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D8.5 Platform Analysis and Feedback Report

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1. Executive summary

This deliverable presents the results from the various evaluation activities that have been conducted in order to evaluate the IMPReSS SDP, the pilot applications that have been developed, and the potential business models related to the two pilot applications.

User validation is the answer to the question: Have we built the right system? (i.e., is this what the end users need and want?). Thus, validation is the process of evaluating a subsystem or system at the end of the development process in order to establish whether it satisfies specified user needs. The user requirements have been validated against their predefined and specific fit criteria.[1] The fit criteria acts as a metric which can be measured either quantitatively or qualitatively in order to assess if the requirement has been satisfied.

In IMPReSS, a distinction is made between four different types of end-users (or stakeholders): i) IMPReSS Partners, ii) Application Developers, iii) Solution Integrators, and iiii) Final Recipients.[2] A total of 41 user requirements for the IMPReSS SDP were created. They have been solved with the following resolutions:

Resolution	Issues
Validated	31 (76%)
Quality Check failed	8 (20%)
Out of scope	1 (2%)
Duplicate	1 (2%)

Table 1: SDP Requirements Resolution

Taking into consideration the Final Recipient End-User (our two pilot sites, UFPE and TAO), resulted in a total of 58 user requirements for the two IMPReSS pilot applications were created. They have been solved with the following resolutions:

Resolution	Issues
Validated	34 (59%)
Out of scope	15 (26%)
Duplicate	9 (15%)

Table 2: Pilot Applications Requirements Resolution

A usability evaluation of the IMPReSS SDP was also carried out where potential application developers tested five distinct IMPReSS tools which were afterwards evaluated using the established User Experience Questionnaire (UEQ). The results for each of the tested and evaluated component as well as for the complete IMPReSS SDP have been interpreted using the tools provided by the UEQ and analysed in context, i.e. by taking the complexity of the task and the component into account. The response rate has also been considered in the analysis. Overall, the result of the usability evaluation is very satisfactory. The graph below illustrates the results for the IMPReSS SDP, i.e. participants overall impression with using the tools provided by the SPD:

[1] Defining the fit criteria is part of the Volere requirements mastering process to ensure that a requirement is adequately described. This process ensures that all user requirements pass through different steps (as in a workflow), the final step being that a requirement has been validated against its fit criteria. The Volere process has been used in the project's requirement engineering approach and is described in detail in *D2.1.1 Initial Requirement Report*.

[2] This distinction has been described in *D2.2.1 SDP Initial Architecture Report*

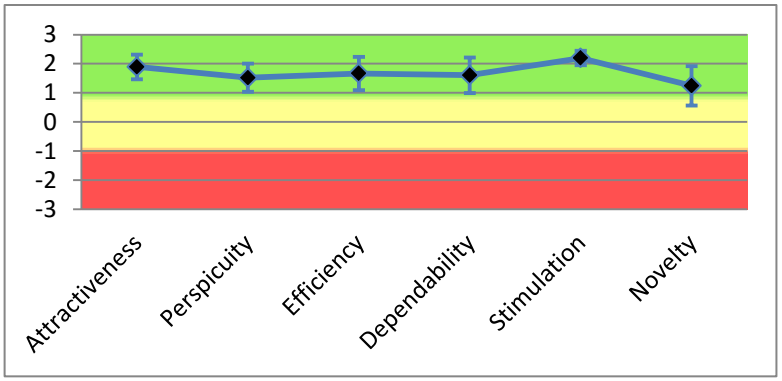


Figure 1: IMPReSS SDP Usability Evaluation Results

The business models that were developed in M12 of the project have also been updated as the project progressed and our insights into the end-users' business needs and opportunities were expanded as a result of a business model workshop with end-users. Based on actual figures regarding the pilot sites' energy consumption and energy prices in Brazil, we have developed two sustainable business models and cases using a unique tool called e3value which allows us to do complex calculations for the value exchanges in the model. A complete description of actors and value transactions are presented in Chapter 6.

The table below summarises the profitability of the actors in the business model for UFPE:

Profitability of actors in the FIRST year when the service is installed

Segment / actor (k€)	Revenues	Payments	Expenses	Gross profits	Investments	Cashflow
UFPE	0	-13.606.000				-13.606.000
Engetron	1.000.000	-200.000		150.000	-650.000	-850.000
CELPE	13.356.000	-10.400.000		2.956.000		
CHESF	10.400.000	-4.699.000		5.701.000		-4.699.000
ANEEL	0	0		0		+0
Power Plant	1.001.000	0		1.001.000		1.001.000
ONS (Aggregator)	3.198.000	0		3.198.000		3.198.000
IMPReSS	850000	0		850.000		850.000
Total						-15.107.000

Table 3: Profitability of actors in the UFPE business model

Likewise, the table below summarises the profitability of the actors in the business model for TAO:

Profitability of actors in the FIRST year when the service is installed

Segment / actor (k€)	Revenues	Payments	Expenses	Gross profits	Investments	Cashflow
City of Manaus	1.500.000	-1.300.000		200.000		200.000
Smart Energy Systems Supplier	1.300.000	-850.000		450.000		450.000
Public Buildings	2.250.000	-500.000		1.750.000		1.750.000
The Public	0	-1.000.000		-1.000.000		-1.000.000
Energy Provider	0	-2.250.000		-2.250.000		-2.250.000
IMPReSS Service Provider	850.000	0		850.000		850.000
Total						+0

Table 4: Profitability of actors in the TAO business model

In conclusion, all the evaluation activities that were conducted have yielded positive results both technically speaking but also importantly of the commercial potential of the IMPReSS SDP.

2. Introduction

The IMPReSS project has developed a Systems Development Platform (SDP) that enables developers to develop smart society systems and applications in a cost-effective and efficient manner. And being IMPReSS a research and development work, a proper and extensive evaluation of the results is expected.

This deliverable will present the results from the various evaluation activities that have been conducted in order to evaluate the IMPReSS SDP, the pilot applications that have been developed, and the potential business models related to the two pilot applications. The IMPReSS SDP was evaluated in the form of a technical evaluation and validation of the user requirements and the SDP components and a usability evaluation of five different application development tools. Moreover, the smart energy efficiency applications that were developed in WP8 were used to evaluate the SDP in a production environment. The SDP evaluation activities have involved both internal SDP and application developers, and external novices and future application developers.

The pilot applications were evaluated with respect to a validation of their user requirements and with respect to their business value through the development of sustainable business models. The sustainability of the business models was evaluated through complex calculations of the values in and values out for each stakeholder, thus allowing us to demonstrate the sustainability for all stakeholders in the business model. Feedback on the value transactions and value objects in the models was also collected from main stakeholders (e.g. energy provider and distributor, energy system manager, and final recipient end-users).

1.1 Purpose, context and scope of this deliverable

The purpose of this deliverable is to present an overall evaluation report of the IMPReSS project. The evaluation activities have engaged the users both directly in the form of questionnaires (usability) and workshop discussions, and indirectly in the form of validating all the user requirements that have guided the development work in the project. As different aspects of the IMPReSS project results have been evaluated, so different activities have been conducted using different methods. The deliverable is organised as follows:

Chapter three will describe the methodologies used for each activity.

Chapter Four presents the results of the user validation, i.e. the results of the internal system and integration testing.

Chapter Five provides the analysis of the usability evaluation that was conducted with five IMPReSS tools. External developer users in Recife, Brazil, carried out specific tasks for each tool and subsequently evaluated their user experience of the tool.

Chapter Six presents the evaluation and stakeholder feedback of the two business models that have been developed for the pilots. The stakeholders and the value objects and transactions are also described in this chapter.

The Appendices contain the User Experience Questionnaire and a full list of the SDP and Pilot Application requirements current resolution.

1.2 Background

Validation is part of the implementation of a user-centred development process. The main aim is to assure that the IMPReSS SDP adhere to the necessary quality standards for professional services, meet the needs and requirements of users and customers, and can be recommended for adoption.

Finally, the deliverable *D2.3 Evaluation Framework* has functioned as guidance for the different evaluation activities and has ensured that the evaluation has included both quantitative and qualitative metrics.

3. Evaluation Methodology

This chapter will describe methods that have been used to carry out the user validation of IMPReSS. The user validation activities that have been conducted include user requirement validation, usability testing and business model evaluation.

Due to the fact that the Brazilian side of the project will continue after the official end (M31), additional development and evaluation activities are planned by Brazilian partners targeted at prospective end-users (i.e. Final Recipients, see explanation in below) of the IMPReSS smart energy management application. More specifically, UFPE is planning to demonstrate the UFPE pilot application to different groups of Final Recipient end-users, e.g. university administrators, building managers, energy system administrators, and energy system technicians. Their feedback will be used to evaluate the cost-benefits of the IMPReSS enabled smart energy management systems and its potential business values. A usability evaluation of the application may also be carried out. The results will be published as an appendix to this deliverable later in 2016.

The methodology for system testing and verification is described in *D7.1 Test and Integration Plan* and will therefore not be described here also.

1.3 User Requirement Validation Methodology

User validation is the answer to the question: Have we built the right system? (i.e., is this what the end users need and want?). Thus, validation is the process of evaluating a subsystem or system at the end of the development process in order to establish whether it satisfies specified user needs.

In IMPReSS, a distinction is made between four different types of end-users (or stakeholders): i) IMPReSS Partners, ii) Application Developers, iii) Solution Integrators, and iiii) Final Recipients.[3] The typical end-user of IMPReSS SDP would be the application developer (who in some cases will also act as Solution Integrators) whereas the typical end-user of the IMPReSS pilot applications that were developed in the project would be the Final Recipient.

User requirements have been validated from both the Application Developers' perspective, i.e. SDP user requirement validation, and from the Final Recipient's perspective, i.e. pilot application user requirements (for both pilots in the project). The user requirements have been validated against their predefined and specific fit criteria.[4] The fit criteria acts as a metric which can be measured either quantitatively or qualitatively in order to assess if the requirement has been satisfied.

The validation of the user requirements took the form of systematically analysing and testing individual components (see also *D7.1 Test and Integration Plan*), which often consisted of several technical user requirements, in a test lab. The validation activities focused on evaluating each of the main components using specific methods and metrics. The development of the two pilot application prototypes also functions as a means to validate of the IMPReSS SDP.

1.4 Usability Evaluation Methodology

The project consortium decided to carry out an usability test in connection with an integration meeting in Recife, Brazil, on 26 November 2015 despite the fact that some of the IMPReSS components and tools were still under development. Thus, the analysis results of the usability test of the IMPReSS SDP have considered the fact that the SDP was not 100% complete at the time of the test. In total, five IMPReSS tools were evaluated using a standard well-known usability questionnaire, the User Experience Questionnaire (UEQ) which allows end-user of a product to evaluate their experiences using the product in question.

[3] This distinction has been described in *D2.2.1 SDP Initial Architecture Report*

[4] Defining the fit criteria is part of the Volere requirements mastering process to ensure that a requirement is adequately described. This process ensures that all user requirements pass through different steps (as in a workflow), the final step being that a requirement has been validated against its fit criteria. The Volere process has been used in the project's requirement engineering approach and is described in detail in *D2.1.1 Initial Requirement Report*.

From the IMPReSS SDP point of view, end-users are application developers. Therefore, ten students from UFPE, (who fit the description of prospective application developers, acted as our end users for the usability evaluation. They had not previously been involved in the IMPReSS project.

The usability evaluation exercise took place at the UFPE campus in Recife on 26 November 2015 from 10:00-12:00. It is best described as an evaluation workshop which combined power point presentations to introduce the tools and tasks followed by the participants actively working to resolve the tasks at hand.

The participants were first presented with an overall and very brief introduction to the IMPReSS project and the methodology and objective of the usability evaluation. Next, the five IMPReSS tools that were to be evaluated were presented and the tasks involved explained in more or less detail (depending on the complexity of the task and the tool). Participants were given a print out of the task and tutorials, which explained all functions of the respective component. For the more complex tools and their tasks, tutorials were presented by the responsible IMPReSS developers in addition to a hand-out tutorial.

Due to restraints, only five preconfigured machines with a running IMPReSS SDP environment were provided to the participants, which meant that they had to work in pairs to complete a given task. Participants were free to ask questions during the tasks.

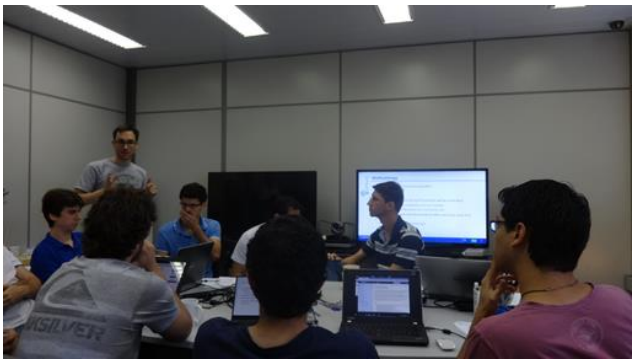


Figure 2: IMPReSS Usability Evaluation Workshop

Figure 3: IMPReSS Usability Evaluation Workshop

Immediately after participants had completed a task, they each filled out the provided UEQ individually (and anonymously) and handed it back to the workshop moderator.

Upon completion of the final task and the corresponding questionnaire, participants were then asked to fill out an additional questionnaire to express their overall experience of using the five tools provided by the IMPReSS SDP when resolving the different tasks.

1.4.1 User Experience Questionnaire

As described above, we used the User Experience Questionnaire (UEQ) which originally consists of twenty-six statements or items. We added six additional statements (number 27-32 on the questionnaire) in order to stress certain quality aspects that were important to the project to evaluate. The questionnaire can be found in Appendix A.

The items have the form of a semantic differential, i.e. each item is represented by two terms with opposite meanings. The order of the terms is randomized per item, i.e. half of the items of a scale start with the positive term and the other half of the items start with the negative term. A seven-stage scale is used to reduce the well-known central tendency bias for such types of items. The items are scaled from -3 to +3. Thus, on the questionnaire -3 represents the most negative answer, 0 a neutral answer, and +3 the most positive answer.

The items are categorised into six dimensions each of which consists of 4-6 items on the UEQ which thus describes a distinct quality aspect of an interactive product, namely attractiveness, efficiency, perspicuity, dependability, stimulation and novelty:

- Attractiveness: General impression towards the product. Do users like or dislike the product? This scale is a pure valence dimension.
- Efficiency: Is it possible to use the product fast and efficient? Does the user interface look organised?
- Perspicuity: Is it easy to understand how to use the product? Is it easy to get familiar with the product?
- Dependability: Does the user feel in control of the interaction? Is the interaction with the product secure and predicable?
- Stimulation: Is it interesting and exciting to use the product? Does the user feel motivated to further use the product?
- Novelty: Is the design of the product innovative and creative? Does the product grab users' attention?[5]

The UEQ comes with a complete data analysis tool in Excel including a benchmark data set.

The data analysis tool calculates the mean score for each of the six dimensions (quality aspects) that are represented in the questionnaire. The UEQ does not produce an overall score for the user experience. Because of the construction of the questionnaire it does make no sense to build such an overall score (for example by calculating the mean over all scales), since this value cannot be interpreted properly. The values for the single items are listed in a sheet to allow the analysist to detect outliers in the evaluations. If an item shows big deviations to the evaluations of the other items of the same scale this can be a hint that the item is misinterpreted (for example because of a special context in the evaluation) by a higher number of participants.

Values between -0.8 and 0.8 represent a neural evaluation of the corresponding dimension, values > 0,8 represent a positive evaluation and values < -0,8 represent a negative evaluation. The range of the scales is between -3 (horribly bad) and +3 (extremely good). But in real applications in general only values in a restricted range will be observed. It is due to the calculation of means over a range of different persons with different opinions and answer tendencies, for example the avoidance of extreme answer categories, extremely unlikely to observe values above +2 or below -2. Thus, even a quite good value of +1.5 for a scale looks from the purely visual standpoint on a scale range of -3 to +3 not as positive as it really is.

For the benchmark analysis, the measured scale means are set in relation to existing values from a benchmark data set. This data set contains data from 4818 persons from 163 studies concerning different products (business software, web pages, web shops, social networks).[6] The comparison of the results for the evaluated product with the data in the benchmark allows conclusions about the relative quality of the evaluated product compared to other products.

The benchmark classifies a product into 5 categories (per scale):

- **Excellent**: In the range of the 10% best results.
- **Good**: 10% of the results in the benchmark data set are better and 75% of the results are worse.
- **Above average**: 25% of the results in the benchmark are better than the result for the evaluated product, 50% of the results are worse.
- **Below average**: 50% of the results in the benchmark are better than the result for the evaluated product, 25% of the results are worse.

[5] Please see Appendix A for a complete list of the items associated with each dimension.
[6] UEQ Data Analysis Tool.

- **Bad**: In the range of the 25% worst results.

Using the data analysis tool, the results can easily be visualised by the means of graphs which illustrate the average result for each of the six dimensions. Moreover, these results are compared to the fixed benchmark data set which is also illustrated by graphs. It is also interesting to compare the individual result for each dimension with its results against the benchmark; this comparison can add a wider perspective on the analysis.

1.5 Business Model Evaluation Methodology

A business model was developed for each of the two pilot applications. The business models were developed using the e3 value modelling tool. The business models focus on creating values for all the stakeholders in the business eco-system. Initial business models were developed already in M12 (presented in *D9.1 Exploitation and Business Strategy Report*), and it was therefore foreseen that as the project progressed the business models would need to be updated.

It was decided that the project consortium meeting in Recife in November 2015 was a good occasion to organise a half day workshop to present, discuss and evaluate the initially proposed business models with representatives from Brazilian energy suppliers and energy users. The participants represented the Brazilian energy suppliers: CHESF (generation, transmission, distribution and sales), suppliers of energy control equipment and services: Engetron (UPS, switches and control equipment) as well as energy users: UFPE (energy management in large scale public building complexes).

The workshop format allowed the participants to exchange information on their specific needs, interests, and challenges, and to discuss and exchange ideas of how the IMPReSS enabled smart energy system and applications could meet those needs, interest and challenges. The workshop methodology thus focused on gathering qualitative information and feedback which could be used to assess the business value and potential of IMPReSS as well as to enrich the initial business model thus improving its sustainability.

The business model workshop is also described in *D9.3 Innovation Transfer Report* where the focus is on how it allowed for different stakeholders to exchange knowledge about existing technologies in the energy sector in Brazil.

4. User Validation Results

The IMPReSS SDP architecture consists of a number of components and each component may be associated with one or more SDP user requirement. The components have been tested and evaluated and the internal test results are presented in this chapter.

The IMPReSS project operated with two separate, but intrinsically linked, sets of user requirements that reflected who the typical end-user was: 1) the IMPReSS SDP (Application Developer end-user) and 2) the IMPReSS Pilot Applications (Final Recipient end-user). The resolution for both sets of user requirements is also presented in this chapter.

1.6 Results of the Internal System and Integration Testing

The table below contains information on the components that have been tested, the metrics, method(s) used and the results.

Component	Metrics	Method	Results
IoTLink Tool	Variables to be measured according to ISO 9241-11 usability test comprise efficiency, effectiveness & satisfaction. The goal of the study is to find out if: There is an efficiency increase when developers who are not experts on internet of things create a functional prototype using model driven tool compared to java libraries (with same abstraction layer). ➢ H0 : there is no significant difference on the efficiency between using libraries and MDD approach To find out whether there is an efficiency difference between novice developers and experienced developers in creating the prototype using the proposed tool. ➢ H0 : there is no significant difference on the efficiency between using libraries and MDD approach The study should investigate at least 12 users divided into two groups of users, experts and novices. The expert users should have 2-4 years experiences in internet of things related programming e.g. web service, mqtt. The novice developers should have 0.5 to 2 years experiences in object oriented	Combination of case studies and controlled experiments. Streamlined cognitive walkthrough.	• Reduced efforts for application development by 75% by consistent quality of code • Applicable for real-world development • Facilitates the cooperation between software- and electrical engineers • Optimizes required implementation steps • Reduces number of mistakes by inexperienced developers • Positive perception by users.

	software development. The users should solve common development tasks in the IoT such as: • Representing physical objects as a software objects • Subscribe events using pub-sub pattern (MQTT) • Applying filter to the data stream • Persist the sensor data on a database • Define software interface to access the data (REST & MQTT). Qualitative usability feedback was investigated for the following questions: • Evaluating whether the proposed meta-model and layered architecture are easy to understand and adequately designed. • Evaluating whether IoTLink including the user interface and the workflow are easy to understand and adequately designed. • Evaluating whether the generated source code is easy to understand and adequately designed.		
Global Resource Manager	Application-level mixed criticality: All of the scenarios below need to be fulfilled: • When application is registered to	System tests	The GRM has been tested to work and provide the specified functionality. All scenarios fulfilled.

	the GRM, the GRM starts to search suitable resources for each resource specification defined in the application description. GRM has all the time an up-to-date list (i.e., list is updated within 5s whenever status of the system changes) of suitable resource for each resource specification of each applications. • When an application makes a reservation to a resource matching a specification in shared mode, the GRM selects the resource from suitable resources in following order: 1) resource with lowest utilization rate of free resources (i.e., resources that are not reserved for applications in exclusive mode) 2) resource that is exclusively reserved by the least critical application. • When an application makes a reservation to a resource matching a specification in exclusive mode, the GRM selects the resource from suitable resources that is used by the least critical application. • When an application makes an exclusive reservation to a resource, which is used by more critical application in exclusive access mode, access to the resource is not granted. • When an application makes an		

	exclusive reservation to a resource, which is used by less critical application in exclusive access mode, access to the resource is granted. AND if possible new resource is allocated to the less critical application. AND the Local Resource Manager is informed that new application is authorized to access. • When an application makes an exclusive reservation to a resource, which is used by more critical application in shared access mode, access to the resource is not granted. • When an application makes an exclusive reservation to a resource, which is used by less critical application in shared access mode, access to the resource is granted AND if possible new resource is allocated to the less critical application. AND the Local Resource Manager is informed that new application is authorized to access. • When an application makes a shared reservation to a resource, which is used by more critical application in shared access mode, access to the resource is granted. AND the Local Resource Manager is informed that the new application is authorized to access.		

	• When an application makes a shared reservation to a resource, which is used by less critical application in shared access mode, access to the resource is granted. AND the Local Resource Manager is informed that the new application is authorized to access. • Whenever resource reserved for an application is not available anymore (e.g. it disappears or is assigned to more critical application) a new resource is assigned to the application automatically. AND if no suitable resources are available the application and the Local Resource Manager are notified about the authorization. • Device-level mixed criticality resource manager should be able to perform following tasks: • It provides an interface for registering new devices. • It provides an interface for modifying the criticality level of the devices. • It provides an interface for creating rules that specify which devices should be turned off when certain level of energy is remaining in the backup energy store. • It provides an interface to		

	configure how long is waited before power feed to different devices is restored after a power outage is over (grid stability). • It provides an interface to indicate about a power outage (and when the power outage is over). • When power outage happens the devices are turned off according to the configuration. • When power outage is over the devices are turned back on according to the schedule.		
Local Resource Manager	Application-level mixed criticality / security: All of the scenarios below need to be fulfilled: • When an unauthorized application sends a request to a resource, the request is discarded. • When an authorized application sends a request to a resource, the request is passed to the resource. AND the response generated by the resource is sent to the application. • Whenever there are multiple requests in a queue, the LRM processes the request made by the most critical application first. • The LRM has to provide through a REST interface the descriptions of all the resources controlled. • The LRM has to provide through a	System tests	The LRM has been tested to work and provide the specified functionality. All scenarios fulfilled.

	REST interface the list of the services provided by the resources controlled.		
Resource Adaptation Interface (RAI)*	RAI component has been tested performing the following tasks: 1. Selection and download of relevant Device Manager to be installed in RAI from the repository: http://rai_ip_address:port/rai-gui/configuration.html 2. Insertion of a new physical Device into the IMPReSS platform 3. Fetching data measured by sensing Devices 4. Controlling Devices using services exposed by RAI 5. Removing a physical Device from the IMPReSS platform 6. Uninstalling a Device Manager from the RAI using the following graphical interface: http://rai_ip_address:port/rai-gui/configuration.html 7. Polling sensing Devices getting measures.	Controlled experiments using a Cause and Effect approach.	List of results got from relevant tests: 1. The selected Device Manager is listed in the Device Manager(s) list: http://{rai_ip_address}:{port}/rai-gui/platform.html 2. ○ The inserted device is listed in the available Device(s) list: http://{rai_ip_address}:{port}/rai-gui/devices.html ○ The inserted Device is registered into the Resource Catalogue here: http://linksmart.cnet.se:44441/* 3. ○ Incoming MQTT events with sensed data are shown in relevant Device view: http://{rai_ip_address}:{port}/rai-gui/device.html?deviceId={deviceID} ○ Incoming MQTT events with sensed data are fetched using "MQTT.fx" desktop application subscribing to relevant MQTT broker using the following topic: /impress/observation/iotentity/{deviceID} 4. ○ Actuators are controlled through the relevant Device view provided by the RAI Web GUI:

			http://{rai_ip_address}:{port}/rai-gui/device.html?deviceId={deviceID} (e.g. Philips Hue bulbs are switched on/off, their color has been changed, Plugwise smart plugs are switched on/off) ○ Using an online REST client, actuators are controlled following instructions documented here: IoTResource - RAI API 5. ○ The removed Device disappear from the list available in Devices(s) list view: http://{rai_ip_address}:{port}/rai-gui/devices.html ○ The removed Device is deregistered from the Resource Catalogue here: http://linksmart.cnet.se:44441/* 6. ○ The removed Device Manager is not listed anymore in the Device Manager(s) list: http://{rai_ip_address}:{port}/rai-gui/platform.html ○ All the Devices managed by the removed Device Manager are not listed anymore in the available Device(s) list here: http://{rai_ip_address}:{port}/rai-gui/devices.html ○ All the Devices managed by the removed Device Manager are deregistered from the Resource

			Catalogue here: http://linksmart.cnet.se:44441/* 7. Using an online REST client, sensors are polled using REST interface provided by RAI and documented here: IoTResource - RAI API (e.g. Plugwise smart plugs return measured consumed power using the relevant REST service)
Data Manager	The Data Analysis module must be able to perform the following tasks: • Provide a Data Analysis API responsible to perform studies with a set of statistic, optimization, data mining and machine learning algorithms. • Data Analysis module should be able to be accessed via a web service. Developers can develop strategies to act in the following scenarios: • Predict energy consumption to help users to efficiently use appliances of a given ambient.	Applied regression algorithms to predict energy consumption.	Data Analysis API provides a REST API that allows access the algorithms. In order to improve the API performance, the dataset used by the algorithms are generated on own IMPReSS Cloud. The developer informs to API only the prediction interval desired. Energy forecasting has been tested in real data from TAO. Energy forecasting has a better result when applied to next one time. For example, next hour, next month and so on. Because of this, the energy consumption data can be group by time (minutes, hour, day, and month).
Context Manager*	The Context Manager must be able to perform the following tasks: • The Context Manager must allow adapting system's behaviour according to the current context conditions without explicit user intervention, using rule-based context reasoning. • The Context Manager must provide an object-oriented	Preliminary implementation of the Context Manager, used to demonstrate the Classroom Scenario in the IMPReSS Review 2015. Paper published in the 2015 World Forum of IoT (WF-IoT 2015), reporting the experience with the Context Manager using the	The scenario modelled with the Context Manager is able to change its behaviour according to current conditions of temperature and presence in a classroom. Different context-aware smart entities have been implemented, which are configured via the Context Web UI and stored in the Context Manager via the Context API. This also validates requirement IMP-26, which states that "Application developers may be allowed to create

	modelling of different context entities, such as resource (sensors and actuators), place, fusion, rule, action and context (context is an entity that comprises a variety of different other entities). • Whenever sensor data arrives at the Context Manager, it must go through fusion criteria in order to generate outputs by applying certain predefined filters and/or to by computing statistics (e.g., average, max, min, etc.). • Whenever the Context Manager applies a fusion criterion, its output must be considered a virtual sensor which in turn may be used in the used as an input, like a physical sensor. • The output of a fusion must be forwarded to the rule-based reasoner, in order to fire a rule whose attributes are matched by the incoming data. • When a rule is fired, a set of actions must be executed, which reconfigure actuators for changing system's behaviour. • The Context Manager must expose a REST API in order to be easily accessible from other IMPReSS components, such as a User Interface. • The Web User Interface (UI) of the Context Manager must allow	Classroom Scenario Stable implementation of the Context Manager, used to obtain results from a performance analysis study, which resulted in a paper to the Brazilian Symposium on Computer Networks (SBRC 2016)	new templates for smart entities". Sensor data arrive at the system though the RAI using the MQTT protocol, pass through a Pre-Processor and get forwarded to the Fusion Engine (Esper), which applies fusion criteria (called streams in Esper). The modelling of context entities in IMPReSS and its implementation allow fusion output to be forwarded back to the Fusion Engine, as normal data coming from sensors. The Context Manager exposes a REST API, which allows applications to perform CRUD (create, read, update, delete) operations on context entities. One example of application that uses the Context API is the Context Web User Interface.

	users to change context options in order to take advantage and test different sensors, fusion criteria and context rules.		
Mixed Criticality Resource Management Tool*	Mixed Criticality Resource Management Tool should enable system administrators to: • View information about apps, IoT resource, IoT entities. • View which IoT resource matches the needs of which application. • View which IoT resources is used by which app at the moment. • View associations between IoT resources and IoT entities. • Modify the criticality level of applications. • Configure how devices are shutdown during a power outage • Set energy & criticality level thresholds • Define criticality for individual devices • Configure the schedule for restoring power feed for individual devices.	System tests to validate the functionality of the Tool. Usability of the tool evaluated by external users during evaluation Workshop 26.11.2015 Recife	The Mixed Criticality Resource Management Tool has been tested to work provide the specified functionality. Usability of the tool was evaluated to be good by external developers.
IoTStore	IoTStore provides services of data storage and retrieval, and its data model should be generic enough to cover most IoT use cases. Besides, it has an API that should also be evaluated in terms of usability.	Feedback from partners (UFAM, FIT) and internal tests through the development of different applications to use the IoTStore to save and	The first version needed to be remade with another backend technology in order to improve Perspicuity and Reliability. The updated version performed better in the aforementioned metrics and proved to be more

	Concerning these, some observed metrics are similar to UEQ: • Attractiveness: General impression towards the product. Do users like or dislike the product? This scale is a pure valence dimension. • Efficiency: Is it possible to use the product fast and efficient? Does the user interface look organized? • Perspicuity: Is it easy to understand how to use the product? Is it easy to get familiar with the product? • Reliability: ability to function, given environmental conditions, for a particular amount of time • Resiliency: ability to recover quickly and continue operating when there has been a failure e.g. power outages and system crashes.	retrieve data, also performing aggregation policies organized in different use cases.	stable and easy to use and maintain. The IoTStore facilitates data management in IoT contexts, providing developers with a reliable storage and a simple and easy to understand and use API. IoTStore deals well with huge amounts of data, allows data aggregation and its modelling suits a wide range of use cases.

Table 5: Results of internal system testing and integration

*also tested for usability (see the results in Chapter 5)

4.1 IMPReSS SDP User Requirement Final Resolution

A total of 41 user requirements for the IMPReSS SDP were created. They have been solved with the following resolutions:

Resolution	Issues
Validated	31 (76%)
Quality Check failed	8 (20%)
Out of scope	1 (2%)
Duplicate	1 (2%)

Table 6: SDP Requirements Resolution

The user requirements are presented in more detail in the table below.

Key	Summary	Rationale	Fit Criterion	Resolution
IMP-41	RAI shall provide a tool that help developer while creating new device managers	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	Validated
IMP-40	Common objects should be used to enhance buildings management functionalities	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 enhance building management effectiveness	Quality check failed
IMP-39	IMPReSS platform components shall expose interfaces for their configuration	Platform components have to be configured properly depending on the application	Generic APIs for configuration purposes are available	Validated

IMP-38	Sensors integrated into Impress platform shall provide data both generating events periodically and responding to direct requests from other platform components.	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).	Validated
IMP-37	IMPReSS platform shall integrate also low power sensors and actuators	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.	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)	Validated
IMP-36	IMPReSS platform shall measure energy consumption of appliances with plugs	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	Validated
IMP-35	Runtime service/devices configuration	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	Validated
IMP-34	IMPReSS platform searches suitable resources for applications based on resource description	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.	Validated

IMP-33	IMPReSS platform should solve conflicts between applications that access resources interfering with each other	Many types 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.	Validated
IMP-32	IMPReSS platform should schedule/manage resource access based on application criticality	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.	Validated
IMP-31	Data transmitted in the IMPRESS network is classified to different classes based on the confidentiality.	Data transmitted in the IMPRESS network needs to be secured using to different level of security based on the confidentiality.	Confidentiality levels are set for the data	Validated
IMP-30	Availability of the critical IMPRESS resources must be measured	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.	Validated
IMP-29	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	Quality check failed

IMP-28	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.	Validated
IMP-27	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.	Quality check failed
IMP-26	Templates for smart entities	Application developers may be allowed to create new templates for smart entities	Application developer may need to create a new template to modelling a new smart entity in application development.	Validated
IMP-25	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	Quality check failed
IMP-24	Resource adaptation interface shall provide APIs for sensors and devices interaction	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.	Validated

IMP-23	Development toolkit for resources integration	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.	Validated
IMP-22	Runtime services/devices 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.	Validated
IMP-21	Graphical model-driven deployment 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	Validated
IMP-20	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.	Validated
IMP-19	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.	Quality check failed

IMP-18	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.	Quality check failed
IMP-17	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.	Validated
IMP-16	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 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.	Validated

IMP-15	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.	Validated
IMP-14	IoT resources run on a low cost Gateway	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.	Validated
IMP-13	Annotate application with the level of criticality	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	Validated
IMP-12	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.	Duplicate
IMP-11	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.	--	Quality check failed

IMP-10	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	Validated
IMP-9	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	Validated
IMP-8	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. This will make it 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
IMP-7	SDP should allow storing data in a 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	Validated

IMP-6	Energy consumption data should be analysed and predictions made possible	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.	IMPReSS platform is able to analyse energy consumption data and make predictions concerning energy usage.	Validated
IMP-5	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 modelling data.	--	Quality check failed
IMP-4	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.	Devices can be allocated to groups	Validated
IMP-3	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.	Validated

IMP-2	Impress' cloud must scale horizontally	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).	Out of scope
IMP-1	Sensors must be unobtrusive	It is very important that the project show respect of the building. Equipment must fit into the theatre seamlessly. The application cannot be deployed if the criterion is not met.	The equipment that is installed must be unobtrusive.	Validated

Table 7: IMPReSS SDP User Requirements

4.2 Pilot Application User Requirement Final Resolution

A total of 58 user requirements[7] for the two IMPReSS pilot applications were created. They have been solved with the following resolutions:

Resolution	Issues
Validated	34 (59%)
Out of scope	15 (26%)
Duplicate	9 (15%)

Table 8: Pilot Application Requirements Resolution

The requirements are presented in more detail in the table below.

Key	Summary	Rationale	Fit Criterion	Resolution
PILOT-2	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 pilot user application is implemented and can demonstrate the required functionalities.	Validated
PILOT-3	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.	Validated

[7] Final recipient user

PILOT-4	Device properties in the database	A list of the basic properties of devices in the database is necessary for device identification and functioning status.	At least one device of each type of devices connected to the system is registered in a Device Properties database with description of its corresponding properties.	Validated
PILOT-5	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.	Validated
PILOT-6	The Power meter control function	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	Out of scope (non-sense)
PILOT-7	Display of devices/appliances in a room/area	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.	Validated
PILOT-8	View of current measured data	Being able to select between current and historical measurement data allows for smart energy management.	It should be possible to view current measurement data for a selected area or device.	Validated
PILOT-9	View of historical data	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-10	Viewing current measurement data for several devices/areas	Energy monitoring on both small (one device) and 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.	Validated
PILOT-11	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.	Different types of devices can be selected by clicking on the name/icon.	Validated
PILOT-12	Supported display devices	For flexibility and mobility it should be possible to use different display devices.	The system runs on an android based Tablet	Validated
PILOT-13	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.	Validated
PILOT-14	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.	Validated
PILOT-15	The Administration user	The Administration user will be able to manage electrical energy usage more efficiently by analysing consumption data.	100% implemented.	Validated

PILO -16	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.	Validated
PILOT-17	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 current and historical (from a set start date to end date) energy consumption can be shown on the display.	Validated
PILOT-18	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.	Validated
PILO -19	Operator's control of the devices	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.	Validated
PILO -20	Comfort control – Room definition	The Operator should be able to set the basic comfort parameters for a room to optimise electric energy usage.	The Operator can set the ideal temperature and humidity for selected rooms.	Validated
PILOT-21	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 database is implemented and integrated.	Validated

PILOT-22	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.	Validated
PILOT-23	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

PILOT-24	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	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	A list has been established with description on areas and priority. At least one UPS must be connected.	Out of scope

		must be connected in order to		
PILOT-26	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.	Validated
PILOT-27	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
PILO -28	Automatic on/off control of equipment and devices	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 air-con 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	Priority system managing access to sensor and actuator network	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-30	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	Device prioritizing system	Priority system is part of mixed-criticality requirement.	Devices are handled by a priority system.	Out of scope
PILOT-32	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	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	Analysis of energy storage systems	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	Out of scope

PILOT-35	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.	Public user can select specific rooms and areas of interest and see the energy consumption for those selected.	Validated
PILOT-36	Display the temperature and humidity	The display of temperature and humidity is basic informative data for a smart energy management system	The temperature and humidity of least one room is displayed.	Validated
PILOT-37	Display the saving of energy for an area	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.	Validated
PILOT-38	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.	Validated
PILO-39	Public display of the maximum/minimum energy usage 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.	Out of scope

PILOT-40	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	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 selected period of time and for a selected area.	Validated
PILOT-42	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	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	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.	Building drawings can be selected and displayed on the screen.	Validated
PILOT-45	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.	Validated
PILOT-46	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
PILOT-47	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.	Validated

PILOT-48	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.	Validated
PILOT-49	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.	Out of scope
PILOT-50	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	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	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

PILOT-53	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.	Energy consumption data can be extracted for selected rooms/areas. The database is established.	Validated
PILOT-54	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. A simple control of the lighting system is established.	Validated
PILOT-55	Measurement of the temperature and humidity	Basic functionality of the system.	The system is able to measure the temperature and humidity in selected the rooms in the buildings.	Validated
PILOT-56	Define temperature	Basic functionality of the system.	Temperature can be pre-set for selected rooms in building.	Out of scope
PILOT-57	Energy Display System	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).	Validated
PILOT -58	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.	Out of scope

Table 9: Pilot Application Requirements

5. Usability Evaluation Results

As described above, we used the standard User Experience Questionnaire (UEQ), slightly modified as we have added six additional items: one additional item associated with both stimulation and perspicuity, and two additional items associated with both efficiency and dependability.

The results for each of the tested and evaluated component as well as for the complete IMPReSS SDP are presented in the following subchapters. The results have been interpreted using the tools provided by the UEQ and analysed in context, i.e. by taking the complexity of the task and the component into account. The response rate has also been considered in the analysis.

The results represent the average result for each of the six dimensions. In addition, the benchmark results are also presented, i.e. each tool has been compared against the benchmark data offered by the UEQ data analysis tool.

As noted in section 3.1.1, the range of the scales is between -3 (horribly bad) and +3 (extremely good). But in real applications in general only values in a restricted range will be observed. It is due to the calculation of means over a range of different persons with different opinions and answer tendencies, for example the avoidance of extreme answer categories, extremely unlikely to observe values above +2 or below -2. Thus, even a quite good value of +1.5 for a scale looks from the purely visual standpoint on a scale range of -3 to +3 not as positive as it really is.

5.1 The Resource Adaptation Interface (RAI)

The Resource Adaptation Interface (RAI) is a software layer that allows developers to integrate different resources from the physical world to the IMPReSS SDP. RAI acts as the glue between the IMPReSS system and the physical world. One can see this layer as the hardware drivers needed for IMPReSS in order to communicate with physical resources. Specifically, the RAI contains a set of Device Managers, one for each hardware technology supported, which discover and control the physical devices.

The RAI was developed in WP3: Resource Abstraction and IoT Communication Infrastructure.

5.1.1 The Task for the Resource Adaptation Interface (RAI)

Participants were given the following tasks:

In the RAI, you can see all devices which are currently managed by the RAI instance.

You are the Manager of a building management system and you want to add new devices to the RAI instance for monitoring consumptions:

- Download the Plugwise driver from the repository

Check the "Platforms" tab:

- What are the different connected resource networks?

Check the "Devices" tab:

- How many devices are currently connected?

Click on a device and check:

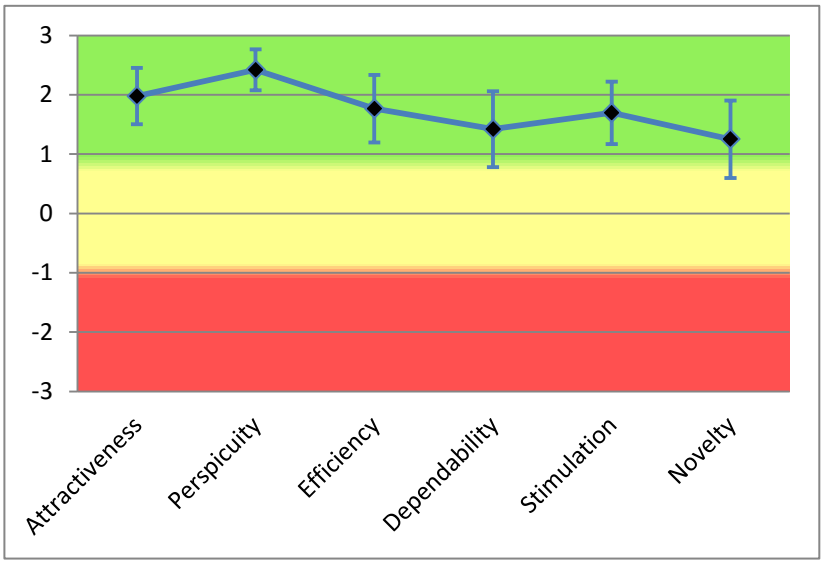
- How much power consumption in Watt is the device currently measuring?

You decide that the Plugwise network is currently not needed and want to save resources:

- Stop the Plugwise network from "Platform" tab.
- Select the "Devices" tab and check if Plugwise devices are connected to the system or not.

5.1.2 Results

The evaluation results for the RAI are excellent; the scores for the individual dimensions were the highest for attractiveness and perspicuity and the second highest for stimulation and novelty.



Attractiveness	1,977
Perspicuity	2,420
Efficiency	1,767
Dependability	1,420
Stimulation	1,695
Novelty	1,250

Figure 4: RAI Results

The item secure/not secure, which is part of the Dependability dimension, had a very low response rate of 60% which indicate that respondents were uncertain of its meaning which may also have caused them to think it was irrelevant. The creators of the UEQ has noted that this item on the questionnaire is often misinterpreted as "Are my data secure?" rather than in the sense that the interaction is safe and controllable by the user.[8]

Benchmark Results

The graph below illustrates the result for the RAI relative to the benchmark. It shows that 5 out of 6 dimensions received an excellent score, 1 a good score, and 1 (Dependability) lies just below "good" in the high end of the "above average" score. The latter is interesting as it did not get the lowest scores; Novelty got the lowest score out the six dimensions but when comparing to the benchmark, it actually lies in the high end of the "good" score.

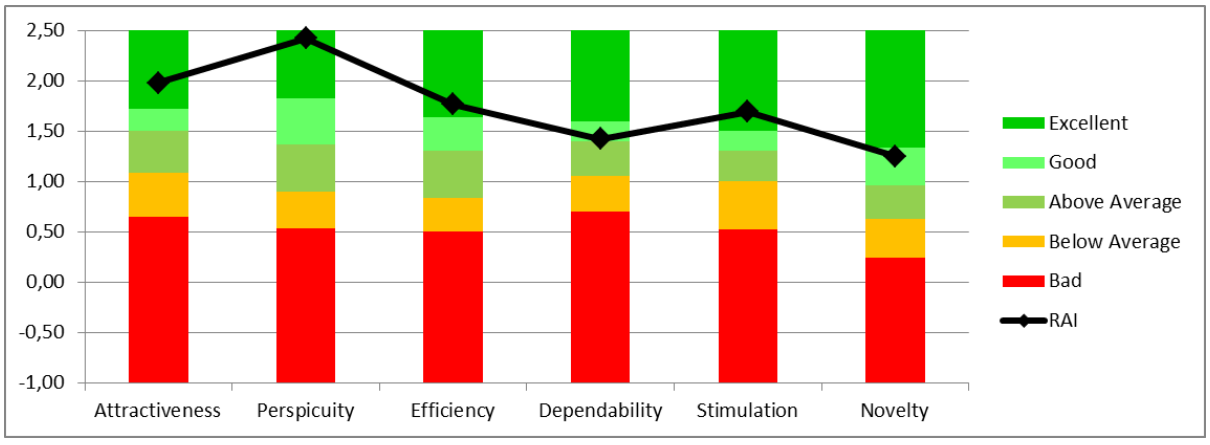


Figure 5: RAI benchmark Results

[8] UEQ Handbook, 2015

5.2 The IoT Resource Catalogue and Supportive Tools

The IoT Resource Catalogue provides the means to store more elaborate metadata regarding the services compared to the Network Manager Service Catalogue. The IoT Resource Catalogue uses service descriptions that are expressed in an extended version of SCPD (Service Control Protocol Description) which is the standard for service descriptions in DLNA/UPnP.

The usability testing of the IoT Resource Catalogue component involved the following three tools each with specific tasks:

- **The IoT Resource Catalogue Service**
  This tool provides mechanisms for routing requests regarding the physical world to the appropriate software resource that is able to fulfil the request, such as reporting the temperature in a particular office space or the current electricity consumption of a household appliance.

  The IoT Resource Catalogue discovers and keeps track of available IoTResources in the network. It provides a REST-based interface to select and retrieve data about IoTResources and their services. The discovery uses the UPnP standard SCPD for the service descriptions, see http://www.iotworldservices.com/wiki/iotworldserviceswiki/iot-resource/service-control-point-document/

- **IoT Resource Catalogue Browser**
  This is a tool for browsing the currently available IoT Resources on the network. The main focus is supporting developers for means to browse the available IoTResources and to interact with them.

  The tool is built on top of the IoT Resource Catalogue services utilising its REST API.

- **The IoT Resource Builder**
  Allows you to define your IoT Resources and automatically generate the necessary IoT Resource code stubs. Services can then be built using these IoT Resources. The tool also allows for annotations of IoT Resources and their services. The code stub can directly be compiled and run providing both metadata and the services defined. What is left to the developer is the interaction with the actual device.

The IoT Resource Catalogue was developed in WP3: Resource Abstraction and IoT Communication Infrastructure.

The tasks that participants were given are described in the next section. It is important to note, at given the format and constraints of the usability workshop, it was decided to have fairly simple and instructed tasks since there was also limited time for a tutorial.[9] For example, tasks were instructed as: "Click there and then there and then write this and see what happens", rather than in a more complex way: "Find out which devices are available and which one of them is consuming most energy at the moment, and figure out how to use the API to turn this device off".

[9] Mainly time constraints reinforced by the fact that several IMPReSS tools were evaluated at the same time; we therefore aimed to make the duration of instructions and estimated time to complete the different tasks as equal as possible. In other words, tasks were defined following a similar level of complexity (or simplicity).

5.2.1 The Tasks for the IoT Resource Catalogue[10]

Participants were given the following tasks:

- Use the IoT Resource Catalogue to determine who has manufactured the IoT resource "DiscoBall" using http://linksmart.cnet.se:44441/iotresources/DiscoBall ?
- Determine if "DiscoBall" has a "switch" service using http://linksmart.cnet.se:44441/iotresources/DiscoBall/services ?
- Does the DiscoBall have a service for turning it on http://linksmart.cnet.se:44441/iotresources/DiscoBall/services/switch/actions?
- Open a new browser tab with http://webcam.cnet.se , Then invoke the action turn on using http://linksmart.cnet.se:44441/iotresources/DiscoBall/services/switch/actions/TurnOn.
- Is the "DiscoBall" running?
- invoke the action turn off using http://linksmart.cnet.se:44441/iotresources/DiscoBall/services/switch/actions/TurnOff
- Has the "DiscoBall" stopped?

5.2.2 The Tasks for the IoT Resource Catalogue Browser[11]

Participants were given the following task:

- Find the "DiscoBall" IoTResource by expanding the tree; it should be part of resources belonging to Armstrong.
- Select the "DiscoBall" node, look at the switchstatus tab, when was it turned on the last time?
- Expand the "DiscoBall" node. Can you see the switchservice?
- Expand the switschservice node, double click on GetSwitchStatus. What is the result?
- Right click on the "DiscoBall" node, select Get Device XML. What is the current consumption?

5.2.3 The Task for the IoTResource Builder[12]

Participants were given the following task:

- Start IoT Resource Builder from the desktop.
- "Open from file" Desktop\example.xml, which version of the service is it?
- Which state variable does the service have?
- Which Actions do exist for the service?

---

[10] Participants were also given links to the following background information:
The Resource Catalogue service API: http://www.iotworldservices.com/wiki/iotworldserviceswiki/iotresource-catalogue/services-and-actions/
The Resource Catalogue search API: http://www.iotworldservices.com/wiki/iotworldserviceswiki/iotresource-catalogue/iotresource-catalogue-searching-for-iotresources/
Using The Resource Catalogue service for invoking action in IoT Resources:
http://www.iotworldservices.com/wiki/iotworldserviceswiki/iotresource-catalogue/actuating-on-iotresources/
The OGC based parts used in IMPReSS for retrieving meta data of resources: IMPReSS OGC Meta API
Participants were also given links the following further examples:
This tutorial uses the gateway and IoT Resources located in the CNet office in Stockholm Sweden.
Walk through the example IoT Resource Catalogue invocations here:
http://www.iotworldservices.com/wiki/iotworldserviceswiki/iotresource-catalogue/demo-links-for-iot-resource-catalogue/
NB! For the actuation you can look at CNets webcam: http://webcam.cnet.se

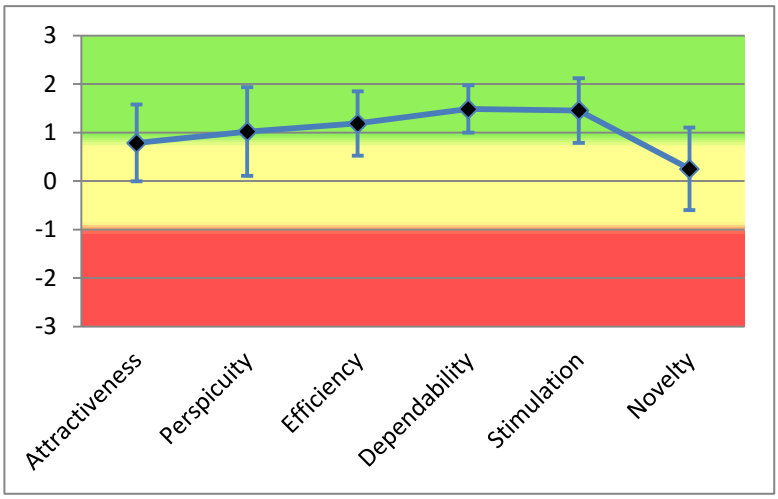
[11] The participants were also given a link to a supplementary description of the tool:
http://www.iotworldservices.com/wiki/iotworldserviceswiki/iotresource-catalogue-browsers/windows-version/

[12] Participants were given access to further information via this link: http://www.iotworldservices.com/wiki/iotworldserviceswikind /iot-resource-builder/iotresource-builder/

- Add a new state variable by right clicking in the state variable tab, name it "humidity" with the type integer 16 and make it logged.
- Add a new Action in the actions tab by right clicking inside the tab.
- Name the action GetHumidity, add argument, select variable humidity and name the Argument "humidity". Right Click on the new argument, select Return, click Ok.
- Create the code stub by selecting File->Generate IoT Resource stub..., name it TestResource, Select Desktop\test for Output Path and click OK to generate the stub.
- Open the created stub in the desktop folder test by double clicking on it, in Visual Studio select Debug-> Start without debugging. The stub will be built and started.
- On the desktop start the local IoT Resource Catalogue. Can you find your resource and its services?

5.2.4 Results

The three tools were evaluated as one as they are all integral parts of the IoT Resource Catalogue component. The results are illustrated here:



Attractiveness	0,783
Perspicuity	1,020
Efficiency	1,187
Dependability	1,483
Stimulation	1,453
Novelty	0,250

Figure 6: The IoT Resource Catalogue Results

As mentioned above in section 5.2, the tasks for the IoT Catalogue were made quite simple thereby dressing an otherwise complex tool up as simple as possible. The results for Novelty, which are quite low, may be a reflection of the nature of the task, particularly the way they were phrased (instructive rather than open for interpretation). At the same time, the score for Stimulation is quite high which should also caution us to interpret the Novelty score too negatively. The score for Attractiveness is a very high neutral score (the neutral score range between -0,8 and 0,8) and is therefore acceptable. Overall, the results are satisfactory, particularly the tool scored very well on Dependability.

As we saw for the RAI, the item secure/not secure also had a low response rate of 60% indicating again that the question may have been misunderstood, or not understood, by 40% of the participants.

Benchmark Results

The benchmark results show that the IoT Catalogue does not score so well in relation to the benchmark data for Attractiveness and Novelty. As mentioned above, a likely explanation for the low score in these two dimensions could be the simplification of otherwise complex tasks thereby giving users the impression that the novelty factor is low.

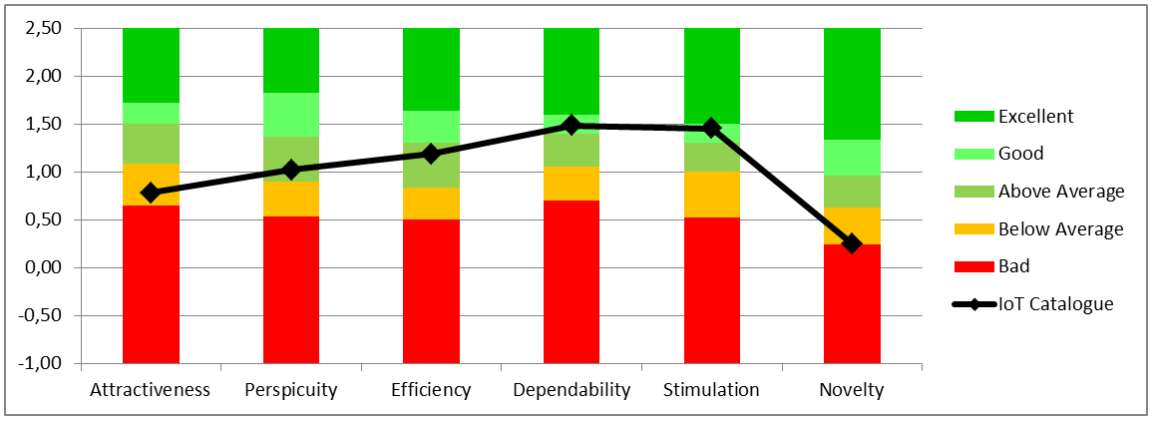


Figure 7: The IoT Resource Catalogue Benchmark Results

The benchmark results also show a stark difference between the results for Stimulation and Novelty which would have been interesting to explore further, e.g. by doing follow-up focus group interviews with participants (unfortunately not possible within the scope of the project).

5.3 The Mixed Criticality Resource Management Tool

The mixed criticality resource management tool provides system administrators, integrators and maintenance personnel with means to monitor and manage their IMPReSS based IoT systems.

As a concept, Mixed Criticality IoT Resource Management is quite complex. On scale 1-5 (5 being the most complex), the application-level mixed criticality management is 4 and the device-level mixed criticality resource management is 2.

The given tasks represented all the tasks that the user, i.e. a system administrator, would need to execute with the tool in practice.

The Mixed Criticality Resource Management Tool was developed in WP4: Mixed Criticality Resource Management.

5.3.1 The task for the Mixed Criticality Resource Management Tool

The tool, the concept behind it, and some of the tasks at hand were quite complex (level 4 out of 5) and therefore required some pre-existing knowledge and rationale were applied to complete the certain tasks. Participants were consequently given a full tutorial (5-8 minutes) about the mixed criticality concept and shown how the tool works with practical examples. No further guidance was given after the presented tutorial, i.e. while participants completed the tasks at hand.

The Mixed Criticality Resource management Tool evaluation task consisted of two parts. In the first part, the goal is to evaluate the application-level mixed criticality resource management view. The second part focuses to the device-level mixed criticality management aspects.

Task Part One: Application-level view

First, check the properties of some entities and acquire some knowledge about the system:

- What is the ID of the Belkin Wemo smart plug?
- Which IoT Resource is associated to the Biology lab server?
- Which application is using PhilipsHue resources at the moment?
- What is the criticality level of the Energy saver application?
- What is the criticality level of the Alarm system application?

Then, you want to manage application criticality levels so that the right application can take control of the resources.

- Increase the criticality of the Lighting system app to 150. What happens?

- Change the criticality level of the alarm system application so that it takes control of the lights.

Task Part Two: Device-level view

Switch to device-level view in order to configure how the system behaves during power outage, as well as, when the power outage is over.

First, configure the power outage phase by creating following rules (threshold levels):

- When 90 percent of energy is remaining, all devices with criticality lower than 100 will be turned off.
- When 50 percent of energy is remaining, all devices with criticality lower than 170 will be turned off.
- When 10 percent of energy is remaining, all devices with criticality lower than 300 will be turned off.

Then, configure following three rules for the wake-up phase:

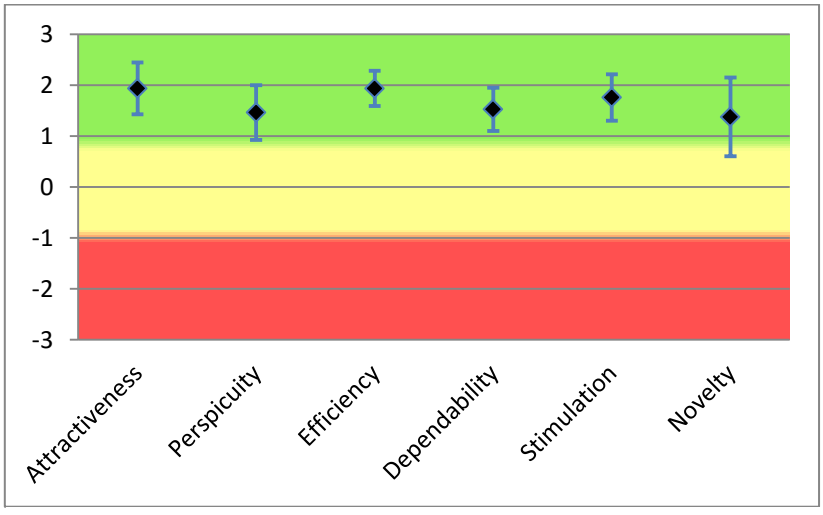
- Immediately after power outage is over (i.e., 0 seconds) all devices with criticality value 350 or higher are turned on.
- When 10 seconds has passed all devices with criticality value 180 or higher are turned on.
- When 20 seconds has passed all the rest of the devices are turned on (i.e. criticality level 0).

Finally, adjust the criticality of devices as follows:

- Set criticality value 310 for the smart plug associated to the Biology lab server.
- Adjust the criticality value of the smart plug associated to the classroom PC so that it is turned off when 50 percent of the energy is remaining.
- Adjust the criticality value of the smart plug associated to the ICT lab server so that following conditions are met:
  - it is turned off when 10 percent of the energy is remaining
  - it is turned on 10 seconds after the power outage is over.

5.3.2 Results

The usability evaluation of the Mixed Criticality Resource Management tool got an excellent result; in fact it received the most positive evaluation of the five tools. This excellent result is significant because the complexity level of this tool is also the highest; the very high score for efficiency suggests that it scored high despite its complexity or, in other words, that it was an efficient tool for completing a complex task.



Attractiveness	1,933
Perspicuity	1,460
Efficiency	1,933
Dependability	1,523
Stimulation	1,755
Novelty	1,375

Figure 8: The Mixed Criticality Resource Management Tool Results

As additional feedback, participants found the mixed criticality concept, functionality and tool quite interesting which support the results from the UEQ; this tool scored the highest for dependability, stimulation and novelty, it scored 2nd highest for attractiveness and efficiency, and came in third with regards to perspicuity. The latter is not surprising as it did represent the most complex tool and concept. Still, the result for perspicuity is quite high and thus considered very positive.

Some participants also had some recommendations regarding the User Interface which were in complete line with already planned modifications.

Benchmark Results

The benchmark results are very good. It is not surprising that the tool fared the lowest (albeit still scored within the "good" range) for Perspicuity given the fact that the concept *per se* and the tool are quite complex.

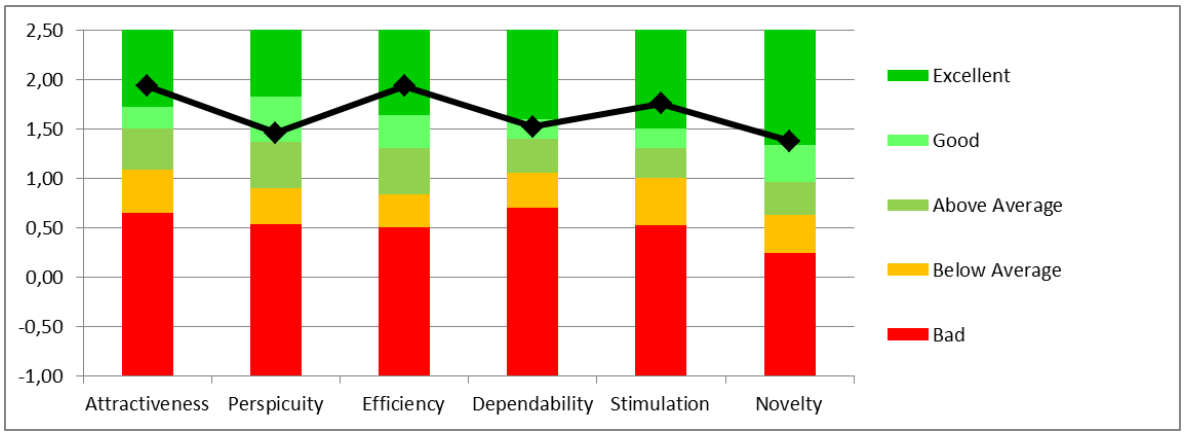


Figure 9: The Mixed Criticality Resource Management Tool Benchmark Results

5.4 The Application Description Generator

The Application Description Generator is considered the least complicated tool of those tested and evaluated during the workshop.

The IMPReSS Mixed Criticality component manages the access of different applications to the same resource. For this purpose, each application must be registered and request the needed resources from the IMPReSS SDP. The registration is done by providing an application description file in JSON format. The resource manager then stores the information about the application in the knowledge base, and finds the suitable resources that meet its needs. The Application Description Generator is a GUI for generating this file.

The Application Description Generator was developed in WP4: Mixed Criticality Resource Management..

5.4.1 The Task for Application Description Generator

Participants were briefly introduced to the tool's purpose (as described above) before they were given the following tasks without any further explanation of the tasks or how to complete them:

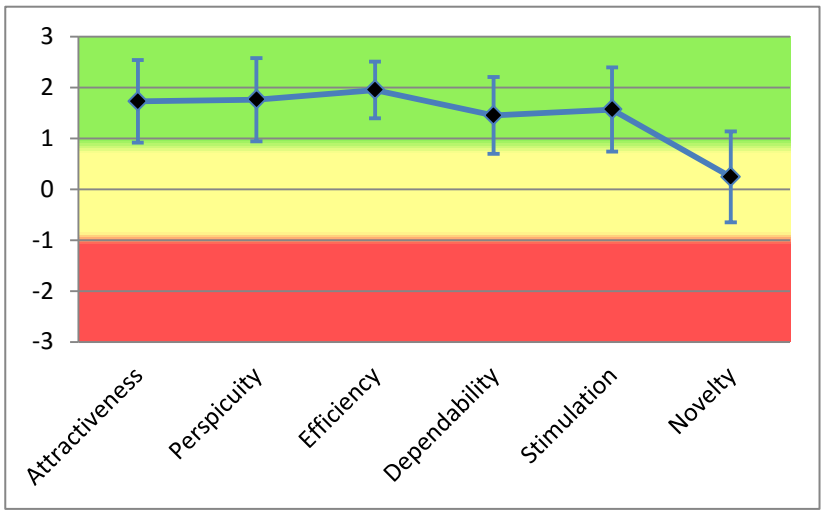
- First, you want to add a new application, which controls the light in a classroom in an intelligent way. For this, you need to create the JSON file using the application description generator:
- Generate a random application ID
- Give a proper application name and description
- Set criticality level to 10 and security level low
- Add 2 shared, obligatory lighting resources, one for row 3 and one for row 4 in classroom 10

- Download the app description.

The difficulty level of these tasks was considered to be moderate.

5.4.2 Results

The graph below illustrates the average results for the six dimensions covered by the questionnaire:



Attractiveness	1,725
Perspicuity	1,760
Efficiency	1,950
Dependability	1,450
Stimulation	1,565
Novelty	0,242

Figure 10: Application Description Generator Results

The evaluation results show that the tool scored the highest for its efficiency. For attractiveness and perspicuity the score was also very satisfying and for dependability and stimulation the score is also satisfactory. The result for the novelty dimension was significantly lower compared to the other dimensions. Novelty received a "neutral score" with an average value of 0,242 thus placing it just above the middle within the neutral score (values between -0.8 and 0.8 represent a neutral evaluation). The novelty dimension is covered by four statements (3, 10, 15 and 26) and the response rate was the lowest with 92%.The Application Description Generator Tool's score for novelty is perhaps not surprising as it is the least complex and innovative of the tools evaluated and considering that the scores for the other four dimensions are good, the overall result for this tool is still satisfactory.

Additional feedback on the tasks *per se* was also collected. Thus some participants felt that it was unclear that a first resource is already added when starting with the tool and that is was unclear how to find a resource when the resource ID is unknown.

Benchmark Results

The graph below illustrates the results for relative to the benchmark data set:

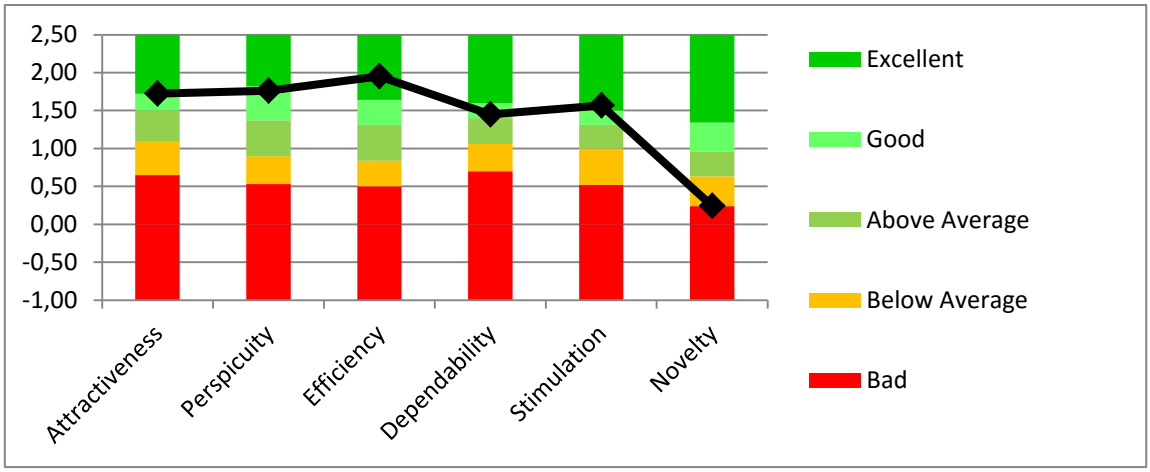


Figure 11: Application Description Generator Benchmark Results

The results for the Application Description Generator tool compared to the benchmark are good for all dimensions except Novelty. The poor result for Novelty only supports the notion that although the tool is efficient, easy to use and learn (associated with Perspicuity), interesting and motivating (associated with Stimulation), it is also considered quite conventional and not leading edge; this experience could have been reinforced by the rather simplicity of the tasks and the tool itself.

5.5 The Context Manager

The Context Manager is in charge of providing background software components that a typical context-aware middleware offers to its users, such as context templates, context models, context reasoning engine, and algorithms for sensor and data fusion.

As the core component of the context management framework, the context reasoning engine provides the context awareness services to the application. It processes the context model provided by the application (and created through the tools included in the framework) and constantly monitors the state of the smart entities. It utilises the sensor and data fusion services in order to obtain the required information, and detects the occurrence of situations (i.e., specified states of a given set of smart entities) defined within the context model.[13]

The Context Manager was developed in WP6: Software System Engineering and Context Management.

5.5.1 The Task for the Context Manager

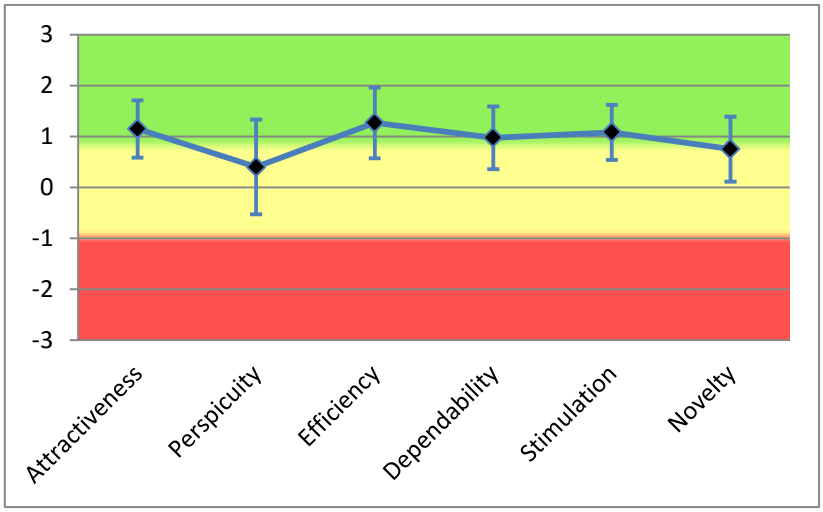
Participants were given the following tasks:

- Add a presence sensor and a Kinect sensor to the context
- Add a fusion which combines the presence sensor and the Kinect sensor to this context
- Add a rule which defines that if the before defined fusion detects presence, a light shall be switched on
- For that rule, you must add a light actuator.

5.5.2 Results

The average results are illustrated in the graph below:

[13] For more detailed information on the IMPReSS Context Manager please see *D6.3 Context Management Framework Architecture and Design of Context Templates* and *D6.4 Implementation of Context Reasoning Engine*. Both deliverables are available for download on the IMPReSS website: http://www.impressproject.eu/viewpage.php?page_id=4



Attractiveness	1,147
Perspicuity	0,400
Efficiency	1,267
Dependability	0,973
Stimulation	1,080
Novelty	0,750

Figure 12: The Context Manager Results

The Context Manager Tool fared – overall – the lowest of the evaluated tools, nevertheless, the results for Attractiveness, Efficiency, Dependability and Stimulation are satisfactory. The results for Perspicuity and Novelty are neutral which is less than aimed at and hoped for. The Novelty score is placed, however, in the very high end of the neutral range which is acceptable.

When interpreting the results for Perspicuity, some inconsistency with regards to the answers to the individual items associated with this dimension becomes apparent, and the low result should therefore be interpreted with some caution and reservations. For example, item 4 "easy to learn/difficult to learn" received a mean score of 0,9 thus just placing it in the positive range as -0,8 to 0,8 is considered neutral. In comparison, item 21 "clear/confusing" scored the absolute lowest with a mean result of -0,3. When looking at the consistency level for each respondent, 6 out of 10 show inconsistency between item 4 and 21. The three other items in this dimension all scored within the high end of the neutral range (0,3 and 0,5 and 0,6) which indicates that the inconsistency is more related to the negative score of -0,3.

A possible explanation could be that participants interpreted the item(s) associated with Perspicuity in an unexpected way. In conclusion, the result for perspicuity must be interpreted with care but by comparing the score for each individual item seems likely that the inconsistency is related to the one negative score, thus indicating that the result can be interpreted slightly more positive that the figures suggest.

Benchmark Results

The benchmark result confirms that the results could have been better. As noted above, it is important, however, to consider the apparent inconsistency that were found with respect to the items related to Perspicuity. Also, the relatively poor result for this particular tool becomes less negative when evaluating the IMPReSS SDP as a whole, i.e. the overall user experience with all the IMPReSS tools, then the result is actually excellent (see SDP results below).

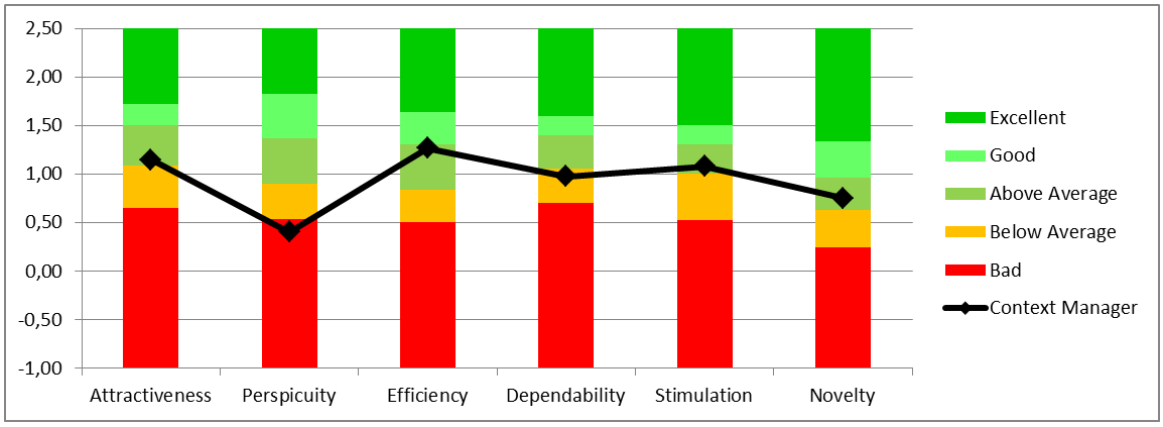


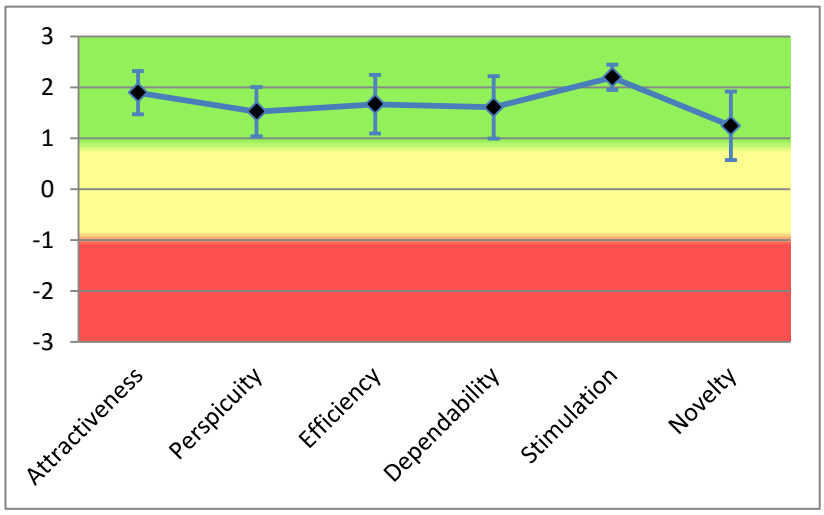
Figure 13: Context Manager Benchmark Results

5.6 The IMPReSS SDP Overall Results

After having completed all the tasks and the usability questionnaires for the individual components, participants were asked to fill out an additional usability questionnaire with respect to their overall experience using the IMPReSS tools. The results are used here to represent an overall usability evaluation of the five selected tools in IMPReSS SDP. Seeing that the usability evaluation was carried out in M27, thus 3 months before the end of the project, it was not possible to test all the SDP tools as some tools were still in a stage of development deemed not immature for any valuable usability testing to be carried out. Thus, while the result presented here only reflects the overall user experience of the five available tools, it nevertheless provides a useful evaluation of the user experience of the IMPReSS SDP in terms of its usability for the various tasks – of different complexity levels and using different tools – involved when developing applications.

The response rate on the questionnaires was 97%. As seen for the individual tools, the item with the lowest response rate (50%) was item 17 "secure/not secure" (Dependability), which is likely an indication of misinterpretation of the context and meaning as described in section . Only five other individual items did not have a 100% response rate, namely item number 5 (associated with Stimulation), 15 (associated with Novelty), 19 (associated with Dependability), 24 (associated with Attractiveness) and 28 (associated with Dependability). In total, we see that 3 of the items associated with Dependability did not have a 100% response rate, suggesting that the meaning of these items may have been too unclear in relation the IMPReSS SDP, thus resulting in a blank answer.

The average result for each of the six dimensions is illustrated in the graph below. Overall, the result is very positive.



Attractiveness	1,893
Perspicuity	1,520
Efficiency	1,667
Dependability	1,605
Stimulation	2,195
Novelty	1,242

Figure 14: IMPReSS SDP results

Benchmark Results

The benchmark results are very good and it is indeed positive to see that Novelty, which was the dimension which received the lowest score for some of the individual tools, lies within the "good" range. It is also quite exciting to note that four out of six dimensions got the "excellent" score (Attractiveness, Efficiency, Dependability, and Stimulation).

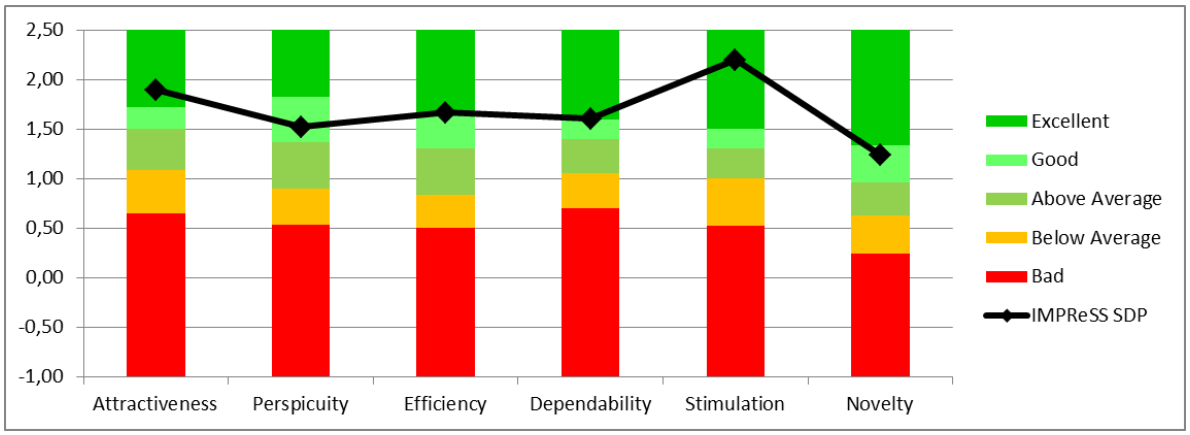


Figure 15: IMPReSS SDP Benchmark Results

6. Business Model Evaluation Results

Based on the input and knowledge gained at the workshop in Recife in November 2015, the initial business models for the Pilot Applications have been updated. The e3 value tool allows us to do complete calculations on the cash flow for each of the actors in the model.[14] It is important to note that the e3 value model is focusing on identifying the value objects that are being exchanged between the actors and these value objects do not need to be of monetary value. This means that money will not need to be exchanged between all the actors in the model. The evaluation of the business models is based both on analysing the cash flow for relevant actor and on feedback from relevant stakeholders.

The updated business models are presented and described in detail in the following subchapters.

6.1 UFPE Business Model

The following model has been created:

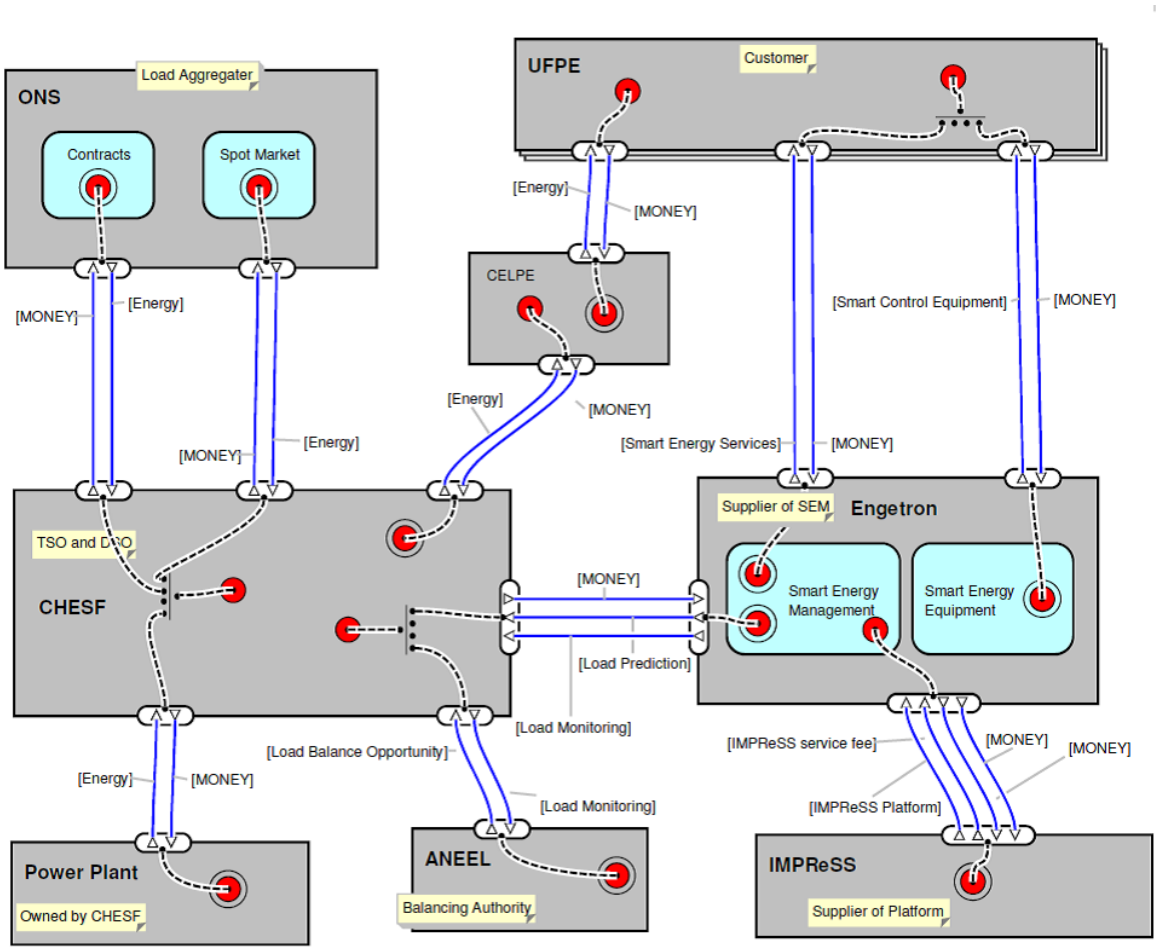


Figure 16: UFPE Business Model

6.1.1 Actors and value objects

The actors in the business model and all the value objects they exchanged will now be described in more detail. The values represent annual payments.

[14] The business model and e3 value methodology have been described in *D9.1 Exploitation & Business Strategy Report*.

UFPE

The UFPE campus is a large consumer of energy and can be compared to a small town; using electrical energy for public lightning, water treatment and pumping, traffic control, etc. On average, UFPE uses 28.000MWh per year. They pay R$530 per MWh. Their energy provider is the Pernambuco Electrical Company (CELPE).

UFPE has requested that their energy system is updated including installing smart meters and an automatic criticality system. The lack of clarity of where, to what and how much energy is consumed on campus represents a real problem because it makes it virtually impossible to implement efficient energy and energy cost reduction savings. The university campus wishes to be on the forefront with respect to being sustainable and energy efficient. Also, as one of the top ranking universities in Brazil, there is a need for more power stability achieved through an automated criticality system.

UFPE is now using the IMPReSS enabled SmartEnergy application provided by Engetron, a supplier of Smart Energy Management solutions, to manage, monitor and control their energy system. They are able to reduce their annual energy consumption by 10%.

Value objects received from Engetron (supplier of Smart Energy Solutions)

- Smart Energy services
- Smart Energy control equipment, including Smart Energy Management application

Value objects offered to Engetron (supplier of Smart Energy Solutions)

- Annual fee for Smart Energy services: R$250.000
- Payment for Smart Energy control equipment, including Smart Energy Management application: R$250.000

Value objects received from CELPE (provider of energy)

- Energy: A 10% reduced energy consumption because they now have the IMPReSS enabled Smart Energy management system in place. Annual consumption is therefore now reduced to 25.200MWh.

Value objects offered to CELPE

- Payment for energy: R$530 per MWh. This amounts for an average annual energy bill of R$13.356.000.

Engetron (supplier of Smart Energy Solutions)

This actor is representative of a service provider/supplier of Smart Energy Solutions. They provide control equipment for controlling the energy use and distribution (e.g. USP, switches, monitors). Lately they have been engaged in also providing software solutions and services that allow the customers to manage energy consumption in a smart way. They can now access data to be able to monitor and control energy consumption and have tools to forecast consumption in order for energy utilities to monitor and control/manage the load on the grids. Their preferential supplier is developing the software with the IMPReSS SDP tools.

Value objects received from UFPE

- Annual fee for Smart Energy services (R$200.000)
- Payment for Smart Energy control equipment, including Smart Energy Management application (R$650.000)

Value objects offered to UFPE

- Smart Energy services
- Smart Energy control equipment, including Smart Energy Management application.

Value objects received from IMPReSS Service Provider:

- The IMPReSS SDP
- IMPReSS cloud services

Value objects offered to IMPReSS Service Provider:

- Payment (investment) in the IMPReSS SDP: R$650.000
- Annual service charge for the IMPReSS cloud services: R$200.000.

Value objects offered to CHESF:

- Load monitoring to CHESF to allow them to perform better grid/load management
- Load prediction to CHESF to allow them to perform better grid/load management

Value objects received from CHESF

- Payment for load monitoring and prediction data: R$500.000.

CELPE

CELPE – the Pernambuco Electrical Company – buys energy from CHESF and sells it to UFPE. All the energy consumed by UFPE is provided by CELPE; due to regulations UFPE is not allowed to buy energy from the spot market but must buy energy from an electric company (in this case CELPE). CELPE sells energy to UFPE at an average price of R$530MWh. With IMPReSS, UFPE is able to cut down their energy consumption by 10%.

Value objects offered to UFPE:

- Energy: 25.2000MWh

Value objects received from UFPE:

- Payment for energy: R$13.356.000

Value objects offered to CHESF:

- Payment for energy: R$10.400.000.

Value objects received from CHESF:

- Energy to cover needs of UFPE: 26.000MWh

CHESF (Local Power Company/TSO/DSO)

This actor is representative of an all-inclusive Brazilian energy company. They operate a local power generation plant in their dedicated region. They also buy extra energy from other regions on a 6 months usage/distribution contract for providing the energy to their customers that cannot be covered by local production. The also cover any extra need for energy by buying on the sport market. The actor must carefully assess the future energy demand and local production in order to buy extra capacity on long term contracts rather than on the spot market, which is considerably higher priced. The actor also transmits energy from outside the region and distributes it within its own region.

Value objects offered to Engetron:

- Payment for load monitoring and prediction data: R$500.000.

Value objects received from Engetron

- Load monitoring to CHESF to allow them to perform better grid/load management
- Load prediction to CHESF to allow them to perform better grid/load management

Value objects offered to ANEEL (national agency for energy management):

- Load monitoring data to ANEEL for it to forecasts longer term demands at the national level

Value objects received from ANEEL:

- Load balance opportunity: approval/acceptance for buying extra energy supplies from other regions, either on contract or on the sport market.

Value objects offered to Power Plant:

- Money for energy: cost of producing energy (R$55 per MWh)

Value objects received from Power Plant:

- Energy: 18.200MWh

Value objects offered to ONS:

- Money for energy on 6 month contract: R$260 per MWh
- Money for energy bought on spot market: R$710 per MWh

Value objects received from ONS:

- Energy bought on 6 month contract: 5.200MWh
- Energy bought on the spot market: 2.600MWh

Value objects offered to CELPE:

- Energy (to cover UFPE customer): 26.000MWh

Value objects received from CELPE:

- Payment for energy: R$10.400.000.

ANEEL (Brazilian Electricity Regulatory Agency)

This actor is linked to the MME (Ministério de Minas e Energia) and controls the distribution of energy and associated prices between the different regions in Brazil in accordance with the policies and guidelines of the Federal Government. It needs to get the best possible forecasts for regional energy demand and supply.

Value objects offered to CHESF:

- Load balance opportunity: approval/acceptance for buying extra energy supplies from other regions, either on contract or on the sport market.

Value objects received from CHESF:

- Load monitoring data that allows it to forecasts longer term demands at the national level.

Power Plant (owned by CHESF)

This actor is the ensemble of local electricity generating power plants owned by CHESF. The actor delivers locally produced electricity within its capacity.

Value objects offered to CHESF:

- Energy: 18.200MWh

Value objects received from CHESF:

- Money for energy: cost of producing energy (R$55 per MWh)

ONS (Aggregator)

This actor is an independent grid operator that sells and delivers energy across regions based on the authorization and prices established by ANEEL. The actor thus acts as an aggregator that balances the different regional grids/companies energy demand and supply of energy. Energy can either be sold on long term contracts (typically 6 months) with reasonable prices. Or it can be sold on the sport market for immediate delivery with high prices. The better the forecasts from regional DSOs and TSO, the better the stabilisation of the grid load.

Value objects offered to CHESF:

- Energy bought on 6 month contract: 5.200MWh
- Energy bought on the spot market: 2.600MWh

Value objects received from CHESF:

- Money for energy on 6 month contract: R$260 per MWh
- Money for energy bought on spot market: R$710 per MWh

IMPReSS

This actor is the supplier of the IMPReSS SDP, custom applications, as well as the IMPReSS cloud and energy data. For simplicity of the model, we have not included the cost of delivering the SDP (on time cost and recurrent charges).

Value objects received from Engetron:

- Annual payment of R$200.000 for IMPReSS cloud services
- Payment for delivering the IMPReSS SDP (R$650.000).

Value objects offered to Engetron:

- The IMPReSS SDP
- IMPReSS cloud services.

1.6.1 Profitability

Based on the monetary values and MWh data we have received from CHESF and UFPE, we can now set up a table to show the value transactions for each actor and the economic value assigned to the monetary value objects. As mentioned above, UFPE is expecting a 10% reduction of energy consumption and it is based on this that we have calculated the business case. For simplicity, the business case and the tables below are only based on the transactions in the model.

Actor / Market Segment (R$)	Value object in	Value in		Value object out	Value out		Cashflow	
UFPE							-13.856.000	R$
CELPE	Energy			Paying for energy usage	13.356.000	R$		
Engetron	Smart Energy Control equipment			Payment for equipment	250.000	R$		
Engetron	Smart Energy services			Payment for smart energy services	250.000	R$		
CELPE							2.956.000	R$
UFPE	Payment for energy usage	13.356.000	R$	Energy				
CHESF	Energy			Payment for energy	10.400.000	R$		
Engetron							150.000	R$
UFPE	Payment for equipment	250.000	R$	Smart Energy Control equipment				
UFPE	Payment for smart energy services	250.000	R$	Smart Energy services				
CHESF	Payment for load prediction & monitoring data	500.000	R$	Load prediction & monitoring data				
IMPReSS	IMPReSS service			Payment for IMPReSS service	200.000	R$		
IMPReSS	IMPReSS SDP			Payment for IMPReSS SDP	650.000	R$		
CHESF							5.701.000	R$
Engetron	Load prediction & monitoring data			Payment for load prediction & monitoring data	500.000	R$		
ANEEL	Load balance opportunity			Load monitoring				
Power Plant	Energy			Cost of energy production	1.001.000	R$		
ONS (Aggregator)	Energy bought on contract			Payment for energy bought on contract	1.352.000	R$		
ONS (Aggregator)	Energy bought on spot market			Payment for energy bought on spot market	1.846.000	R$		
CELPE	Payment for energy	10.400.000	R$	Energy				
ANEEL							0	R$
CHESF	Load monitoring			Load balance opportunity				
Power Plant							1.001.000	R$
CHESF	Payment for energy production	1.001.000	R$	Energy				
ONS (Aggregator)							3.198.000	R$
CHESF	Payment for energy bought on contract	1.352.000	R$	Energy bought on contract				
CHESF	Payment for energy bought on spot market	1.846.000	R$	Energy bought on spot market				
IMPReSS							850.000	R$
CHESF	Payment for IMPReSS service	200.000	R$	IMPReSS service				
CHESF	Payment for IMPReSS SDP	650.000	R$	IMPReSS SDP				
Total		29.805.000	R$		29.805.000	R$	0	

Table 10: Value transactions in UFPE business model

Table 2 below shows the profitability of the actors in the business model. One actor in particular, namely Engetron, can expect a higher profitability in the subsequent years as the investment in IMPReSS (R$650.000) will not be included in subsequent year's calculations.

Profitability of actors in the FIRST year when the service is installed

Segment / actor (k€)	Revenues	Payments	Expenses	Gross profits	Investments	Cashflow
UFPE	0	-13.606.000				-13.606.000
Engetron	1.000.000	-200.000		150.000	-650.000	-850.000
CELPE	13.356.000	-10.400.000		2.956.000		
CHESF	10.400.000	-4.699.000		5.701.000		-4.699.000
ANEEL	0	0		0		+0
Power Plant	1.001.000	0		1.001.000		1.001.000
ONS (Aggregator)	3.198.000	0		3.198.000		3.198.000
IMPReSS	850000	0		850.000		850.000
Total						-15.107.000

Table 11: Profitability of actors in the UFPE business model

6.2 TAO Business Model

Based on the Teatro Amazonas (TAO) scenario and use case, a business model has been developed for this pilot site too. The business model takes as its starting point the perspective of the City of Manaus. The City of Manaus has a strategic goal improve citizens' lives and to attract new residents by promoting itself as a smart city. One of the main smart city target areas is smart environment focusing specifically on how smart energy management can reduce energy consumption and CO2 emissions; the geographical location of Manaus in the Amazon Rainforest makes environmental sustainability an obvious choice of focus. Teatro Amazonas is included in the market segment "Public Buildings".

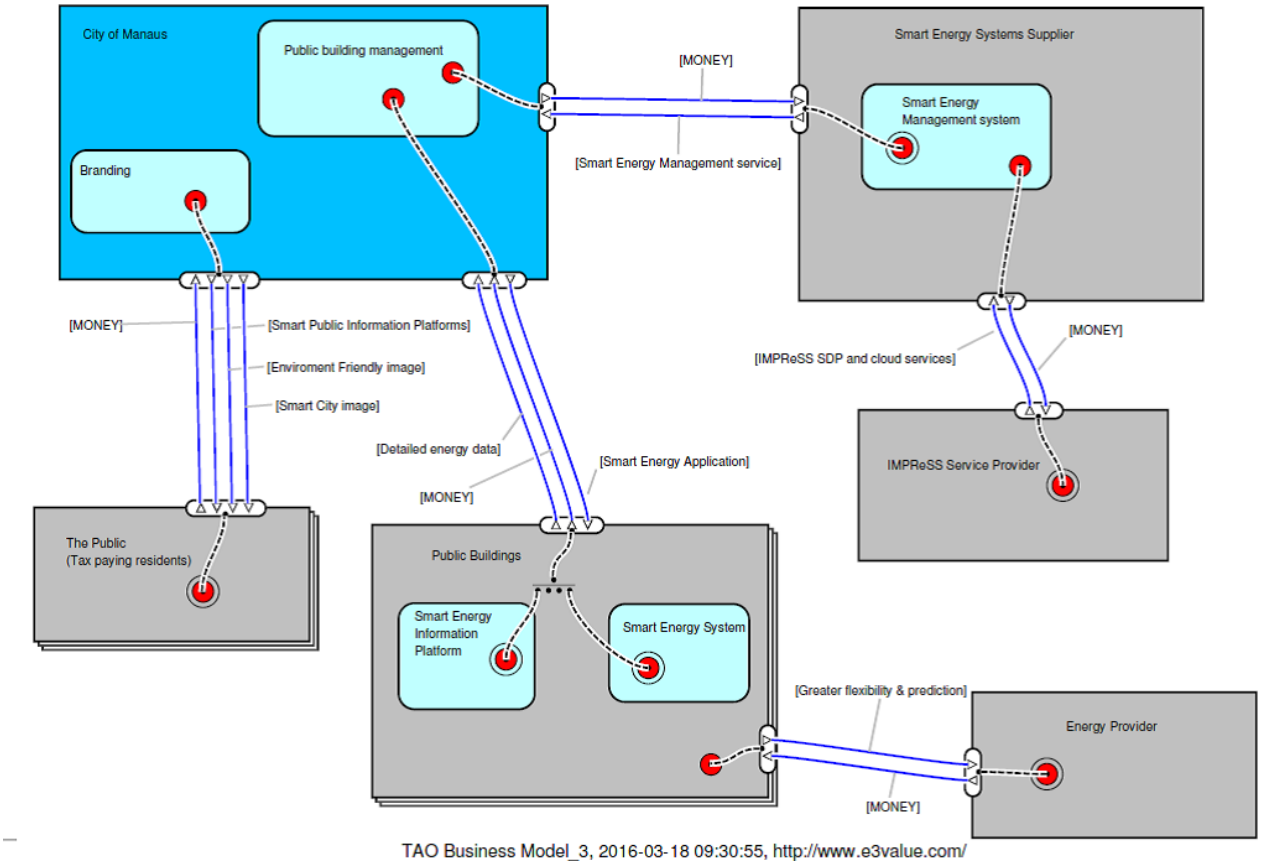


Figure 17: TAO business model

The energy market and the various actors involved in the distribution and provision of energy would have been too complex to illustrate, so for simplicity we have included just one Energy Provider actor in the model. Nevertheless, the model shows the main value transactions that occur between the key involved actors in the business eco system.

The business model has been populated with realistic figures (energy consumption and energy prices) and calculations show that it is sustainable for all actors. This is described in more detail below.

6.2.1 Actors and value objects

The actors in the business model and all the value objects they exchanged will now be described in more detail.

City of Manaus

The city of Manaus carries out a range of activities; thereby the business model focuses on branding activities and building administration.

Branding activities have a high priority as they are useful instruments in both keeping residents happy and in attracting new residents to the city. Branding is also important in a more global perspective as Manaus is visited by millions of national and international tourists each year who come to experience the natural wonders of the Amazon rainforest. Branding the city as a smart city, particularly as a sustainable city with smart energy solutions implemented, actually supports the branding of the city as environmental friendly; drawing attention to efforts to reduce energy consumption and CO_2 footprint fits in nicely with the focus on the nature experiences in the Amazonas rainforests that the tourist industry in Manaus promotes.

In this business model, the branding activities and building administration becomes linked: building administration has improved with the installation of smart energy management systems in public buildings and the results are used to support the branding activities.

The following value objects are received and offered between the City of Manaus, the Public Buildings, and the Smart Energy Solutions Provider:

Value objects received from the Smart Energy Solutions Provider:

- The city of Manaus wants the Smart Energy Management system and services offered by the Smart Energy Solutions Provider.

Value objects offered to the Smart Energy Solutions Provider:

- Annual payment for the Smart Energy Management system and services of R$ 1.300.000.

Value objects received from Public Buildings:

- The city of Manaus wants to access to detailed energy consumption data in Public Buildings which they can share with the Public via smart public information SDP
- An annual commissioning and service fee for the smart energy application of R$10.000 per building (R$ 500.000 in total).

Value objects offered to Public Buildings:

- The Smart Energy Application.

Value objects received from the Public:

- Taxes earmarked for branding activities (R$1.000.000 in total per year)

Value objects offered to the Public:

- Access to Smart Public Information Platforms
- Environment Friendly image
- Smart City image.

Public Buildings

This market segment includes 50 public buildings in Manaus city. They may be owned by the city, the state of Amazonas or by the federal government (e.g. the military). Common for all the non-city owned public buildings is that the City of Manaus is responsible for the infrastructure supporting the buildings.

In the case of the federally owned Teatro Amazonas, the existing electric installations and systems is old-fashioned. The energy consumption is high and detailed energy consumption data are not available. Frequent power failures also make it difficult to manage the energy consumption.

For the business case, it is assumed that 50 public buildings have been fitted with the non-intrusive energy sensors and integrated with the IMPReSS enabled smart energy system. The system is supporting an IMPReSS smart energy application developed by the actor Smart Energy Systems Supplier. The energy system is contracted by the City of Manaus as part of their Smart City strategy. The IMPReSS smart energy system gives the Manaus's building administration access to remote monitoring and control of the energy system, and for extracting detailed energy data, such as

energy consumption temporal data with high granularity as well as consumption prediction algorithms. Overall, there will be a better control and monitoring of energy consumption in public buildings which results in reduced consumption (estimated at 10%); this is represented by the money flow from the Energy Provider (i.e. lower electric bill).

To calculate the average energy usage in a public building per year, we have used the actual figures from Teatro Amazona's energy consumption in 2014 which was 850MWh. We did not have access to how much TAO pays per MWh, but we did have access to the auction prices for energy per MWh and how much UFPE (the other pilot site) pays per MWh. Based on this information, we have used an average price of R$530 per MWh.

The following value objects are received and offered between the Public Buildings, the City of Manaus and the Energy Provider:

Value object received from the City of Manaus:

- The smart energy application.

Value objects offered to the City of Manaus:

- Energy data is made available via smart energy information platforms (e.g. PC, tablet, mobile, public screens placed in the building)
- A commissioning and service fee of R$ 10.000 annually (for the Smart Energy Application).

Value object received from the Energy Provider:

- An estimated 10% reduction of energy consumption, which translates into a saving of R$ 45.000 per building per year (R$ 2.250.000 for the entire market segment).

Value objects offered to the Energy Provider:

- Access to detailed energy consumption data which Energy Provider uses to predict energy needs.

The Public

The public represents tax-paying residents in Manaus. They are interested in all improvements to their city and to their lives as residents. They expect high level of service and quality of living from their city administration. The public provides an inflow of money to the city in the form of taxes; for the business model we have calculated with 1.000.000 tax paying resident (about half the population) and with just R$1 earmarked to branding activities.

Value objects received from the City of Manaus:

- Access to Smart Public Information Platforms: The public get access to smart public information platforms as those installed in the public buildings
- Environment Friendly image: The Public perceives the city as environmental friendly due to its focus on smart energy
- Smart City image: The Public perceives the city as a Smart City due to the smart energy data available via information platforms.

Value objects offered to the City of Manaus:

- Taxes of which R$1 is earmarked to branding activities. (R$1.000.000 for entire market segment per year)

Energy Provider

The Energy Provider is responsible for delivering energy to consumers, such as the public buildings in Manaus. As Public Buildings are large consumers of energy, access to energy consumption data with the opportunity for prediction calculations will improve the Energy Provider's insights into

customers' energy needs more precisely. This will allow them to plan energy purchases more precisely thus reducing the amount of energy bought on the spot market to meet demands; energy bought on the spot market is up to three times more expensive. Figures provided to us from CHESF show that on average the action price per MWh in 2014 were R$260 whereas the spot price was R$710 per MWh.

Value object received from the Public Buildings:

- Access to detailed energy consumption data which Energy Provider uses to predict energy needs.

Value objects offered to the Public Buildings:

- An estimated 10% reduction of energy consumption, which translates into a saving of R$ 45.000 per building per year (R$ 2.250.000 for the entire market segment).

This actor thus appears to come out with a loss of R$2.250.000 per year as the customer (Public Building market segment) is able to reduce their energy consumption by 10%. However, this figure should not be seen a direct loss for several reasons:

1. We have not included the actual income from the selling of energy to the same market segment, if we had the Energy Provider would still be in plus albeit with a 10% less profit
2. The business model is based on the premise that the Energy Provider will now be able to better predict the consumption needs of its customers thereby reducing the amount of energy bought on the spot market to cover needs. The huge difference in MWh price between regular auction prices and spot market prices mean that even a small reduction in the amount bought to spot prices would cover for the reduced income caused by the Public Buildings' reduced consumption
3. The R$2.250.000 in reduced income does not actually take the difference between the price the Energy Providers buys for compared to what they sell for.

Smart Energy Solutions Provider

This actor has purchased the IMPReSS Systems Development Platform (SDP) and subscribe to the IMPReSS cloud services in order to provide a non-intrusive, easy to install and cost-effective complete smart energy solution to their existing and new customers. With the SDP, this actor can easily create customised Smart Energy Management Applications to their customers.

Value objects received from the City of Manaus:

- Annual payment for the Smart Energy Management system and services of R$ 1.300.000.

Value objects offered to the City of Manaus:

- The Smart Energy Management system, application and services.

Value objects received from the IMPReSS Service Provider:

- The IMPReSS SDP and cloud services which they use to develop customised smart energy solutions and applications

Value objects offered to the IMPReSS Service Provider:

- Annual payment of R$200.000 for IMPReSS cloud services
- One time investment in the IMPReSS SDP (R$650.000).

IMPReSS Service Provider

- This actor is the supplier of the IMPReSS Systems Development Platform (SDP) and the IMPReSS cloud. For simplicity of the model, we have not included the cost of delivering the SDP (on time cost and recurrent charges).

Value objects received from the Smart Energy Solutions Provider:

- Annual payment of R$200.000 for IMPReSS cloud services
- Payment for delivering the IMPReSS SDP (R$650.000).

Value objects offered to Smart Energy Solutions Provider:

- The IMPReSS SDP and cloud services.

6.2.2 Profitability

Based on the monetary values and MWh data we have received from CHESF and TAO, we can now set up a table to show the value transactions for each actor and the economic value assigned to the monetary value objects. With the installation of IMPReSS Smart Energy Management system, public buildings are expecting a 10% reduction of their energy consumption and based on this we have calculated the business case. For simplicity, the business case and the tables below are only based on the transactions in the model.

Actor / Market Segment (R$)	Value object in	Value in		Value object out	Value out		Cashflow
City of Manaus							200.000 R$
Smart Energy Systems Supplier	Smart Energy Management service			Paying for Smart Energy Management services	1.300.000	R$	
Public Buildings	Detailed energy data						
Public Buildings	Payment for smart energy application	500.000	R$	Smart Energy Application			
The Public	Taxes	1.000.000	R$	Smart Public Information Platforms			
The Public				Environment Friendly image			
The Public				Smart City image			
Smart Energy Systems Supplier							450.000 R$
City of Manaus	Payment for Smart Energy Management service	1.300.000	R$	Smart Energy Management service			
IMPReSS Service Provider	IMPReSS SDP			Payment for IMPReSS SDP	650.000	R$	
IMPReSS Service Provider	IMPReSS Cloud service			Payment for IMPReSS Cloud service	200.000	R$	
Public Buildings							1.750.000 R$
City of Manaus	Smart Energy Application			Payment for smart energy application	500.000	R$	
City of Manaus				Detailed energy data			
Energy Provider	Reduced energy bill	2.250.000	R$				
The Public							-1.000.000 R$
City of Manaus	Smart Public Information Platforms			Taxes	1.000.000	R$	
City of Manaus	Environment Friendly image						
City of Manaus	Smart City image						
Energy Provider							-2.250.000 R$
Public Buildings	Greater flexibility & prediction			Money (reduced energy bill)	2.250.000	R$	
IMPReSS Service Provider							850.000 R$
Smart Energy Systems Supplier	Payment for IMPReSS SDP	650.000	R$	IMPReSS SDP and cloud service			
Smart Energy Systems Supplier	Payment for IMPReSS Cloud service	200.000	R$				
Total		3.650.000	R$		5.900.000	R$	0

Table 12: Value transactions in TAO business model

Two actors have a negative cash flow but it is important to note that this is not a real loss as their income is not included in the model. Thus, the Public's income is not included and the loss the Energy Provider experience in this model represents the reduced income as public buildings can reduce their energy consumption. As explained above, this relative loss can easily be covered by the more precise prediction of energy usage which can reduce the Energy Provider's need to buy energy on the spot market for a high price.

Profitability of actors in the FIRST year when the service is installed

Segment / actor (k€)	Revenues	Payments	Expenses	Gross profits	Investments	Cashflow
City of Manaus	1.500.000	-1.300.000		200.000		200.000
Smart Energy Systems Supplier	1.300.000	-850.000		450.000		450.000
Public Buildings	2.250.000	-500.000		1.750.000		1.750.000
The Public	0	-1.000.000		-1.000.000		-1.000.000
Energy Provider	0	-2.250.000		-2.250.000		-2.250.000
IMPReSS Service Provider	850.000	0		850.000		850.000
Total						+0

Table 13: Profitability of actors in the TAO business model

7. Conclusion

In order to carry out an evaluation of the IMPReSS project, a variety of different user validation and evaluation activities were carried out. The methods used included internal system testing and integration testing, usability evaluation and profitability testing from a business model perspective. The results of the internal system testing and integration testing showed that the technology works as intended. The user requirements for the IMPReSS SDP and for the pilot applications have been evaluated against their pre-defined fit criteria and a majority have been validated. The results of the usability evaluation were also very good and demonstrate that even inexperienced users can use the IMPReSS tools. Finally, the two business models that were first presented in D9.1 Exploitation and Business Strategy Report were discussed with key stakeholders at a business model workshop in November 2015 and the feedback from stakeholders used to refine the models. Real economic values have been inserted in the model and the cash flow and profitability of all the stakeholders in the business model have been calculated. The results show that the business models are sustainable and thus support the premise that the IMPReSS project has produced good and prospective exploitable results.

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(Schrepp, 2015) Dr. Martin Schrepp (2015): User Experience Questionnaire Handbook. All you need to know to apply the UEQ successfully in your project.

(IMPReSS, 2015) IMPReSS Project (2015): D9.1 Exploitation and Business Strategy Report.

Appendix A: User Experience Questionnaire

Instructions

For the assessment of the product, please fill out the following questionnaire. The questionnaire consists of pairs of contrasting attributes that may apply to the product. The circles between the attributes represent gradations between the opposites. You can express your agreement with the attributes by ticking the circle that most closely reflects your impression.

Example:

attractive	○ ⊗ ○ ○ ○ ○ ○	unattractive

This response would mean that you rate the application as more attractive than unattractive

Please decide spontaneously. Don't think too long about your decision to make sure that you convey your original impression.

Sometimes you may not be completely sure about your agreement with a particular attribute or you may find that the attribute does not apply completely to the particular product. Nevertheless, please tick a circle in every line.

It is your personal opinion that counts. Please remember: there is no wrong or right answer!

	1	2	3	4	5	6	7		
annoying	○	○	○	○	○	○	○	enjoyable	1
not understandable	○	○	○	○	○	○	○	understandable	2
creative	○	○	○	○	○	○	○	dull	3
easy to learn	○	○	○	○	○	○	○	difficult to learn	4
valuable	○	○	○	○	○	○	○	inferior	5
boring	○	○	○	○	○	○	○	exciting	6
not interesting	○	○	○	○	○	○	○	interesting	7
unpredictable	○	○	○	○	○	○	○	predictable	8
fast	○	○	○	○	○	○	○	slow	9
inventive	○	○	○	○	○	○	○	conventional	10
obstructive	○	○	○	○	○	○	○	supportive	11
good	○	○	○	○	○	○	○	bad	12
complicated	○	○	○	○	○	○	○	easy	13
unlikable	○	○	○	○	○	○	○	pleasing	14
usual	○	○	○	○	○	○	○	leading edge	15
unpleasant	○	○	○	○	○	○	○	pleasant	16
secure	○	○	○	○	○	○	○	not secure	17
motivating	○	○	○	○	○	○	○	demotivating	18
meets expectations	○	○	○	○	○	○	○	does not meet expectations	19
inefficient	○	○	○	○	○	○	○	efficient	20
clear	○	○	○	○	○	○	○	confusing	21
impractical	○	○	○	○	○	○	○	practical	22
organized	○	○	○	○	○	○	○	cluttered	23
attractive	○	○	○	○	○	○	○	unattractive	24
friendly	○	○	○	○	○	○	○	unfriendly	25
conservative	○	○	○	○	○	○	○	innovative	26
useless	○	○	○	○	○	○	○	useful	27
expandable	○	○	○	○	○	○	○	unexpansive	28
helpful	○	○	○	○	○	○	○	harmful	29
difficult to use	○	○	○	○	○	○	○	easy to use	30
time-consuming	○	○	○	○	○	○	○	time-saving	31
complicating	○	○	○	○	○	○	○	facilitating	32

The items associated with each dimension:

Attractiveness

annoying / enjoyable
good / bad
unlikable / pleasing
unpleasant / pleasant
attractive / unattractive
friendly / unfriendly

Design Quality

Stimulation

valuable / inferior
boring / exiting
not interesting / interesting
motivating / demotivating
useless / useful

Novelty

creative / dull
inventive / conventional
usual / leading edge
conservative / innovative

Use Quality

Efficiency

fast / slow
inefficient / efficient
impractical / practical
organized / cluttered
time-consuming / time-saving
complicating / facilitating

Perspicuity

not understandable / understandable
easy to learn / difficult to learn
complicated / easy
clear / confusing
difficult to use / easy to use

Dependability

unpredictable / predictable
obstructive / supportive
secure / not secure
meets expectations / does not meet expectations
extensive / limited
helpful / harmful