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1. Executive summary

IMPReSS aims at providing a Systems Development Platform (SDP) for enabling rapid development of mixed criticality complex systems involving Internet of Things and Services (IoTS). The demonstration and evaluation of the IMPRESS platform will focus on energy efficiency systems addressing the reduction of energy usage and CO_2 footprint in public buildings. Application developers will develop applications using the SDP for a variety of purposes, including energy efficiency management.

In order to provide an efficient use of energy in buildings the IMPReSS SDP will need to be context aware, which means that it must know what happens inside the buildings so that opportunities to save energy can be identified and effectively fulfilled. An application aimed at saving energy must have an overall knowledge of the place where it is deployed to be able to act according to its purposes by means of pervasive deployment of sensors and actuators.

The IMPReSS SDP is divided into IDE and Middleware, where the IDE contains a series of GUI modules and the middleware contains modules with background management responsibilities. So is divided context management mechanisms. The Context IDE is a graphical tool for managing context information, for allowing Developers to specify which features of context-awareness they need in their applications, ranging from template specification for smart entities and situations to context modelling and rule authoring. The Context Manager encompasses all 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.

This report presents an analysis of entities involved in energy efficiency context management, as well as its relationships and presents some templates that can be inferred from them. Entities identified are Subject, Resource, Place, Fusion and Rule. Subjects represent people who have a paramount role in energy efficiency. Resources are equipment, devices, appliances, sensors and actuators, interacting directly with subjects. Places are the locus where subjects and resources interact and where context situations occur and must be manage by IMPReSS. Places may include offices, rooms, halls, corridors, atria, etc. Sensor data fusion is highly needed by any context management system, since a high volume of context information may be produced by sensors and must be deal by the system at any time. Common sensor fusion algorithms that may be used by the context manager are also presented. Rules describe how the context management system deals with situations that occur frequently, according to pre-specified energy efficiency parameters and conditions.

A variety of different scenarios with opportunities for energy saving are presented and for each one some scenes and the templates filled for all entities are described. The selected scenarios are: a) efficient use of elevators; b) efficient use of the air conditioning system; c) efficient use of lighting; d) automatic curtains; e) reducing standby power; f) price-based energy usage; g) use the entrance turnstiles to generate energy; h) turning off unused computers; i) using solar energy. These scenarios aim at defining the templates and helping to refine requirements for energy efficiency context management. In other words, they will not necessarily be implemented in a prototype, even though they will be very useful for the development of the IMPReSS platform.

2. Introduction

2.1 Purpose and context of this deliverable

The aim of the IMPRESS project is to provide a Systems Development Platform (SDP), which enables rapid and cost effective development of mixed criticality complex systems involving Internet of Things and Services (IoTS) and at the same time facilitates the interplay with users and external systems. The IMPRESS development platform will be usable for any system intended to embrace a smarter society. The demonstration and evaluation of the IMPRESS platform will focus on energy efficiency systems addressing the reduction of energy usage and CO_2 footprint in public buildings, enhancing the intelligence of monitoring and control systems as well as stimulating user energy awareness.

The IMPRESS project aims at solving the complexity of system development platform (SDP) by providing a holistic approach that includes an Integrated Development Environment (IDE), middleware components, and a deployment tool. The main technical and scientific objectives of the IMPRESS project are:

- Developing an Integrated Development Environment (IDE) to facilitate Model-Driven Development of Smarter Society Services.
- Providing a Service-Oriented Middleware to support Mixed Criticality Applications on Resource-Constrained Platforms.
- Developing easy-to-use and configurable tools for Cloud-based Data Analysis and Context Management.
- Develop Network and Communication management solution to handle the heterogeneity of Internet of Things.
- Creating efficient Deployment Tools for Internet of Things applications.

The project's results will be deployed in the Teatro Amazonas Opera House as an attractive showcase to demonstrate the potential of a smart system for reducing energy usage and CO_2 footprint in an existing public building. Another deployment will be in the campus of the Federal University of Pernambuco.

The present document is the output of Task 6.1 (Templates for Smart Entities, Situations and Context Rules), whose main goal is to study and evaluate typical patterns for energy efficiency context management. This includes patterns of smart entities and their properties, relations between smart entities, situations pertaining to these smart entities, and also rules describing recurring actions. Here we define entity as any object, equipment, place or person that interact in a context for saving energy and reducing CO_2 footprint. The results of this deliverable will be further used by the remaining tasks of Workpackage 6, which are Task 6.2 (Sensor and Data Fusion Service), Task 6.3 (Context modelling templates) and Task 6.4 (Context Model & Rule Authoring tool).

2.2 Scope of this deliverable

The IMPReSS Platform will need to understand and to deal with context information, so that energy can be saved in a very fine-grained way. This is because energy is produced to be used and not the opposite, and only what is strictly not necessary should be saved, unless said otherwise. In other words, an application aimed at saving energy must have an overall knowledge of the place where it is deployed to be able to act according to its purposes by means of pervasive deployment of sensors and actuators.

This deliverable is aimed at providing a clear understanding of the features needed by a context management module in the IMPReSS SDP, considering the requirements gathered in Task 2.1 and based on the pilot prototype deployments in Teatro Amazonas and UFPE. Five entities were chosen to model a context situation and nine scenarios are specified with templates for each entity.

2.3 Document Structure

The reminder of this document is organized in four chapters.

- Chapter 3 presents the IMPReSS System Development Platform (SDP) as specified by a former work within IMPReSS, which is based on two main modules, IDE and middleware.
- Chapter 4 briefly introduces context-aware computing and multi-sensor data fusion, which are the main state of the art used in this report.
- Chapter 5 presents some relevant information on energy efficiency management, varying from energy sources to energy management approaches.
- Chapter 6 introduces the templates for energy efficiency context, aimed at making it easier to understand, model and program the context-awareness features of the IMPReSS project. Templates involve entities, their relationships and properties.
- Chapter 7 defines and specifies scenarios for energy efficiency management with a focus on university and theater environments. For each scenario, some scenes and the templates of all entities are filled with relevant information.
- Chapter 8 presents some final remarks and the next steps.

3. The IMPReSS System Development Platform

IMPReSS software architecture is divided up into four views, where the Partner's view is the most complete one and therefore is presented here (IMPReSS D2.2.1 2014)[1]. The other views are for the Application Developer, Solution Integrator and Final Recipient. Figure 1 shows that the SDP is divided into IDE and Middleware, where the IDE contains a series of GUI modules and the middleware contains modules with background management responsibilities. IMPReSS assumes that data is stored somewhere in the cloud, using conventional databases or novel ones. Modules in the IDE component of the IMPReSS Platform have counterparts in the Middleware component and they communicate through the Middleware API.

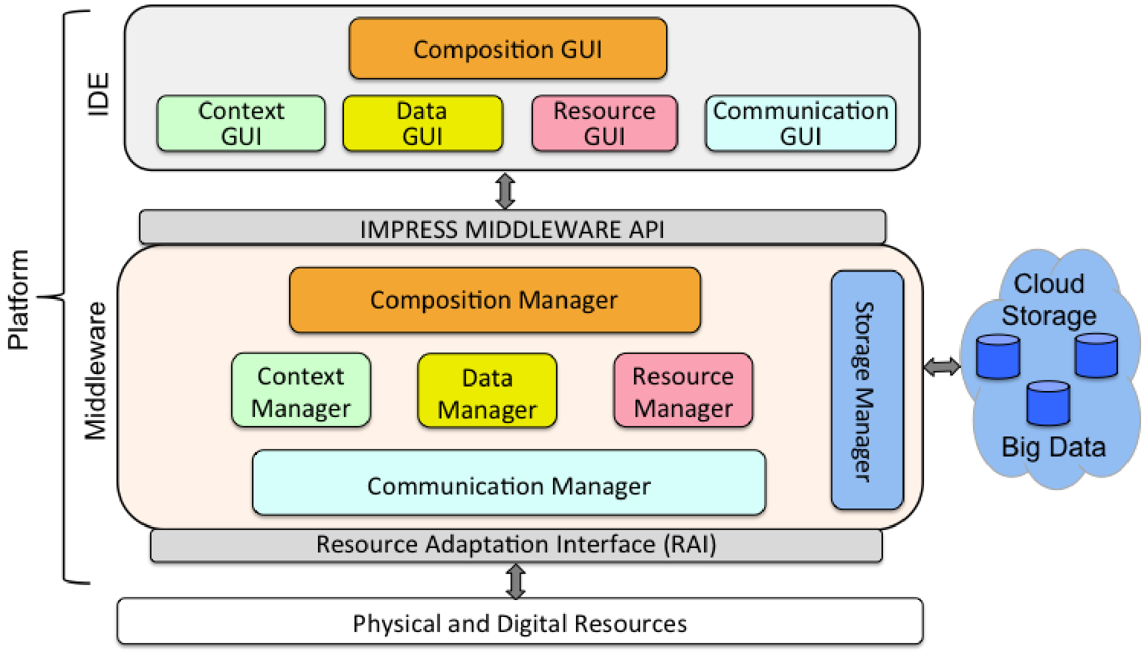

Figure 1 - IMPReSS SDP Architecture–Partner's View

Both IDE and Middleware are comprised of five main modules, which are related to each other. In addition, Middleware has a module to establish communication with the remote storage. The IMPReSS Platform IDE modules are:

- Composition GUI: A graphical tool for allowing Developers to interconnect the various modules of the platform in a way that better fits the purpose and the needs of their particular applications. This module is based on Model-driven development (MDD), a software engineering approach where developers create technology-agnostic models using high levels of abstraction. The Composition GUI runs in foreground and communicates with its twin module Composition Manager in the Middleware, which runs in background.
- Context GUI: A graphical tool for managing context information, for allowing Developers to specify which features of context-awareness they need in their applications, ranging from template specification for smart entities and situations to context modeling and rule authoring. In other words, the Context GUI discloses to Developers all context-related features of the IMPReSS Platform that they choose to add into their applications. Based on the model defined by Developers, this tool communicates with the background context manager module that implements the templates, rules, sensor and data fusion, context model, and the context-reasoning engine. Developers must also select and developed particular configuration options to be disclosed to Integrators and even Recipients.
- Data GUI: A graphical tool for allowing Developers to enter the needed configuration for the data analysis and support module that uses supervised and unsupervised learning for

[1] The contents of this section have been directly adapted from IMPReSS D2.2.1 2014.

helping IMPReSS applications to make more informed decisions, based not only on real time but also historic data. The Data GUI will configure and interact to the Data Manager module that runs in the IMPReSS Middleware.

- Resource GUI: A graphical tool for allowing Developers to specify all particular information needed for the mixed criticality resource management, which may be performed through parameterization or through a specially designed applications classification language. This language is used for describing the run-time requirements of an application in terms of its priority, device access scheme (exclusive or shared) and security. The Resource GUI outputs this information formally as an application criticality description that will be understood by the Resource Manager in the IMPReSS Middleware.
- Communication GUI: A graphical tool for allowing Developers to specify all information needed for dealing with communication in the IMPReSS Middleware. This tool is called integration support tool in the IMPReSS DoW and it will provide a collection of templates for different technologies.

The IMPReSS Platform Middleware modules offer background services for their IDE counterparts:

- Composition Manager: This module is an engine that runs in background and supports the Composition GUI. For example, it may be implemented as a Web Services Engine that supports the MDD approach disclosed by the Composition GUI to Developers.
- Context Manager: This module encompasses all background software components that a typical context-aware middleware offers to its users (Perera 2013), such as context templates, context models, context reasoning engine, and algorithms for sensor and data fusion. It also interacts with the Storage Manager to data storage and retrieval. Resources might be accessed directly or preferentially through the Resource and Communication Managers.
- Data Manager: This module provides all software components needed to implement data analysis and historic context information that will be used by IMPReSS applications. The Data Manager also stores and retrieves its raw and processed data using the Storage Manager. The machine learning algorithms used to process context-aware information for energy efficiency systems are within the Data Manager. As for the Context Manager, resources can be accessed directly or through the Resource and Communication Managers.
- Resource Manager: This module contains all software components needed for managing mixed-criticality resources, such as device and subsystem resource management, resource management and access scheduler, and security features for resource-constrained subsystems.
- Communication Manager: This module implements all communication features of the IMPReSS Platform, such as resource and service discovery and communication and networks management. Also, it plays the role of a proxy (an intermediate module) for the other modules to the Resource Adaptation Interface (RAI).
- Storage Manager: This module is logically represented as a single and centralized software component in Figure 1, though its implementation can be as decentralized and distributed as the other modules need to. It provides an interface to different storage approaches, ranging from traditional relational databases stored in the cloud to big data and NoSQL databases.

4. Background

This section briefly presents background on context-aware computing and multi-sensor data fusion, which are the main state of the art used in this report.

4.1 Context-aware Computing

Context awareness is a core feature of ubiquitous and pervasive computing systems and has been around for more than 20 years (Perera 2014). In the last decade, context-aware computing evolved from typical pre-Internet platforms such as desktops to web-based applications and mobile computing, surfing on the pervasive/ubiquitous computing wave and finally is now considered as an important component for the Internet of Things (IoT).

Context-aware systems can be defined as systems able to adapt their operations to the current context conditions without explicit user intervention (Baldauf 2007). Makris et al also define context awareness as the ability of computing systems to acquire and reason about the context information and adapt the corresponding applications accordingly" (Makris 2013). The term context usually refers to locations, but actually can comprise different information used to characterize the situation of entities that play an important role in the interaction of user and application (Dey 2007). Entities are usually classified in three categories, which are: a) places, e.g. rooms, buildings, etc.; b) people, both individuals and groups, and; c) things, which are physical objects, computer components, etc. (Dey 2001).

The context life cycle is composed of four phases, which are context acquisition, context modelling, context reasoning and context distribution (Perera 2014). There are many techniques for acquiring context and also context distribution. However, central to any context-aware system are the context model and the context reasoning approach, which are intrinsically related to each other.

A context model is needed for defining, handling, storing and distributing context data in a machine processable form (Baudalf 2007). Different context models have been proposed and tested, such as key-value, markup, graphical, object oriented and ontology-based models. Among them, the latter is considered to have high and formal expressiveness and to allow the use of ontology reasoning techniques, although with lower performance. Context reasoning refers to information that can be inferred or deducted from analyzing data and combining different context information (Makris 2013). The most common reasoning techniques are rule-based, ontological and probabilistic.

The choice of a context model is a very important step in any context-aware system because it influences the following process and also limits the choice of a context reasoning technique.

4.2 Multi-sensor Data Fusion

Context management in IMPReSS will require sensor data fusion coming from different sensors.

4.2.1 Definitions

The concept of Multi-sensor data fusion concept is born from humans and animals behavior as they learn using multiple senses for inferring situations. Over the past few decades, researchers have tried to mimic this behavior to sense situation within the scope of military and non-military applications. In the past, there have been many ambiguous terms and definition caused by the broad range application of multi-sensor fusion. In order to prevent further confusions, The Joint Directors of Laboratories (JDL) tried to standardize Multi-sensor fusion definition. They suggested multi-sensor fusion as (White 1991): "Multilevel, multifaceted process dealing with the automatic detection, association, correlation, estimation, and combination of data and information from multiple sources." This definition was revised by Hall as "the combination of data from multiple sensors, and related information provided by associated databases, to achieve improved accuracy and more specific inferences than could be achieved by the use of a single sensor alone." (Hall 1997). Wald argued that the previous definitions focus only to methods, means and sensors, he defines Multi-sensor fusion as "data fusion is a formal framework in which are expressed means and tools for the alliance of data originating from different sources. It aims at obtaining information of greater quality; the exact definition of 'greater quality' will depend upon the application." (Wald 1999).

4.2.2 Models and Classifications

Data fusion model describes various tasks and processes that need to be considered when fusing data and information. There have been various models defined to get a common understanding of sensor fusion.

- Information Based: Information based models focuses on abstracting the information handled in the tasks. This model represents the first generation of multi-sensor fusion. The first generic model was introduced by a data fusion-working group of Joint Directors of Laboratories (JDL), a joint effort within the U.S. department of defense (Liggins et. al 2009). However it was intended for decision support system in defense systems.
- Activity Based: This model concentrates on the abstraction of activities and their sequences of execution. Boyd introduced a control loop cycle, which is known as Observe-Orient-Decide-Act (OODA) cycle (Boyd 1987). Information is first gathered in observe phase, then it is fused in the orient phase to get an interpretation of situation, action plan is defined in decide phase, and it is executed in act phase. One continues to cycle through the OODA Loop by observing the results of one's actions, seeing whether one has achieved the intended results, reviewing and revising the initial decision, and moving to the next action
- Role Based: This model shifts the focus on how information fusion can be modeled. In contrast to previous models, role based models do not specify specific task and activities of information fusion explicitly. On the other hand they specify the roles of components and their relationships to each other. Object oriented model, introduced in Kokar (2000) defines four roles: Actor who is responsible to interact with real world in terms of collecting information and acting, Perceiver assesses information and provides contextualized analysis to the director, Director builds an action plan specifying the system goals, and Manager controls the actor to execute the plans.
- WSN Model: Sensor fusion in Wireless Sensor Networks (WSN) is closely related to wireless communication due to limited resources characteristic of WSN (Nakamura 2007). In-Network aggregation aims to reduce the resource consumptions by applying local processing and fusing data while it is being routed to the sink node. In WSN model, the network topology influences how the data fusion is applied. For instance, in multi-hop networks the Directed Diffusion takes advantage of publish-subscribe events. The nodes in paths subscribe to the event that a sink is interested in and they implement filters that decide whether the data should be fused, forwarded or dropped.

4.2.3 Existing Methods for Information Fusion

Techniques and methods in fuse data involve a various traditional disciplines such as digital signal processing, statistical estimation, control theory, artificial intelligence, and classic numerical methods. Nakamura classifies the existing methods based on their purposes into several classes such as inference, estimation, classification, feature maps, abstract sensors, and compression (Nakamura 2007).

- Inference: A famous inference strategy that is often used in information fusion is Bayesian inference. Bayesian inference solves uncertainty by applying conditional probability theory (Bayes Rule) to the evidence obtained from the observations. Bayesian inference has been applied for several works, for instance, to reach better accuracy and robustness an advance driving assistance fuses data from different sensors such as laser, radar and video (Coue 2002), to determine whether an electricity voltage is stable by observing three stability indicators of a power system (Sam 2001).
- Estimation: Estimation techniques in data fusion reduce the uncertainty of sensed data as a result of sensors physical limitation such as noise, accuracy, reliability, and coverage. the

most well known techniques to estimate the raw data includes maximum likelihood, least squares, moving average filter, Kalman filter, and particle filter.

- Feature map: Applications such as guidance systems require spatial information about environment. Feature map provides feature analysis of an environment. An example of feature map includes occupancy grid and network scans. Occupancy grid (also called occupancy map) estimates the occupancy of environment in a multidimensional space. The observed space is divided into multidimensional cells (e.g.: square, cubes), which have probability of being occupied. The probability is computed based on information obtained from sensors, using different inference methods such as Bayesian, fuzzy set.
- Aggregation: Data aggregation in WSN aims at solving overlap and implosion problems. Implosion happens when data is duplicated many times when it is being routed (e.g.: simple flooding technique). Overlap happens when more sensors disseminate a same data of an event. Aggregation techniques are often used together with data-centric model in WSN.
- Compression: Compression techniques that utilize information fusion in WSN take advantage of spatial correlation among sensor nodes and the correlation of the sensed data. An example of these techniques is called Distributed Source Coding (DCS). The main idea is to reduce the number of bits sent from node A to B if their data is correlated. And the possible values of observation can be grouped and indexed.

5. Energy Efficiency Management

Energy is a public asset that must be efficiently managed by using different approaches and techniques. This section presents relevant state of the art varying from energy sources to energy management approaches.

5.1 Energy in the World

The world demand for energy has been increasingly growing in the last years and consumption tends to grow further. The most common energy source comes from fossil fuels, which releases gases into the atmosphere causing the well-known greenhouse effect. Its implications are very noticeable, such as the changes in climate and weather around the globe and the emergence of phenomena and natural catastrophes such as storms, floods and droughts in places rarely affected in the past. A solution proposed by scientists and environmentalists for the complicated current energy model – based on fossil and finite fuels – is the adoption of a new sustainable model based on clean and renewable energy sources. New investments in technology improvements for speeding up the adoption of renewable energy sources and also the careful management of energy for obtaining higher efficiency levels are increasingly making the world less dependent of current fossil-based energy sources.

There are a variety of clean and renewable energy sources and many of them are in full activity today. Renewable energy is any energy coming from natural sources, such as the sun, wind, rain, tide and geothermal energy, which are naturally replenished (Sauter & Hung 2010). Brazil started the development of a renewable energy model based on forest biomass, sugar cane and other organic sources, especially due to the world energy crisis in the 1970s. Other noticeable clean energy sources are wind energy, solar energy, tidal energy and biogas (Sauter & Hung 2010). Obviously, the transition from any fossil-based energy model to sustainable ones requires a considerable time and, mainly, additional costs, because most alternative energy sources are still too expensive and therefore impractical in large scale, such as solar energy.

5.2 Solar Energy

Using the energy generated by the sun, which is inexhaustible in a terrestrial time scale both as a heat and light source, today is one of the most promising alternatives for facing the challenges of the new millennium. Photovoltaic solar energy is directly obtained from the conversion of light into electricity (Duffie 1991) (Jacobson 2011), using photovoltaic cells on a solar panel (Figure 2). In Brazil, the potential for exploring solar energy is high according to Pereira *et al.* 2012.

Figure 2 – Solar panels

Solar panels can provide energy to a building, theater or university campus or house. Figure 3 depicts how solar energy can be obtained from solar panels, converted to electrical energy by an and used in different ways. Also, the exceeding energy can be made available to the electric grid in order to obtain a discount in a future bill.

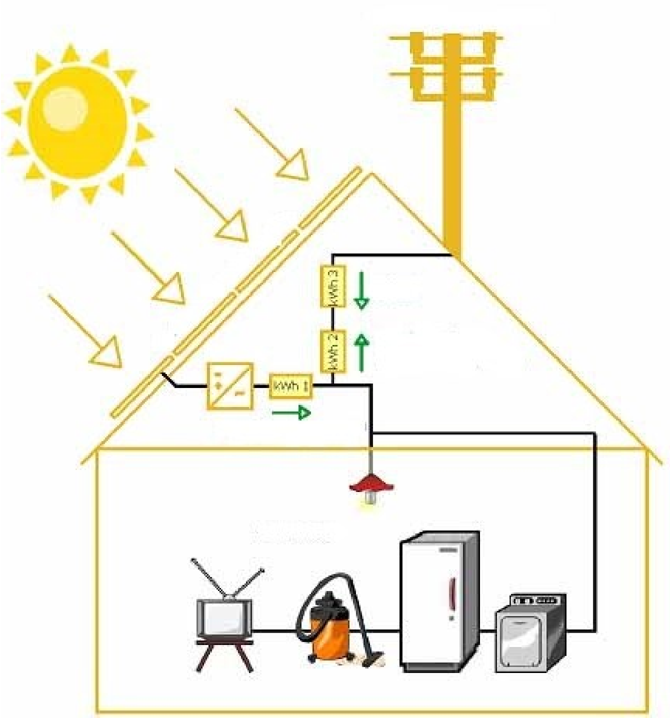

Figure 3 – Using solar energy

5.3 Wind Energy

Mankind has used wind energy since ancient times, mainly in ships and mills. Currently, wind energy is considered an important clean energy source, although it is still not used in large scale (Richardson 1993) (Amarante 2001) (Jacobson 2011). Energy is generated by a generator driven by large turbines placed into open spaces where wind is plenty available (Figure 4). Energy can be used directly or saved for future use into storage units.

Figure 4 – Types of wind generators[2]

Isolated systems rely on some kind of energy storage usually using batteries for operating electrical devices since they are not connected to the grid. Systems based on batteries need a device for controlling battery load (load controller), for avoiding damages caused by overloading or underloading. An inverter is needed for devices that operate with alternating current (AC), usually conventional appliances. This scenario is depicted by Figure 5.

[2] Adapted from http://www.cresesb.cepel.br/content.php?cid=251

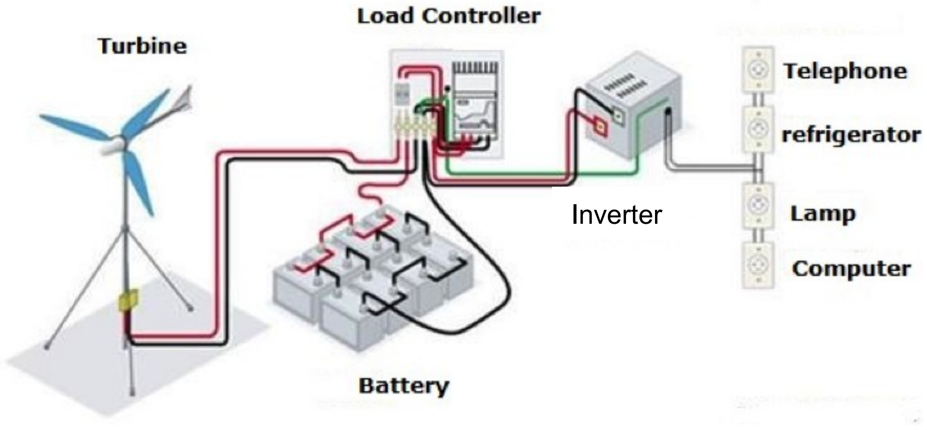

Figure 5 – Configuration of an isolated wind system[3]

5.4 Smart Grid

The Smart Grid aims at using technology in the whole energy cycle for allowing energy efficiency gains (Amin 2005). The goals of the Smart Grid go far beyond installing smart meters and controlling remotely. Several management and control layers must be created for controlling energy usage, from energy generating companies to the final consumer. The Smart Grid has been introduced for meeting the ever-growing energy demand and for decreasing the carbon dioxide footprint.

Smart Grid systems must satisfy four requirements:

- Capacity: the huge demand for electric energy must be fulfilled;
- Reliability: electricity must be available whenever it is needed, within quality parameters and without disruptions;
- Efficiency: energy must be saved and losses must be avoided in generation, transmission, distribution and consumption;
- Sustainability: energy sources that decrease the CO_2 footprint must be systematically integrated to the system.

The intensive use of information and communication technology (ICT) is one of the main strengths of the Smart Grid. Telecommunication and remote sensing systems, combined with the current infrastructures will allow a more efficient use of the energy system and of the energy itself. Smart meters and sensors are expected to be deployed in large scale so that the system will be smarter as a whole, to allow a higher technical, economic, social and environmental efficiency.

5.5 White Tariff

The energy tariff structure is organized so that consumers pay for the aggregated cost of generation, transmission of electric energy. While the Smart Grid is not a reality, intermediate solutions have been implemented around the world. As an example, the Brazilian Regulatory Agency (ANEEL) created a three-band time-of-use tariff structure called White Tariff (Bueno et al. 2013), intended for low voltage consumers, who can choose to use energy when it is cheaper.

The White Tariff is based on smart meters and is divided into three colors, inspired in a semaphore, that indicate low, intermediate and high prices using green, yellow and red flags respectively. Figure 6 shows the White Tariff with different tariffs for different hours of a day.

[3] Adapted from http://www.cresesb.cepel.br/content.php?cid=251.

Figure 6 – White Tariff: different tariffs for different hours of the day

Figure 7 compares the White Tariff with the conventional one. As one can observe, the White Tariff is cheaper in most part of the day, except between 5pm and 10pm, and during weekends the whole day.

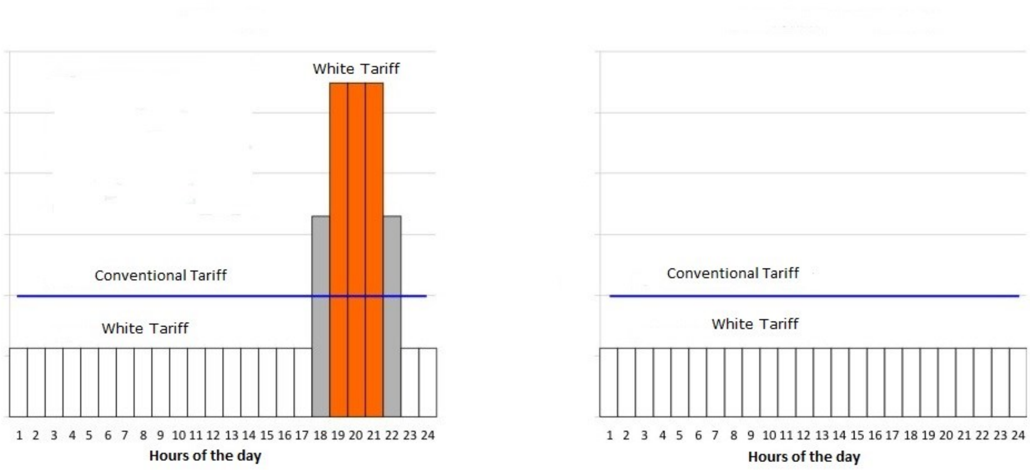

Figure 7 – Comparing White and Conventional Tariffs

5.6 Energy Efficiency Techniques

This document will explore different techniques for making a more efficient use of energy in in public buildings in different scenarios for deriving templates related for context management in IMPReSS. Some techniques considered in section 7 are:

- Efficient lighting systems: lights can be switched off whenever they are not needed and switched on again when there are people in the space. Even though this might seem quite logic and straightforward, lights frequently remain on when they are not being used.
- Efficient use of elevators: elevators consume a lot of energy and there are ways of limiting the total consumption if a proper context management is used.
- Efficient use of air conditioning: there is a great opportunity for saving energy when it comes to using air conditioning in a more efficient way.
- Energy storage: when energy is generated but is not needed, storing it for future use might be an appropriate solution.
- Turning off unused devices: in any place where many devices, equipment and appliances are used, they are frequently forgotten on, even though no one is using them for a long period.

- Using solar and wind energy: renewable energy sources that might be used together with the normal energy supply.
- Energy usage management: the main challenge with providing energy is being able to fulfill peak demand, so managing energy for using it out of peak hours is a important way of achieving higher efficiency. The Smart Grid is an example of energy efficiency management.

6. Templates for Energy Efficiency Context

The use of templates for energy efficiency context management is aimed at making it easier to understand, model and program the context-awareness features of the IMPReSS project.

6.1 Entities, Relationships and Templates

Five entities of typical scenarios for saving energy in buildings have being identified and each one generated a variety of templates: Subject, Resource, Place, Fusion and Rule. Figure 8 depicts the relationships among those five entities:

- Place has Resource: Resources are located in a Place;
- Resource fires Rule: Rules are fired by Resource usage;
- Fusion uses Resource: Fusion criteria basically combine data coming from sensors, which are classified as resources;
- Fusion influences Rule: Rules are influenced by sensor data that are combined by a fusion criteria;
- Rule relates to Place: Rules affect and are affected by Places;
- Rule affects Subject: Subjects are directly affected by Rules in many different ways;
- Subject interacts with Resource: Subjects use Resources and are affected by them.

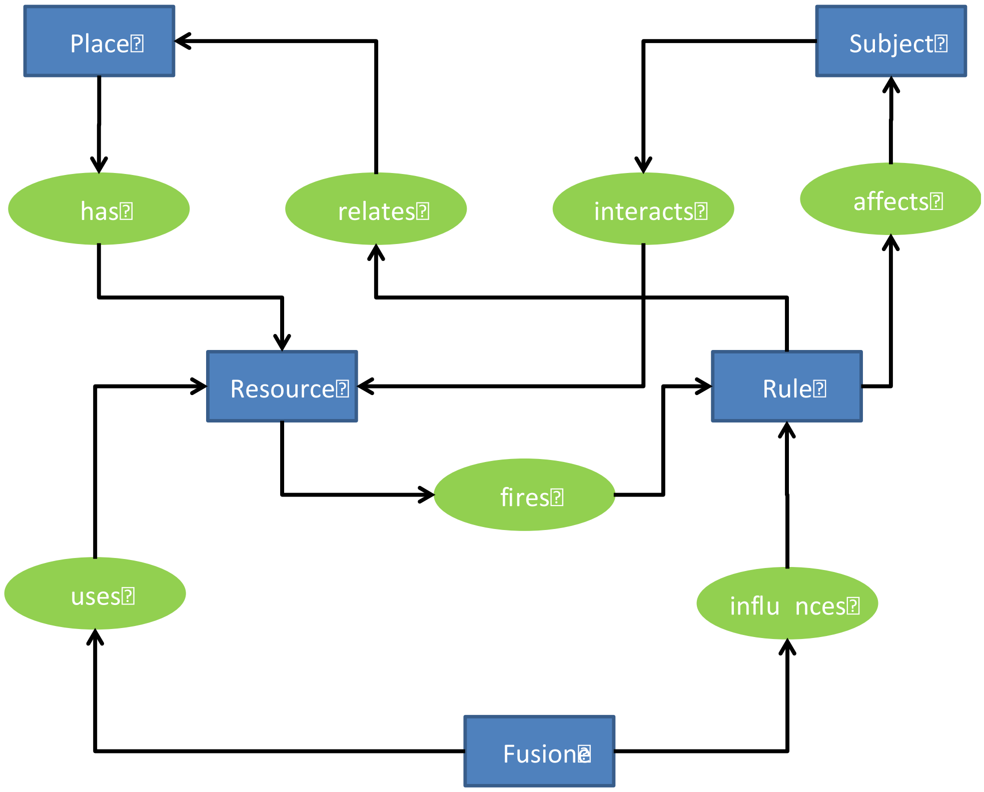

Figure 8 – Entities and Relationships

Entities have templates that are involved in the process of managing energy efficiency context. In the following sections, the templates (models) for entities are presented, which are used for modeling scenarios in section 7.

6.2 Subject Template

Subjects, i.e. people, are of paramount importance for energy efficiency in buildings, since the former inhabits the latter.

A subject template for IMPReSS is specified by the following information:

- Id: a unique identifier for that particular participant in a given scenario;
- Role: the role played by someone in a particular scenario;
- Function: an explanation of the function associated to the role someone is playing; one subject (person) can play different roles in different situations. For example, in a university someone can be both a student and an employee at the same time, but depending on the context they will interact in a different way with certain context features.

6.3 Resource Template

Resources are central for context management, because they interact directly with subjects and are influenced by them.

A device template for IMPReSS is specified by the following information:

- Id: a unique identifier for all resources in a particular scenario;
- Name: resource name;
- Class: the class of the resource, which defines its role in the scenario for context management, such as devices, equipments, sensors and actuators;
- Function: a description of the resource and its role in the scenario;
- Measurement: Additional information specifying exactly what is being measured in case the resource is a sensor.

6.4 Place Template

Places are the locus where subjects and resources interact and where context situations occur and must be manage by IMPReSS. Places may include offices, rooms, halls, corridors, atria, etc.

A place template for IMPReSS is specified by the following information:

- Id: a unique identifier for a place in a particular scenario; places may host different scenarios, and in each one they may be used in a different way;
- Name: the name of a place;
- Type: an attribute used to better specify the place according to the conditions people find and the way they interact with the place.
- Function: the function of the place in a particular scenario;
- Volume/area: an attributed used to better characterize the place according to its capacity of holding people, equipments and its needs of lightening and temperature.
- Condition: typical operation conditions encountered by people and managed by the IMPReSS-enabled context-aware application.

6.5 Fusion Template

Sensor data Fusion is highly needed by any context management system, since a high volume of context information may be produced by sensors and must be deal by the system at any time. Fusion is needed for reducing the amount of data available to the system according to some criteria.

A fusion template for IMPReSS is specified by the following information:

- Id: a unique identifier for a particular fusion criterion;
- Name: the name of the fusion criterion;
- Sensor: a sensor, a set of sensors of the same type in different places or a set of sensors of different types that provide data for a particular fusion criterion.
- Algorithm: algorithm, or formula, used by the system to fuse sensor data.

6.6 Rule Template

Rules describe how the context management system deals with situations that occur frequently, according to pre-specified energy efficiency parameters and conditions.

A rule template for IMPReSS is specified by the following information:

- Id: a unique identifier for a particular context rule;
- Name: the name of a rule;
- Subject: the subject, or people, who request a rule application or who are affected by a rule;
- Resource: a resource of a set of resources that are considered by a particular rule;
- Action: action to be taken in case a given rule
- Fusion: fusion criteria to be used by a rule
- Condition: a specific condition that must occur in order for a rule to be processed;
- Result: the result of the rule processing after the action has been executed.

7. Scenarios for Energy Efficiency Context

In this section some scenarios with high potential for energy efficiency are presented. For each scenario a set of scenes representing typical opportunities for energy savings is included, as well a model with subjects, resources, places, rules and sensor data fusion criteria. Please notice that these scenarios are aimed at defining our templates and helping to refine requirements for energy efficiency context management. In other words, they will not necessarily be implemented in a prototype, even though they will be very useful for the development of the IMPReSS platform.

7.1 Scenario 1: Efficient use of elevators

Tall buildings with intense flow of people and goods usually have a many elevators, which are not evenly used throughout the day. There are times during the day when the elevators' request rate is very high (e.g. arrival at morning, lunch, departure at evening), times when the request rate is low (e.g. during normal working hours) and times when the request rate is almost insignificant (e.g. during the early hours of the day, when the building is closed and eventually only security officers are there). In a university building the flow might be somewhat different, but still have similarities with typical commercial buildings. Particularly, the flow of students is very high at different hours during the day, when classes start and end.

Figure 9 depicts an approach for decreasing energy consumption by turning off some elevators during hours of low request rates and turning off all elevators when they are not requested at all.

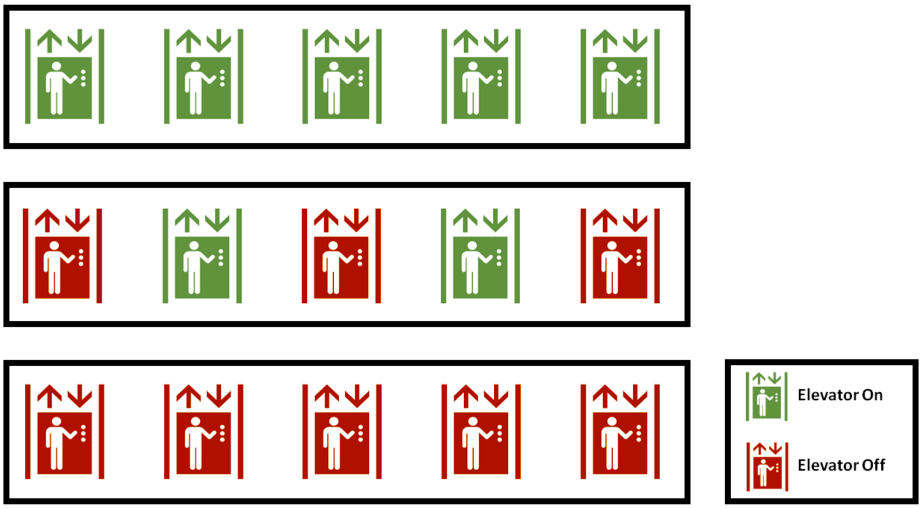

Figure 9 – Saving energy by turning elevators off and on

Another approach for saving energy used by elevators is load management. Although it might be counter intuitive at a first sight, elevators may use up more energy when they are carrying a weight near the maximum allowed load than if they do two trips carrying lighter loads. Figure 10 shows an example where two trips, carrying 1000 Kg and 750 Kg may be more efficient than one trip carrying 1750 Kg.

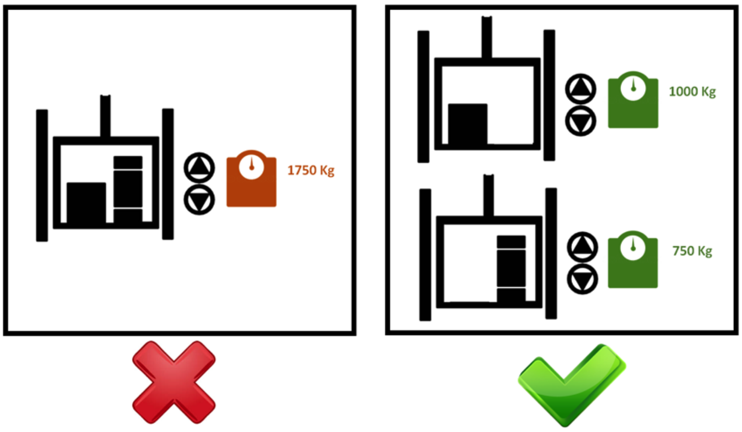

Figure 10 – Saving energy by dividing up excessive load into more trips

7.1.1 Scenario 1: Scenes

Four typical scenes have been identified for this scenario, which were used to extract templates, presented in section 7.1.2. The scenes are as follows:

- **Scene 1.1**: Fernando, our subject, arrives at the building where his company's office is located at 8:30 am, when most employees arrive at the same place. When he approaches at the elevator hall, Fernando press the button for calling the elevator, even though he noticed that other people, also waiting for the elevator, had already pressed the button. This building is powered with the IMPReSS Platform for energy efficiency context management. The system detects a high rate of people calling the elevator, i.e. a high number of button been pressed in a short time period, and decided that all elevators must be turned on.
- **Scene 1.2**: That particular day, Fernando has a lot of work to do and stays late in the office, leaving at 10 pm, far later most people leave. Even though the building was still open, the flow of people calling the elevators is considerably lower and therefore the IMPReSS system keeps only a fraction of the elevators turned on, turning off the others to save energy.
- **Scene 1.3**: During the early hours of the day, when the building is closed, the flow of people is inexistent. Therefore, the IMPReSS system detects the absence of people calling elevators and thus turns of all of them.
- **Scene 1.4**: During the day, a truck arrives at the building to deliver heavy load targeted to the 22th floor. The elevators were designed to carry up to 1750 kg up and down, but since the load is close to their capacity, energy consumption increases significantly. The IMPReSS-enabled application detects the weight put into the elevator as it is loaded and, as the weight reaches the limit, an alarm is fired and a message says that the load must be divided into two trips.

7.1.2 Scenario 1: Templates

Based on the scenes presented in section 7.1.1, templates for five entities belonging to IMPReSS context management were derived.

Table 1 shows three roles played by the entity Subject who take part in this scenario, which are employees, customers and third-party outsourced employees who play a different role than regular employees.

Table 1 – Subject Template for Scenario 1

Subject			
Id	SU01-1	SU02-2	SU03-3
Role	Employee	Customer	Third-party outsourced employee

Function	Work in the company; In a university, examples are professors and staff.	Buy or contract services from the company; In a public university students are not customers, but this class may include them as far as context management is concerned.	Provide services for the company; For example, in Brazil it is common to outsource cleaning and surveillance services.

Table 2 shows five resources involved in this scenario, divided up into three classes: equipment, sensors and actuators.

Table 2 –Resource Template for Scenario 1

Resource					
Id	RE01-1	RE02-1	RE03-1	RE04-1	RE05-1
Name	Elevator	Balance	Touch Counter	Alarm	Automatic switch
Class	Equipment	Sensor	Sensor	Actuator	Actuator
Function	Carrying people and cargo	Weighing people and cargo within elevators	Counting touches in the elevator buttons	Sounding alarm when elevator is overloaded	Turning on and off elevators according to need
Measurement		Measures the load (in Kg) within the elevator	Counts the number of times a group of elevators is called per minute (i.e. number of button touches per minute)		

Table 3 shows the place where this scenario takes place, which is the elevators hall.

Table 3 –Place Template for Scenario 1

Place	
Id	PL01-1
Name	Elevator Hall
Type	Open
Function	Hold people who wait for the elevators
Area	Varied
Condition	Dry, backlit and with comfortable temperature

Table 4 shows the fusion criteria identified for this scenario.

Table 4 – Fusion Template for Scenario 1

Fusion			
Id	FU01-1	FU02-1	FU03-1

Name	Floor counter	All floor counter	Load average
Sensor	Touch counter	Touch counter	Balance
Algorithm	Count the number times elevators were called to a particular floor within a given time period, i.e., count the number of the touches received by all buttons of that floor.	Count the number times a group of elevators were called in all floors within a given time period, i.e., count the number of the touches received by all buttons of all floors.	Compute the average load measure by the balance within a time interval

Table 5 shows rules identified for this scenario.

Table 5 – Rule Template for Scenario 1

Rule					
Id	RU01-1	RU02-1	RU03-1	RU04-1	RU05-1
Name	Activate-all	Activate	Deactivate	Block	Unblock
Subject	Any	Any	Any	Any	Any
Resource	Elevator	Elevator	Elevator	Elevator	Elevator
Action	Turn on all elevators at once, i.e., tell automatic on/off control to do it.	Turn on one or a set of elevators. The right number of elevators is defined by a existing formula	Turn off one or a set of elevators. The right number of elevators is defined by a existing formula	Block overloaded elevator.	Unblock elevator when load is reduced
Place	Hall	Hall	Hall	Hall	Hal
Fusion	All floor counter	Floor counter	Floor counter	Load average	Load average
Condition	If number of calls is higher than a threshold for a period or if current time is within a predefined interval	If number of calls is higher than a threshold for a period or if current time is within a predefined interval	If number of call is lower than a threshold for a period or if current time is within a predefined interval	If load is higher than a predefined value	If load is lower than a predefined value
Result	All elevators are ON	Some elevators are ON	Some elevators are OFF	A particular elevator is blocked	A particular elevator is unblocked

7.2 Scenario 2: Efficient use of the air conditioning system

Air conditioning systems may be based on coolers or heaters depending on the external temperature for keeping temperature within a stable and confortable level. For simplicity reasons, it is assumed here that the system is aimed at cooling internal areas. Cooling large spaces usually require many air conditioners to be placed in strategic places or multiple cooling air exits for central air conditioning systems. Also for simplicity here we will use the name air-conditioner even though they are not autonomous equipments, i.e. they are simple exits in a centralized system. Also, large places can host many people simultaneously, which contribute to increasing the temperature and make cooling more challenging.

However, using the full power of air conditioning is not always required, because even in large spaces, such as a theater, energy can be saved when just a few people are inside. Also, when the place is empty, cooling can be completely turned off. Also, other variables can influence the configuration of an air conditioning system, such as humidity, although they are not explored here.

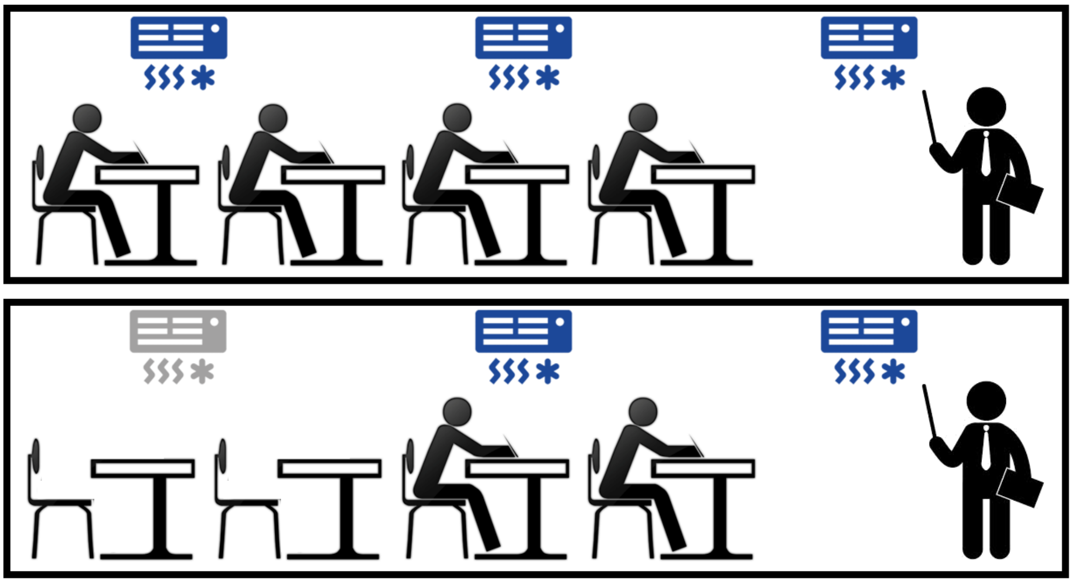

Figure 11 – Reducing air-conditioning power consumption based on the level of occupation of a place

7.2.1 Scenario 2: Scenes

Five typical scenes have been identified for this scenario, which were used to extract templates, presented in section 7.2.2. The scenes are as follows:

- **Scene 2.1**: Daniela, our subject, comes for the first class of the Differential and Integral Calculus I course in her engineering program. The classroom is large and full of students. In addition to the warm summer weather, the large number of people inside the classroom considerably increases the temperature. This university uses an IMPReSS-enabled application for energy efficiency management and all classrooms are equipped with thermometers and presence sensors. The application detects the large number of people and the high temperature and immediately controls the air conditioning system to operate in full capacity.
- **Scene 2.2**: Time goes on and Daniela makes progresses throughout her engineering program. Now she is attending to the Differential and Integral Calculus IV course and although a large classroom is used for this course, the number of students is considerably lower than in the first Calculus course. Also, external temperature is mild in a typical spring day. The application detects both the low occupancy of the classroom and the mild temperature and the air-conditioning system is configured to operate in low capacity.
- **Scene 2.3**: Classrooms usually are completely empty when no classes are taking place there. The application detects the absence of people and completely turns off the cooling system for those classes.
- **Scene 2.4**: Cleaning and maintenance services are scheduled during periods when classrooms are not being used. Maria is works is a cleaner and works for an outsource company. When she enters a classroom for sweeping she usually stays only some minutes. The applications detects

there is someone in the room but does not turn on the cooling system since it is only one person and stays for a short time period. Jose is an IT technician who works for the university. He enters a classroom for fixing a problem in the computer. The problem reveals not trivial and Jose stays inside for over one hour. The application detects there is only one person inside the classroom, but since the temperature is in a slightly uncomfortable level and Jose stays for a larger period (e.g. more than 15 minutes), the cooling system is partially turned on, only around Jose.

- **Scene 2.5**: Luisa is a professor and frequently works in her office. She can program the application to allow a maximum temperature of 22 degrees Celsius inside her office. When she is inside and temperature is over the threshold, the application automatically turns on the cooling system. When temperature is under the threshold or she is not inside, the cooling system remains off.

7.2.2 Scenario 2: Templates

Based on the scenes presented in section 7.2.1, templates for five entities belonging to IMPReSS context management were derived. Table 6 shows three roles for Subject.

Table 6 – Subject Template for Scenario 2

Subject				
Id	SU01-2	SU02-2	SU03-2	SU04-2
Role	Employee	Student	Third-party employee	Professor
Function	Works for the university, such as an IT technician.	Enrolled in one of the university program	Provides services for the company, such as cleaning services.	Teaches and does research in the university

Table 7 shows four resources involved in this scenario, divided up into three classes: equipment, sensors and actuators.

Table 7 –Resource Template for Scenario 2

Resource				
Id	RE01-2	RE02-2	RE03-2	RE04-2
Name	Thermometer	Air conditioner	Presence sensor	Automatic switch
Function	Measures temperature inside rooms and offices	Cools the air	Detects presence of people, i.e., detects movement in the detection area of the sensor	Turns air conditioner on and off
Class	Sensor	Equipment	Sensor	Actuator
Measurement	Temperature in Celsius scale with one decimal place		A binary value, telling whether there are or not people on the detection area of the sensor	

Table 8 shows t two places where this scenario takes place, which are classrooms and professors' offices.

Table 8 – Place Template for Scenario 2

Place		
Id	PL01-2	PL02-2
Name	Classroom	Office
Type	Closed	Closed
Function	Hosts classes with professors and students	Working place of a professor
Volume	Varied, from small classrooms (e.g. 5mx5mx4m = 100m^3) to large amphitheaters (e.g. 20mx10mx5m = 1000m^3)	Normally small (e.g. 3mx3mx3m = 27m^3)
Condition	Dry, backlit and with confortable temperature	Dry, backlit and with confortable temperature

Table 9 shows the fusion criterion identified for this scenario. Please notice that this fusion criterion is more complex than the ones identified for scenario 1, because it must coordinate information from sensors of different types.

Table 9 – Fusion Template for Scenario 2

Fusion	
Id	FU01-2
Name	Temperature-presence
Sensor	Thermometer Presence sensor
Algorithm	Measures and computes temperature average values on non-empty rooms; presence sensor and thermometer must work together

Table 10 shows rules identified for this scenario.

Table 10 – Rule Template for Scenario 2

Rule				
Id	RU01-2	RU02-2	RU03-2	RU04-2
Name	Turn on all	Turn on (or off) some	Turn off all	Turn on (or off) one
Subject	Student or Employee	Student or Employee	Any	Professor
Resource	Air-conditioner	Air-conditioner	Air-conditioner	Air-conditioner
Action	Turn on all air-conditioners available in a room	Turn on or off a set of air-conditioners available in a room, depending on the temperature and location of the people inside	Turn off a set of air-conditioners available in a room, depending on the temperature and location of the people inside	Turn on or off the air conditioner in a professor's office
Fusion	Temperature-presence	Temperature-presence	Temperature-presence	Temperature-presence

Place	Classroom	Classroom	Classroom	Office
Condition	Temperature must be over a threshold and the room must be completely occupied and at least one person must belong to Student or Employee Subject Class	Temperature must be over of under a threshold and there must be people concentrated in some area of the room and at least one person must belong to Student or Employee Subject Class.	Temperature must be below a threshold or room must be empty; or all people inside the room belong to the Subject Class Third-Party Employee and they remain a short time inside	Professor must be inside and the temperature is over or under a threshold
Result	All air-conditioners are ON	Some air-conditioners are ON. The application must decide which air conditioners to turn on or off based on the area where people are concentrated and on the temperature	Some air-conditioners are OFF	One air conditioner is ON or OFF

7.3 Scenario 3: Efficient use of lighting

The full lighting of large spaces is not always needed. Presence sensors may help detecting people in particular areas and determine the amount of lighting and consequently the number of lamps that need to be lighted. Also, corridors and vestibules may be low or nothing lighted in the absence of people. Figure 12 shows an example of a classroom where energy can be saved by turning off some lights when there are few students inside.

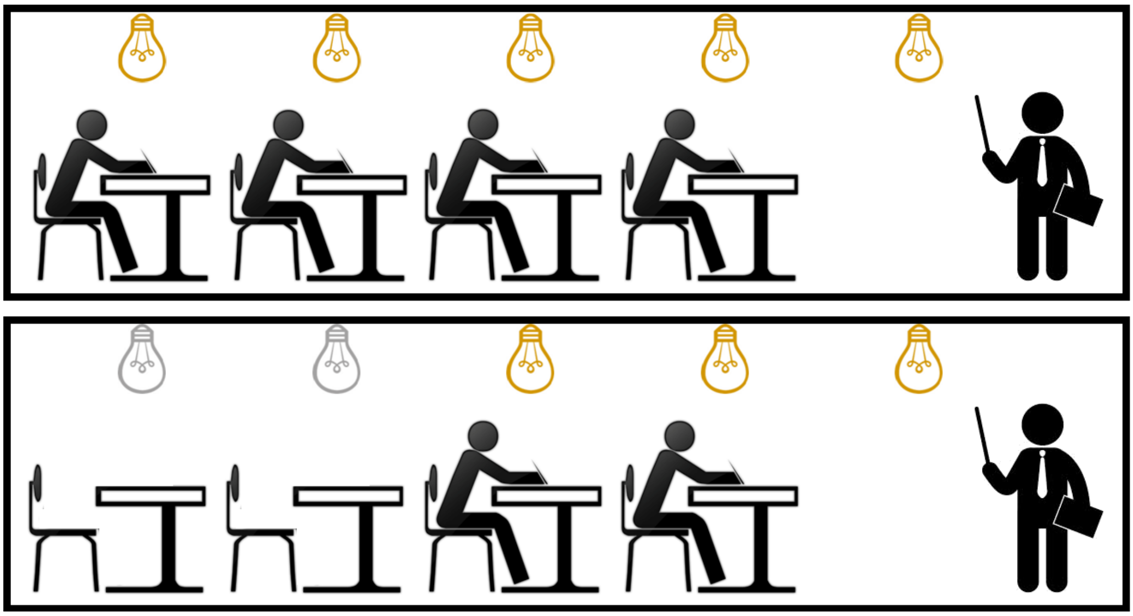

Figure 12 – Reducing lighting power consumption based on the level of occupation of a place

7.3.1 Scenario 3: Scenes

Three typical scenes have been identified for this scenario, which were used to extract templates, presented in section 7.3.2. The scenes are as follows:

- **Scene 3.1**: Julian arrives for the first class of the Differential and Integral Calculus I course in his engineering program. The classroom is large and full of students. In this evening there the level of light coming in from the window is minimum. This university is using an IMPReSS-enabled applications for energy efficiency management and the classrooms have presence and light sensors. The application detects people spread all over the classroom and the low level of light and turn on all available lamps in this space.
- **Scene 3.2**: Time goes on and Julian makes progresses throughout his engineering program. Now he is attending to the Differential and Integral Calculus IV course and although a large classroom is used for this course, the number of students is considerably lower than in the first Calculus course. His Calculus class now in in the morning and thus the applications detects the low number of people within the classroom and that there is a medium level of light in the space in that sunny day so only some lamps are lighted, near the students.
- **Scene 3.3**: When no classes are taking place, the classroom is completely empty. The application detects the absence of people and keeps all lamps turned off within this space.

7.3.2 Scenario 3: Templates

Based on the scenes presented in section 7.3.1, templates for five entities belonging to IMPReSS context management were derived.

Table 11 shows four roles for Subject, which is equal to Table 6. However, although there are many places where lighting may be reduced to save energy, n this scenario the subject Professor will not be used.

Table 11 – Subject Template for Scenario 3

Subject				
Id	SU01-3	SU02-3	SU03-3	SU04-3
Role	Employee	Student	Third-party employee	Professor
Function	Works for the university, such as an electrician	Enrolled in one of the university program	Provides services for the company, such as cleaning services.	Teaches and do research in the university

Table 12 shows four resources involved in this scenario, divided up into three classes: equipment, sensors and actuators.

Table 12 – Resource Template for Scenario 3

Resource				
Id	RE01-3	RE02-3	RE03-3	RE04-3
Name	Lamp	Light sensor	Presence sensor	Automatic switch
Function	Illuminates a space	Illuminates a space	Detects presence of people, i.e., detects movement in the detection area of the sensor	Turns lights on and off
Class	Device	Sensor	Sensor	Actuator
Measurement	Level of lighting	Detects the level of lighting in a space	A binary value, telling whether there are or not	

			people on the detection area of the sensor	

Table 13 shows the place where this scenario takes place, which is a classroom.

Table 13 – Place Template for Scenario 3

Place		
Id	PL01-3	PL02-3
Name	Classroom	Office
Type	Closed	Close
Function	Hosts classes with professors and students	Working place of a professor
Volume	Varied, from small classrooms (e.g. 5mx5mx4m = 100m^3) to large amphitheaters (e.g. 20mx10mx5m = 1000m^3)	Normally small (e.g. 3mx3mx3m = 27m^3)
Condition	Dry, backlit and with confortable temperature	Dry, backlit and with confortable temperature

Table 14 shows the fusion criterion identified for this scenario, similar to the on identified for scenario 2.

Table 14 – Fusion Template for Scenario 3

Fusion	
Id	FU01-3
Name	Lighting-presence
Sensor	Light sensor Presence sensor
Algorithm	Measures and computes averages for light values on non-empty rooms; presence and light sensors must work together

Table 15 shows rules identified for this scenario.

Table 15 – Rule Template for Scenario 3

Rule				
Id	RU01-3	RU02-3	RU03-3	RU04-3
Name	Turn on all	Turn on (or off) some	Turn off all	Turn on (or off) one
Subject	Student or Employee	Student or Employee	Any	Professor
Resource	Lamp	Lamp	Lamp	Lamp
Action	Turn on all available lamps in a room	Turn on or off a set of available lamps in a room, depending on the lighting level and location of the	Turn off a set of available lamps in a room, depending on the lighting levels and location of the people	Turn on or off the lamps in a professor's office

		people inside	inside	
Fusion	Lighting-presence	Lighting-presence	Lighting-presence	Lighting-presence
Place	Classroom	Classroom	Classroom	Office
Condition	Lighting level must be over a threshold and the room must be completely occupied and at least one person must belong to Student or Employee Subject Class	Lighting level must be over of under a threshold and there must be people concentrated in some area of the room and at least one person must belong to Student or Employee Subject Class.	Lighting level must be below a threshold or room must be empty; or all people inside the room belong to the Subject Class Third-Party Employee and they remain a short time inside	Professor must be inside and the lighting level is over or under a threshold
Result	All lamps are ON	Some air-conditioners are ON. The application must decide which lamp to turn on or off based on the area where people are concentrated and on the lighting level	Some lamps are OFF	One lamp is ON or OFF

7.4 Scenario 4: Automatic Curtains

Natural light is little used in buildings where the curtains are always closed, avoiding light to come in through the windows. Curtain automation allows the detection of external lighting and the automatic opening of the curtains when there is enough light coming from outside (or closing them).

Please notice that this scenario must be used together with scenario 3, because both aim at saving energy. Also, even if considering light coming from outside in some situations artificial lighting might still be needed.

Figure 13 shows an illustration of this scenario for a meeting room. When there are people there, the curtains open automatically, but when there is no one there any longer, the curtains close again.

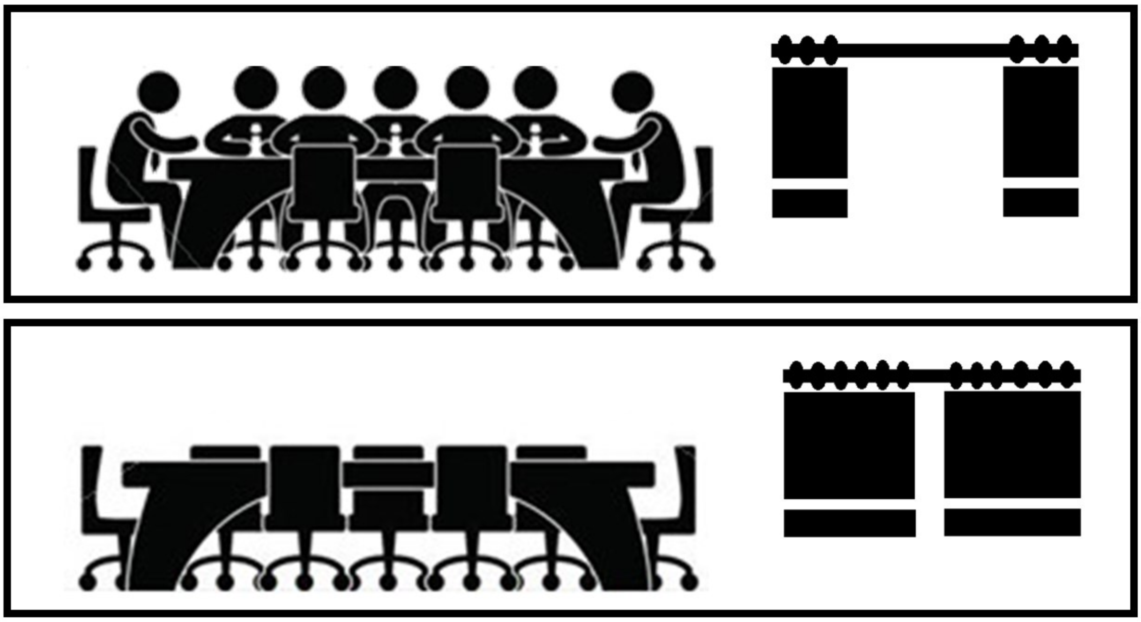

Figure 13 – Reducing lighting power consumption by opening and closing curtains

7.4.1 Scenario 4: Scenes

This scenario is comprised of one scene, as follows:

- **Scene 4.1**: A group of employees meet in the main meeting room of the company and in spite of the day being vey clear outside the room is dark because of the heavy curtains used to decorate the windows. The IMPReSS-enabled application detects that a groups of people enters the room and compares the low level of internal lighting to the high level of lighting coming from outside. Thus, curtains are automatically opened to make use of the natural light to illuminate the space during the meeting. The same happens whenever employees have meetings with customers, suppliers and visitors.

7.4.2 Scenario 4: Templates

In Table 16 the four roles for Subject identified for this scenario are presented.

Table 16 – Subject Template for Scenario 4

Subject				
Id	SU01-4	SU02-4	SU03-4	SU04-4
Role	Employee	Customer	Supplier	Visitor
Function	Works for the company	Buy products from a company	Provides services or sell products for the company	Visits the company

Table 17 shows the four resources identified for this scenario (similar to the previous scenarios).

Table 17 – Resource Template for Scenario 4

Resource				
Id	RE01-4	RE02-4	RE03-4	RE04-4
Name	Automatic curtain	Light sensor	Presence sensor	Automatic switch
Function	Opens and Closes without manual	Detects the level of lighting in a	Detects presence of people, i.e., detects movement	Controls the curtain opening

	action	place	in the detection area of the sensor	and closing
Class	Equipment	Sensor	Sensor	Actuator
Measurement		Level of lighting	A binary value, telling whether there are or not people on the detection area of the sensor	

Table 18 shows the template for Place in this scenario, which is a meeting room.

Table 18 – Place Template for Scenario 4

Place	
Id	PL01-4
Name	Meeting Room
Type	Closed
Function	Hosts meetings with employees, customers, suppliers or visitors
Volume	Not relevant
Condition	Level of external lighting

Table 19 shows the fusion criterion needed, which is similar to Table 14.

Table 19 – Fusion Template for Scenario 4

Fusion	
Id	FU01-4
Name	Lighting-presence
Sensor	Light sensor Presence sensor
Algorithm	Measures and computes averages for light values on non-empty rooms; presence and light sensors must work together

Table 20 shows the two rules identified for this scenario.

Table 20 – Rule Template for Scenario 4

Rule		
Id	RU01-4	RU02-4
Name	Open Curtain	Close Curtain
Subject	Any	Any
Resource	Automatic Curtain	Automatic Curtain
Action	Open curtains of the place	Close curtains of the place
Fusion	Lighting-presence	Lighting-presence
Place	Meeting room	Meeting room
Condition	If there are at least one person	It there is no one inside the room

	(subject) inside the room	
Result	Curtains open	Curtains close

7.5 Scenario 5: Reducing standby power

Most electronic devices or appliances – such as computers, TV sets, DVD / Blu-Ray players, audio systems, videogames, projectors, microwave ovens – are always plugged into an energy source even when they are not in use. In some cases they are turned off but remain in a standby state that uses up energy even though people are not aware of it[4].

For this scenario, the idea for saving energy is just cutting the power supply when equipments are not in use. There are automatic circuit automation techniques available to cut power supply from idle equipment and to resume it when the equipment is needed[5]. An example is a smart plug that may act both as a sensor and an actuator. Figure 14 depicts a situation where the power supply may be cut from an appliance whenever it is not used. In that case it is assumed the use of a smart plug that detects reduction in electric consumption when the equipment goes to standby mode and may be controlled to resume power whenever needed. This example shows a residential use of this technique since it is still not well developed for using it in corporations.

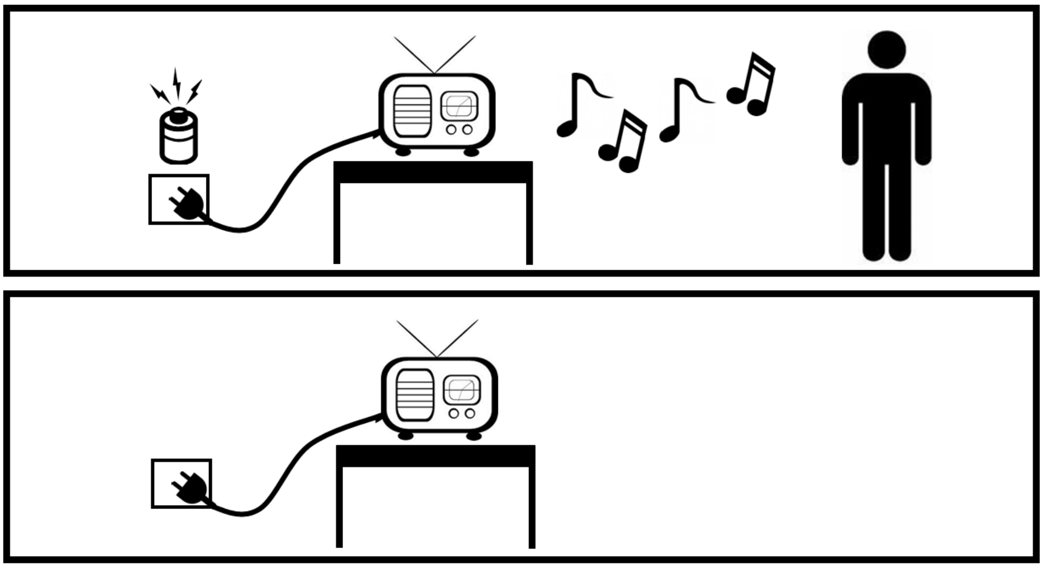

Figure 14 – Cutting power supply from unused equipment

7.5.1 Scenario 5: Scenes

This scenario is comprised of one scene, as follows:

- **Scene 5.1**: Cecilia and her family, husband and two children, have a busy life. The couple works during the day and kids go to school and other activities. Their house is fully equipped with different types of appliances that remain unused during the day. Some of them are used at night but others are frequently not used for several days in a row. An IMPReSS-enabled application is controlling energy in Cecilia's house and they use smart plugs that detect standby mode by measurement electric current and can cut off power and resume it again through a remote control system.

[4] http://standby.lbl.gov
[5] http://www.energy-saving-electronics.info/standby-power.htm

7.5.2 Scenario 5: Templates

In Table 21 the Subject identified for this scenario is presented.

Table 21 – Subject Template for Scenario 5

Subject	
Id	SU01-5
Role	Resident
Function	Lives in a house

Table 22 shows the two resources identified for this scenario.

Table 22 – Resource Template for Scenario 5

Resource		
Id	RE01-5	RE02-5
Name	Appliance	Smart plug
Function	Device or equipment used for a particular purpose, such as radio or Blu-Ray player	Detects standby low power use, cut power, resume power
Class	Equipment	Sensor and actuator
Measurement		Level of electrical current

Table 23 shows the template for Place in this scenario, which is a resident's house.

Table 23 – Place Template for Scenario 5

Place	
Id	PL01-5
Name	House
Type	Closed
Function	House people in leisure, resting or entertaining situations
Volume	Not relevant
Condition	Not relevant

Table 24 shows the fusion criterion needed for this scenario.

Table 24 – Fusion Template for Scenario 5

Fusion	
Id	FU01-5
Name	Usage pattern
Sensor	Smart plug
Algorithm	Measures typical recurring usage patterns for different days or hours for each appliance for building a stronger decision whether or not to cut the power supply

Table 25 shows the two rules identified for this scenario.

Table 25 – Rule Template for Scenario 5

Rule		
Id	RU01-5	RU02-5
Name	Cut power supply	Resume power supply
Subject	Any	Any
Resource	Appliance	Appliance
Action	Cut power supply	Resume power supply
Fusion	Usage pattern	Usage pattern
Place	House	House
Condition	If electric current is below a threshold and appliance is not commonly used in that period	If a resume command is received from a remote control; If an automatic control is available, a command may be sent based on usage patterns.
Result	Power unavailable to the appliance	Power available to the appliance

7.6 Scenario 7: Price-based energy usage

Nowadays in a typical family parents work during the whole day and children stay in school most of the time. Therefore, when everyone is home, from 6 PM on up to 8 PM or 9 PM, a significant increase in energy consumption can be observed, once many appliances and lighting is turned on all at once. Energy providers (generators, transmitters, distributors) are frequently challenged in order to keep the grid stable mainly during consumption peak hours. Smart grid (section 5.4) and a white tariff (section 5.5) are examples of using energy price for providing incentives to users to use energy during alternative hours. Users can program their electrical products to work in hours where the price is lower, even when they are not home.

Figure 15 shows an example of postponing the use of a washing machine and a dishwasher due to a cheaper price.

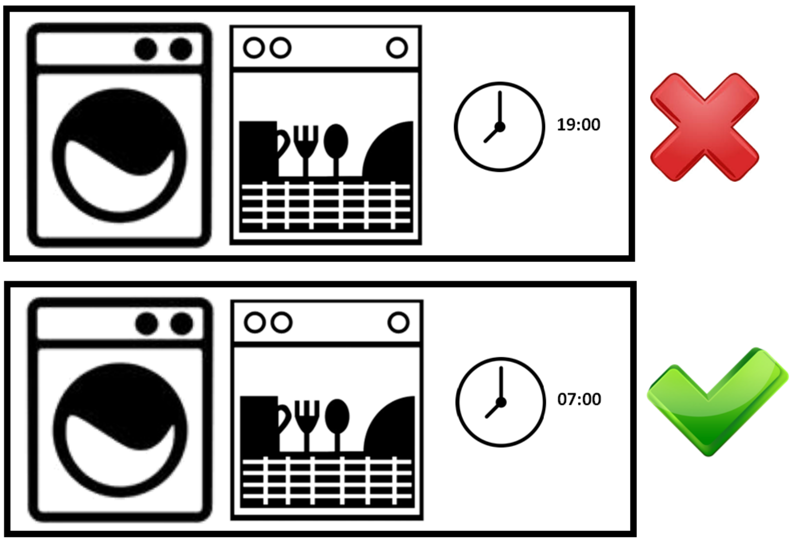

Figure 15 – Reducing energy consumption using a price-based approach

7.6.1 Scenario 6: Scenes

This scenario is comprised of one scene, as follows:

- **Scene 6.1**: Helena is single and lives alone. She works during the day and thus housework must be done at night. When she arrives home at night energy is more expensive and therefore she must postpone turning on as many appliances as she can. She prepares and programs her washing machine and dishwasher to start working when energy is cheaper, even though she is not home.

7.6.2 Scenario 6: Templates

In Table 26 the Subject identified for this scenario is presented.

Table 26 – Subject Template for Scenario 6

Subject	
Id	SU01-6
Role	Resident
Function	Lives in a house

Table 27 shows the three resources identified for this scenario.

Table 27 – Resource Template for Scenario 6

Resource			
Id	RE01-6	RE02-6	RE03-6
Name	Washing machine	Automatic switch	Energy price
Function	Washing	Switch the machine on based on a prescheduled program; it is a device that comes with the washing machine	Logical sensor that finds out when energy is cheaper; it is a service run by the energy provider
Class	Equipment	Actuator	Sensor
Measurement			Each request to the service returns the current time and price

Table 28 shows the place identified for this scenario.

Table 28 – Place Template for Scenario 6

Place	
Id	PL01-6
Name	Laundry room
Type	Closed
Function	Holds washing machine and clothes dryer
Volume	Not relevant
Condition	Not relevant

Table 29 shows the fusion criterion needed for this scenario.

Table 29 – Fusion Template for Scenario 6

Fusion	
Id	FU01-6
Name	Price average and variation
Sensor	Energy price
Algorithm	Computes the price average and standard variation for a time period, in order to provide a statistical guarantee that the price is stable

Table 30 shows the two rules identified for this scenario.

Table 30 – Rule Template for Scenario 6

Rule		
Id	RU01-6	RU02-6
Name	Washing machine ON	Washing machine OFF
Subject	Any	Any
Resource	Appliance	Appliance
Action	Turns on the washing machine	Turns off the washing machine
Fusion	Price average and variation	Price average and variation
Place	Laundry room	Laundry room
Condition	If the average price of the Kilowatt hour (KWh) is below a certain threshold and the variation is small	If the average price increases suddenly
Result	Washing machine is ON	Washing machine is OFF

7.7 Scenario 7: Use the entrance turnstiles to generate energy

Turnstiles are frequently used in commercial buildings, public transport systems and also universities. Most common uses of turnstiles are controlling speed and density of people, people counting and access control to restricted areas. However, this device has a significant potential to convert kinetic energy into electric energy. The energy generated by the circular movement made by the turnstile when a person pushes it may be stored into a battery a used by other electrical devices, such as the lighting of the area where the turnstiles are located (see Figure 16).

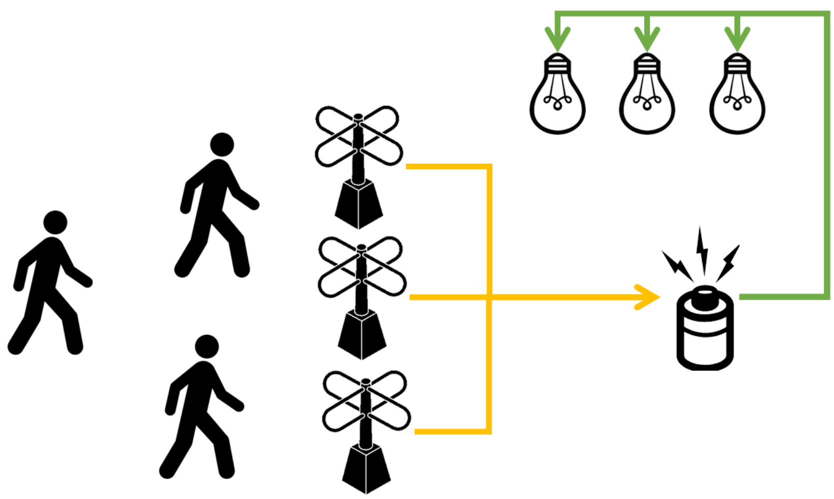

Figure 16 – Energy-generating turnstile

7.7.1 Scenario 7: Scenes

This scenario is comprised of two scenes, as follows:

- **Scene 7.1**: João comes to the university in the evening. The entrance is well lighted and the number of people going in and out is high, mainly in class switching hours. This university used an IMPReSS-enabled application and it is saving energy by lighting the entrance using the energy generated by the turnstiles. When João walks through the turnstile the kinetic energy generated by the circular movement is converted to electric energy and stored into batteries. The IMPReSS-based application manages the use of the battery-stored energy in order to decide whether it will be used, or not, to light the lamps in the entrance. Managing the use of batteries or the regular electric source require a combination of information, which is the current battery level and the level of current light in the entrance to decide how many lamps need to be lighted.
- **Scene 7.2**: When João comes to the university in the morning he observes that entrance lights are only switched on when the day is cloudy and therefore the level of lighting is low. However, even during the day the turnstiles keep storing energy into the batteries.

7.7.2 Scenario 7: Template

Table 31 shows four roles for Subject, which is equal to Table 6.

Table 31 – Subject Template for Scenario 7

Subject				
Id	SU01-3	SU02-3	SU03-3	SU04-3
Role	Employee	Student	Third-party employee	Professor
Function	Works for the university, such as an electrician	Enrolled in one of the university program	Provides services for the company, such as cleaning services.	Teaches and do research in the university

Table 32 presents resources identified for this scenario.

Table 32 – Resource Template for Scenario 7

Resource							
Id	RE01-7	RE02-7	RE03-7	RE04-7	RE05-7	RE06-7	RE07-7
Name	Battery sensor	Light sensor	Flow sensor	Turnstile	Lamp	Automatic switch	Battery
Function	Detects the level of energy stored	Detects light	Detects the flow of people going through the turnstiles	Controls access	Illuminates the space	Switches on lamps	Stores energy
Class	Sensor	Sensor	Sensor	Equipment	Device	Actuator	Equipment
Measurement	Level of energy	Level of lighting	Rate of people				

Table 33 shows the place identified for this scenario.

Table 33 – Place Template for Scenario 7

Place	
Id	PL01-7
Name	Entrance
Type	Open
Function	Controls people access to the building
Area	Not relevant
Condition	Not relevant

Table 34 shows the fusion criteria needed for this scenario.

Table 34 – Fusion Template for Scenario 7

Fusion		
Id	FU01-7	FU02-7
Name	Energy source	Lighting-flow
Sensor	Light sensor and battery sensor	Light sensor and flow sensor
Algorithm	Combines information coming from light and battery sensor to determine which energy source must be used depending on the number of lamps to be lighted and the level of energy stored in the batteries. The number of lamps depends on the level of light detected by the light sensor.	Measures and computes averages for light values on the university's building entrance; flow and light sensors must work together; a minimum lighting is always needed even in late hours, which is identified by a small amount of people going through the turnstiles

Table 35 shows the rules identified for this scenario.

Table 35 – Rule Template for Scenario 7

Rule				
Id	RU01-7	RU02-7	RU03-7	RU04-7
Name	Switch on lamps	Switch off lamps	Set minimum lighting	Switch energy source
Subject	Any	Any	Any	Any
Resource	Lamp	Lamp	Lamp	Battery
Action	Switch on some lamps in the entrance	Switch off some lamps in the entrance	Switch on only the minimum preconfigured number of lamps	Switch the energy source from battery to regular electric current
Fusion/sensor	Lighting-flow	Lighting-flow	Flow sensor	Energy source
Place	Entrance	Entrance	Entrance	Entrance
Condition	If the flow of people is above a threshold and the lighting is	If the flow of people is above a threshold and the lighting is above a threshold	If the flow of people is below the minimum threshold, set the lighting to the minimum	If the level of energy in the battery is enough for keeping the required number of lamps lighted until the next decision event, keeps the battery

	below a threshold decides the number of lamps to be lighted	decides the number of lamps to be switched off		working; otherwise, switch the energy source of the lamps to the regular energy source
Result	Some lamps are ON in the entrance	Some lamps are ON in the entrance	Minimum number of lamps is ON in the entrance	Energy source is switched (or not)

7.8 Scenario 8: Turning off unused computers

Many computers and peripherals simply remain turned on even when they not used for long periods. Operating systems usually have means of managing energy by turning computers to energy saving modes whenever they are not being used for a certain time period. Also, software sensors may be installed to shut down or put to an energy saving mode the operating system for saving energy. This is particularly interesting for large companies with a large number of computers spread over different rooms and offices and also for datacenters. Figure 17 represents such a situation.

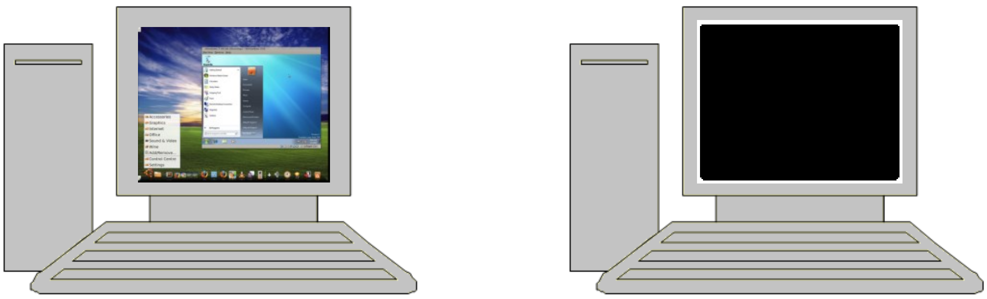

Figure 17 – Turning off unused computers

7.8.1 Scenario 8: Scenes

This scenario is comprised of one scene, as follows:

- **Scene 8.1**: Jamal is a professor who always forgets to shut down his desktop computer in his office. As he consented to install an IMPReSS-enabled software sensor in his computer, now after some time the computer is shut down automatically.

7.8.2 Scenario 8: Templates

Table 36 shows one role for Subject.

Table 36 – Subject Template for Scenario 8

Subject	
Id	SU01-6
Role	Professor
Function	Works in the university

Table 37 shows the two resources identified for this scenario.

Table 37 – Resource Template for Scenario 8

Resource

Id	RE01-8	RE02-8
Name	Desktop computer	Computer activity agent
Function	General purpose desktop computer	Measures the level of activity in the computer and shuts it down when commanded to do so
Class	Equipment	Sensor and Actuator
Measurement		Tells its manager (e.g. the IMPReSS context manager) that the computer is not being used for some time

Table 38 shows the place identified for this scenario.

Table 38 – Place Template for Scenario 8

Place	
Id	PL01-8
Name	Professor's office
Type	Closed
Function	Professor's workplace
Volume	Not relevant
Condition	Not relevant

This scenario does not need a particular fusion criterion to be created because the sensor is software-based and can compute its own fusion algorithm. For example, the activity to be measured in the computer will probably be an average of the last minutes in order not to shut down the computer when this may be considered inappropriate.

Table 39 shows the single rule identified for this scenario.

Table 39 – Rule Template for Scenario 8

Rule	
Id	RU01-8
Name	Shut down computer
Subject	Professor
Resource	Desktop computer
Action	Shuts computer down
Fusion/sensor	Computer activity agent
Place	Professor's office
Condition	If computer is not used for some time, given by a threshold, shut down the operating system
Result	Computer inactive because the operating system was shut down

7.9 Scenario 9: Using Solar Energy

Solar energy is a highly available renewable energy source, although it is still too expensive to deploy in large scale due to the high cost of the photovoltaic panels (section 5.2). This scenario is concerned with making use of the energy coming from the photovoltaic panels, storing it in batteries and using it for lighting or pumping water to water tanks. It can be used in public buildings but particularly it focuses on Teatro Amazonas, which is one of the IMPReSS' pilots.

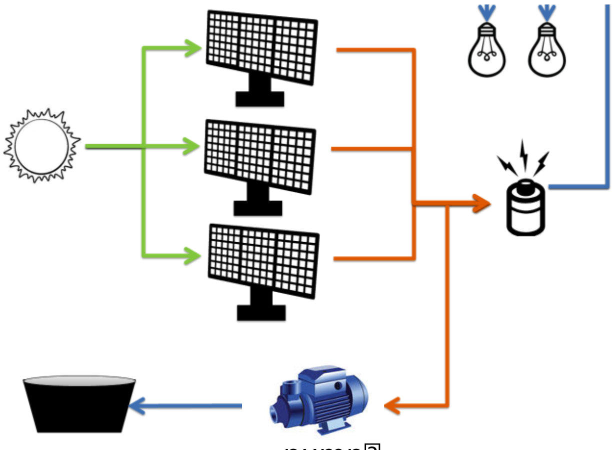

Figure 20 – Using solar energy for lighting and pumping water

7.9.1 Scenario 9: Scenes

This scenario is comprised of two scenes, as follows:

- **Scene 9.1**: In a sunny day in Manaus the photovoltaic panels in Teatro Amazonas generate enough energy for loading completely the batteries they are connected to. In the evening, when there is a concert, batteries are used to light the entrance of the theater. Before seeking their way to seat, people spend some minutes to relax in this area, where they can hear good music, drink some wine and chat with friends. In the same place there are displays that show at any time how much energy the theater is saving by making an efficient use of it.
- **Scene 9.2**: In a sunny day in Manaus the photovoltaic panels in Teatro Amazonas generate energy that are automatically used for operating the theater's water pump, thus guaranteeing that the water tank is always full and can be made available to general usage or for fire-fighting.

7.9.2 Scenario 9: Templates

Table 36 shows three roles for Subject who take part in this scenario.

Table 40 – Subject Template for Scenario 9

Subject			
Id	SU01-1	SU02-2	SU03-3
Role	Employee	Artist	Audience
Function	Works in the theater, such as an electrician	Works in a concert, opera, ballet, etc.	Audience of any concert or performance

a – Solar energy usage for water pumping
b – Solar energy usage for lighting

Table 41 shows that ten different types of Resource have been identified for this scenario, since it mixes together two different ways of using solar energy.

Table 41 – Resource Template for Scenario 9

Resource				
Id	**Name**	**Class**	**Function**	**Measurement**

RE01-9	Photovoltaic panel	Equipment	Energy generation	
RE02-9	Battery	Equipment	Energy storage	
RE03-9	Water pump	Equipment	Water pumping	
RE04-9	Lamp	Equipment	Lighting	
RE05-9	Water sensor	Sensor	Measures the level of water in the tank	Water level
RE06-9	Presence sensor	Sensor	Detects presence of people in a place	Detects movements
RE07-9	Light sensor	Sensor	Detects the level of lighting in a place	Levels of lighting
RE08-9	Solar energy sensor	Sensor	Detects if there is energy coming from the photovoltaic panels	Energy
RE09-9	Water pump automatic switch	Actuator	Turning on and off the water pump according to the water level sensor	
RE010-9	Light automatic switch	Actuator	Switching on and off the lights	

Table 42 shows the two Places for this scenario.

Table 42 – Place Template for Scenario 9

Place		
Id	PL01-9	PL02-9
Name	Basement	Theater Hall
Type	Closed	Closed
Function	Equipment installations	People reception
Volume	Varied	Large
Condition	Not relevant	Not relevant

No particular Fusion criteria were identified for this scenario.

Table 43 shows three Rules for this scenario. Please notice that, similarly to scenario 7 (Table 35), scenario 9 will require rules for switching energy sources for water pumping and lighting, although they are not shown in Table 43.

Table 43 – Rule Template for Scenario 9

Rule			
Id	RU01-9	RU02-9	RU03-9

Name	Turn on pump	Turn off pump	Switch on Hall lights
Subject	Any	Any	Any
Resource	Water pump	Water pump	Hall Lamp
Action	Turn on water pump	Turn off water pump	Switch on lamps in the theater hall
Fusion/Sensor	Water sensor Solar energy sensor	Water sensor Solar energy sensor	Light sensor Presence sensor
Condition	If solar panels are generating energy and tank is not full	If tank is full	If there are people in the hall and the level of lighting is low
Result	Water pump is working	Water pump is stopped	Hall lights are on

8. Conclusion

This reports described an analysis of entities involved in energy efficiency context management, as well as its relationships and presents some templates that can be inferred from them. Entities identified are Subject, Resource, Place, Fusion and Rule. Sensor data fusion is highly needed by any context management system and therefore known sensor fusion algorithms are also presented. A variety of different scenarios with opportunities for energy saving are presented and for each one some scenes and the templates filled for all entities are described. The entities, its relationships and templates, and the scenarios will be further for the design and implementation of Context aware modules of the IMPReSS SDP, namely the Context IDE and the Context Manager.

As the main output of Task 6.1 (Templates for Smart Entities, Situations and Context Rules) this report is expected to play a paramount role in the development of the upcoming activities, which are Task 6.2 (Sensor and Data Fusion Services), Task 6.3 (Context modelling templates) and Task 6.4 (Context Model & Rule Authoring tool). The next step is to choose a context model – e.g. object-oriented or ontology-based – and to design and implement a context reasoning engine.

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