the Lessons Learned that have been collected in all the Research and Technological Development (RTD) work packages during the first cycle of the project (M01-M15). Some Lessons Learned have already had a direct impact on project partners' approach to the development work while some Lessons Learned will influence work yet to be undertaken during the second cycle of the project.

2.2 Background

The IMPReSS project aims to provide a Systems Development Platform (SDP) that enables rapid and cost-effective development of mixed criticality complex systems involving Internet of Things and Services (IoTS) and at the same time facilitates the interplay with users and external systems.

The IMPReSS development platform will be usable for any system intended to embrace a smarter society. The demonstration and evaluation of the IMPReSS platform will focus on energy efficiency and awareness in two public buildings in Brazil: The Teatro Amazonas Opera House in Manaus and the University of Pernambuco in Recife. More precisely, the demonstration and evaluation will be done through real world system development, which targets extension to the conventional energy management systems by adding the following key features:

- Development of a building management system that gives different priority to specific devices and rooms when the energy supply is limited (e.g.: refrigerators for storing dangerous substances, fire alarms, sprinklers, and ventilation have different certifications and priorities)
- Seamless and autonomous integration of distributed energy sources (e.g., renewable energy sources) into the considered scenario and exploiting specific systems to store the generated energy for use at a later time.

[1] The pilot sites are here considered to be end-users. As such, the term also includes employees, staff and students at the pilot sites, i.e. people who are affected by and/or interact with the IMPReSS solution. The term end-user here is thus synonymous with the term "recipients" referred to in the deliverable *D2.2.1 SDP Initial Architecture Report*.

- Development of a micro-grid that interacts with the energy providers to receive real-time cost information, thus opportunistically balancing the consumption of energy from the provider and local storage systems.
- Development of energy management extensions that take into account context information such as the users' behaviour, habits, preferences, work activities, environmental conditions etc. This information could be used to educate the users to be more energy aware.
- Minimal retrofitting through the adoption of wireless sensors (e.g., energy meters) and actuators (remotely controlled switches) which allow new device installations in preserved historical buildings.

3. Methodology

The evolutionary requirements engineering, specification and design methodology used in the IMPReSS project has already been described in detail in the deliverable *D2.1.1 Initial Requirement Report*. We will therefore only present a brief overview in this chapter before reporting from the activities carried out in a requirement workshop in Copenhagen in October 2014.

3.1 The Requirement Engineering Process

The IMPReSS project applies an iterative approach and participatory design (Asaro 2000) for developing the technological parts of the SDP platform which is initiated from the requirement engineering process. The methodology involves iterative methods with annual evaluations and milestones.

After the successful completion of a prototype cycle, each RTD work package analyses and reports their development results, RTD experiences, Lessons Learned during the development, integration and testing, and any other relevant knowledge gained during the development cycle.

The elicitation of the initial user requirements has done through careful analysis of the scenarios and use cases that were defined by the two IMPReSS pilots. The documentation of requirements is based on the Volere template and recorded using the web-based issue tracker JIRA. Each requirement is given a short title (summary), is described, the rationale is explained and a fit criteria is defined.

In JIRA, the requirement engineering process follows a predefined workflow. The quality and management control of the progress of implementation of requirement is realised by processing all requirements along the steps of the workflow. As a requirement progresses along the workflow, its status is changed accordingly.

We operate with the following steps: Open, Quality Check passed, Part of Specification, Implemented, Validated and Rejected. The latter can happen for different reasons: A requirement can be a duplicate of another requirement, it may be conflicting with another requirement(s), it may be nonsensical or it may be out of the project's scope.

The final step for an implemented requirement is its validation. Validation is conducted according to the framework defined in *D2.3 Validation Framework.*

3.1.1 IMPReSS User Requirements

In the IMPReSS project, we distinguish between three types of users:

- Developer User: Develops applications using the IMPReSS SDP platform
- Integrator User: Configures, installs and deploys the application
- Recipient User: Uses the application.

The three user types and their perspectives are explained in more detail in *D2.2.1 SDP Initial Architecture Report*.

As a result of a Lessons Learned (see Chapter 4.1), we operate with two parallel and embedded sets of user requirements: i) SDP technical requirements for the Developer user, and ii) Pilot Application requirements for the Recipient end-user, e.g. a building manager or operator.

3.1.2 Requirement Workshop in Copenhagen

A half-day user requirements workshop was held in connection with the consortium meeting in Copenhagen in October 2014. The workshop focused particularly on the Pilot Application requirements as these had not earlier been discussed in plenum. The purpose of the workshop was to carry out a quality check of *all* the requirements (both SDP and Pilot Application requirements) and update and refine them as appropriate.

Prior to the workshop, we had analysed the scenarios and use cases that had been defined by the pilot sites in *D2.1.1 Initial Requirement Report.* As a result, we defined seven use cases and 25 requirements for the Teatro Amazonas Pilot Application and nine use cases and 30 requirements for the University UFPE Campus Pilot Application. We documented these in an internal working document *WD2.1.2 Pilot Application Requirements* made available to all project partners.

Based on the internal working document, *WD2.1.2 Pilot Application End-User Requirements*, each use case was first presented and next the requirements that had been elicited were discussed. This allowed us to analyse and conduct a quality check of the user requirements in an efficient manner. The workshop made it possible for technical partners and the pilot sites (representing the Recipient end-user) to discuss and agree upon the best solutions for the Pilot Application and we were able to verify that the work done so far is in alignment with the SDP and Pilot Application requirements.

As a result of the workshop, some Pilot Application use cases and requirements were rejected as “duplicates” or “out of scope” and some requirements were refined. Finally, some requirements were defined as “part of specification” and “implemented” (please see Chapter 6 for details).

Through this thorough assessment of SDP and Pilot Application requirements, it also transpired that some terminology, definitions and visions differed between partners. The Copenhagen workshop thus allowed us to reach a profound common understanding of the visions, SDP and Pilot Application requirements, and the tasks ahead.

3.2 The Lessons Learned Process in IMPReSS

We have already described the Lessons Learned process in *D2.1.1 Initial Requirement Report*, but to sum up the most important points:

Lessons Learned support project goals in the RTD work by promoting recurrence of successful outcomes and precluding the recurrence of unsuccessful outcomes.

A Lesson Learned should have the following characteristics:

- It must be significant in terms of the project progress and ability to meet its goal
- It must be valid, i.e. the experience gained must be repeatable
- It must be applicable to the IMPReSS project
- It may contain or address pertinent info
- It may provide information of interest.

The IMPReSS Lesson Learned process has six steps:

- Collection
- Verification
- Storage
- Dissemination
- Reuse
- Identification of improvement opportunity.

After the successful completion of a prototype cycle, each RTD work package will analyse and report their development results, RTD experiences, lessons learned in the development and integration work and other relevant knowledge gained during the development cycle.

As part of the continuous improvement program adopted by the IMPReSS Project, a systematic and continuous collection, indexing and dissemination of lessons learned will be undertaken in WP2. All project partners are responsible for documenting their Lessons Learned in the online tool Confluence.

4. Lessons Learned

This chapter presents the 30 Lessons Learned in the different work packages.

4.1 Lessons Learned in WP2

Two Lessons Learned have been identified in WP2 Requirement Engineering and SDP Architecture.

LL No.	Experience and knowledge gained	Lesson Learned
WP2-1	There has been some confusion about the terminology used and different partners understand certain terms (e.g. system and application) differently. The term "user" is also tricky as it is very broad and as there are different types of users. This can lead to serious misunderstandings which may affect how partners understand the task involved in the development work. It was therefore necessary spend some time discussing the terminology used.	The terminology used should be discussed and the meaning of terms used in the project should be clearly defined as a first task when a project begins. This will avoid later misunderstandings and confusions. We use the following terms to distinguish between relevant types of users: Developer, Integrator, and Recipient. We use “system” to refer to the SDP platform and “application” to refer to the applications built (using the IMPReSS SDP) for the two pilot sites.
WP2-2	At the consortium meeting in Manaus in April 2014, ways to reinforce the user-centric focus of the requirement engineering process were discussed. While we distinguish between three types of users, two of these, i.e. the Developer user and the Recipient user perspective will be focused upon as they constitute the main end-user of the IMPReSS SDP platform and the pilot applications respectively. The requirements for the pilot applications / recipient users should be given more attention.	While the overall objective of the project is to develop the IMPReSS SDP, the applications that the pilot sites require and have described in the scenario are also important. It is therefore important to define clear end-user (Recipient user) requirements for the applications that will be developed for the IMPReSS pilot sites. A specific set of pilot application level requirements should therefore be defined. This will be especially useful for the application development work in WP8. Pilot application requirements should follow the same workflow as SDP requirements using JIRA.

4.2 Lessons Learned in WP3

Six Lessons Learned have been identified in WP3 Resource Abstraction and IoT Communication Infrastructure.

LL No.	Experience and knowledge gained	Lesson Learned
WP3-1	Commercial sensors and actuators with completely public internet enabled APIs are rare.	Since Philips Hue/Belkin supports RESTfull & UPnP, they are very useful devices to demonstrate control & ambient notification in IoT applications.
WP3-2	Actuation through pub/sub mechanisms is not recommended due to challenges in terms of reliability of message delivery and the possible conflict of multiple clients	Synchronous REST approach has been selected for controlling actuators.

WP3-3	The classification of resources with respect to the type of wireless communication technology adopted is not useful the design the RAI modules. The integration is made at Gateway level.	Gateway communication protocol classification is more useful
WP3-4	Device Managers handling different technologies still share some part of source code	Automatic generation mechanisms can be used to support the development of Device Managers. As a result, a new requirement has been created: *IMP-41 RAI shall provide a tool that help developer while creating new device managers*.
WP3-5	Building P2P networks introduces high efforts for maintaining & propagating the information. The use cases so far do not need P2P capabilities but they require local and global (across internet) connectivity	MQTT (local) & 0MQ (global) have been considered
WP3-6	A Wireless Sensors and Actuators Network (WSAN) can have a huge number of devices that can be polled with different polling time in order to retrieve data/status information.	Polling different devices with different polling time enormously multiply the number of needed threads. This is a waste of resources. Device managers calculate the maximum common divisor in order to use just one thread for managing all polling time requests. A new requirement has been created: *IMP-38 Sensors integrated into Impress platform shall provide data both generating events periodically and responding to direct requests from other platform components.*

4.3 Lessons Learned in WP4

Three Lessons Learned have been identified in WP4 Mixed Criticality Resource Management.

LL No.	Experience and knowledge gained	Lesson Learned
WP4-1	The Internet and wireless networks are not suitable for safety critical systems, because connectivity of devices and worst case latencies of communication cannot be guaranteed	The resources of safety critical systems must be connected through reliable real-time communication links.
FIT WP4-2	The centralized approach for resource allocation and management is not suitable for safety critical systems, because no additional overheads in resource access should be imposed to this type of systems.	If we want to incorporate safety critical subsystems in the IMPReSS system we can utilize following approach. The safety critical system can share its resources for other applications in the IMPReSS system but if it needs the resources it can directly access them without a need to go through the global resource manager.
WP4-3	Many resources in IoT systems can interfere with each other if deployed into the same	The mixed criticality resource management solution needs to be

	environment (e.g. audio devices, lights, heaters, etc.).	able to manage resource access in the case applications try to access two or more resources that may interfere with each other in the real world. A new requirement has therefore been created: *IMP-32 IMPReSS platform should schedule/manage resource access based on application criticality*.

4.4 Lessons Learned in WP5

Eleven Lessons Learned have been identified in WP5 Data Storage, Analysis & Decision Support.

LL No.	Experience and knowledge gained	Lesson Learned
WP5-1	Managing multiple cloud servers, as in the case of the Storage Module, can be a great time consumer.	Automating deployment among different machines should be a priority from the get go. Solutions like Ansible, Puppet and Fabric avoid inconsistencies (e.g. different versions, configuration) in environments, therefore diminishing operational costs for developers.
WP5-2	Graphs are a straightforward way to model relations between data.	Domain data can be easily modelled with simple tools (e.g. pen and paper).
WP5-3	Historical data, in graph databases, are better represented as a hierarchical balanced tree (year -> month -> day -> ...) for faster historical data retrieval.	Linked lists are O(N) and should be avoided for performance reasons. Tree transversals, on the other hand, would have a constant time complexity for retrieving its historical data, no matter how old the data is.
WP5-4	Although NoSQL solutions tend to be schema-less, indexes, as in RDBMS, have to be carefully taken into account.	Proper indexes setup can be the source of huge performance gains. Developers must rely on them from the very beginning, since, as the data size grown, bottlenecks caused by scanning all data will become more and more difficult to deal with.
WP5-5	Managing multiple graph instances, for different clients, is not the best approach for isolating data.	Managing multiple graphs instances for different clients that requires their data to be isolated is not practical for use cases that the number of clients changes or grows too much. In that sense, multi-tenancy deployments are more elegant and future-proof.
WP5-6	Developers may experience difficulties on querying graph databases, due to the differences to well-known alternatives like SQL.	Although Gremlin has powerful constructs for enhancing querying capabilities (e.g. loops), its functional model and syntax may impose difficulties for newcomers.
WP5-7	Graphs databases are better than traditional ontologies technologies in terms of scalability and performance.	RDF, OWL and the like are well-known among academia and certain circles of developers; however they have no proper means to scale vast amounts of entities and links among them (i.e. millions and billions of

		vertices and edges). Also, even though current ontologies processors have evolved a lot, their lack of distributed horizontal scaling capabilities may hinder its usage in traditional cloud scenarios (i.e. large quantities of concurrent users). In that sense, NoSQL graph databases fits better in the requirements of having great performance for multiple concurrent users.
WP5-8	Graphs databases provide less overhead for querying relationships among different entities than RDBMS.	Due to index-free adjacency algorithms, graph databases are more performant transversing links between entities than traditional join operations in RDBMS' tables.
WP5-9	Most Java-based NoSQL solutions can leverage on embedded micro-services, running in the same JVM, to achieve better performance.	Despite facilitating deployments, this approach can eliminate the serialisation overhead present when a network is used for services to exchange data with the database.
WP5-10	Authorization that takes long times are required to work with public buildings in Brazil.	Try to take these authorizations and make a schedule of visits before the project starts
WP5-11	During the development of the Rest machine learning APIs we got a problem when passing the information because machine learning algorithms requires a lot of data to be passed.	Pass the data in a Json format via post inside a file

4.5 Lessons Learned in WP6

Three Lessons Learned have been identified in WP6 Software System Engineering and Context Management.

Partner LL No.	Experience and knowledge gained	Lesson Learned
WP6-1	A rule-based context reasoning system may got stuck into an infinite loop.	When working with a rule-based engine for context reasoning, different rules can command conflicting actions successively (over and over again) so that the application may get unstable. A rule-based system must be carefully designed and tests must be performed to assess whether there have a chance of ending up in an infinite loop.
WP6-2	Data fusion criteria (like Esper streams) must be well equalized with the speed sensors send data.	A fusion engine (such as Esper) is an excellent tool for dealing with huge amounts of data coming from sensors. The fusion engine controls the flow of information fed to the rule engine and consequently controls the speed actions are send to the actuators. There is a trade-off between response time for changing

		behaviour and amount or information to be dealt with by the rule engine.
WP6-3	There is a trade-off when sending actions to actuators, regarding the reaction time and data overloading.	Low capacity devices (such as actuators) may be overloaded by excessive actions that are send by the rule processing engine inside de Context Manager. On the one hand, since communication might not be reliable it is save to send a new actions whenever a rule is fired (the same rule may be fired multiple times and actions can be send multiple times as well). On the other hand, successive actions sent in short periods may overload the buffer of low capacity devices, thus causing them to have unexpected behaviours.

4.6 Lessons Learned in WP7

One Lesson Learned has been identified in WP7 IDE Framework for Model-driven development.

Partner LL No.	Experience and knowledge gained	Lesson Learned
WP7-1	Tools need consider different preferences/experiences of the developer. For instance not all developers prefer GUIs but rather command line tools.	The tools should if possible be usable, either with a pure command line interface or by a GUI depending on user developer preferences.

4.7 Lessons Learned in WP8

Four Lessons Learned have been identified in WP8 Platform Evaluation and Application Development.

LL No.	Experience and knowledge gained	Lesson Learned
WP8-1	IoT kits focused on developers may not be calibrated by default.	Digi Smartplug and Sensor Station are not calibrated by default. Calibration needs to be done via software, at the client level, what is certainly troublesome
WP8-2	XBee based kits are really easy to interface.	Digi provides great abstractions on top of their XBee module. Radio configuration and the like are really straightforward when using XCTU. Despite that, there are a lot of libraries for controlling XBee's radios via USB (i.e. XBee Explorer).
WP8-3	Most ready-to-use smartplugs and sensors stations does not provide interfaces for third-party providers to integrate with their solutions.	Traditional players tend to develop the whole stack, from the hardware, to the cloud that stores the data and applications to manage it. Proper APIs or interfaces supporting the whole set of functionalities, for third-

		parties, are rarely available. Some unofficial libraries exist, but with no guarantee that future updates in manufactures' protocols will be supported.
WP8-4	Developers may not have knowledge to use machine learning algorithms.	Create a tool and tutorials to help the developers

5. IMPReSS SDP Requirements

This chapter presents the re-engineered requirements related to the IMPReSS System Development Platform (SDP). As the development work progresses, requirements are continuously refined and their status updated in JIRA. This chapter presents the SDP requirements as they are at the time of writing, i.e. M18 status. The actual refinements made to the initial SDP requirements and the new requirements that have been created since the submission of *D2.1.1 Initial Requirement Report* in M5 are illustrated in Appendix A.

5.1 Overview

The SDP requirements cover all fields of the IMPReSS architecture and the two prototypes. Each requirement has been assigned to a specific architectural component or demonstrator prototype.

35 SDP requirements have passed through the Quality Check while 6 SDP requirements are still open as they were created following the knowledge gained from the M18 demonstration of the first prototype. The 41 SDP requirements have one of the following statuses in accordance with the predefined workflow in JIRA:

- Open: 6
- Quality Check Passed: 6
- Part of Specification: 14
- Implemented: 7
- Validated: 2
- Rejected: 6

The pie chart below presents a clear overview of the current status M18 of the SDP requirements:

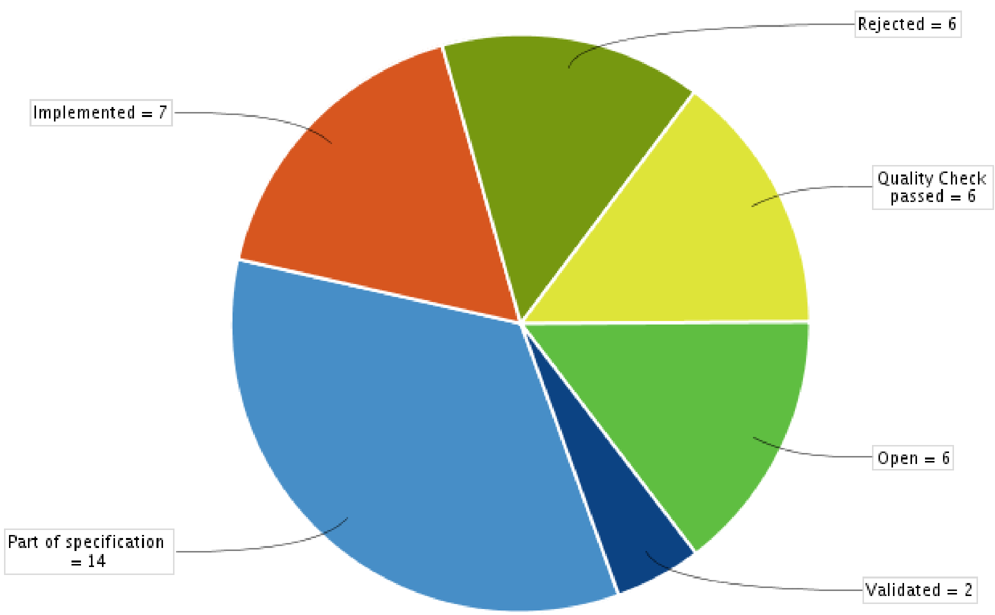

Figure 3: Current (M18) status of IMPReSS SDP requirements

The current status of requirements reflects progress of the project as the first iterative cycle has ended and the first prototype has been developed. The results of and experiences from the first cycle will feed into the development work in the next cycle. As the work now begins on the second and final IMPReSS SDP prototype, the requirements will be engineered further along the workflow as the work on them progresses. A final list of all the SDP requirements will be documented in *D8.5 Platform Analysis and Feedback Report* (M30) including the results from the validation of SDP requirements.

The following subchapters present the updated SDP requirements according to their current M18 status.

5.2 Validated SDP Requirements

Two SDP requirements have been validated as of date.

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-3	Devices should be allocated to a logical area	Functional	Critical	Device and Subsystem Resource Management	It would be interesting, for clients of the Impress' Cloud, if different devices could be allocated to a logical area, created by the user that represents a physical area (e.g. a room, an office, a bathroom) in the real world.	UFPE	Validated
IMP-8	The application should provide historical energy consumption and use of electrical devices.	Functional	Major	Theatre Amazonas Demonstration	The history of power consumption is important to control the consumption of energy to assist in identifying periods of higher power or even possible irregularities which may occur. Through it is possible to develop consumer policies in order to save energy.	It is possible to select a historical time frame and extract the energy consumption data for this time frame.	Validated

5.3 Implemented SDP Requirements

A total of seven SDP requirements have been implemented as of date.

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-4	Devices should be allocated to one or more groups	Functional	Critical	Device and Subsystem Resource Management	It would be interesting, for clients of the IMPReSS Cloud, if different devices (e.g. heaters, TVs and etc.) could be allocated to one or more groups, which is not an equivalent of the physical area these devices are. For instance, one could compare the energy usage patterns among all the heaters, in the same group.	UFPE	Implemented
IMP-32	IMPReSS platform should schedule/manage resource access based on application criticality	Functional	Major	Resource management and access scheduler	To optimize the behaviour of the IMPReSS system there is a need to manage how the applications can access the system resources (e.g sensors and actuators) based on the criticality of the applications.	IMPReSS platform is able to schedule resource access based on application criticality.	Implemented

IMP-34	IMPReSS platform searches suitable resources for applications based on resource description	Functional	Major	Resource management and access scheduler	To make the resource access as simple as possible for applications the IMPReSS platforms needs the search suitable resources for application based on resource specification.	IMPReSS platform is able to search resources matching a resource specification.	Implemented
IMP-13	Annotate application with the level of criticality	Functional	Major	Application Classification Language, Resource management and access scheduler	Developers may want to explicitly categorize the criticality of applications	Developers are able to define the level of criticality e.g.: - user interaction --> soft real time, delay max 300ms. - monitoring office consumption --> non critical delay max 1 minute	Implemented
IMP-14	IoT resources run on a low cost Gateway	Non-Functional - operational	Major	Lightweight Communication Management	IMPReSS aims at affordable intelligent system than can be produced within near future; therefore the price of the required hardware must be affordable.	The core IMPReSS middleware could run on a gateway which cost below USD 50. The core middleware should enable communication among heterogeneous devices and applications.	Implemented
IMP-15	Model driven tool for orchestrating impress components	Functional	Major	Configuration and Composition Manager	Developers may want to wire components without having to understand the APIs	A model driven tool is available which allow developers to connect the required components for his application.	Implemented

IMP-16	Reusable components for trend analysis and forecasting of energy and occupancy data	Functional	Major	Data Analysis and Forecast	Non-Expert developers would like to provide trend analysis and forecasting of energy consumption and occupancy data without having in depth knowledge of statistics and machine learning algorithms,	Reusable components for analysing energy consumption and occupancy are available, and evaluated with developers without statistic & machine learning background.	Implemented

5.4 Part of Specification SDP Requirements

Fourteen SDP requirements have been made part of the specification as of date.

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-35	Runtime service/devices configuration	Functional	Major	Configuration and Composition Manager	It may happen that new devices or services are added while the platform is already running. The platform should provide means for devices and services configuration at runtime.	New devices/services can be configured without having to restart the platform	Part of specification

IMP-33	IMPReSS platform should solve conflicts between applications that access resources interfering with each other	Functional	Minor	Resource management and access scheduler	Many type of resources such as heaters, audio devices, and lights can interfere with each other if deployed in the same location. To this end, it is necessary that the IMPReSS platform is able to schedule resources access so that conflicts between application accessing resources that interfere with each other can be solved.	IMPReSS platform is able to schedule resource access between mixed-criticality applications that request access to resources that interfere with each other in the real world.	Part of specification
IMP-31	Data transmitted in the IMPReSS network is classified to different classes based on the confidentiality.	Non-Functional - security	Major	Security architecture for resource-constrained devices	Data transmitted in the IMPReSS network needs to be classified to different classes based on the confidentiality. Data types can be e.g.: -Level 1 confidentiality (such as patient data) -Level 2 confidentiality (such as energy consumption monitoring data) -Level 3 confidentiality (device or network status data)	Confidentiality levels are set for the data	Part of specification

IMP-30	Availability of the critical IMPRESS resources must be measured	Non-Functional - security	Major	Resource management and access scheduler	IMPRESS platform must be able to provide the information about the availability of the resources for the applications.	Availability information can be used by the applications when selecting the most suitable resource.	Part of specification
IMP-29	Integrity of the messages between IMPRESS devices can be guaranteed	Non-functional	Major	Security architecture for resource-constrained devices	IMPRESS platform must guarantee the integrity of the critical messages between devices. Critical messages cannot be modified by unauthorized parties.	Critical messages cannot be modified by unauthorized parties in 100% of all cases	Part of specification
IMP-28	Confidentiality of the messages between IMPRESS platform devices can be guaranteed	Non-Functional - security	Major	Security architecture for resource-constrained devices	Data transmitted between IMPRESS devices can contain confident information e.g. about the house energy consumption. IMPRESS platform needs mechanism for preventing unauthorized access to confident information.	Transmitted data between IMPRESS devices can be correctly interpreted only by authorized devices.	Part of specification
IMP-23	Development toolkit for resources integration	Functional	Major	Resource Adaptation Interface	Developers wants to integrate new resources in a fast and simple way	An development toolkit is available for for a rapid model-driven implementation of interfaces for resources integration.	Part of specification

IMP-22	Runtime services/devices discovery	Functional	Major	Resource and Service Discovery	It may happen that new devices or new functionalities are added while the platform is already running. The platform should support runtime device and service discovery without the platform restarting.	New devices/services can be discovered without having to restart the platform.	Part of specification
IMP-20	The IMPRESS SDP should be easy to use	Non-functional	Major	N/A	To make the SDP acceptable by the developers it should be easy to learn and use. Requires on-line API development tools and tutorials	The basics of IoT system development with the SDP can be learned in one day. Availability of online APIs and tutorials.	Part of specification
IMP-17	Dynamically adjustable security level for resource constrained devices	Functional	Major	Security architecture for resource-constrained devices	The IMPRESS platform should enable developers to design systems where security levels and mechanisms can be adjusted at run-time.	The functionality described is implemented to the IMPRESS platform.	Part of specification
IMP-7	SDP should allow storing data in a Cloud	Functional	Major	Data Mining and Machine Learning Tools	Facilitates access to data generated by applications from anywhere on the planet, besides having all apparatus and infrastructure services more cheaply, avoiding unnecessary expenses.	Data storage is possible	Part of specification

IMP-1	Sensors must be unobtrusive	Non-Functional - cultural and political	Blocker	Theater Amazon Demonstration	It is very important that the project show respect of the building. Equipment must fit into the theater seamlessly. The application cannot be deployed if the criterion is not met.	The equipment that is installed must be unobtrusive.	Part of specification
IMP-27	Data in the IMPReSS network is classified to different categories based on the criticality	Non-functional	Major	Security architecture for resource-constrained devices	Data transmitted in the IMPReSS network needs to be classified to different classes. Data types can be e.g.: -Emergency data such as fire or burglar alarm data -Monitoring data such as temperature monitoring data -Device control messages -Device condition data such as remaining energy	Sensor data can be classified into different classes.	Part of specification
IMP-10	The SDP shall support multiple communication protocols	Non-Functional - operational	Major	Resource Adaptation Interface	This requirement is fundamental since there are many different devices using different communication technologies and SDP must support these technologies to allow integration of these devices	Should be able to work with all protocols used in demonstrators.	Part of specification

IMP-24	Resource adaptation interface shall provide APIs for sensors and devices interaction	Functional	Major	Resource Adaptation Interface	Users may want to interact with the platform through software applications in order to visualize data from sensors and control actuators.	A set of APIs are available for sensors and actuators interaction and management.	Part of specificaition

5.5 Quality Check Passed SDP Requirements

Six requirements are currently at the stage "Quality Check Passed".

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-2	IMPReSS' cloud must scale horizontally	Non-Functional - operational	Major		The architecture needs to support the means for the Impress Cloud to scale horizontally, by adding more clusters running Impress' instances.	Support addition of new machines (several MQTT brokers & distributed storage managers).	Quality Check passed

IMP-21	Graphical model-driven deployment tool	Functional	Nice to have	Development Tools	The platform manager could not be a computer scientist: the platform should be commissioned without writing code.	A model-driven tool with a graphical user interface is available for platform commissioning	Quality Check passed
IMP-26	Templates for smart entities	Functional	Major		Application developers may be allowed to create new templates for smart entities	Application developer may need to create a new template to modeling a new smart entity in application development.	Quality Check passed
IMP-9	The SDP should hide the complexity of heterogeneous devices	Non-Functional - operational	Major	SDK Component	The creation of single implementation logic for different technologies, help inexperienced developers create specific applications without having in-depth knowledge in different technologies involved.	Should be able to handle all devices used for demonstrators	Quality Check passed
IMP-6	Energy consumption data should be analysed and predictions made possible	Functional	Major	Data Mining and Machine Learning Tools	The large volume of data generated by applications may hide important information that can be easily discovered by advanced data analysis. These	IMPReSS platform is able to analyse energy consumption data and make predictions concerning energy usage.	Quality Check passed

					techniques enable knowledge discovery, and assist in decision making.		
IMP-30	Availability of the critical IMPReSS resources must be measured	Non-Functional - security	Major	Resource management and access scheduler	IMPRESS platform must be able to provide the information about the availability of the resources for the applications.	Availability information can be used by the applications when selecting the most suitable resource.	Quality Check passed

5.6 SDP Open Requirements

Six SDP requirements are currently open as they were created following the completion of the first SDP prototype.

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-36	IMPReSS platform shall measure energy consumption of appliances with plugs	Functional	Major	Resource Adaptation Interface	IMPReSS platform will be evaluated by applying it for monitoring of UFPE campus energy consumption, where are present a lot of appliances with plugs (e.g. printers, monitors, PCs)	At least one type of energy meter is integrated in the platform	Open
IMP-37	IMPReSS platform shall integrate also low power sensors and actuators	Non-Functional - operational	Minor	Resource Adaptation Interface	IMPReSS platform will be used also for monitoring and control in building energy efficiency scenarios. It is worth to use sensors and actuators that don't consume too much energy while	Integration of at least one type of sensors and/or actuators that consume less than 1W (e.g. ZigBee devices) or use energy	Open

					working.	harvesting (e.g. EnOcean devices)	
IMP-38	Sensors integrated into Impress platform shall provide data both generating events periodically and responding to direct requests from other platform components.	Functional	Major	Resource Adaptation Interface	Components using data from sensors can have different needs: they may want data just in specific moments or they may want to be alerted just when new data are available	RAI component can be queried for getting data from sensors (e.g. using REST-based protocols). RAI component can generate autonomously events representing data from sensors (e.g. using pub-sub protocols).	Open
IMP-39	IMPReSS platform components shall expose interfaces for their configuration	Functional	Major	Configuration and Composition Manager	Platform components have to be configured properly depending on the application	Generic APIs for configuration purposes are available	Open
IMP-40	Common objects should be used to enhance buildings management functionalities	Functional	Major	Theatre Amazon Demonstration, University Demonstration	In order to enhance system management effectiveness, common objects can be used for further scopes beyond traditional ones (e.g. using lighting system for alarms signalling)	Applications can control one or more common objects types (e.g. bulbs of the lighting system) using them beyond their traditional usage in order to	Open

						enhance building management effectiveness	
IMP-41	RAI shall provide a tool that help developer while creating new device managers	Functional	Major	Resource Adaptation Interface	The implementation of new device manager should be done minimizing the code the developer needs to write. It helps to minimize errors while writing code.	A development-support tool for RAI is available	Open

5.7 SDP Rejected Requirements

Six requirements have been rejected as of date due to being either a duplicate, non-sense or out of scope.

Key	Summary	Requirement Type	Priority	Component/s	Rationale	Fit Criterion	Status
IMP-25	IMPReSS architecture views	Functional	Major	N/A	IMPReSS architecture must offer different views according to different usages and needs, such as: application developer application user, dataflow/control flow	Documentation describing architecture for application user and application developer	Non-sense: It is not a requirement for the architecture per se, but for the way it is presented to other stakeholders.

IMP-18	The IMPReSS platform should support development of IoT systems that are extendable for future needs	Non-Functional	Major	Application Classification Language, Resource Adaptation Interface, Resource and Service Discovery, Resource management and access scheduler, Security architecture for resource-constrained devices	Devices and environments have different life cycles. For instance, mobile phones and laptops last typically couple years, whereas refrigerators and electric ovens have at least a five year lifespan and houses can last hundreds of years. At the design time we are also not able to know all devices and applications that will be part of the system in the future. Therefore, the IMPRESS platform should support development of IoT systems that are extendable for the future needs. In practise this means that the Resource and Application descriptions and all the related components should be based on technologies that are flexible and thus easily extendable for the future.	IMPRESS platforms based on flexible technologies that support development of extendable IoT systems.	Out of scope: Impossible to validate during the project's life cycle.
IMP-19	The IMPReSS platform should be agnostic to the application domain	Non-Functional	Major		The aim should be to develop a system development platform that can be used in various IoT application domains (e.g. Healthcare, retail, logistics, transports, energy, home automation, etc.).	The platform is based on general purpose technologies and not optimized to a certain application domain.	Out of scope: Not relevant for the project. The project targets only for building automation domain.

IMP-12	Access prioritization to resources (devices, services, computing power, power supply)	Functional	Major	Resource management and access scheduler	Applications with different criticality may use the same resources. IMPReSS should be able to prioritize the access to the shared resources particularly when the demands are bigger than available resources.	Best effort algorithms to guarantee the access to the resources and prioritize the access to the shared resources available.	Duplicate of IMP-32
IMP-11	The software components of the middleware should be modularized, facilitating the inclusion of different technologies with the purpose of integrating heterogeneous resources	Non-Functional - maintainability	Major		Modularization of components facilitates maintenance of middleware, in addition to facilitating integration of different technologies.	CNET	Non-sense: The requirement is self-conflictory.
IMP-5	The data should be persisted in NoSQL database	Functional	Major		Since the data does not have a well-defined pattern, the solution with NoSQL technologies proved to be more attractive for the flexibility it offers in modelling data.	UFPE, UFAM and FIT	Non-sense: Design choice, not a requirement.

6. Pilot Application Level Requirements

The Pilot Application Level requirements focus, as the name indicates, especially on the Recipient end-user requirements for the Pilot Applications that will demonstrate the energy management at the two IMPReSS pilot sites. These Pilot Application level requirements have been separated from the IMPReSS SDP requirements in order to emphasise the user-centric requirement approach adopted by the project and to pay proper attention to the Pilot Applications that will demonstrate the technologies of the IMPReSS SDP. It has also proved to be a useful way to create consistency and transparency between the IMPReSS platform (the SDP) technical requirements and the pilot Recipient end-user requirements for the applications.

This chapter presents the re-engineered requirements related to the two Pilot Applications that will be deployed at the two IMPReSS pilot sites.[2] As the development work progresses, the Pilot Application requirements are continuously refined and their status updated in JIRA.

6.1 Overview

All 58 Pilot Application requirements have passed through the Quality Check and now have one of the following statuses in accordance with the predefined workflow:

- Part of specification: 13
- Implemented: 14
- Validated: 12
- Rejected: 19

The pie chart below presents a clear overview of the current M18 status of the Pilot Application requirements:

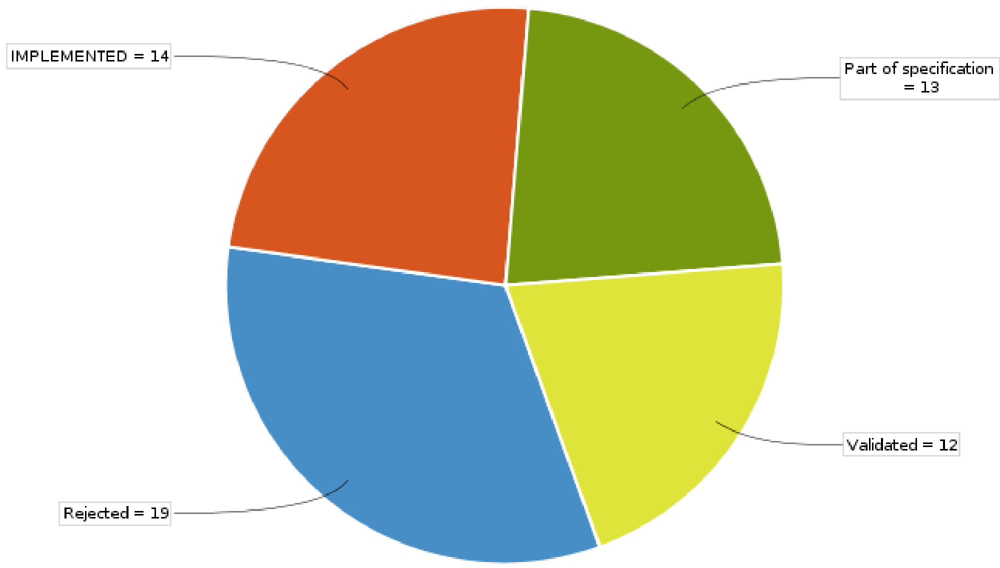

Figure 4: Current status of Pilot Application level requirements (M18)

[2] The re-engineering is mainly based on results from the Copenhagen workshop.

The following subchapters present the updated Pilot Application level requirements according to their current status (M18). The column "Label" indicates to which pilot the requirement refers to.[3]

[3] TAO refers to Teatro Amazonas pilot. UFPE refers to the Federal University of Pernambuco.

6.2 Validated Pilot Application Requirements

Twelve Pilot Application requirements have been validated to date.

Key	Summary	Label	Status	Priority	Rationale	Fit Criteria
PILOT -10	Viewing current measurement data for several devices/areas	TAO	Validated	Major	Energy monitoring on both small (one device) or large scale (several devices) allows for detailed analysis. Large scale monitoring could be for the same type of devices in several areas (e.g. lights) or for several different types of devices (e.g. light, air con) in one area.	The current measurement data can be viewed for a group of devices/areas.
PILOT -11	Selection of a device	TAO	Validated	Major	Basic feature of the application that allows the user to select which device he/she wants to see measurement data from.	Different types of devices can be selected by clicking on the name/icon.

PILOT -17	The energy information system	TAO	Validated	Critical	Data on historical and current energy consumption is a basic feature of the smart energy management system and must be displayed on demand.	The total current and historical (from a set start date to end date) energy consumption can be shown on the display.
PILOT -19	Operator's control of the devices	TAO	Validated	Critical	The Operator must be able to control the devices in a room thereby being able to override a pre-set configuration such as air-con off/on.	The operator must be able to turn lights and air con on and off in a selected room using the application.
PILOT -20	Comfort control – Room definition	TAO	Validated	Major	The Operator should be able to set the basic comfort parameters for a room to optimise electric energy usage, e.g. temperature, humidity and lightening requirements.	The Operator can set the ideal temperature and humidity for selected rooms.

PILOT -28	Automatic on/off control of equipment and devices	TAO/UPFE	Validated	Critical	The automatic on/off control of equipment and devices is basic function of the application that will result in a reduction of unnecessary energy consumption.	Lights and aircon in at least one room must turn on/turn off automatically according to presence/non-presence of persons and temperature in the room.
PILOT -35	Public display of energy consumption	TAO/UPFE	Validated	Critical	The electrical energy consumption for areas of interest should be displayed on public displays. The display of energy consumption will increase staff and the public's awareness on energy related issues and potentially encourage more motivation to save energy and reduce CO_2 footprint.	Public user can select specific rooms and areas of interest and see the energy consumption for those selected.

PILOT -41	Display of historical energy consumption	TAO/UPFE	Validated	Critical	Information on the historical energy consumption should be available as it will allow for thorough knowledge of energy consumption leading to better energy management.	The historical data can be shown for a selected period of time and for a selected area.
PILOT -44	Public display of the building drawing	TAO/UPFE	Validated	Trivial	Being able to view the building drawings is an aesthetics feature of the application which should be available for the public display.	Building drawings can be selected and displayed on the screen.

PILOT -54	Control of lighting and air conditioners	TAO/UPFE	Validated	Minor	Automated control of lightening and air conditioning based on context information (room usage) will be an improvement of the current system.	The need for cooling and lighting is established. The automatic control of air conditioner considers the schedule of the room, number of people in the room, outside, and indoor temperature to enable pre-cooling and the possibility to turn off the AC early (e.g, 2 minutes before the shows / lectures are over).
PILOT -7	Display of devices/appliances in a room/area	TAO	Validated	Major	Information on the devices/appliances installed in a room/area is a basic feature for smart energy management.	All the devices and appliances in at least one room/area are listed when selecting the room/area.

PILOT -8	View of current measured data	TAO	Validated	Major	The measurement and display of current energy consumption data is a basic feature of a smart energy management system.	It should be possible to view current measurement data for a selected area or device.

6.3 Implemented Requirements

Fourteen Pilot Application requirements have been implemented to date.

Key	Summary	Label	Status	Priority	Rationale	Fit Criterion
PILOT -2	Management system for Electrical energy used	TAO/UPFE	IMPLEMENTED	Critical	The IMPReSS pilots want to measure how much energy they use in selected areas. They need an application which displays all the required information regarding electric energy consumption and which allows for monitoring and management of energy consumption and electrical equipment.	The pilot user application is implemented and can demonstrate the required functionalities.
PILOT -3	Devices connected to a Power Meter	TAO/UPFE	IMPLEMENTED	Major	Equipment (devices) that use electric energy must be connected to the power meter in order to calculate energy usage.	The cooling and lightening systems in at least one area/room are connected to the power meter.
PILOT -4	Device properties in the database	TAO	IMPLEMENTED	Major	A list of the basic properties of devices in the database is necessary for device identification and functioning status.	All devices connected to the system are registered in a Device Properties database with description of its corresponding properties
PILOT -5	The Power Meter measuring capabilities	TAO	IMPLEMENTED	Major	In order to provide information on energy usage, the Power Meter must be able measure the power consumption of the selected	The energy consumption for each device can be measured at least every 2 minute. Data is stored in the database.

					devices/equipment in the building and store data in the database for later analysis.	
PILOT -12	Supported display devices	TAO	IMPLEMENTED	Major	For flexibility and mobility it should be possible to use different display devices, e.g. PC and Android based tablet devices.	The system runs on an android based Tablet
PILOT -13	Types of users	TAO	IMPLEMENTED	Blocker	Different users will want to/need to use the application differently. For the pilot application there are two users: Operator and Administrator. A third user, the Public, is also defined for the purposes of the public display screen.	Different types of users are created and implemented.
PILOT -14	The Operator user	TAO	IMPLEMENTED	Blocker	Operators are responsible for the electrical system management in the building and must be able to configure the energy monitoring and control system.	All 3 purposes are implemented.
PILOT -16	The Public user	TAO	IMPLEMENTED	Major	A specific display and functionalities must be defined for the public. The public display of energy consumption data for the building/room will create more public awareness of energy consumption and potential savings.	100% implemented.
PILOT -21	Comfort control – Database	TAO	IMPLEMENTED	Major	The comfort control database will contain all relevant data for the smart energy management of the building/room, e.g. information on devices, measurement data, performance data, and room usage data.	The database is implemented and integrated.
PILOT -22	Comfort control, setup control of a room	TAO	IMPLEMENTED	Major	The comfort control set-up of a room will set the basic parameters that define e.g. the ideal temperature and humidity in a room. Automatic light control should also be implemented. The comfort control set-up functions as a basis for the energy management system that will be	It is possible to register a set-up of a room's comfort parameters including temperature and humidity.

					implemented.	
PILOT -45	Storage of energy consumption data	TAO/UPFE	IMPLEMENTED	Critical	A database for the storage of energy consumption data is necessary to make it possible to view historical data.	The database is established and energy consumption data can be stored.
PILOT -53	Energy consumption monitoring	TAO/UPFE	IMPLEMENTED	Critical	The system must enable a monitoring of the energy consumption in all rooms in the buildings of interest. The management of energy consumption and storage of energy data in a database are essential features of the application.	Energy consumption data can be extracted for selected rooms/areas. The database is established.
PILOT -56	Define temperature	TAO/UPFE	IMPLEMENTED	Major	Basic functionality of the system.	Temperature can be pre-set for selected rooms in building.
PILOT -57	Energy Display System	TAO/UPFE	IMPLEMENTED	Critical	The system must be able to display the energy consumption for the selected room, a group of rooms or an area.	Display the energy consumption for a single room is established in selectable intervals (every 2-3 minutes).

6.4 Part of Specification Requirements

Currently, thirteen Pilot Application requirements are part of the specification.

Key	Summary	Label	Status	Priority	Rationale	Fit Criteria
PILOT -15	The Administration user	TAO	Part of specification	Major	The management user will be able to manage electrical energy usage more efficiently by analysing consumption data.	100% implemented.
PILOT -18	Display of saved energy	TAO	Part of specification	Critical	The amount of saved energy should be registered and displayed to allow the user to improve the current energy consumption management.	Energy savings can be calculated and displayed.

PILOT -26	Prediction of energy consumption	TAO	Part of specification	Major	An algorithm must be implemented. It should be robust and able to predict the energy required for a room or an area.The prediction of energy consumption will allow for more efficient energy management and control in the future.	A simple algorithm is implemented.
PILOT -31	Application priority system	TAO/UPFE	Part of specification	Major	Black-outs and power instability are common and the application should allow for a priority system defining the priority of electrical equipment.	Devices are handled by a priority system that can be defined using the application..
PILOT -34	Analysis of the duration that energy storage system is able to supply energy	UFPE	Part of specification	Major	Black-outs and power instability are not uncommon and if the pilot site has units for energy storage they will be able to supply energy to the site during black-outs. Stored energy can also be used during peak periods where energy is more expensive, thus enabling a reduction of overall costs.	The analysis is prepared
PILOT -36	Display the temperature and humidity	TAO/UPFE	Part of specification	Critical	It must be possible to view the current temperature and humidity both inside and outside. The display of temperature and humidity is basic informative data for a smart energy management system	The temperature and humidity of least one room and outside the building is displayed.
PILOT -37	The potential saving of energy can be shown for different areas	UFPE	Part of specification	Major	It would be interesting to be able to show how much energy would be saved if all devices in a specified area are switched off for a selected period. This can motivate energy awareness and lead to better energy consumption management.	The users could see the energy that could be saved in a room by installing new sensors, add automation, and more efficient lighting as well as air conditioners.

PILOT -38	Display the saving of energy for a single device	UFPE	Part of specification	Critical	It would be interesting to be able to show how much energy would be saved if a certain device (e.g. lights, air con) in a room is switched off for a selected period, e.g. when the room is vacant.	The potential saving of energy can be shown for at least one device in a chosen room.
PILOT -39	Public display of the maximum/minimum energy usage for an area	TAO/UPFE	Part of specification	Critical	It should be possible to get a simple overview of which areas use the most/least energy. For the public display, this detailed information on energy usage and savings will help to promote public awareness and makes for an interesting showcase.	The max/min energy and energy/m2 can be displayed for at least two areas.
PILOT -47	Room usage database	TAO/UPFE	Part of specification	Minor	Room context data should be available to allow for better prediction of energy consumption.	Room usage data can be specified/registered and is available upon request.
PILOT -48	UPS for priority equipment	UFPE	Part of specification	Critical	The prioritising of equipment will come into effect in cases of power instability or failure, thereby ensure that the most critical equipment will have power supply.	The system has information of the priority of the different equipment connected to the power line. All equipment is registered, including a definition of the priority of the equipment.
PILOT -49	Ensuring power supply with a UPS	UFPE	Part of specification	Critical	If a UPS is connected, the power supply to critical equipment will not be affected by black-outs or power instabilities.	At least one UPS is established with shut down in a controlled manner is established.
PILOT -55	Measurement of the temperature and humidity	TAO/UPFE	Part of specification	Critical	The system should be able to measure the temperature and humidity in all rooms in the buildings..	The system is able to measure the temperature and humidity in selected the rooms in the buildings.

6.5 Rejected Requirements

As a result of the careful quality check at the workshop, nineteen requirements have been discarded because they were either duplicates or out of scope for the project, e.g. due to time or budget constraints. The many duplicates occurred because requirements were first defined separately for each pilot and the quality check later revealed that many requirements actually applied to both pilots. The requirements that have been rejected are presented here.

Key	Summary	Priority	Label	Rationale	Fit Criterion	Status
PILOT-58	Interface to energy suppliers	Minor	UFPE	The LinkSmart engine must be able to communicate with the energy provider through a gateway system, specifically CHESF. The exchange of information could be used to: • Exploit information on energy prices in real time in order to use or store the energy when it is cheapest • Provide real time information to CHESF about the current and future energy needs	Interface to CHESF is established.	Duplicate
PILOT-52	Energy cost forecast	Minor	UFPE	The system should be capable of receiving forecast reports of current and future energy cost from the providers.	Forecast can be received from at least one provider.	Out of scope
PILOT-51	Control of energy supply to devices	Minor	UFPE	The system should be capable of controlling the total energy consumption and turn off non-vital devices, if the consumption reaches a predefined maximum level.	Implemented on one device.	Out of scope
PILOT-50	Display total Energy consumption	Critical	UFPE	The system must be capable of displaying the current total energy consumption for the whole installation in real time. Based upon the current total energy consumption and the	Display of the current total energy consumption for the whole installation is possible on request.	Out of scope

				current cost from the provider, the system should be able to display the current total energy cost. The current total energy consumption compared to budget should also be displayed.		
PILOT-46	Prediction of energy consumption	Minor	UFPE	The availability of historical energy consumption data and room context information will make it possible to estimate future energy consumption.	A simple prediction is established.	Duplicate
PILOT-43	Selection of a device	Critical	UFPE	Basic selection feature of the application that improves management.	A single device can be selected. For the device data can be shown both as historically data or current data.	Duplicate
PILOT-42	Display of current data for a device	Critical	UFPE	Being able to choose to view data for either one or more devices will allow for better overview and analysis of energy consumption.	Current data for a single device can be displayed.	Duplicate
PILOT-40	Display of device information	Critical	UFPE	Device properties and data measured by a device should be displayed in a form that gives a good and instant overview of energy usage.	All the data for at least one device can be displayed.	Duplicate
PILOT-33	Energy management systems	Major	UFPE	Cheaper energy may be purchased and stored during off-peak hours and distributed during high consumption hours. A publish/subscribe model may be used to dynamically manage the distribution of stored energy among the different storage and consumption sites.	Energy can be stored and distributed according to need.	Out of scope

PILOT-32	Energy storing systems	Minor	UFPE	Include Renewable Energy Sources (RES) and energy storage units (chillers in water Air Conditioning Systems) in the network. The system should store energy from the utility company at night and supply the energy during day.	Energy storing system available.	Out of scope
PILOT-30	Start/stop of a task	Minor	UFPE	The system must be able to stop a task executed on a device, if a higher priority task is requesting access, and grant the higher priority task access to the device instead.	At least one task can be started and stopped	Duplicate
PILOT-29	Priority system managing access to sensor and actuator network	Minor	UFPE	A priority system is inherent in the application as part of a mixed-criticality requirement feature.	All devices are handled by a priority system	Duplicate
PILOT-27	Renewable Energy Resources	Major	TAO	If Renewable Energy Resources are available, these should be integrated into the system. The first priority is to use energy from these, and the system should be able to switch to these systems, when it is beneficial. If it is not possible to use all the produced energy, it should be possible to store the energy for later use. If energy storage facilities are available, they should also be used to store energy when the energy price is low, to be used when the energy price is high.	Integration of one Renewable Energy Resources to the system	Out of scope
PILOT-25	Stabilizing energy supply	Major	TAO	The main function of the system is to stabilize the power supply to the building.	A list has been established with description on areas and priority. At least one	Out of scope

				For this purpose the system needs information of the priority of the different areas and the equipment installed in that area. The system must register all the equipment in a database, where the priority of the areas is described. For the high priority areas, a UPS must be connected in order to ensure the power supply.	UPS must be connected.	
PILOT-24	Comfort control, setup control of a room	Major	TAO	A typical setup control of a room must include: • The devices available for that room • Temperature and humidity selection for the entire day. It must be specified for periods with activity, for periods with no activity and for closed periods (e.g. nights) • Automatic light control when the room is used, and when the room is not used • The system must be able to read temperature meters and be able to compensate dynamically for weather/people/equipment variations by increasing/decreasing the temperature in the room • When a room is not used, it must be possible to switch off lights and other power consuming devices. The control of the light in a room is coordinated by use of the information in the Open/Close	At least 3 parameters are implemented	Duplicate

				Schedule database, the Performance database and the Room reservation system.		
PILOT-23	Comfort control – Database	Major	TAO	The comfort control of the building is a vital component of the system, which includes: • A Device database that specifies the devices used for every room in the building (the type of device, where it is placed in the building) • A Measurement database, with measurements from all the devices, including also the outside temperature and humidity. Additionally the weather for the period could be registered in order to be able to verify if the need of energy is different than for a "normal" day • A Performance database with information on when and where a performance is scheduled. It must also include the combination of rooms used for that particular performance • An Open/Close Schedule database. This information must be used for each room in order to specify the temperature, humidity, and lightening in the open and closed periods.	The Device and measurement database is implemented	Duplicate

PILOT-9	View of historical data	Minor	TAO	Being able to view historical measurement data for a specific room on a map or building drawing makes it possible to easily relate energy consumption to the periodical usage of the room.	The historical data can be viewed for at least one device for a fixed period of time.	Duplicate
PILOT-6	The Power meter control function	Blocker	TAO	The Power Meter must be able to switch the power of the device on and off.	At least one Power meter can switch a device on and off	Non-sense (Power meter can only make measurements)

7. Conclusion

As a result of a Lessons Learned, the user-centric approach to requirement engineering has been strengthened through the elicitation and definition of additional Pilot Application Level requirements. These requirements follow the same workflow as defined for the SDP requirements.

Following on the from the initial list of SDP requirements documented in *D2.1.1 Initial Requirement Report*, the SDP requirements have been re-engineering and passed along the workflow showing a satisfying progress within the project's development work. A total of 10 new SPD requirements have been created since the submission of the initial list of SDP requirement in M05 and several SDP requirements have been refined as a result of the development and testing work done to date. The status of the SDP requirements in M18 is as follows:

- Open: 6
- Quality Check passed: 7
- Part of specification: 13
- Implemented: 7
- Validated: 2
- Rejected: 6.

Similarly, the initial Pilot Application requirements have been refined since they were first elicited and analysed (documented in an internal working document *WD2.1.1 Pilot Application Level End-User Requirements*). Several Pilot Application requirements have been refined as a result of the Copenhagen requirement workshop, development work and testing during the development work in the first cycle. The status of the Pilot Application requirements in M18 is:

- Part of specification: 13
- Implemented: 14
- Validated: 12
- Rejected: 19.

The re-engineered requirements and the Lessons Learned documented here will feed into the second and final iteration of the development work. This also means that all the requirements which currently are still in progress, i.e. have not yet reached the final step in the workflow (validated), will be engineered during the next 15 months of the project.

As this deliverable represents the final requirement report in WP2, a final list of all requirements will be presented in the deliverable *D8.5 Platform Analysis and Feedback Report* in M30. This deliverable will also document the specific validation activities and results for all requirements.

As this first iterative cycle comes to an end, the first IMPReSS prototype has been finalised and demonstrated successfully.

Appendix A: Refined SDP Requirements

In the following table, the changes made to the initial SDP requirements documented in D2.1.1 are illustrated. Red writing indicates additional added text.

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-1	Non-Functional - cultural and political	Blocker	Sensors must be unobtrusive	It is very important that the project show respect of the building. Equipment must fit in the theatre seamlessly.	~~The application cannot be deployed if the criterion is not med~~ The equipment that is installed must be unobtrusive.
IMP-2	Non-Functional - operational	Major	Impress' cloud must scale horizontally	~~Provide the means for the Impress Cloud to scale horizontally, by adding more clusters running Impress' instances.~~ The architecture needs to support the means for the Impress Cloud to scale horizontally, by adding more clusters running Impress' instances.	Support addition of new machines (several MQTT brokers & distributed storage managers).
IMP-3	Functional	Critical	Devices should be allocated to a logical area	It would be interesting, for clients of the Impress' Cloud, if different devices could be allocated to a logical area, created by the user that represents a physical area (e.g. a room, an office, a bathroom) in the real world.	It is possible to query devices per (major) area and see graphs representing the mean energy usage of an area.
IMP-4	Functional	Critical	Devices should be allocated to one or more groups	It would be interesting, for clients of the Impress' Cloud, if different devices (e.g. heaters, TVs and etc) could be allocated to one or more groups, which is not an equivalent of the physical area these devices are. For instance, one could compare the energy usage patterns among all the heaters, in the same group.	UFPE
IMP-5	Functional	Major	The data should be persisted in NoSQL database	Since the data does not have a well-defined pattern, the solution with NoSQL technologies proved to be more attractive for the flexibility it offers in modeling data.	UFPE, UFAM and FIT

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-6	Functional	Major	The data should be analyzed using data mining and machine learning techniques to find relevant information and make predictions.	The large volume of data generated by applications may hide important information that can be easily discovered by advanced data analysis. These techniques enable knowledge discovery, and assist in decision making.	~~UFAM and UFPE~~ IMPReSS platform is able to analyse energy consumption data and make predictions concerning energy usage.
IMP-7	Functional	Major	SDP will have a communication layer that allows storing data in the IMPReSS Cloud	Facilitates access to data generated by applications from anywhere on the planet, besides having all apparatus and infrastructure services more cheaply, avoiding unnecessary expenses.	Data storage is possible
IMP-8	Functional	Major	The application should provide historical energy consumption and use of electrical devices.	The history of power consumption is important to control the consumption of energy to assist in identifying periods of higher power or even possible irregularities which may occur. Through it is possible to develop consumer policies in order to save energy.	It is possible to select a historical time frame and extract the energy consumption data for this time frame.
IMP-9	Non-Functional - operational	Major	~~The SDP should encapsulate the complexity of different technologies, developing a single logic to devices manipulation.~~ The SDP should hide the complexity of heterogeneous devices	The creation of single implementation logic for different technologies, help inexperienced developers create specific applications without having in-depth knowledge in different technologies involved.	Should be able to handle all devices used for demonstrators
IMP-10	Non-Functional - operational	Major	The SDP shall support multiple communication protocols	This requirement is fundamental since there are many different devices using different communication technologies and SDP must support these technologies to allow integration of these devices	Should be able to work with all protocols used in demonstrators

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
~~IMP-11~~	~~Non-Functional - maintainability~~	~~Major~~	~~The software components of the middleware should be modularized, facilitating the inclusion of different technologies with the purpose of integrating heterogeneous resources~~	~~Modularization of components facilitates maintenance of middleware, in addition to facilitating integration of different technologies.~~	~~CNET~~
~~IMP-12~~	~~Functional~~	~~Major~~	~~Access prioritization to resources (devices, services, computing power, power supply)~~	~~Applications with different criticality may use the same resources. IMPReSS should be able to prioritize the access to the shared resources particularly when the demands are bigger than available resources.~~	~~Best effort algorithms to guarantee the access to the resources and prioritize the access to the shared resources available.~~
IMP-13	Functional	Major	Annotate application with the level of criticality	Developers may want to explicitely categorize the criticality of applications	Developers are able to define the level of criticality e.g. : - user interaction --> soft real time, delay max 300ms. - monitoring office consumption --> non critical delay max 1 minute
IMP-14	Non-Functional - operational	Major	The impress core runs on a Gateway that cost below USD50	IMPReSS aims at affordable intelligent system than can be produced within the near future; therefore the price of the required hardware must be affordable.	The core IMPReSS middleware could run on a gateway which cost below USD 50. The core middleware should enable communication among heterogeneous devices and applications.
IMP-15	Functional	Major	Model driven tool for orchestrating impress components	Developers may want to wire components without having to understand the APIs	A model driven tool is available which allow developers to connect the required components for his application.

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-16	Functional	Major	Reusable components for trend analysis and forecasting of energy and occupancy data	Non-Expert developers would like to provide trend analysis and forecasting of energy consumption and occupancy data without having in dept knowledge of statistics and machine learning algorithms,	Reusable components for analyzing energy consumption and occupancy are available, and evaluated with developers without statistic & machine learning background.
IMP-17	Functional	Major	Dynamically adjustable security level for resource constrained devices	The IMPReSS platform should enable developers to design systems where security levels and mechanisms can be adjusted at run-time.	The functionality described is implemented to the IMPReSS platform.
~~IMP-18~~	~~Non-Functional~~	~~Major~~	~~The IMPRESS platform should support development of IoT systems that are extendable for future needs~~	~~Devices and environments have different life cycles. For instance, mobile phones and laptops last typically couple years, whereas refrigerators and electric ovens have at least a five year lifespan and houses can last hundreds of years. At the design time we are also not able to know all devices and applications that will be part of the system in the future.~~ ~~Therefore, the IMPReSS platform should support development of IoT systems that are extendable for the future needs. In practise this means that the Resource and Application descriptions and all the related components should be based on technologies that are flexible and thus easily extendable for the future.~~	~~IMPReSS platforms based on flexible technologies that support development of extendable IoT systems.~~
IMP-19	Non-Functional	Major	The IMPRESS platform should be agnostic to the application domain	The aim should be to develop a system development platform that can be used in various IoT application domains (e.g. Healthcare, retail, logistics, transports, energy, home automation, etc.).	The platform is based on general purpose technologies and not optimized to a certain application domain.

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-20	Non-Functional	Major	The IMPRESS SDP should be easy to use	To make the SDP acceptable by the developers it should be easy to learn and use. Requires on-line API development tools and tutorials	The basics of IoT system development with the SDP can be learned in one day. Availability of online APIs and tutorials.
IMP-21	Functional	Nice to have	Graphical model-driven commissioning tool	The platform manager could not be a computer scientist: the platform should be commissioned without writing code.	A model-driven tool with a graphical user interface is available for platform commissioning
IMP-22	Functional	Major	Runtime services/devices discovery and commissioning	It may happen that new devices or new functionalities are added while the platform is already running. The platform should support runtime device and service discovery and commissioning, without platform restarting.	New devices/services are can be discovered without having to restart the platform. and displayed on commissioning tool as available resources.
IMP-23	Functional	Major	Development toolkit for resources integration	Developers wants to integrate new resources in a fast and simple way	A development toolkit is available for a rapid model-driven implementation of interfaces for resources integration.
IMP-24	Functional	Major	APIs definition	Users may want to interact with the platform through software applications in order to visualize data from sensors and actuators. some data/info/alerts/ recommendations, direct control of some devices or for fine-grained configurations/customizations.	A set of APIs are available for sensors and actuators interaction and management. application development in order to interact with the platform.
IMP-25	Functional	Major	IMPReSS architecture views	IMPReSS architecture must offer different views according to different usages and needs, such as: application developer application user, dataflow/control flow	Documentation describing architecture for application user and application developer
IMP-26	Functional	Major	Templates for smart entities	Application developers may be allowed to create new templates for smart entities	Application developer may need create a new template to modeling a new smart entity in application development.

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-27	Non-Functional	Major	Data in the IMPRESS network is classified to different categories based on the criticality	Data transmitted in the IMPReSS network needs to be classified to different classes. Data types can be e.g.: -Emergency data such as fire or burglar alarm data -Monitoring data such as temperature monitoring data -Device control messages -Device condition data such as remaining energy	Sensor data can be classified into different classes.
IMP-28	Non-Functional - security	Major	Confidentiality of the messages between IMPRESS platform devices can be guaranteed	Data transmitted between IMPReSS devices can contain confident information e.g. about the house energy consumption. IMPReSS platform needs mechanism for preventing unauthorized access to confident information.	Transmitted data between IMPReSS devices can be correctly interpreted only by authorized devices.
IMP-29	Non-Functional - security	Major	Integrity of the messages between IMPRESS devices can be guaranteed	IMPReSS platform must guarantee the integrity of the critical messages between devices. Critical messages cannot be modified by unauthorized parties.	Critical messages cannot be modified by unauthorized parties in 100% of all cases.
IMP-30	Non-Functional - security	Major	Availability of the critical IMPRESS devices must be guaranteed	~~The most critical devices and services needs to be available all the time (for example >99% uptime. TBD). Security mechanisms in IMPReSS platform needs to guarantee the availability of the most critical devices and services.~~ IMPRESS platform must be able to provide the information about the availability of the resources for the applications.	~~Most critical devices and services are available (for example. >99% uptime TBD)~~ Availability information can be used by the applications when selecting the most suitable resource.

Key	Requirement Type	Priority	Summary	Rationale	Fit Criterion
IMP-31	Non-Functional - security	Major	Data transmitted in the IMPReSS network needs to be classified to different classes based on the confidentiality.	Data transmitted in the IMPReSS network needs to be classified to different classes based on the confidentiality. Data types can be e.g.: -Level 1 confidentiality (such as patient data) -Level 2 confidentiality (such as energy consumption monitoring data) -Level 3 confidentiality (device or network status data)	Confidentiality levels are set for the data

Appendix B: New SDP requirements (M05-M18)

The following table lists the new SDP requirements that were created after M05:

Key	Requirement Type	Priority	Summary	Fit Criterion	Rationale	Status
IMP-41	Functional	Major	RAI shall provide a tool that help developer while creating new device managers	A development-support tool for RAI is available	The implementation of new device manager should be done minimizing the code the developer needs to write. It helps to minimize errors while writing code.	Open
IMP-40	Functional	Major	Common objects should be used to enhance buildings management functionalities	Applications can control one or more common objects types (e.g. bulbs of the lighting system) using them beyond their traditional usage in order to enhance building management effectiveness	In order to enhance system management effectiveness, common objects can be used for further scopes beyond traditional ones (e.g. using lighting system for alarms signalling)	Open
IMP-39	Functional	Major	IMPReSS platform components shall expose interfaces for their configuration	Generic APIs for configuration purposes are available	Platform components have to be configured properly depending on the application	Open
IMP-38	Functional	Major	Sensors integrated into Impress platform shall provide data both generating events periodically and responding to direct requests from other platform components.	RAI component can be queried for getting data from sensors (e.g. using REST-based protocols). RAI component can generate autonomously events representing data from sensors (e.g. using pub-sub protocols).	Components using data from sensors can have different needs: they may want data just in specific moments or they may want to be alerted just when new data are available	Open

IMP-37	Non-Functional - operational	Minor	IMPReSS platform shall integrate also low power sensors and actuators	Integration of at least one type of sensors and/or actuators that consume less than 1W (e.g. ZigBee devices) or use energy harvesting (e.g. EnOcean devices)	IMPReSS platform will be used also for monitoring and control in building energy efficiency scenarios. It is worth to use sensors and actuators that don't consume too much energy while working.	Open
IMP-36	Functional	Major	IMPReSS platform shall measure energy consumption of appliances with plugs	At least one type of energy meter is integrated in the platform	IMPReSS platform will be evaluated by applying it for monitoring of UFPE campus energy consumption, where are present a lot of appliances with plugs (e.g. printers, monitors, PCs)	Open
IMP-35	Functional	Major	Runtime service/devices configuration	New devices/services can be configured without having to restart the platform	It may happen that new devices or services are added while the platform is already running. The platform should provide means for devices and services configuration at runtime.	Part of specification
IMP-34	Functional	Major	IMPReSS platform searches suitable resources for applications based on resource description	IMPReSS platform is able to search resources matching a resource specification.	To make the resource access as simple as possible for applications the IMPReSS plaforms needs the search suitable resources for application based on resource specification.	Implemented
IMP-33	Functional	Minor	IMPReSS platform should solve conflicts between applications that access resources interfering with each	IMPReSS platform is able to schedule resource access between mixed-criticality applications that request	Many type of resources such as heaters, audio devices and lights can interfere with each other if deployed in the same	Part of specification

			other	access to resources that interfere with each other in the real world.	location. To this end, it is necessary that the IMPReSS platform is able to schedule resources access so that conflicts between application accessing resources that interfere with each other can be solved.	
IMP-32	Functional	Major	IMPReSS platform should schedule/manage resource access based on application criticality	IMPReSS platform is able to schedule resource access based on application criticality.	To optimize the the behavior of the IMPReSS system there is a need to manage how the applications can access the system resources (e.g sensors and actuators) based on the criticality of the applications.	Implemented

Appendix C: Refined Pilot Application Requirements

In the following table, the changes made to the initial SDP requirements are illustrated. Red writing indicates additional added text.

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-2	Critical	Management system for Electrical energy used	The IMPReSS pilots want to measure how much energy they use in selected areas. They need an application which displays all the required information regarding electric energy consumption and which allows for monitoring and management of energy consumption and electrical equipment.	~~The electrical energy can be displayed for at least one Power Meter.~~ ~~The Power Meter can switch the power to a device on and off~~ The pilot user application is implemented and can demonstrate the required functionalities.	Implemented
PILOT-3	Major	Devices connected to a Power Meter	Equipment (devices) that use electric energy must be connected to the power meter in order to calculate energy usage.	The cooling and lightening systems in at least one area/room are connected to the power meter.	Implemented
PILOT-4	Major	Device properties in the database	A list of the basic properties of devices in the database is necessary for device identification and functioning status.	All devices connected to the system are registered in a Device Properties database with description of its corresponding properties	Implemented
PILOT-5	Major	The Power meter measuring capabilities	In order to provide information on energy usage, the Power Meter must be able measure the power consumption of the selected devices/equipment in the building and store data in the database for later analysis	The energy consumption for each device can be measured at least every 2 minute. Data is stored in the database.	Implemented
~~PILOT-6~~	~~The Power meter control function~~	~~Blocker~~	~~TAO~~	~~The Power Meter must be able to switch the power of the device on and off.~~	Implemented

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-7	Major	Display of the devices	Information on the devices/appliances installed in a room/area is a basic feature for smart energy management.	~~At least one device can be displayed.~~ All the devices and appliances in at least one room/area are listed when selecting the room/area.	Validated
PILOT-8	Major	View of current measured data	The measurement and display of current energy consumption data is a basic feature of a smart energy management system.	It should be possible to view current data for a selected area or device	Validated
~~PILOT-9~~	~~View of historical data~~	~~Minor~~	~~TAO~~	~~Being able to view historical measurement data for a specific room on a map or building drawing makes it possible to easily relate energy consumption to the periodical usage of the room.~~	~~Duplicate~~
PILOT-10	Major	~~View of current data~~ Viewing current measurement data for several devices/areas	Energy monitoring on both small (one device) or large scale (several devices) allows for detailed analysis. Large scale monitoring could be for the same type of devices in several areas (e.g. lights) or for several different types of devices (e.g. light, air con) in one area.	~~At least the current measuring data can be viewed for one device~~ The current measurement data can be viewed for a group of devices/areas.	Validated
PILOT-11	Major	Selection of a device	Basic feature of the application that allows the user to select which device he/she wants to see measurement data from.	~~At least one of the devices can be selected by clicking on the icon/Picture of the device.~~ Different types of devices can be selected by clicking on the name/icon.	Validated

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-12	Major	Supported display devices	For flexibility and mobility it should be possible to use different display devices, e.g. PC and Android based tablet devices.	The system runs on an android based Tablet	Implemented
PILOT-13	Blocker	Types of users	Different users will want to/need to use the application differently. For the pilot application there are two users: Operator and Administrator. A third user, the Public, is also defined for the purposes of the public display screen.	Different types of users are created and implemented.	Implemented
PILOT-14	Blocker	The Operator user	Operators are responsible for the electrical system management in the building and must be able to configure the energy monitoring and control system.	All 3 purposes are implemented.	Implemented
PILOT-15	Major	The ~~Management~~ Administrator user	The management user will be able to manage electrical energy usage more efficiently by analysing consumption data.	100% implemented	Part of specification
PILOT-16	Major	The Public user	A specific display and functionalities must be defined for the public. The public display of energy consumption data for the building/room will create more public awareness of energy consumption and potential savings.	100% implemented	Implemented
PILOT-17	Critical	The energy information system	Data on historical and current energy consumption is a basic feature of the smart energy management system and must be displayed on demand.	~~The total energy consumption can be shown on the display.~~ The total current and historical (from a set start date to end date) energy consumption can be shown on the display.	Validated
PILOT-18	Critical	Display of saved energy	The amount of saved energy should be registered and displayed to allow the user to improve the current energy consumption management.	Energy savings can be calculated and displayed.	Part of specification

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-19	Critical	~~Manual control of the devices~~ Operator's control of the devices	~~The main function is to switch the device on or off manually.~~ The Operator must be able to control the devices in a room thereby being able to override a pre-set configuration such as air-con off/on.	~~The operator can control at least one of the devices on and off~~ The operator must be able to turn lights and air con on and off in a selected room using the application.	Validated
PILOT-20	Major	Comfort control – Room definition	~~The comfort control of the room must include the following parameters:~~ The Operator should be able to set the basic comfort parameters for a room to optimise electric energy usage, e.g. temperature, humidity and lighting requirements for each room	~~At least one of the parameters is implemented.~~ The Operator can set the ideal temperature and humidity for selected rooms.	Validated
PILOT-21	Major	Comfort control – Database	The comfort control database will contain all relevant data for the smart energy management of the building/room, e.g. information on devices, measurement data, performance data, and room usage data.	The ~~Device and measurement~~ database is implemented and integrated.	Implemented
PILOT-22	Major	Comfort control, setup control of a room	The comfort control set-up of a room will set the basic parameters that define e.g. the ideal temperature and humidity in a room. Automatic light control should also be implemented. The comfort control set-up functions as a basis for the energy management system that will be implemented.	It is possible to register a set-up of a room's comfort parameters including temperature and humidity.	Implemented

Key	Priority	Summary	Rationale	Fit Criterion	Status
~~PILOT-23~~	~~Major~~	~~Comfort control – Database~~	~~The comfort control of the building is a vital component of the system, which includes:~~ ~~• A Device database that specifies the devices used for every room in the building (the type of device, where it is placed in the building)~~ ~~• A Measurement database, with measurements from all the devices, including also the outside temperature and humidity. Additionally the weather for the period could be registered in order to be able to verify if the need of energy is different than for a "normal" day~~ ~~• A Performance database with information on when and where a performance is scheduled. It must also include the combination of rooms used for that particular performance~~ ~~• An Open/Close Schedule database. This information must be used for each room in order to specify the temperature, humidity, and lightening in the open and closed periods.~~	~~The Device and measurement database is implemented.~~	~~Duplicate~~

Key	Priority	Summary	Rationale	Fit Criterion	Status
~~Pilot-24~~	~~Major~~	~~Comfort control, setup control of a room~~	~~A typical setup control of a room must include:~~ ~~• The devices available for that room~~ ~~• Temperature and humidity selection for the entire day. It must be specified for periods with activity, for periods with no activity and for closed periods (e.g. nights)~~ ~~• Automatic light control when the room is used, and when the room is not used~~ ~~• The system must be able to read temperature meters and be able to compensate dynamically for weather/people/equipment variations by increasing/decreasing the temperature in the room~~ ~~• When a room is not used, it must be possible to switch off lights and other power consuming devices. The control of the light in a room is coordinated by use of the information in the Open/Close Schedule database, the Performance database and the Room reservation system.~~	~~At least 3 parameters are implemented.~~	~~Duplicate~~
~~Pilot-25~~	~~Major~~	~~Stabilizing energy supply~~	~~The main function of the system is to stabilize the power supply to the building. For this purpose the system needs information of the priority of the different areas and the equipment installed in that area. The system must register all the equipment in a database, where the priority of the areas is described.~~ ~~For the high priority areas, a UPS must be connected in order to ensure the power supply~~	~~A list has been established with description on areas and priority. At least one UPS must be connected~~	~~Out of scope~~

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-26	Major	Prediction of energy consumption	An algorithm must be implemented. It should be robust and able to predict the energy required for a room or an area.The prediction of energy consumption will allow for more efficient energy management and control in the future.	A simple algorithm is implemented.	Part of specification
~~PILOT-27~~	~~Major~~	~~Renewable Energy Resources~~	~~If Renewable Energy Resources are available, these should be integrated into the system.~~ ~~The first priority is to use energy from these, and the system should be able to switch to these systems, when it is beneficial. If it is not possible to use all the produced energy, it should be possible to store the energy for later use.~~ ~~If energy storage facilities are available, they should also be used to store energy when the energy price is low, to be used when the energy price is high.~~	~~Integration of one Renewable Energy Resources to the system~~	~~Out of scope~~
PILOT-28	Critical	Automatic on/off control of equipment and devices	The system shall be able to switch off equipment and devices left on unintentionally. The automatic on/off control of equipment and devices is basic function of the application that will result in a reduction of unnecessary energy consumption.	Lights and aircon in at least one room must turn on/turn off automatically according to presence/non-presence of persons and temperature in the room.	Validated
~~PILOT-29~~	~~Minor~~	~~Priority system managing access to sensor and actuator network~~	~~The access to sensor and actuators devices must be managed by a priority system to ensure that access to the devices by a high-priority task is favoured over a low-priority task.~~	~~All devices are handled by a priority system~~	~~Duplicate~~

Key	Priority	Summary	Rationale	Fit Criterion	Status
~~PILOT-30~~	~~Minor~~	~~Start/stop of a task~~	~~The system must be able to stop a task executed on a device, if a higher priority task is requesting access, and grant the higher priority task access to the device instead.~~	~~At least one task can be started and stopped~~	~~Duplicate~~
PILOT-31	~~Minor~~ Major	Application priority system	Black-outs and power instability are common and the application should allow for a priority system defining the priority of electrical equipment.	Devices are handled by a priority system that can be defined using the application.	Part of specification
~~PILOT-32~~	~~Minor~~	~~Energy storing systems~~	~~Include Renewable Energy Sources (RES) and energy storage units (chillers in water Air Conditioning Systems) in the network. The system should store energy from the utility company at night and supply the energy during day.~~	~~Energy storing system available~~	~~Out of scope~~
~~PILOT-33~~	~~Major~~	~~Energy management systems~~	~~Cheaper energy may be purchased and stored during off-peak hours and distributed during high consumption hours. A publish/subscribe model may be used to dynamically manage the distribution of stored energy among the different storage and consumption sites.~~	~~Energy can be stored and distributed according to need~~	~~Out of scope~~
PILOT-34	Major	Analysis of the duration that energy storage system is able to supply energy	Black-outs and power instability are not uncommon and if the pilot site has units for energy storage they will be able to supply energy to the site during black-outs. Stored energy can also be used during peak periods where energy is more expensive, thus enabling a reduction of overall costs.	The analysis is prepared.	Part of specification

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-35	Critical	Visualization the Public display of energy consumption	The electrical energy consumption for areas of interest should be displayed on public displays. The display of energy consumption will increase staff and the public's awareness on energy related issues and potentially encourage more motivation to save energy and reduce CO2 footprint.	The energy consumption can be displayed Public user can select specific rooms and areas of interest and see the energy consumption for those selected.	Validated
PILOT-36	Critical	Display the temperature and humidity	It must be possible to view the current temperature and humidity both inside and outside. The display of temperature and humidity is basic informative data for a smart energy management system	The temperature and humidity of least one room and outside the building is displayed.	Part of specification
PILOT-37	Major	~~Display the saving of energy for an area~~ The potential saving of energy can be shown for different areas	It would be interesting to be able to show how much energy would be saved if all devices in a specified area are switched off for a selected period. This can motivate energy awareness and lead to better energy consumption management.	~~The potential saving of energy can be shown for one area.~~ The users could see the energy that could be saved in a room by installing new sensors, add automation, and more efficient lighting as well as air conditioners.	Part of specification
PILOT-38	Critical	Display the saving of energy for a single device	It would be interesting to be able to show how much energy would be saved if a certain device (e.g. lights, air con) in a room is switched off for a selected period, e.g. when the room is vacant.	The potential saving of energy can be shown for at least one device in a chosen room.	Part of specification
PILOT-39	Critical	Public display of the maximum/minimum energy for an area	It should be possible to get a simple overview of which areas use the most/least energy. For the public display, this detailed information on energy usage and savings will help to promote public awareness and makes for an interesting showcase.	The max/min energy and energy/m2 can be displayed for at least two areas.	Part of specification

Key	Priority	Summary	Rationale	Fit Criterion	Status
~~PILOT-40~~	~~Critical~~	~~Display of device information~~	~~Device properties and data measured by a device should be displayed in a form that gives a good and instant overview of energy usage.~~	~~All the data for at least one device can be displayed~~	~~Duplicate~~
PILOT-41	Critical	Display of historical energy consumption	Information on the historical energy consumption should be available as it will allow for thorough knowledge of energy consumption leading to better energy management.	The historical data can be shown for a single device selected period of time and for a selected area.	Validated
~~PILOT-42~~	~~Critical~~	~~Display of current data for a device~~	~~Being able to choose to view data for either one or more devices will allow for better overview and analysis of energy consumption.~~	~~Current data for a single device can be displayed~~	~~Duplicate~~
~~PILOT-43~~	~~Critical~~	~~Selection of a device~~	~~Basic selection feature of the application that improves management.~~	~~A single device can be selected. For the device data can be shown both as historically data or current data.~~	~~Duplicate~~
PILOT-44	Trivial	Public display of the building drawing	Being able to view the building drawings is an aesthetics feature of the application which should be available for the public display.	Preselected Building drawings can be selected and displayed on the screen.	Validated
PILOT-45	Critical	Storage of energy consumption data	A database for the storage of energy consumption data is necessary to make it possible to view historical data.	The database is established and energy consumption data can be stored.	Implemented
~~PILOT-46~~	~~Minor~~	~~Prediction of energy consumption~~	~~The availability of historical energy consumption data and room context information will make it possible to estimate future energy consumption.~~	~~A simple prediction is established~~	~~Duplicate~~

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-47	Minor	Room usage database	Room context data should be available to allow for better prediction of energy consumption.	Room usage data can be specified/registered and is available upon request.	Part of specification
PILOT-48	Critical	UPS for priority equipment	The prioritising of equipment will come into effect in cases of power instability or failure, thereby ensure that the most critical equipment will have power supply.	The system has information of the priority of the different equipment connected to the power line. All equipment is registered, including a definition of the priority of the equipment.	Part of specification
PILOT-49	Critical	Ensuring power supply with a UPS	If a UPS is connected, the power supply to critical equipment will not be affected by black-outs or power instabilities.	At least one UPS is established with shut down in a controlled manner is established.	Part of specification
~~PILOT-50~~	~~Critical~~	~~Display total Energy consumption~~	~~The system must be capable of displaying the current total energy consumption for the whole installation in real time.~~ ~~Based upon the current total energy consumption and the current cost from the provider, the system should be able to display the current total energy cost. The current total energy consumption compared to budget should also be displayed.~~	~~Display of the current total energy consumption for the whole installation is possible on request~~	~~Out of scope~~
~~PILOT-51~~	~~Minor~~	~~Control of energy supply to devices~~	~~The system should be capable of controlling the total energy consumption and turn off non-vital devices, if the consumption reaches a predefined maximum level.~~	~~Implemented on one device~~	~~Out of scope~~
~~PILOT-52~~	~~Minor~~	~~Energy cost forecast~~	~~The system should be capable of receiving forecast reports of current and future energy cost from the providers.~~	~~Forecast can be received from at least one provider~~	~~Out of scope~~

Key	Priority	Summary	Rationale	Fit Criterion	Status
PILOT-53	Critical	Energy Management of the rooms Energy consumption monitoring	The system must enable a monitoring of the energy consumption in all rooms in the buildings of interest. The management of energy consumption and storage of energy data in a database are essential features of the application.	Management of one room is implemented. Energy consumption data can be extracted for selected rooms/areas. The database is established	Implemented
PILOT-54	Critical	Control of lighting and air conditioners	Automated control of lightening and air conditioning based on context information (room usage) will be an improvement of the current system.	The need for cooling and lighting is established. The automatic control of air conditioner considers the schedule of the room, number of people in the room, outside, and indoor temperature to enable pre-cooling and the possibility to turn off the AC early (e.g, 2 minutes before the shows / lectures are over).	Validated
PILOT-55	Critical	Measurement of the temperature and humidity	The system should be able to measure the temperature and humidity in all rooms in the buildings.	The system is able to measure the temperature and humidity in selected the rooms in the buildings.	Part of specification
PILOT-56	Major	Define temperature and humidity	Basic functionality of the system.	Temperature and humidity can be pre-set for selected rooms in building.	Implemented
PILOT-57	Critical	Energy Display System	The system must be able to display the energy consumption for a room, a group of rooms or an area.	Display the energy consumption for a single room is established in selectable intervals (every 2-3 minutes).	Implemented

Key	Priority	Summary	Rationale	Fit Criterion	Status
~~PILOT-58~~	~~Minor~~	~~Interface to energy suppliers~~	~~The LinkSmart engine must be able to communicate with the energy provider through a gateway system, specifically CHESF.~~ ~~The exchange of information could be used to:~~ ~~Exploit information on energy prices in real time in order to use or store the energy when it is cheapest~~ ~~Provide real time information to CHESF about the current and future energy needs~~	~~Interface to CHESF is established~~	~~Duplicate~~

8. References

(Asaro 2000) Asaro, P. M. (2000). "Transforming society by transforming technology: the science and politics of participatory design." Accounting, Management and Information Technologies 10(4): 257-290.