NRG4CAST

Deliverable D1.2

Requirements for fully functional prototype

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Executive Summary

This Deliverable aims at gathering and systemizing requirements for the NRG4Cast system based on the project pilot cases. Combined with the Deliverable 1.1 Report & library on existing technology and data and the forthcoming deliverable D1.3 Early Toolkit architecture specification (due M5) is setting the scene framework for the NR4Cast development.

The first part of this Deliverable describes the overall methodology for gathering the NRG4Cast user requirements and tasks of the requirements identification process: pilot description phase, preliminary user requirements extraction & classification phase and the requirements integration phase.

A main focus of the Deliverable is the overview of the pilot cases, the design of use cases and the extraction of requirements for each pilot scenario. During this stage, the NRG4Cast team is using an iterative procedure to expand a broad statement of the system requirements into a complete and detailed specification of each function, which the system must perform and each criterion that it must meet.

Requirements collection starts from the existing business cases and their value chains, existing systems and applications and interoperability issues with other systems (i.e. electric cars, street lighting, energy monitoring systems for buildings etc.). Special attention is given to the underlying theoretical concepts i.e. integrated energy environments, energy efficiency models in different contexts of rural environments, systems and metrics for different energy sources.

Project partners have critically reviewed each pilot scenario describing the AS-IS and TO-BE situation and providing the structured use cases description. This document structures the aspired goals , the most successful scenario, possible exceptions, limitations or variations and additional comments. The user requirements are successively extracted for each pilot scenario and classified into three main categories: functional requirements, non-functional requirements, restrictions and limitations that apply to the project and the system.

Subsequently the preliminary requirements gathered from each single pilot scenario (MIREN, CSI, NTUA) and virtual pilot site (MIREN-FIR-CSI) are organised, taking into account the description as well as the user importance and the user need. Requirements that describe similar functionalities are generalised and merged, representing the System Requirements, which implement all of the expressed functionalities.

This deliverable is constructed as follows. Chapter 1 provides the introduction. Chapter 2 describes the methodology for gathering the NRG4Cast user requirements. Chapter 3 provides an overview, use cases description and the list of functional and non-functional requirements for each project pilot scenario. Chapter 4 illustrates the list of NRG4Cast system preliminary requirements classified into categories with an integrated rating.

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1 Introduction

The purpose of the Deliverable 1.2 is to gather and systemize requirements for the NRG4Cast system based on the project pilot cases. The requirements gathered in this report represent the basis for setting the scene framework for the NR4Cast development.

NRG4Cast project focuses on a number of pilot sites previously described in the Deliverable 1.1. The pilot site within the Municipality of MIREN in Slovenia, CSI public building in Italy and NTUA campus in Greece will be accomplished with the virtual pilot MIREN-FIR-CSI. This city-like pilot scenario aims at correlating energy consumption data of Italian public buildings (CSI building, school and university building, public offices etc.), energy street light consumption data collected through a cognitive sensor network installed in Slovenia by Envigence partner, and forecasting energy demand by electrical vehicles realised by partner FIR at RWTH Aachen. The energy provider partner IREN will assure the energy data availability for the buildings involved.

In this report each use case partner provided requirements collection starts from the existing business cases and their value chains, existing systems and applications and interoperability issues with other systems (i.e. electric cars, street lighting, energy monitoring systems for buildings etc).

Following the overall methodology for gathering the NRG4Cast user requirements, the preliminary functional and non- functional requirements were extracted for each pilot scenario. Subsequently, the preliminary requirements gathered from each pilot were organised taking into account the description as well as the user importance. Requirements that describe similar functionalities were generalised and merged. The completeness and feasibility of requirements were examined as well.

The resulting table 10 *The NRG4Cast system preliminary requirements* concludes the Deliverable 1.2. It is the first attempt the NRG4Cast project team made to resolve the ambiguities and discrepancies within the requirements list.

However the requirements list will be examined, integrated and updated within the project life. During the project, other requirements might emerge, which, not being foresee able at the very beginning of the NRG4Cast project.

2 Requirements methodology

This chapter describes the methodology for gathering and definition of the NRG4Cast system requirements. The crucial questions to be answered before starting with the requirements process are “who is the user” and “who, how and why will benefit” . NRG4Cast system addresses public sector decision makers, municipalities’ energy management commissions, public authorities, Mayors as well as energy providers, technical providers, Energy monitoring/forecasting software developers. Indeed, the definition of requirements starts from analysis of user’s needs.

The preliminary functional and non-functional requirements are to be extracted for each pilot scenario. Functional requirements are actions that the system must do or allow the user to do in order to provide useful functionality for its user. The non-functional requirements are generally defined as properties, or qualities that the product must have. Non-functional requirement are critical to the NRG4Cast system success and cover a number of common aspects such as system’s appearance, usability , performance, maintainability and security.

Subsequently, the preliminary requirements gathered from each pilot are to be organised taking into account the description as well as the user importance. Requirements that describe similar functionalities are to be generalised and merged. The project team will be using an iterative procedure to expand a broad statement of the system requirements into a complete and detailed specification of each function, which the system must perform and each criterion that it must meet. The completeness and feasibility of requirements will be examined as well.

2.1 User Requirement Categories

This chapter describes the methodology for gathering and definition of the NRG4Cast system requirements. The crucial questions to be answered before starting with the requirements process are "who is the user" and "who, how and why will benefit". NRG4Cast system addresses public sector decision makers, municipalities' energy management commissions, public authorities, mayors as well as energy providers, technical providers, energy monitoring/forecasting software developers. Indeed, the definition of requirements starts from analysis of user's needs.

User requirements can be classified into two main categories: Functional and Non-Functional requirements. The preliminary functional and non-functional requirements are to be extracted for each pilot scenario. Functional requirements are actions that the system must do or allow the user to do in order to provide useful functionality for its user. The non-functional requirements are generally defined as properties, or qualities that the product must have. Non-functional requirement are critical to the NRG4Cast system success and cover a number of common aspects such as system's appearance, usability, performance, maintainability and security.

Subsequently, the preliminary requirements gathered from each pilot are to be organised taking into account the description as well as the user importance. Requirements that describe similar functionalities are to be generalised and merged. The project team will be using an iterative procedure to expand a broad statement of the system requirements into a complete and detailed specification of each function, which the system must perform and each criterion that it must meet. The completeness and feasibility of requirements will be examined as well.

2.1.1 Functional requirements

Functional requirements are actions that the system must do or allow the user to do in order to provide useful functionality for its user.
Common definitions of functional requirements are:

- specifications of the systems functionalities;
- actions the systems must take – check, calculate, record, retrieve

Requirements are to be derived from the fundamental purpose of the system. Functional requirements will be derived from the scenarios' use cases. Each use case in the scenario represents a task that one of the involved actors will want to perform. Each use case will present a sequence of steps, from the examination of which its functional requirements will be derived.

These steps will be described in natural language, allowing an immediate understanding of the actions that will be performed, but, being high-level and targeted to the customer, will not delve into the details of the system's capabilities.

On the other hand, the extracted functional requirements, present the same steps from the system's functionalities point of view, thus they will be useful in order to identify what the system will need to do to achieve the goal of the use case.

2.1.2 Non-Functional requirements

Non-functional requirements are generally defined as properties, or qualities that the product must have.
In some cases they are critical to the system success. Common aspects covered by non-functional requirements are:

- Look and Feel Requirements – the intended system's appearance

- Usability Requirements – based on the intended users
- Performance Requirements – how fast, big, accurate, safe, reliable, etc.
- Operational Requirements – the system's intended operating environment
- Maintainability and Portability Requirements – how changeable the system must be
- Security Requirements – the security, confidentiality and integrity of the system

1. **Look and Feel Requirements** describe the mean of the system's appearance.
2. **Usability Requirements** describe the appropriate levels of usability, given the intended users of the system.
3. **Performance Requirements** are written when there is a need for the system to perform some tasks in a given amount of time, or for some tasks to be done at a specific level of accuracy. For example: "The system shall show a list within 5 seconds"
4. **Operational Requirements** describe the environment in which the system is to be used. In some cases, the environment creates special circumstances that have an effect on the way the system must be constructed.
5. **Maintainability Requirements** have a big effect on the system's designer. Indeed, they design the interface in such a way as to make it easy to add new languages, or for example you can desire that platform run on several types of operating systems.
6. **Security Requirements** point out that security can be thought of as having three aspects:

- Availability – the system's data and functionality are accessible to authorized users, and can be produced in a timely manner
- Integrity – the system's data is the same as the source, or authority of the data
- Confidentiality – data stored and elaborated within the system is protected from unauthorized access and disclosure.

The other kinds of non-functional requirements may still emerge.

Like all requirements, the non-functional ones can appear at any time. Non-functional requirements may also be revealed during the functional requirements analysis. For each functional requirement, it is possible to define what properties this functionality must have in terms of Look and Feel, Usability, etc.

2.1.3 Constraints requirements

Constraints are global requirements. They apply to the entire system, and preferably are defined before starting work on gathering the requirements. The constraints are determined early in the requirements process, and thereafter used to gauge the correctness and appropriateness of the requirements as they are gathered.

2.2 Overall Methodology

2.2.1 Requirements process tasks

As it was stated before, the purpose of the requirements analysis phase is to produce specifications of the technical and non-technical requirements for the NRG4Cast system. Requirements analysis process initiates the NRG4Cast toolkit development life cycle. During this process, the NRG4Cast team uses an iterative procedure to expand a broad statement of the system requirements into a complete and detailed specification of each function that the system must perform and each criterion that it must meet.
The complete requirements and specifications, combined with the system and operations concept, will describe the system in sufficient detail.

The user requirements process that will be used in the NRG4Cast project is made up of four different phases (Figure 1).

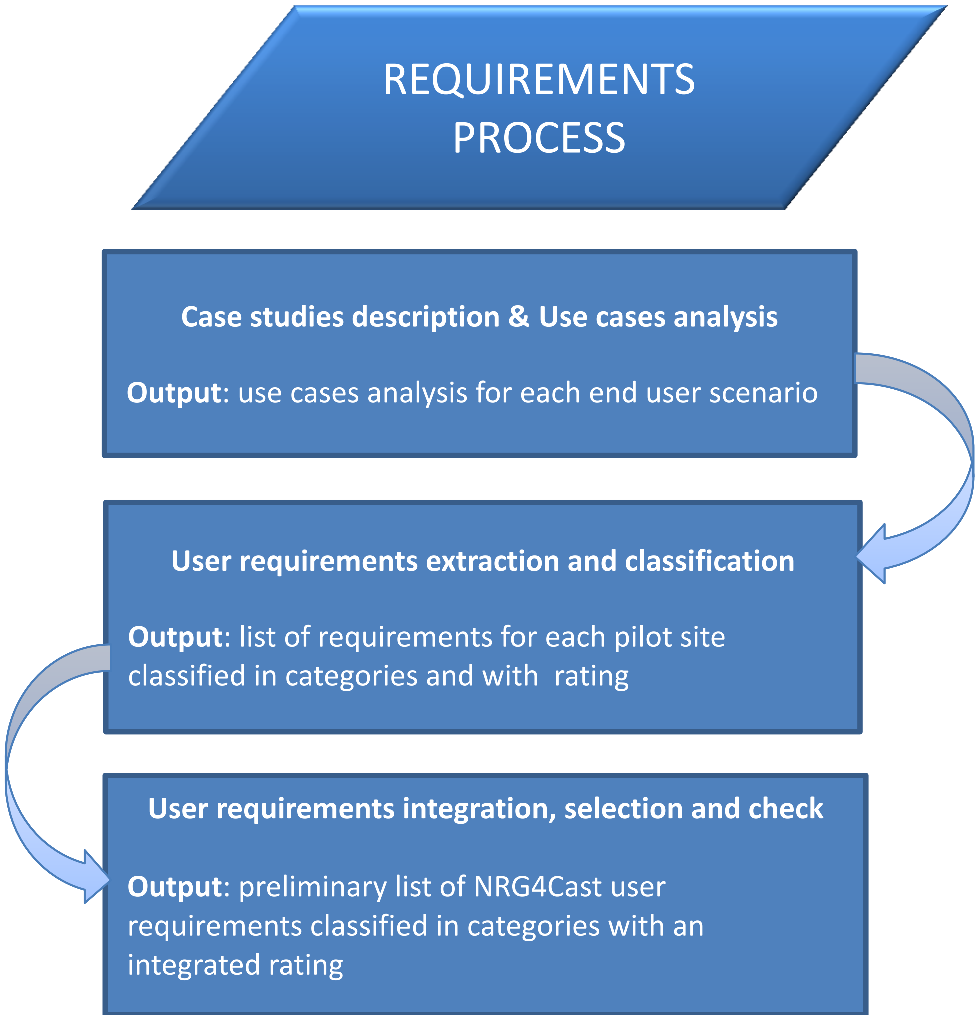

Figure 1 NRG4Cast user requirements process

2.2.1.1 Phase 1. Pilot description

In the first phase the NRG4Cast team will define the TO-BE scenarios showing how the system will be operated. This phase gives an overview of each pilot and describes the Use cases.

Use cases are to be described in the following form:

- **Actor**: The role/actor/person who interacts with NRG4Cast
- **Goals** (generic goal and expectation from the particular case
- **Trigger conditions**: When the particular case is being generated
- **Use case steps**: the steps of interaction between user and NRG4cast
- **Frequency**: how often this use case happens, frequency of sensor metrics, etc.
- **Success end conditions**

2.2.1.2 Phase 2. Preliminary user requirements Extraction & Classification

The aim of the second phase of NRG4Cast user requirements process is to extract preliminary user requirements from each scenario and to classify them on the basis of a set of criteria (see figure2).

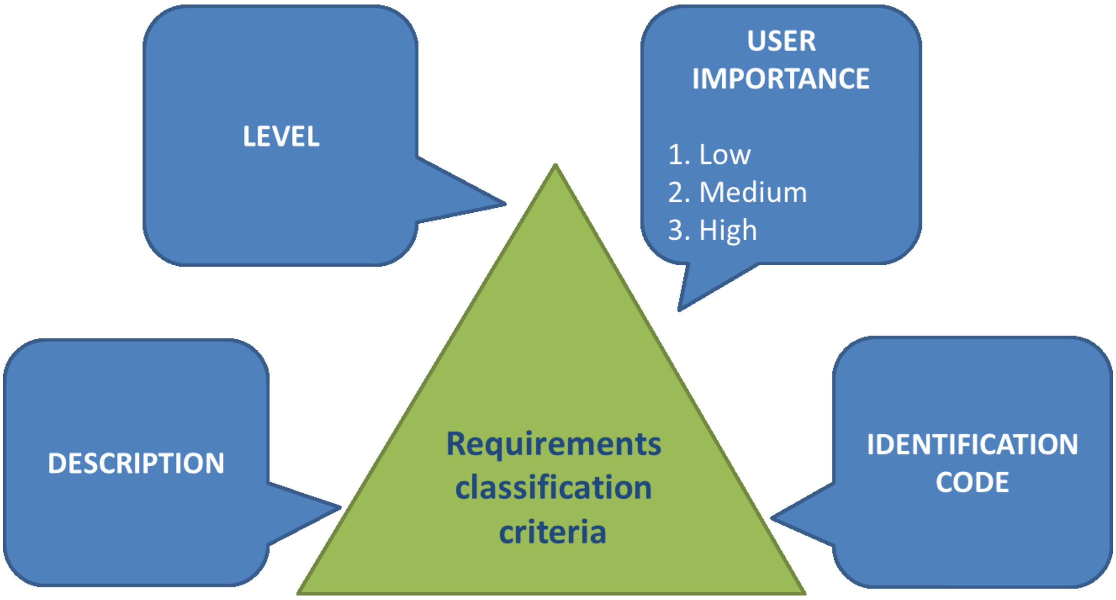

Figure 2 Requirements classification criteria

The user requirements extracted for each pilot scenario are to be classified into three main categories:

- Functional requirements: functionality of the product
- Non-functional requirements
- Integration: restrictions and limitations that apply to the project and the system.

For each category of requirements, a list of information is to be compiled:

1. Identification code: an unambiguous code obtained joining the pilot name and a sequential number
2. Description: a description in natural language of the requirement
3. level of requirement (Functional Requirements, Non- functional Requirements, Constraints
4. User Importance: a number showing how important the requirement is for the user :

    - 1 = low; (could be implemented after the end of the project)
    - 2 = medium; (to be decided at later stages whether to be implemented or not within the project time)
    - 3 = high (must be implemented within the project time)

Requirement code	Description	Level	User importance
CSIFunReq.1	NRG4Cast will provide the necessary interface to register the sensors	Functional	High=3

Table 1 An example of information to be provided for each NRG4Cast requirement

2.2.1.3 Phase 3. Requirements integration, selection and check

The next action aims at integrating the user preliminary requirements into unique list of final user requirements. The preliminary requirements gathered from each pilot will be organised taking into account the description as well as the user importance and the user need. Requirements that describe similar functionalities will be generalised and merged, producing the System Requirements, which will cover all of the functionalities expressed. During this phase, other requirements might emerge, which, not being foreseeable from the end-user's point of view, were not expressed in the preliminary requirements, but considered necessary by the project team. Moreover requirements emerging from the generalisation of the user requirements will be added, as well as financial requirements.

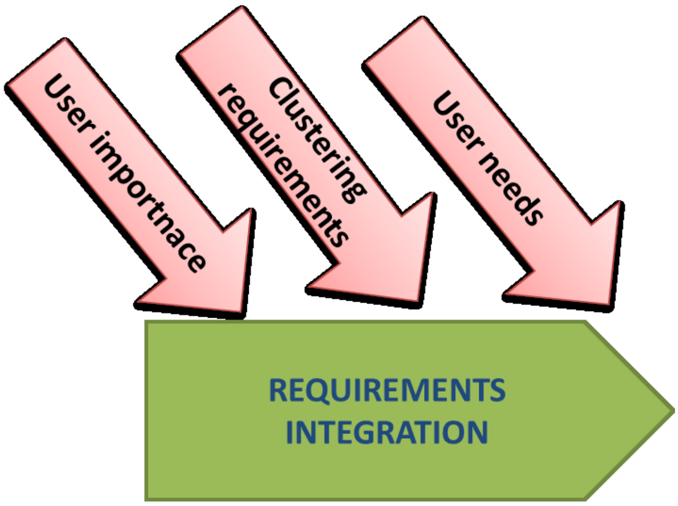

Figure 3 Requirements integration criteria

The requirements and specifications are to be analysed by the NRG4Cast team for completeness and feasibility. The selection criteria include measures about user importance gained appropriately from preliminary user requirements ratings. During this phase the team has to resolve the ambiguities, discrepancies, in order to validate the requirements or specifications (Figure 4),

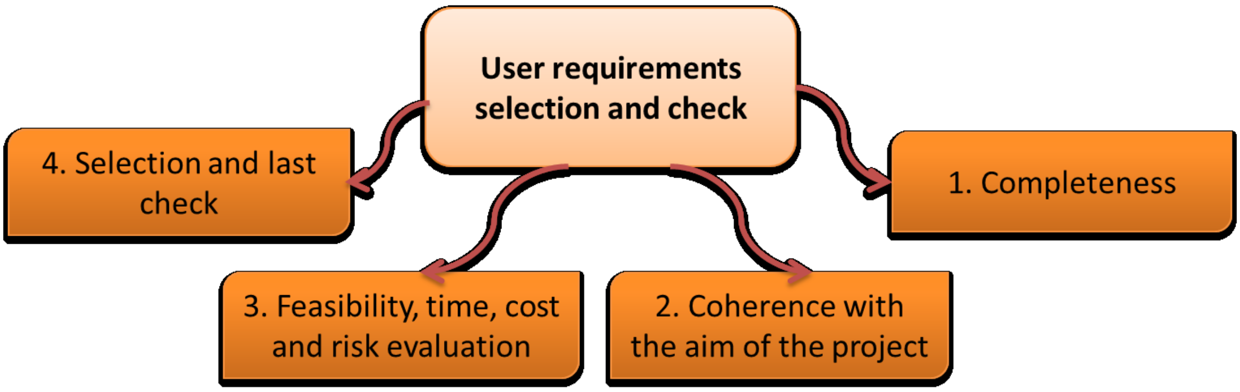

Figure 4 Requirements selection and check process

3 User Requirements

Coherent with the aspired process, the requirements are derived of the case study description and the use case analysis. Therefore each pilot case and use case is examined regarding the dependent requirements. After having defined the requirements definition methodology, this section will identify requirements for each pilot case.

The composition of each section is organized as follows:

- Overview
- Use Case Description: a more analytical description of the To-Be scenario
- User Requirements: the categorized list of user requirements

3.1 NTUA University Campus Scenario

3.1.1 Overview

The National Technical University of Athens includes nine academic schools. The main campus is located in the Zografou area of Athens, housing all the schools of NTUA except Architecture. The main campus spreads over an area of about 770,000 m^2; 260,000 m^2 of them are the buildings. Apart from offices, lecture rooms and laboratories, the campus hosts also the Central library, a sports centre, a conference centre, a restaurant and cafes. The annual energy demand of the NTUA campus is:

- Installed heating capacity 25 MW. There are 42 LV boards in different buildings for the heating loads.
- Installed cooling capacity 14.5 MW. Heat pumps account for 70% of the total.
- Annual electricity demand: 16000 MWh (6.1MW peak)
- Annual thermal demand: 8100 MWh

The objective of the NTUA pilot plant is firstly, to monitor the energy consumption of the whole Campus and secondly, to be able to predict its energy demands. To this end, electricity meters and natural gas flow meters are scheduled to be installed across all Campus buildings. Furthermore, an office will be monitored, in terms of thermal comfort level, so temperature sensors, relative humidity sensors and lux meters will be installed. The measuring data will be used as inputs for the energy forecasting software that will be developed in the framework of this project. For demonstration purposes, a screen will be installed in the Rector's building that will show the real time energy consumption of the NTUA campus.

The geographical location of the electricity sensors is illustrated in the following map:

Figure 5 NTUA Campus map showing the lodges of the electricity meters

3.1.2 Use cases

3.1.2.1 Use Case 1. Pilot Plant installation and configuration

Primary actor

The primary actor is the *NRG4Cast Administrator.*

At NTUA this role will be held by the Assistant Professor Koronaki Irene and the research personnel of Laboratory of Applied Thermodynamics, Thermal Engineering Section, School of Mechanical Engineering. Access to the pilot plant will also have the technical personnel of the NTUA and the building managers.

Goal in context

The objective of the NRG4Cast pilot plant in NTUA is to provide to all possible stakeholders (Rector, Energy Management Commission, Building managers, Students) the necessary information on the energy consumption of the Campus, the thermal comfort level and the prediction of energy demand, with the view to assist in the energy management and decision making process. Specifically, the information that will be produced will be used to select the best cost-efficient measures for building renovation, to upgrade or to implement maintenance services to the heating, ventilation and air-conditioning systems, to select the optimum renewable energy solution for the Campus, to select the most profitable electricity provider for a specific amount of time and to inform the employees/building users on the energy consumption in their building.

More specifically, the NRG4Cast pilot plant in NTUA will improve the energy management of the Campus through the following actions:

- Increasing the quantity and quality of electricity data, by exploiting existing monitoring systems and installing new monitoring systems.
- Ability to measure the actual gas consumption, through installation of a natural gas flow meter.
- Ability to evaluate the thermal comfort level in an indicative office, through the installation of temperature sensors, relative humidity sensors and lux meters.
- Better energy management through data analysis and forecasting of energy consumption.
- Production of energy consumption reports in daily, monthly and annual basis, addressed to all stakeholders or to a specific stakeholder group.

The NRG4Cast pilot plant in NTUA includes the following activities:

- Acquisition and installation of electricity sensors for all buildings in the Campus,
- Acquisition and installation of a natural gas flow meter for measuring the gas consumption in a group of buildings in the Campus,
- Acquisition and installation of sensors for measuring the thermal comfort level in an office in the Campus,
- Development of a data acquisition system to collect and integrate data from different network topologies and heterogeneous sources (sensors, online databases, existing applications and services) into the same architecture,

Use case steps

- The *NRG4Cast Administrator* installs the NRG4cast solution
- The *NRG4Cast Administrator* through a specific interface registers the (installed) sensors in NRG4cast system

Trigger conditions

- Identification of the decisions and goals to achieve through NRRG4Cast
- Identification of sensor needs and information sources

Success End Condition

- System installed and ready for use

3.1.2.2 Use Case 2. User management

Primary actor

The primary actor is the *NRG4Cast Administrator*

Goal in context

The objective is to register users for NRG4Cast system. Users will have different roles depending on the access and view (for information) rights as well as on the actions to perform.

The *NRG4Cast Administrator* will be the default user created when NRG4Cast is installed. Then the *NRG4Cast Administrator* is responsible to define roles, rights per role and assign them to real users.

Use case steps

- The *NRG4Cast Administrator* creates a new role in NRG4Cast
- The *NRG4Cast Administrator* assigns rights per role (edit, view, act) on different functionalities
- The *NRG4Cast Administrator* creates a new user
- The *NRG4Cast Administrator* assigns a role in the user

Trigger conditions

- Installation of NRG4Cast solution
- Creation of *NRG4Cast Administrator* as default user by the system

Success End Condition

- Successful user creation
- The User enters NRG4cast with his/her credentials and works according to his/her role assignments.

3.1.2.3 Use Case 3. Integrate different data sources

Primary actor

The primary actor is the *NRG4Cast Administrator*

The data integration and management tool will be developed from the related project partners. The users of the NRG4Cast data integration and management tool will be the Assistant Professor Koronaki Irene and the research personnel of the Laboratory of Applied Thermodynamics, Thermal Engineering Section, School of Mechanical Engineering.

Goal in context

The objective is to develop a software tool that, by using the installed sensors (use case 1), will integrate, analyse and visualise the data, produce energy reports & graphs and predict the energy demand of the Campus. More specifically, the NRG4Cast data integration and management tool will implement the following actions:

- Integrate and store all data from all existing sensors and existing data sources:
    - meteorological data,
    - occupancy schedule,
    - Lampadario building
    - Hydraulics building
    - Central Library building.
- Integrate and store all data from the newly installed sensors:
    - electricity data (2 power, 3 volts, 3 amperes, 1 cosϕ), at regular intervals.

- thermal comfort data, at regular intervals.
- natural gas data (real time data m³, real time data kWh, total consumption m³, total consumption kWh), at regular intervals.

Use case steps

The *NRG4Cast Administrator* through a specific interface selects:

- The data sources (database, files, etc.) to be integrated
- The data source location

Frequency

- The electricity data will be gathered, shown and stored regularly.
- The thermal comfort data will be gathered, shown and stored regularly.
- The natural gas data will be gathered, shown and stored regularly.

Trigger condition

- Implementation of energy consumption study in NTUA campus,
- Implementation of building/HVAC renovation measures,
- Selection of the most profitable electricity provider,
- Dissemination on energy efficiency,
- Informing the building users on their energy consumption.

Success End Condition

- Successful integration of data sources - Data flow from sources to NRG4Cast solution

3.1.2.4 Use Case 4. Navigation through a data visualisation environment

Primary actor

NRG4Cast user

The data visualisation environment addresses not only the research personnel of the Laboratory of Applied Thermodynamics, but also all of the NTUA community, students, engineers, decision makers and citizens.

Goal in context

The objective is to visualise the data taken from the data integration and management tool (use case 2) in a user friendly way. More specifically, the basic characteristics/demands of the data visualisation environment are:

- The initial page of the program will be the NTUA campus map.
- The displayed information (in clickable buttons) are:
  - Meteorological data,
  - Total NTUA's real time electricity & natural gas consumption (kWh),
  - Each building's real-time electricity & natural gas consumption (kWh/m2)
  - Level of achievement of thermal comfort.
- At each button, the user can click and see the data summary of each sensor.

- Another page that should be available is a List of all available data (real time and consumed).
- The initial page of the program will be displayed in an LCD display screen installed in the Rector's building.
- The initial page should be able to be uploaded in the NTUA website for dissemination purposes.

Use case steps

- The *NRG4Cast Administrator* opens NRG4Cast main screen
- The *NRG4Cast* Administrator selects the visualisation of the campus
- The *NRG4Cast Administrator* clicks in each of the information pop-ups presented in different locations of the campus map
- The *NRG4Cast Administrator* retrieves and sees detailed information of each sensor measurements summary

Frequency

The initial page will be refreshed based on a time that has been preconfigured by the user.

Trigger condition

- Implementation of energy consumption study in NTUA campus,
- Selection of the most profitable electricity provider for NTUA,
- Dissemination on energy efficiency measures.

Success End Condition

Continuous update of NTUA consumption status level from visualised sensors

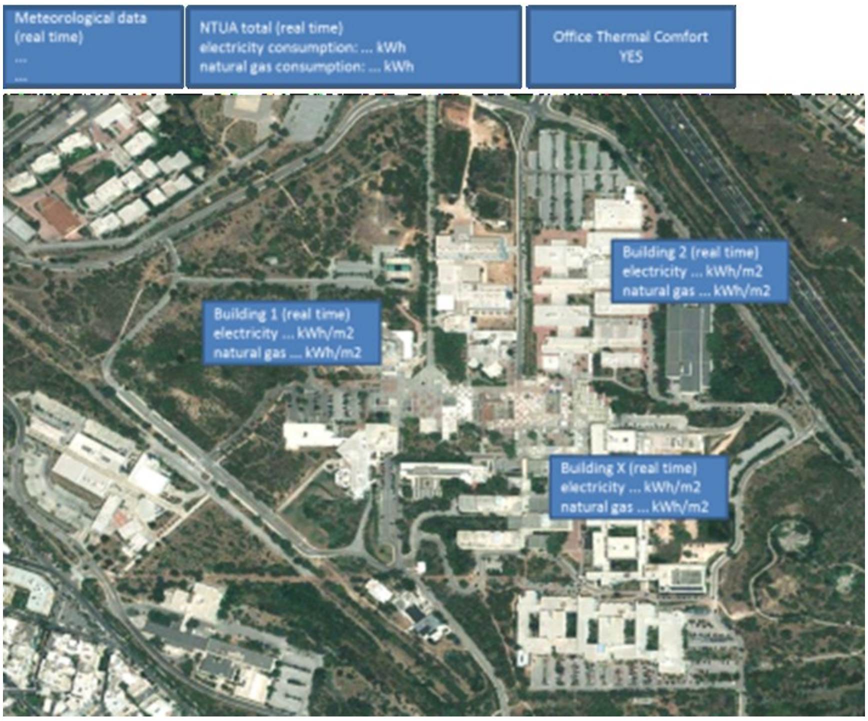

Figure 6 The initial page of the program

3.1.2.5 Use Case 5. Reporting

Primary actor

NRG4Cast User

Reporting will be implemented, to a detailed extent by the research personnel of the Laboratory of Applied Thermodynamics, and to a lesser extent by all NTUA community, students, engineers, decision makers and citizens. The energy reports created automatically or by the research personnel of the Laboratory will be delivered to the NTUA Energy Management Commission and to the Rector, for the necessary decision making process.

Goal in context

The objective is to use a tool that will sufficiently manage the data taken from different sources (use case 3). This considers production of energy reports, graphs and exporting data in a user friendly manner. More specifically, the basic characteristics/demands of the reporting process are:

- Development of diagrams
  - Built-in: Ideally, there will be three built-in diagrams showing the total electricity consumption of NTUA from the start date, the total natural gas consumption (kWh) from the start date and a psychrometric diagram showing the states of the office and the thermal comfort range. There will be an “advanced” button, that when clicked, electricity consumption diagrams for each building will be shown.
- Development of energy reports (indicative examples)
  - Built-in: on a daily, monthly and yearly basis. Will include different consumptions (e.g. electricity, gas) of all Campus and the monthly reports in a group of stakeholders.
  - User-defined: The user can choose the time period and create energy reports (for example, the user should be able to produce an each building separately.
  - Possibility of automatically sending
  - Energy report for the first semester.
- Exporting data in xml format.

Use case steps

- The *NRG4Cast User* opens NRG4Cast main screen
- The *NRG4Cast User* selects to produce a report
- The *NRG4Cast User* defined the report type and parameter
- *NRG4Cast* produces the report

Frequency

- The built-in electricity diagrams will be refreshed regularly.
- The built-in gas consumption diagrams will be refreshed regularly.
- The psychrometric diagram will be refreshed regularly.
- The built-in energy reports will be produced on a daily, monthly and yearly basis.

Trigger condition

- Implementation of energy consumption study in NTUA campus,
- Selection of the most profitable electricity provider for NTUA,

- Implementation of building/HVAC renovation measures,
- Informing the building users on their energy consumption.

Success End Condition

Produced reports

3.1.2.6 Use Case 6. Energy Forecasting

Primary actor

NRG4Cast User

The energy forecasting tool will be used by the research personnel of the Laboratory of Applied Thermodynamics. The energy forecasting reports created automatically or by the research personnel of the Laboratory will be delivered to the NTUA Energy Management Commission and to the Rector, for the necessary decision making process.

Goal in context

The objective is to create a tool that will sufficiently predict the energy demand of the NTUA campus in Zografou. The energy forecasting includes the production of reports and graphs.

Use case steps

- The *NRG4Cast User* selects from the main menu to get an energy consumption forecast
- When selected, the *NRG4Cast User* can:
    - Draw graphs of the same data (i.e. gas consumption in building X) but for different time periods (i.e. first semester in 2013 and 2014).
    - Draw graphs according the ambient state and occupancy. The *NRG4Cast User* will give inputs of ambient state (temperature, solar radiation) and occupancy schedule (weekday, Saturday or Sunday) and the program can search the historical data and give outputs of the expected kWh for electricity and heat for that day.
- Produce energy forecasting reports for a desired time period.
- NRG4Cast sends the report to other users/user roles.

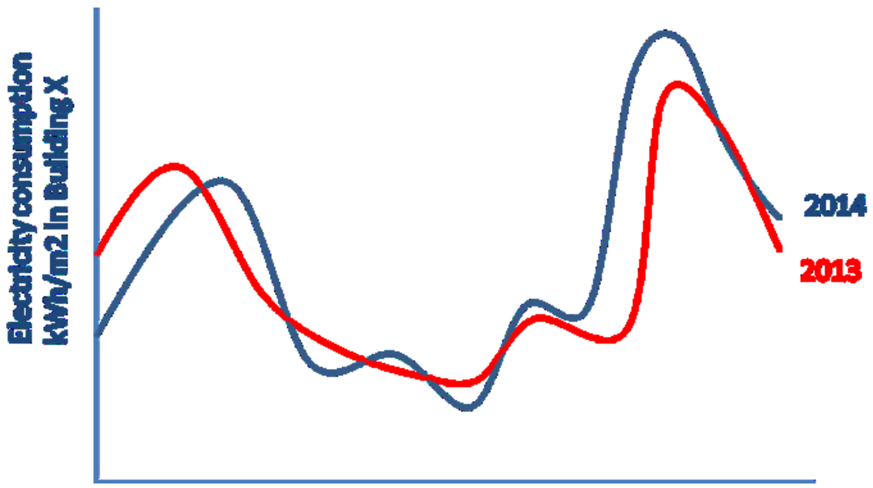

Figure 7 A graphic example of the energy forecast potential of the program

Frequency

On trigger condition

Trigger condition

- Implementation of energy consumption study in NTUA campus,
- Selection of the most profitable electricity provider for NTUA.

Success End Condition

The successful development of the forecasting tool lies on the detailed definition of NTUA's objectives and the cooperative spirit between project partners.

3.1.2.7 Use Case 7. Public view/ public data

Primary actor(s)

NRG4Cast Administrator, Public User

General public for NTUA are students of relative disciplines, building energy managers, software developers, energy companies, architects/engineers, decision-makers.

Goal in context

The goal is that public data for energy consumption at NTUA will be available to different stakeholders; the engineer's community should be informed on the installed pilot plant in NTUA, on the energy consumption of the Campus, on the energy forecasting potential and on the measures implemented to reduce the excessive energy consumption. The public interface will have limited capabilities:

- Visualise the basic data in a user-friendly environment, as described in Use Case 3
- Built-in energy consumption and thermal comfort diagrams, as described in Use Case 4
- Built-in energy reports in daily, monthly and annual basis, as described in Use Case 4

Public information and access to this will be defined by the User Administrator.

Use case steps

- The *NRG4Cast Administrator* selects to define access rights in specific information type(s).
- The *NRG4Cast Administrator* marks the information type(s) as "public", restricted".
- The *NRG4Cast Administrator* saves the entries.
- The *Public User* enters the web interface of NRG4Cast.
- The *Public User* views the public information type(s).

Trigger condition

- Energy analysis in a group of buildings
- Public information regarding NTUA's energy consumption

Success End Condition

View of public information from public users

3.1.3 User Requirements

3.1.3.1 Functional Requirements

Requirement code	Description	Level	User importance
NTUA.FunReq.1	Manually register sensors	Functional	3
NTUA.FunReq.2	NRG4Cast creates by default an *NRG4Cast Administrator*	Functional	3
NTUA.FunReq.3	The *NRG4Cast* Administrator will be able to create a new role	Functional	3
NTUA.FunReq.4	The *NRG4Cast* Administrator will be able to assign rights to a role	Functional	3
NTUA.FunReq.5	The *NRG4Cast Administrator* will be able to create a new user	Functional	3
NTUA.FunReq.6	The user should have an interface thought which will define the information sources to be integrated with NRG4Cast	Functional	3
NTUA.FunReq.7	The user will be able to define the frequency of retrieving measurements from each sensor/ information source	Functional	3
NTUA.FunReq.8	The users will be able to view the campus in a map illustrating also the sensor locations	Functional	3
NTUA.FunReq.9	The users will be able to view the campus in a map illustrating also a summary of each sensor	Functional	3
NTUA.FunReq.10	The user will be able to view 3d plan of office in case of thermal comfort summary	Functional	1
NTUA.FunReq.11	The user will be able to define the frequency under which the overall map of the campus will be refreshed with new metrics (from sensors)	Functional	1
NTUA.FunReq.12	The user will be able to retrieve reports on energy consumption	Functional	2
NTUA.FunReq.13	The user will be able to export reports in different formats	Functional	2
NTUA.FunReq.14	The user will be able to share reports with other actors/roles	Functional	2
NTUA.FunReq.15	The user will be able to define the frequency on which produced reports are refreshed	Functional	2
NTUA.FunReq.16	NRG4Cast will create prediction of energy consumer upon request by the user (per consumption type)	Functional	3

Table 2 Functional Requirements for the NTUA pilot plant

3.1.3.2 Non - Functional Requirements

Requirement code	Description	Level	User importance
NTUA.NonFunReq.1	System appearance: simple, not confusing and user-friendly.	Non-Functional	3
NTUA.NonFunReq.2	System appearance in accordance with the Contents; for uniformity, the order of information seen on the screen should be equal to the order of the Contents.	Non-Functional	3
NTUA.NonFunReq.3	Explanation text in all cells/columns, "User Guide", "Help" section, "Contents" and "Glossary".	Non-Functional	2
NTUA.NonFunReq.4	System performance: minimum response time, but whenever this is not possible, a window should appear that would inform the user of the time needed to perform the task. The accuracy of measurements/data should be also present.	Non-Functional	2

NTUA.NonFunReq.5	System operation: The software will be installed in a PC with Microsoft Windows Server 2003 or newer, Core i3 processor, 2.5 GHz speed, memory DDR3 4 GB and 500 MB capacity. The PC will be installed in an office in the Mechanical Engineering School in NTUA campus and will have internet access through Ethernet cable.	Non-Functional	3
NTUA.NonFunReq.8	The system should operate in two languages; English and Greek.	Non-Functional	2
NTUA.NonFunReq.9	System updates: automatic updates	Non-Functional	1
NTUA.NonFunReq.10	There should be a system log file that will assist in failure/bugs handling.	Non-Functional	1
NTUA.NonFunReq.11	Software driver or download software for installation	Non-Functional	3
NTUA.NonFunReq.12	System security: The data should be accessible only to authorised users in NTUA campus.	Non-Functional	3

Table 3 Non - Functional Requirements for the NTUA pilot plant

3.1.3.3 Application mapping and constrains

The mapping of the application can be seen in the following figure 8 :

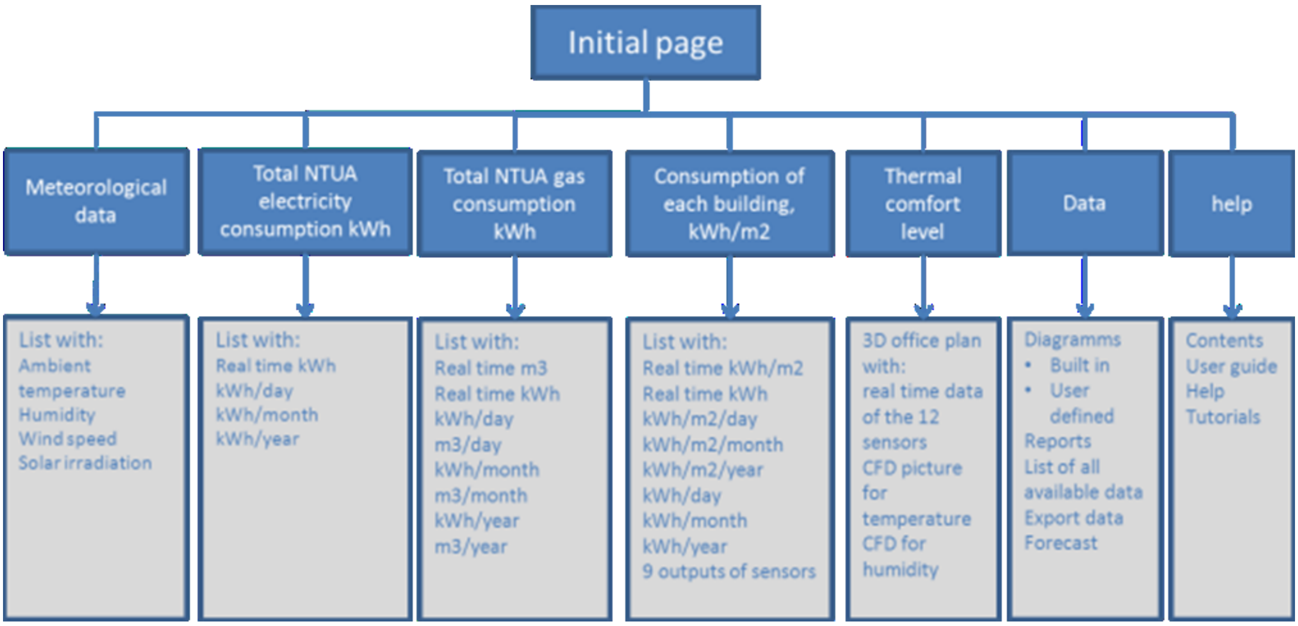

Figure 8 The map of the application developed for NTUA pilot plant

3.2 MIREN Pilot scenario

3.2.1 Overview

The Miren pilot is organized by ENVIGENCE. The company operates the first large scale cognitive network of smart sensor nodes based on public street light infrastructure. The installation is set in rural community environment.

Miren-Kostanjevica municipality is a small municipality (area 64 km2, population of 4790) in Slovenia bordering Italy. The municipality has installed 1000 new public lights with very low consumption. ENVIGENCE has updated the public light infrastructure with wireless multi-sensor nodes on every streetlight (distance between the sensors nodes is 25-30m) in the area that covers two small cities and several villages. This is the first installation of such kind in the world that will be equipped with more than 1000 sensors. These sensors will be able to measure different environmental parameters. Based on the needed scenario the following sensors can be applied (Temperature, Humidity, Luminance, Color, Reflectance, Pressure/Force, Camera, Optical Detector, GPS, Sound (noise), Accelerometer (vibration), Gas (O2, CO2, CO, N2O, CH4, SO2), Hall effect, Motion, presence, range (IR, ultrasonic), Capacitive/inductive touch, Gyroscope, Compass).

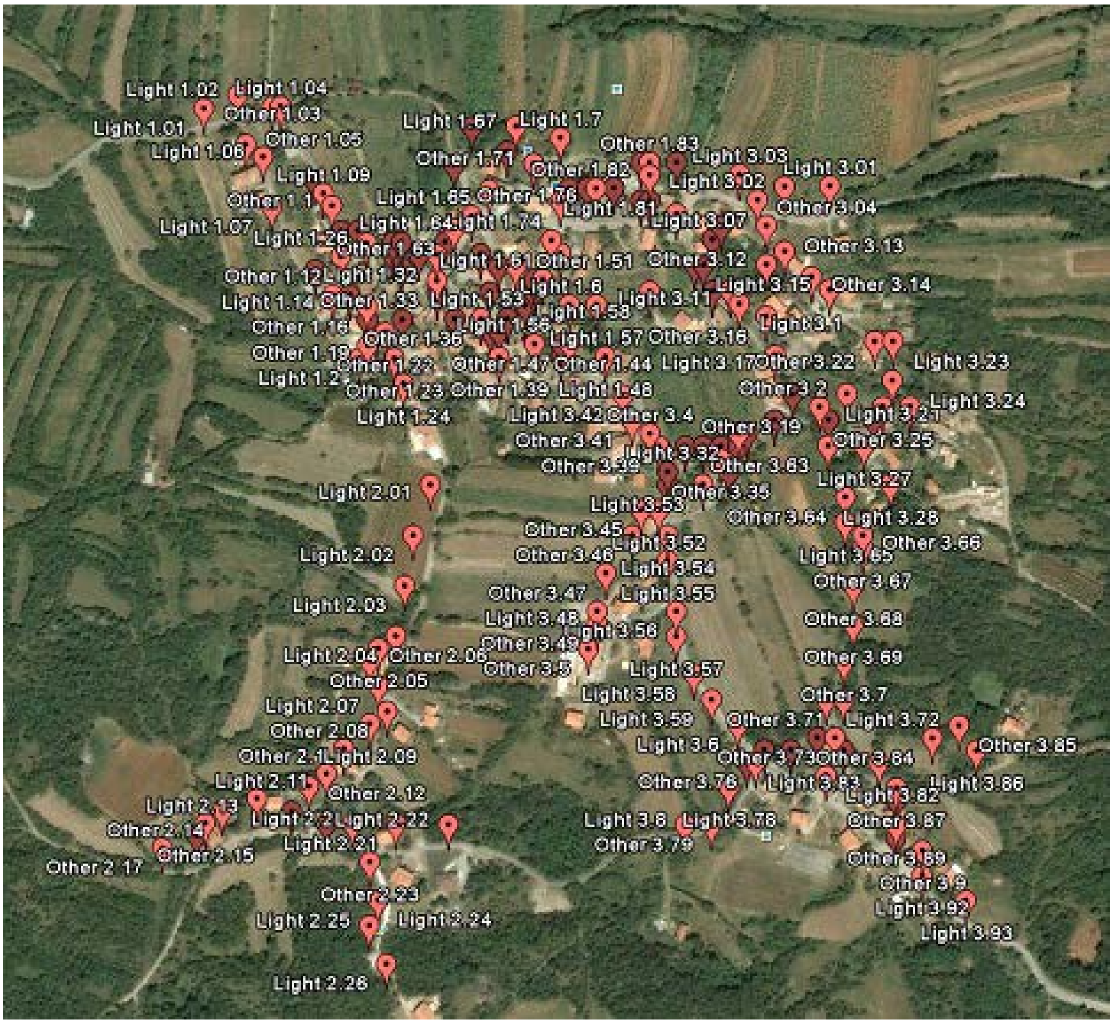

Figure 9 Miren city sensor network (Miren-Kostanjevica by ENVIGENCE)

The actual network is managed by ENVIGENCE's application for monitoring and managing the wireless sensor network. The application allows data collection from the integrated sensors and enables the facility manager to change the network's behavior by sending control commands to particular actuators like dimming etc.. With this approach the usage of electricity by the public light infrastructure can be monitored and controlled dynamically. The present and future efficient use of the purchased energy , can be achieved by predicting the demanded consumption levels. Such predictions allows planning, purchasing and the possibility of relocating already committed energy volumes locally.

ENVIGENCE is already implementing several artificial intelligence methods in order to enable an automatic management system which is able to achieve multiple objectives. In particular: improved energy efficiency, smaller carbon footprint and thereby the increased comfort of the citizens.
The municipality also benefits from a shared infrastructure that supports deep sensing, responsive control in real-time, and high-speed flexible networking.

The network is being expanded to other municipality infrastructures in order to provide a complete overview and management tools. The figure 10 visualizes the idea for this strategy.

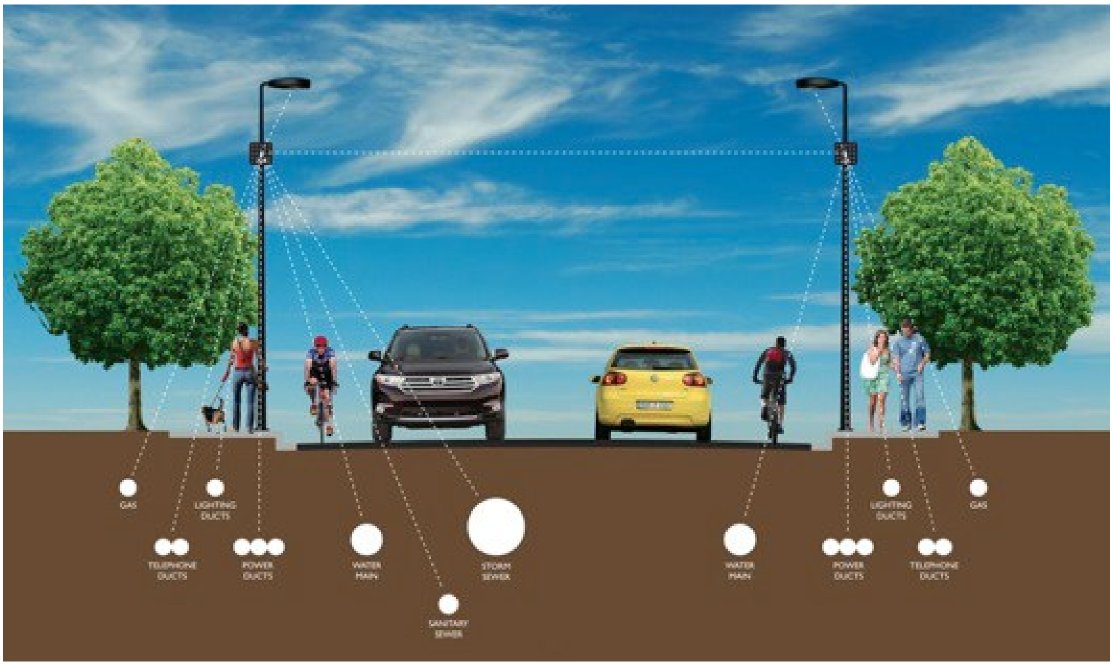

Figure 10 Managing municipality infrastructure (by Envigence)

<u>Expected impact from NRG4Cast</u>

In the sequence of steps for this strategy, the prediction of energy demand and the optimisation of energy consumption and thereby the reduction of energy costs based on these predictions, is of outstanding significance. The NRG4Cast pipeline will be installed in the Miren-Kostanjevica test bed and several scenarios towards energy positive neighborhoods will be tested:

- Energy cost reduction by planning and tracking the energy demand in the municipality and establishing real-time bidirectional communications between energy suppliers and consumers.
- Pricing and regulatory innovation that gives incentives for consumers and producers to invest in energy efficiency. This can include transparent dynamic pricing to the consumer, reflecting variable wholesale rates that include environmental cost and regulatory encouragement for utilities to pursue energy efficiency, such as tax benefits for shareholders.
- Intelligent households, electric cars, energy positive factories, whose devices and appliances energy-efficient, networked, responsive to their environment and costs of use.
- Innovative markets based on accurate behavioral models to ensure that regulations are self-sustaining and produce the desired energy efficiency outcomes. These markets can affect supply

and consumption directly or indirectly by way of building and equipment codes and inspection regimes.

ENVIGENCE offers various web-based informative services and tools on energy efficieny issues to municipalities. These services are addressed to the public administration and the citizens. These systems have been created to improve energy efficiency targets by gathering multimodal energy data, implementing sustainable energy action plans, and developing scenarios analysis for energy efficient interventions. The main functions of the system are:

- Data collection from remote sensing networks such as power consumption data gathered from street lights, luminance level, quality of electricity on the power line etc…
- Real time analysing and monitoring of the collected data
- Manual or semi-automatic operation. (Based on artificial intelligence the implemented systems an collect data and can make independent decisions based on the gathered data.)
- Bi-directional communication between the sensing network and the applications.

<u>AS IS Situation for MIREN pilot case scenario.</u>

ENVIGENCE Lighting Network (ELN) is an intelligent public lighting solution

The components of the ELN are:

- Modern LED light engine, driven by state-of-the are driver/controller
- Dimming control (10-100%)
- Power consumption data collection
- Remote control/monitoring via RF communication
- Compatibility: easy integration with other sensor types
- Data collection, analysis and predictions in back-office application

Figure 11 MIREN pilot site

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ELN Remote Control and Monitoring, Analysis and Prediction

The modern technology allows us to deploy small and intelligent devices in each street light. These devices are connected to the monitoring application on the central site and are able to receive and execute commands like dimming level change, on-demand collection of consumption data etc… They can also collect measurement data from other sensor devices integrated into the ELN.

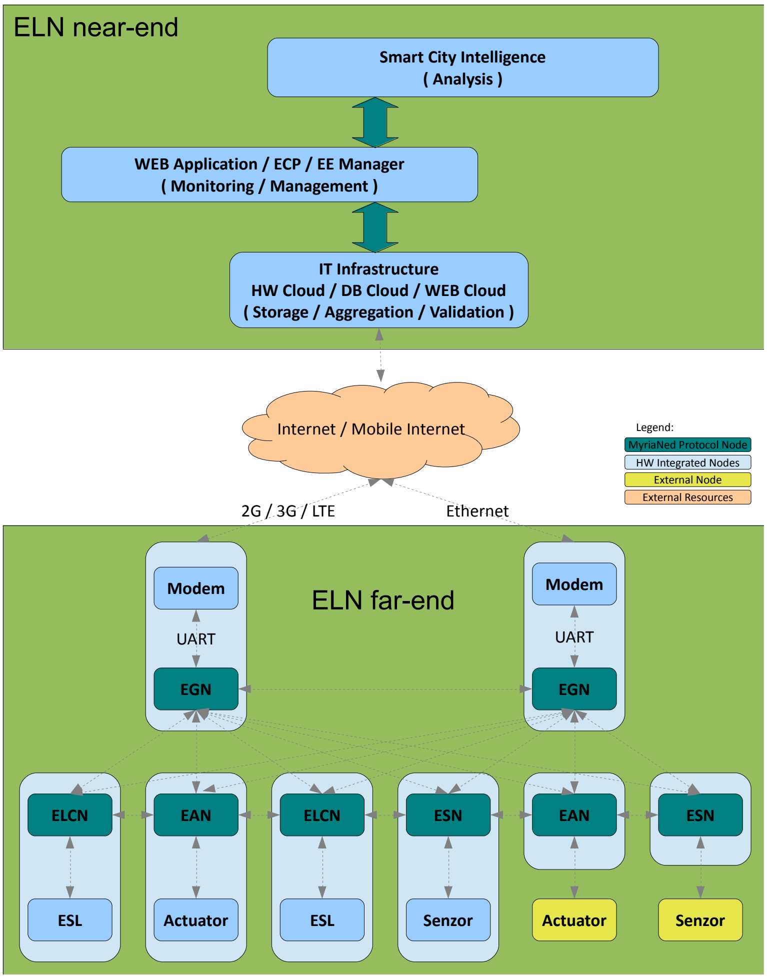

Figure 12 ELN Remote Control and Monitoring

On the central location maintenance staff and facility managers can monitor the public lighting infrastructure. They use the tools to:

- Collect general status reports
- Generate usage reports
- Simple predict future consumption
- Identify faulty units
- Plan interventions

The data collected on the field is sent to the central location utilizing mobile or fixed internet connections.

The building blocks of the ELN installed on the field are:

- EGN, Gateway Node
- ELCN, Light Control Node
- EAN, Actuator Node
- ESN, Sensor Node

All ELN nodes are communicating with each other. They form a mesh network when powered on and without manual intervention or planning find the communication path to the central application.

Figure 13 Envigence Control panel

ELN Features

Stand Alone Operation

ENVIGENCE Street Lights can be installed on remote areas, even in places where there areno ELN neighbours and communication with the central site is not possible. In such situations the light will be controlled by its built in Stand Alone Operation mode, which allows basic dimming control.

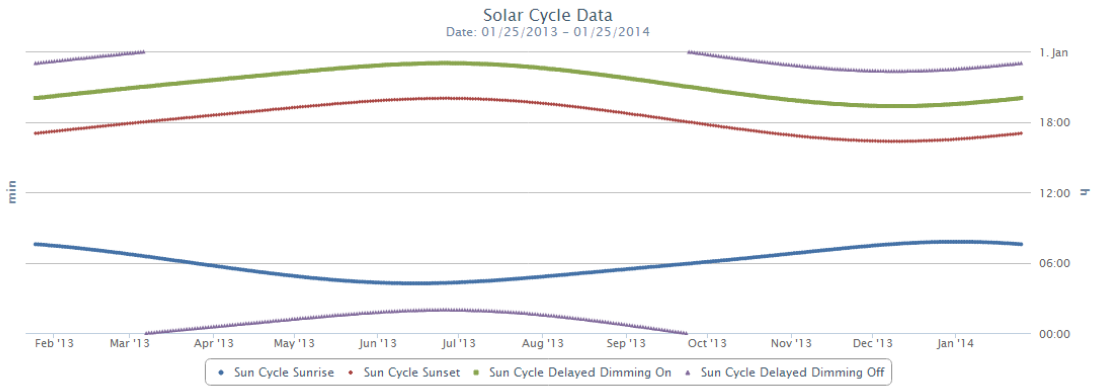

Figure 14 Stand Alone Operation impact chart

The chart (Figure 14) indicates the impact of the Stand Alone Operation. At predefined time interval after sunset the Stand Alone mode activates and for a predefined duration dims the lights. This reduces the power consumption of the light at times where full illumination is not required.

Security

Communication between ELN nodes is secured by a 128bit AES encryption.

Dimming

ELN allows continuous dimming between 10-100%. Individual lights or group of lights can be dimmed at the same time. The facility manager can decide to implement different dimming profiles on different geographical locations, streets, playgrounds, industrial areas etc..

Consumption measurement, analysis and prediction

The integrated Hall-effect sensor allows continuous measurement of the consumption. The measurement data is collected at predefined intervals (15 minutes typical) also measurements are triggered at reaching predefined thresholds (too high or abnormally low consumption, indicating LED or driver failure). Measurements can also be triggered manually by remote control. The data is collected on the central location. The facility manager has overview of the consumption in different granularities. So he can drill down to group of lights, streets and can check consumption of individual lights. The data is stored for longer periods allowing historical trend analysis. This data is also used for predicting future consumption trends and providing municipalities with cost estimations for the future.

User management and security

Users in ELN are assigned different rights when working with the monitoring applications. Depending on their access rights they have access to view, modify, analyse or to export data stored in the system.

Inventory and Lifetime management

The system provides inventory management. Modifications, replacements and repairs can be logged and their history can be monitored and analysed. Reports ot the working hours, types of devices, their installation date, their consumption etc. can be produced and exported for further analysis.
ELN provides basic reporting but customized reports based on the information stored in the system or fetched from external sources can easily be integrated and used to provide more comprehensive reports to facility managers.

<u>TO BE Situation for MIREN pilot case scenario</u>

To be situation for MIREN pilot scenario is to be able to predict its energy demands and simulates the consumption for next 1 hour, regarding different restrictions. This will be the basis for an automatic management mode, controlled by an artificial intelligence.

In this management mode, public lighting is managed by ELN automatic system. Parameters for this management are:

1. **Internal fixed restrictions** that can be changed only by human administrator,
2. **External fixed restrictions** that are gathered and processed periodically and are fixed when processed,
3. **Internal triggers** that are gathered in real time by ELN network,
4. **External triggers** that are gathered in real time by third parity,
5. **Self-generated (AI) rules**.

1. Internal fixed restrictions

Internal fixed restrictions are certain rules that are entered in software and are regulated by government laws or by municipality policy. These rules are inserted in system and are fundamental rules that cannot be overridden by system decisions.

Examples:

1. Regional roads that connect cities may not be dimmed,
2. Pedestrian crossings should be illuminated more than roads,
3. Crossings should be illuminated more than the continuous roads,
4. City centres should not be dimmed on special occasions (New year, …),
5. Some street lights should be dimmed due to citizen requests.

2. External fixed restrictions

External fixed restrictions are certain rules that are gathered and processed periodically and are fixed when processed. These rules are inserted in system periodically (daily, weekly or monthly) depending on type of data. These rules cannot override internal fixed restrictions.

Examples:

1. Traffic density depending on road type gathered by external counting company,
2. Moon light effect,
3. General weather setting (gathered and processed from meteorology data),

4. Daytime for specified location (depending on Longitude and Latitude),

3. Internal triggers

Internal triggers are certain triggers that are gathered from ELN network sensors. These triggers are processed in real time depending on type of trigger. These cannot override internal fixed restrictions but may override external fixed restrictions.

Examples:
1. Traffic density depending on ELN sensor,
2. Fog detection ELN sensor,
3. ELN Weather detection sensor,
4. Other ELN sensors.

4. External triggers

External triggers are certain triggers that are gathered from other network sensors. These triggers are processed in real time depending on type of trigger. These cannot override internal fixed restrictions but may override external fixed restrictions.

Examples:
1. Current electricity price,
2. Current electricity demand,
3. Electricity quality,
4. Traffic crash is reported,
5. Other sensors third parity sensors,
6. Traffic density depending on traffic sensor,
7. Fog detection sensor,
8. Weather detection sensor.

5. Self-generated (AI) rules

Self-generated (AI) rules are certain rules gathered from all data and processed periodically (monthly). These rules cannot override internal fixed restrictions. New rules are generated from processed data.

Examples:
1. Dense traffic in some parts of city is detected from 22.15 to 22.45. To save hardware illumination rises slowly from 22.00 to 22.15 and drops slowly from 22.45
2. If fog is detected/reported many times on certain spot new rule for that part of road is generated,
3. If certain connectivity between weather and street lamp failure is detected system tries to prevent the hardware,
4. If street lamp is constantly overheating or shutting down alerts are implemented,
5. Optimization for electricity consumption is implemented.

3.2.2 Use cases

3.2.2.1 Use Case 1. Installation additional sensors and additional analysers

Primary actor

Street lights network operator

Goal in context

Improve the quality of the electricity measurements. Both their contents (new counters) and the granularity (currently daily collection, measurements are planned every 15 minutes). The collected data should indicate any discrepancies, none-compliance with standards, interruptions, flickers. Such discrepancies should be used to predict future power consumptions, life-time erosion etc.

Trigger Condition

Current public lighting infrastructure does not allow cost efficient operation. Maintenance routines are ad-hoc, oversized or not sufficient. Equipment is installed and swapped on an individual per case basis without keeping history of the events or analysing trends.

Success End condition

The new scenario should empower facility managers to perform cost efficient maintenance on the public lighting infrastructure, perform repairs on lights when and where needed. Maintenance routes can be planned in advance, can use optimised routes to reach as many locations with as little travel possible. Facility managers can also prioritise areas of interest and perform tasks based on the location's priority.

3.2.2.2 Use Case 2. Automatic AI operating mode, Real-time analysis, reasoning and network behaviour prediction

Primary actor

Street Lights Network operator, Smart grid operator

Goal in context

Development of an automatic operating mode based on predictions and optimisation methods that will be able to deal with the mass amount of multimodal data from the sensors and analysers attached to the street lights network and from other external systems in real-time. Specific scenarios will be developed in real-time and with open access to interested stakeholders as follows:

- Energy demand prediction elaborating the information gathered from all the selected data sources by mathematical methods (e.g. simulation and optimisation techniques);
- Self-generated rules for automatic manage of street light network regarding all restrictions for next hour;
- "Order before use" model which will enable the end electricity node to order the needed electricity quantity and quality for the next end process.

Use case steps

- Street Lights Network operator defines rules that are regulated by government laws or by municipality policy and rules that need to be gathered and processed periodically;
- Smart grid operator define standards and norms which define the smart grid;

- Smart Grid operator define requirements for Smart Grid equipment, especially for end smart grid node (end consumer – like street light) and first concentrator node (first concentrator – switcher/meter for one group of street light network);
- The User Administrator through a specific interface defines the data sources (database, files, etc.) and their location to be integrated
- User Administrator, through database process, transfers proprietary internal data recorded by Envigence Energy Monitoring System, as well as data gathered from new installed sensors, into a common relational database provided by an existing web-based service (Envigence CP - the Web based tool for managing street lights network)
- User Administrator, through a set of standard and well-documented Web Services exposes multimodal data gathered by internal and external triggers
- User Administrator provides further web-services (automatic manage of street light network) which connect OGSA-DAI middleware with Envigence relational databases
- User Administrator provides further web-service “Order before use” for Smart Grid Operators

Trigger Condition

Constraining performances of current methods which can deal with limited amount of energy consumption information and can provide few analytical results off-line.

Success End condition

- Users have access to real-time elaborations and predicted scenarios
- “Order before use” working model
- Self-generated rules give back correct rules
- Prediction and optimisation methods give back correct or aleatory results;

3.2.3 User Requirements

3.2.3.1 Functional Requirements

Requirement code	Description	Level	User importance
ENV_FReq1	**Data Acquisition**	**Functional**	**2.7**
ENV_FReq1.1	Identification of the best price of new devices and sensors that gather energy consumption information and improve the quantity, quality and accuracy of the entire building energy data	Functional	2
ENV_FReq1.2	Provision of a planning time to organise the installation of devices and sensors	Functional	2
ENV_FReq1.3	Installation of sensors to record local environmental conditions in real time and analysers for measuring quality of electricity in each transformer station	Functional	3
ENV_Freq2	**Data Treatment**	**Functional**	**3**
ENV_Freq2.1	Provision of artificial intelligence technology for self-generated rules	Functional	3
ENV_Freq2.2	Elaboration of simulating and predicting models for energy demand prediction	Functional	3
ENV_Freq3.3	Final evaluation of the accuracy of results	Functional	3
ENV_Freq3	**Data Visualisation**	**Functional**	**2.7**
ENV_Freq3.1	Implementation of the already existing web-based QRS system in order to include revised data streaming	Functional	2
ENV_Freq3.2	User license definition to gain access to on-line service	Functional	3

ENV_Freq3.3	"Order before use" visualisation model	Functional	3
ENV_Freq3.4	On-line publication of detailed reports on real-time energy consumption, predict scenarios	Functional	3
ENV_Freq4	**Virtual Pilot Site Development**	**Functional**	**3**
ENV_Freq4.1	Upgrade of an EE Monitor platform in which energy consumption data of the virtual infrastructures and correlated parameters are interconnected in real-time	Functional	3
ENV_Freq4.2	Development of real-time analysis, reasoning and network behaviour prediction to identify future patterns of energy demand, and arrange energy saving action plans	Functional	3
ENV_Freq4.3	On-line publication of virtual pilot site results through web-based high technology services.	Functional	3

Table 4 Functional requirements MIREN pilot

3.2.3.2 Non - functional Requirements

Requirement code	Description	Level	User importance
ENV_NFReq1	**Devices and Sensors performance**	**Non Functional**	**3**
ENV_NFReq1.1	Frequency of data acquisition: Electric energy consumption data for street lights will be gathered and shown every 15min, as well as minimum response frequency. .	Non Functional	3
ENV_NFReq1.2	Frequency of data acquisition: Environmental data will be gathered and shown every 1 hour, as well as minimum response frequency. .	Non Functional	3
ENV_NFReq2	**Data Storage Performance**	**Non Functional**	**2.5**
ENV_**NFReq2.1**	Data storage efficiency: The data integration solution should be as fast and flexible as possible.	Non Functional	2
ENV_**NFReq2.2**	Data storage interoperability: The data integration solution should interconnect different systems which use different programming languages, operating platforms, and data formats.	Non Functional	3
ENV_**NFReq2.3**	Open source capability: Aggregate and store the information securely and privately on behalf of the data owner	Non Functional	3
ENV_**NFReq2.4**	Data storage modifiability: The data integration solution should easily get caught of changes in the applications it connects	Non Functional	2
ENV_NFReq3	**Data Elaboration Performance**	**Non Functional**	**2.5**
ENV_NFReq3.1	System usability: The system will be used by researches and technical operators	Non Functional	2
ENV_NFReq3.2	Response Time: The system should provide real-time feedback and analysis results for all users	Non Functional	3

ENV_NFReq4	**Reporting Performance**	**Non Functional**	**2.3**
ENV_NFReq4.1	System appearance: the interface should be as simple as possible. It should user-friendly and not confusing . Explanation text should be provided in all cells/columns, "User Guide", "Help" section, "Contents" and "Glossary".	Non-Functional	2
ENV_NFReq4.2	System maintenance: The system should be able to update automatically when the PC is connected to the internet. If faults appear, they should be automatically sent to the software developers for immediate correction. Backup of the data should be carried out on a daily basis enabling the recovery of data.	Non-Functional	2
ENV_NFReq4.3	System usability: The system will be visualised on-line for all the participating end-users	Non-Functional	3

Table 5 Non-functional requirements MIREN pilot

3.2.3.3 Application mapping and constrains

At the point of the composition of this document, the development of the mapping and constraints within the MIREN case can’t be provided in a correct and complete map.

3.3 CSI Pilot Case Scenario

3.3.1 Overview

The CSI pilot case scenario in the NRG4Cast project is carried out by Environmental Management Area of CSI-Piemonte (Consortium for Information System). CSI-Piemonte is a large ICT organisation specialised in creating innovative public services to support community life and public authority goals and actions.

The environmental management area "natural resources" considers protection and sustainable development strategies as a high profit business for all stakeholders, the costumers (public authorities, environmental agencies, etc.), the citizens, and undoubtedly for the environment. The Consortium wants to improve the process of IT-based tool development and ameliorate the performance of public sector with the developed tools. The primary costumer demand is an efficient and dynamic information service to optimise public actions and promote the dissemination of best practice examples to the community. The citizens' need for code termination in the public administration requires transparency and the open sharing for information. By the provided tools the citizens will be enabled to participate, particularly in issues regarding public incentives and the saving of public expenses.

The consortium offers various web-based informative services and tools on energy efficiently issues addressed to the public administration and citizens. These systems have been created to improve energy efficiency targets by gathering multimodal energy data, implementing sustainable energy action plans, and developing scenarios analysis for energy efficiency interventions. The main applications are as follows:

- The Energy Information System: this system makes available a web-tool for controlling the regional fund given to build renewable energy facilities to the Piemonte Region. It is based on decisional databases in Oracle and Oracle Spatial for geometric functionalities, ESRI ArcIms for delivering dynamic maps and GIS data and services, and specific applications as front-end developed in Java J2EE.
- The SICEE (the Information System for the Energy Performance Certificate of a Building): this system provides on-line services to enrol eligible individuals and companies in the list of professionals authorized to issue energy performance certificates, to pay annual charges, to generate energy performance certificates and to deliver digitally-signed certificates. It is based on operational databases in Oracle 10g and specific applications as front-end developed in Java J2EE and exposed by Apache web server.
- The SIGIT (The Heating Installations Management Information System): the system is a web-based tool for heating plants census, electronic submission and management of audit reports which promote the self-certification of boilers in accordance with the Piemonte Region legislation of 15th October 2009. It is based on operational databases in Postgress 9.0.4, and specific applications as front-end developed in Java J2EE and exposed by Apache web server.
- The Web based tool for energy consumption control and energy saving planning (QRS): this system allows municipalities to automatically load and elaborate energy bills, to generate reports and graphs on consumption monitoring, give suggestions for interventions, savings and to make energy consumption predictions. It is based on operational databases in Oracle 10g and Postgress 9.0.4, and specific applications as front-end developed in PHP.
- The Energy 3D Cadastre for the City of Turin (ENERCAD3D): this data warehouse includes the information of building heating demand, building typologies, building volume and building age. This tool is helpful for the modelling of the energy consumption of public owned building stocks and for carrying out scenario analysis for energy efficiency interventions. It is based on operational databases in Oracle 10g and Postgress 9.0.4, and specific applications as front-end developed in PHP.
- CSIENERGY (CSI Energy Consumption Monitoring System). The consortium monitors the electric energy consumption of the CSI-Piemonte building (216, Corso Unione Sovietica, Turin) in real time. The measurements are managed by means of Schneider Electric software (PowerLogic ION

Enterprice), which basically helps to track real-time power conditions, record historical trend and allocate costs of buildings through sophisticated load aggregation and arithmetic calculation. Moreover, Schneider Electric Software allows the monitoring of the electrical consumption of refrigerators.

At the moment CSI services and tools have the following limitations that could become an opportunity for improvement for the CSI pilot case:

- Monitoring data on energy efficiently issues come from different network topologies and heterogeneous sources (sensors, online databases, existing applications and services) which are not integrated and connected into the same architecture;
- The amount of data recorded by the CSI monitoring system are not used to simulate and analyse alternative scenarios representing different typologies and consumption usage levels;
- Monitoring data about the local consumption of energy are not integrated with other consumption data, such as cooling energy measurements, thermal energy consumptions for heating and hot-water production, internal comfort parameters, and real time weather monitoring data;
- Real time monitoring data on CSI building consumption, historical trend detections and correlated analysis are not integrated into a system that offers access to employees, technical users, and public authorities in a way to gain "good consumer behaviour" and promote energy saving action plans.

The CSI pilot case consists of a historical building in Turin, which has been chosen as an example for the average energy consumption of a publicly owned building in private company use, so that the monitored and measured data will be representative. The building structure is mainly divided in rooms which host a large number of employees, director managers' offices, technological facilities (DEC and associated components) and common spaces (hall, corridors, rest stops, meeting rooms, etc.). Each typology represents different electricity demand situations, which can be detected to enhance energy efficiency and good energy saving practices. In the CSI building, real time data on electric energy consumption are monitored by 41 appliances installed on the switchboards of data centers, within the power center of the substations and within the power center of data center. The measurements are managed through the software of Schneider Electric (PowerLogic ION Enterprice), which helps track real-time power conditions, analyse power quality and reliability, and to respond quickly to alarms to avoid critical situations. Moreover, it helps to study historical data, to detect energy waste and unused capacity, verify the efficiency of improvements and allocate costs of buildings, departments and processes through sophisticated load aggregation and arithmetic calculation. The cooling energy generator is supported by 4 refrigeration units and it is controlled by Tracer Summit System (Trane Inc.), which can generate predefined reports. There is no official system for data center cooling energy measurements established. Furthermore, Schneider Electric Software allows the monitoring of refrigerator electrical consumption as well. Thermal energy for heating and hot water production is supplied by the district heating network of the city of Turin. There are no data on thermal energy consumption. The clearance between CIS-Piemonte the University of Turin and ASL are based on the quotient of the volume and surface of occupied building used by each associate.

The objective of the CSI pilot scenario mainly is to monitor the energy consumption of the entire building and secondly, to be able to predict its energy demands. In particular, the introduction of NRG4Cast services applied to the CSI scenario will improve the integration of outputs provided by different energy efficiency data sources and submit them into the same data architecture. This system will provide unique services for energy consumption, network failure and energy process prediction for all involved stakeholders. With these services energy recovering solutions can be optimized, the options for retrofitting buildings and scaling new equipment can be enhanced, and the use of renewable energies can be evaluated.

In particular, the CSI system will improve energy awareness in four aspects:

- The ability to integrate multimodal data provided by existing monitoring systems and new monitoring devices with an increasing amount of information and in different data qualities.

- The better identification of network failures and the recognition of possible malfunctions by using advanced technologies from artificial intelligence.
- Better control of energy usage and cost by billing and clearing analysis, estimation of cost trends, scenario forecasting and recommendations for saving energy consumption.
- Easy management of reports and communications derived from multiple real time data sources by developing high technology web-based services, addressed to all stakeholders or to a specific stakeholder group.

These challenges will be achieved through a serial process:

- Install new devices to measure thermal energy consumption for heating and hot water production;
- Selection and acquisition of new sensors to measure internal comfort and external parameters;
- Development of a data stream management system to collect and integrate data from different network topologies and heterogeneous sources (sensors, online databases, existing applications and services) into the same architecture;
- Development of advanced technologies from artificial intelligence to better acknowledgment of network failures but also recognition of possible malfunctions;
- Analysis and simulation of alternative scenarios representing different typologies and power consumption usages at the building and city level;
- Prediction of energy demand at the building and city level;
- Some implementation of already existing web-based system for automatic loading and elaboration of energy bills, realisation of reports and graphs on energy consumption monitoring. This new tool will allow converging and integrating data gained from CSI pilot scenario in order to produce more detail reports and energy saving suggestions on CSI scenario addressed to all possible stakeholders.

3.3.2 Use cases

3.3.2.1 Use Case 1. Installation of Integrated Devices and Open Source Sensors

Primary actor

Building owner

Goal in context

Improve the accuracy and quality of electricity measurements and implement these parameters with other energy consumption information, such as cooling and thermal energy consumptions, internal comfort parameters, and real time weather monitoring data into open source devices and intelligent sensors.

Trigger Condition

Find out the best solutions for energy recovering, include retrofitting in cost-benefit analysis, and evaluate the use of renewable energies through the implementation of actual monitoring system of local energy consumptions.

Success End condition

CSI building owner is successful at installing cooling energy consumption devices and thermal energy consumption devices for heating and hot-water production in the CSI building. Moreover, the owner is able to arrange sensors for the recording of thermal comfort parameters (temperature, humidity etc.) into each building space typology which represent different electricity demand situations. Finally, the owner is able to arrange real time monitoring sensors to record local weather conditions (temperature, humidity, wind etc.) which will be positioned outside the building.

3.3.2.2 Use Case 2. Streaming data integration and management

Primary actors

Building owner, ICT technical operator

Goal in context

Integrate and connect aggregated information coming from different network topologies and heterogeneous sources (sensors, online databases, existing applications and services) through a Service-Oriented Pipeline Architecture. The CSI pilot case scenario will deal with the following data sources and information: CSI building Energy Monitoring System, METEO Meteodata, ENERCAD3D, SICEE, SIGIT and QRS. The pipeline architecture will implement the availability of information deriving from real time networks monitoring which support technological/control analysis, and will also make a contribution to the development of meaningful actions for saving energy and reducing cost of building maintenance.

Use case steps

- The building owner defines the user license requisites to gain access to devices and sensor network platform that can act as a hardware extension to a user's identity;

- User Administrator, through a ETL database process, transfers proprietary internal data recorded by CSI building Energy Monitoring System, as well as data gathered from new installed sensors, into a common relational database provided by an existing web-based service QRS (The Web based tool for energy consumption control and energy saving planning);

- User Administrator, through a set of standard and well-documented Web Services provided by OGSA-DAI middleware, exposes multimodal data gathered by QRS, METEO Meteodata, ENERCAD3D, SICEE, and SIGIT systems;

- User Administrator provides further web-services which connect OGSA-DAI middleware with CSI relational databases, since CSI data access is just enabled by a SOA approach.

Trigger Condition

Provide better predicted scenarios on energy efficiency and action plans for the CSI pilot case. For this purpose, energy consumption data and correlated parameters need to be integrated and connected into the same architecture to provide a flexible and unified system in order to collect a mass amount of multimodal data, evaluate the quality of real-time records, identify future patterns of energy demand, and arrange energy saving action plans.

Success End conditions

- Integration solutions allow the access to multimodal data from different sources and transport them across networks;

- The process of sending data across networks is fast and flexible;

-Integration solutions offer an interface for systems that use different programming languages, operating platforms, and data formats;

3.3.2.3 Use Case 3. Real-time analysis, reasoning and network behaviour prediction

Primary actors

Building owner, ICT technical operator.

Goal in context

Development of prediction and optimisation methods that are capable of dealing with the mass amount of multimodal data from the CSI building and other external systems (METEO Meteodata, ENERCAD3D, SICEE, SIGIT and QRS) in real-time. In particular, three specific scenarios will be developed in real-time and with open access to interested stakeholders as follows:

- Actual energy consumption applying parametric and nonparametric analysis based on real-time monitoring data of electric, thermal and cooling energy consumption;

- Network failure prediction using advanced technologies from the artificial intelligence area;

- Energy demand prediction resulting from the connection of the information gathered from all the selected data sources through mathematical methods (e.g. simulation and optimisation techniques).

Use case steps

- User Administrator provides a matrix with information to be monitored at each level regarding energy consumption, network failure analysis and bidding;

- User Administrator provides an energy consumption scenario analysis (as-is and to-be) for each network typology including the whole building block, and the different building space typology applying parametric and non-parametric analysis based on real-time monitoring data of electric, thermal and cooling energy consumption;

- User Administrator provides a real-time alerting service to detect energy network failures and anomalies through artificial intelligence technologies;

- User Administrator through mathematical methods (e.g. simulation and optimisation techniques) designs and implements advanced processing and modelling components for CSI-building energy demand predictions resulting from the connection of the information gathered from all the selected data sources at various time scales.

Trigger Condition

Constrained performances of current methods which can deal with a limited amount of information about energy consumption and can provide few analytical results off-line.

Success End conditions

- Prediction and optimisation methods allow the building owner to detect complex events, network failures and generate consumption patterns by using the enriched energy information integrated with correlated external parameters.

- Users have access to real-time elaborations and predicted scenarios.

3.3.2.4 Use Case 4 . On-line management of reports and communications

Primary actor

Building Owner, ICT Technical Operator, Employee

Goal in context

Easily management of reports and communications derived from real-time analysis, reasoning and network behaviour prediction by developing high technology web-based services addressed to the building owner and CSI employees.

Use case steps

- The building owner and employees can draw graphs of the same data (i.e. electrical consumption in the whole building) but for different time periods (i.e. first semester in 2013 and 2014).

- The building owner and employees can draw graphs according the internal comfort state and occupancy. The user will give inputs of ambient state (temperature, humidity) and occupancy schedule (weekday, Saturday or Sunday) and the program can search the historical data and give outputs of the expected kWh for electricity and heat for that day.

- The building owner and employees can produce energy forecasting reports for a desired time period. There is also the possibility of automatically sending the reports to a group of stakeholders.

Trigger Condition

Lack of strategies to communicate in real-time CSI pilot scenario results in order to optimise energy saving actions and promote the dissemination of good practices to all possible stakeholders.

Success End condition

- Implementation of already existing web-based system for automatic loading and elaboration of energy bills, realisation of reports and graphs on energy consumption monitoring (QRS);

- The implemented tool allows to converge and integrate data gained from CSI pilot scenario in order to publish on-line more detail reports on real-time building energy consumption, predicting scenarios and energy saving suggestions on CSI pilot scenario addressed to the building owner and CSI employees.

3.3.3 User Requirements

3.3.3.1 Functional Requirements

Requirement code	Description	Level	User importance
CSI_FReq1	**Data Acquisition**	**Functional**	**2.7**
CSI_FReq1.1	Research of best price to buy new devices and sensors in order to gather energy consumption information and improve the quantity, quality and accuracy of the whole building energy data	Functional	2
CSI_FReq1.2	Provision of a planning time to organise the installation of devices and sensors	Functional	2
CSI_FReq1.3	Installation of a device to measure in real time thermal energy consumption for heating the whole building and for hot water production.	Functional	3
CSI_FReq1.4	Installation of a device to measure cooling energy consumption for the whole building	Functional	3
CSI_FReq1.5	Installation of sensors to record thermal comfort parameters in selected building space typologies	Functional	3
CSI_FReq1.6	Installation of sensors to record in real time local weather conditions outside the building	Functional	3
CSI_FReq2	**Data Storage Management**	**Functional**	**3**
CSI_FReq2.1	Development of an open source interface to register new devices and sensors	Functional	3
CSI_FReq2.2	User license definition to gain access to devices and sensor network platform that can act as a hardware extension to a user's identity	Functional	3
CSI_FReq2.3	Development of a service oriented architecture that allows the acquisition, the capture and the connection of multimodal data coming from different network topologies and heterogeneous sources	Functional	3
CSI_FReq3	**Data Treatment**	**Functional**	**3**
CSI_FReq3.1	Application of statistical analysis based on real-time monitoring data of electric, thermal and cooling energy consumption in order to trace energy consumption of the whole building	Functional	3
CSI_FReq3.2	Provision of Artificial Intelligence technology for network failure prediction	Functional	3
CSI_FReq3.3	Elaboration of simulating and predicting models for energy demand prediction	Functional	3
CSI_FReq3.4	Final evaluation of the accuracy of results	Functional	3
CSI_FReq4	**Data Visualisation**	**Functional**	**2.7**
CSI_FReq4.1	Implementation of already existing web-based system QRS in order to include revised data streaming	Functional	2
CSI_FReq4.2	User license definition to gain access to on-line service	Functional	3
CSI_FReq4.3	On-line publication of detail reports on real-time building energy consumption, predicting scenarios and energy saving suggestions on CSI pilot scenario.	Functional	3
CSI_FReq5	**Virtual Pilot Site Development**	**Functional**	**3**
CSI_FReq5.1	Development of a platform in which energy consumption data of virtual infrastructures and correlates parameters are interconnected in real-time	Functional	3
CSI_FReq5.2	Development of real-time analysis, reasoning and network behaviour prediction to identify future	Functional	3

	pattern of energy demand, and arrange energy saving action plans		
CSI_FReq5.3	On-line publication of virtual pilot site results through high technology web-based services.	Functional	3

Table 6 Functional Requirements for the CSI pilot scenario

3.3.3.2 Non - functional Requirements

Requirement code	Description	Level	User importance
CSI_NFReq1.2	Frequency of Data Acquisition: Energy consumption data for cooling the whole building will be gathered and shown every 15min, such as minimum frequency of response.	Non Functional	3
CSI_NFReq1.3	Frequency of Data acquisition: In-door thermal comfort data will be gathered and shown every 1min, such as minimum frequency of response.	Non Functional	3
CSI_NFReq1.4	Frequency of Data Acquisition: Local weather conditions outside the building will be gathered and shown every 1min, such as minimum frequency of response.	Non Functional	3
CSI_NFReq2	**Data Storage Performance**	**Non Functional**	**2.5**
CSI_**NFReq2.1**	Data Storage efficiency: The data integration solution should be as fast and flexible as possible.	Non Functional	2
CSI_**NFReq2.2**	Data Storage Interoperability: The data integration solution should interconnect different systems which use different programming languages, operating platforms, and data formats.	Non Functional	3
CSI_**NFReq2.3**	Open source Capability: Aggregate and store the information securely and privately on behalf of the data owner	Non Functional	3
CSI_**NFReq2.4**	Data Storage modifiability: The data integration solution should easily get caught of changes in the applications it connects	Non Functional	2
CSI_NFReq3	**Data Elaboration Performance**	**Non Functional**	**2.5**
CSI_NFReq3.1	System usability: The system will be used by researches and technical operators	Non Functional	2
CSI_NFReq3.2	Response Time: The system should provide real-time feedback and analysis results to all the users	Non Functional	3
CSI_NFReq4	**Reporting Performance**	**Non Functional**	**2.3**
CSI_NFReq4.1	System appearance: the interface should be as simple as possible. It should be not confusing and user-friendly. There should be explanation text in all cells/columns, "User Guide", "Help" section, "Contents" and "Glossary".	Non-Functional	2

CSI_NFReq4.2	System maintenance: The system should be able to be automatically updated when the PC is connected to the internet. If faults appear, they should be automatically sent to the software developers for immediate correction. Backup of data should be performed on a daily basis. Recovery of data should be possible.	Non-Functional	2
CSI_NFReq4.3	System usability: The system will be visualised on-line by all the enabled end-users	Non-Functional	3

Table 7 Non - Functional Requirements for the CSI pilot scenario

3.3.3.3 Application mapping and constrains

At the time of the composition of this document, the development of the mapping and constraints within the CSI case can't be reproduced in a correct and complete map.

3.4 MIREN-FIR-CSI

3.4.1 Overview

The MIREN-FIR-CSI case is the city-like pilot scenario. It aims at correlating energy consumption data of Italian public buildings (CSI building, school and university building, public offices etc.), energy street light consumption data collected through a cognitive sensor network installed in Slovenia by Envigence partner and data and usage profiles for electric cars provided by FIR at RWTH Aachen. The energy provider partner IREN will assure the energy data availability for the buildings involved.

For simulating the energy demand of a region this data sources are combined. Due to the fact that the buildings are in Piemonte, the cars are in Aachen and other German cities and the street lights are in Miren these data objects are virtually put together.

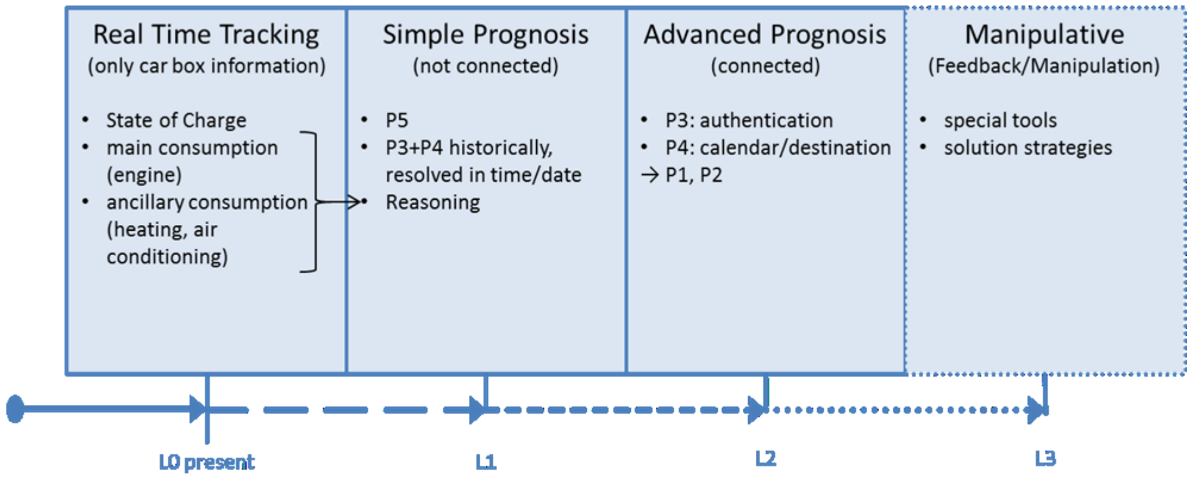

Figure 15 The Smart Charging Algorithm (SCA) in its different levels from basic (L0) to a future manipulative level (L3) which will affect the driver and his car use. The relevant focus in data collecting and prognosis in NRG4Cast are the levels L0-L2

The portability of the data is a main challenge, not in the domain of connecting the data, but in the necessity of abstracting the data and the data profiles from the local criteria. For this the local and relevant criteria, which affect the data and the profiles, have to be identified. With this identified criteria the data and the profiles can be normalised, virtualised and objectified.

In the target region, Miren, the relevant criteria and their characteristics have to be identified and applied on the normalised data. By this process the reliability and probability of the prognosis provided on this data on a different local context is ensured.

The FIR part in the Miren-FIR-CSI use case is providing the car data and historical data and aggregating this collected data in the Smart Charging Algorithm for each car. The Energy Monitor receives the data from each Smart Charging Algorithm and can predict outcomes for parts or all connected vehicles. Therefore prognosis for regions and car fleets are possible.

The Smart Charing Algorithm will be constructed in several layers, levels, which are shown in Figure 16. The higher complement the subjacent layer with additional data and can therefore be the basis for more complex use cases. The intended use cases in the Miren-FIR-CSI case are the simple prognosis and advanced prognosis which are described in detail in chapter 5.1.1.

In general there are two different data sources for the SCA, historical data and the real-time data of the present (e.g. collected in project SmartWheels [1]). The real time data is tracked and transmitted by the car box. This is a device able to access the CAN-data, OBD2-data and other data streams provided by the electric car. This data is then transferred to a data storage based in a cloud solution. The technical framework is researched and provided by the research project oscar (Open Service Cloud for the Smart Car,

[2]). This framework will be modified for the use in NRG4Cast, for example in the data pre-analytics and storage in data-profiles. The collected real time data is analysed and logically separated in different profiles, which are shown in Figure 17. These profiles represent the historical data, they are based on old measurements and data collections and are updated in real time or after each car usage.

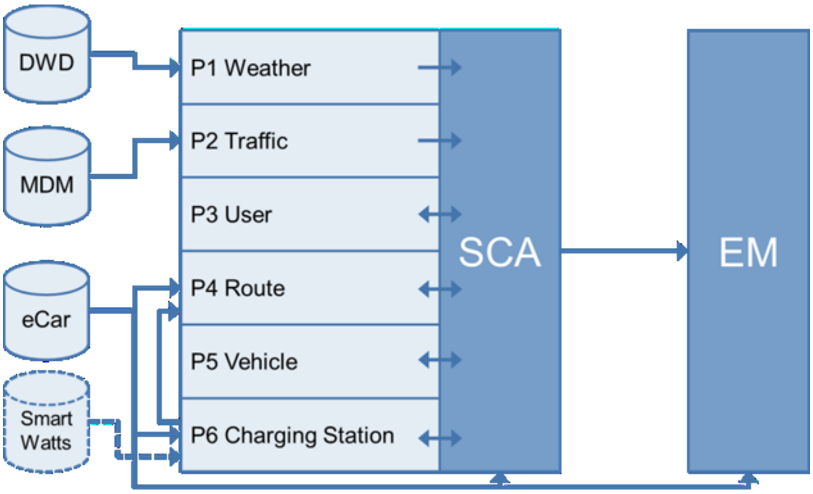

Figure 16 The aspired data profiles and sources which will be integrated for the Smart Charging Algorithm (SCA) and the Energy Monitor (EM)

Level 0 - L0

At the Basic Level 0 the car measures and collects its data. This is the state of charge of the battery and the consumption. The consumption is divided of main and ancillary consumption. The main consumption is the transformation of electric energy to kinetic energy. During this transformation losses occur at several points, at the battery, at every connection and energy transformation in the engine. There are also losses through friction and other physical aspects of a car. Ancillary consumption summarizes all other consumers: heating, radio, controllers (e.g. for the battery), etc.. This collection happens in real time and illustrates the present state of a car. Additional the historical measurements, since start of the ignition, are collected and correlate a short time memory of the car usage.

This level is the fall back if all additional information is corrupted or not accessible, e.g. if a connection cant' be established to the cloud.

Level 1 - L1

At the first level simple prognosis are carried out, based on the data of L0 and some data profiles. The data profile 5 (P5) represents the vehicle state, the values and losses by the build in components and the collected data since start of the ignition (compare Level 0). Additional rough user (P3) and route information (P4) are used. For the user profiling the usual behaviour of the user in a car are used. In this case did no authentication happen, so the car can't use any special historical data which could be provided for by the cloud for an identified user. Also the target of the tour is undisclosed. Therefore only the mean values in the usual domain of the car, e.g. the arithmetic mean of the height profiles of routes in its area, can be used. Reasoning happens on the limited historical data, the collected data since start of the ignition and the profiles P3, P4, P5 within the described restrictions.

This level is the basis for a car which is used by multiple users without exact knowledge of the user and the routes. In its limit the car will learn its 'usual' use, by evaluating all taken tours which it measures. The reasoning interprets other factors, like the traffic or the weather, by its own sensors and measurements. This reasoning is only in small limits accurate but it can provide first improvement of later prognosis.

Level 2- L2

The second level of the SCA can rely on more detailed data. Authentication of the user, target of the tour and a schedule for the next car usages may be given. Depending which of this information is provided the advanced prognosis is more accurate and can estimate its accuracy. The user and route profile (P3 & P4) are unrestricted available. Also additional data from other data sources, e.g. weather (P1) or traffic (P2) are included in the reasoning and prognosis.

This level provides the prognosis for a car within the Energy Monitor. It should be the basis for simulating a car. The data integration between multiple cars, for example traffic or rout data, will be executed in the cloud and stored in the according profiles.

Level 3 - L3

The third level of the algorithm is a future stage of the algorithm which is not focused within NRG4Cast. This stage will be manipulating the user and the car for the cause of grid stability and traffic control. Although it is not part of NRG4Cast its affects with the car usage are important for NRG4Cast because the manipulation of the user's behaviour could be a logical next step to the Energy Monitor. Therefore the requirements and the different possibilities of affecting a user are important. Possible incentives for a manipulation could be monetary, ecological, guidelines by the fleet operator or laws. The way of manipulation could differ from hidden manipulation to direct confrontation with facts. The possibilities also differ from automated technical restrictions (e.g. reducing of maximal speed or maximal acceleration) to suggested enhancements (e.g. suggestion of an alternative route).

3.4.2 Use cases

The Miren-FIR-CSI use case contains two secondary use cases, the simple prognosis use case and the advanced prognosis use case within the Smart Charging Algorithm.

3.4.2.1 Use Case 1. Miren-FIR-CSI scenario (MFC Scenario)

Primary Actor

Drivers of electrical vehicles and their energy monitors and residents trigger the process by their energy consumption. The car owners, street lighting operators and building owners aim for a better energy efficiency and therefore participate in the MFC scenario, i.e. install sensors and supply collected data

Goal in context

The MFC scenario aims to combine the information on energy demand from street lighting, building monitoring, charging of electrical vehicles and traffic conditions in order to monitor the energy behaviour in a broader topology network. This enables an integrative approach to improve the efficiency and usage of energy by combining energy behaviour with a predicted demand and possibly alternate the time of extraction to reduce the chance of grid failures.

Therefore it is necessary that the energy demands relate to each other in a way that enables the short term transfer of energy from energy storages like car batteries to consumers within a local area, not further using grid capacity, to achieve a more constant grid capacity use by alternating energy consumption in time.

Current model of energy supply still holds a lot of room for improvement. The combination of information to a better interaction of energy consumers will benefit all stakeholders and participants.

Use case steps

- Installation of sensors in buildings, cars and street lightning
- Collection of data and aggregation
- Exploration of correlations
- Exploration of measures for improvement on energy consumption and interaction

Frequency

In real time depending on the availability of required data

Trigger condition

- Grid failure becomes apparent
- Alternation of peak energy demands (i.e. in buildings)
- Usage of electrical vehicles

Success end condition

Predictions on the energy consumption of all participants can be made and a reasonable interaction is possible. The forms of energy (heat, electricity) used can be related to each other and recommendations for a more efficient use can be made.

3.4.2.2 Use Case 2. Simple Prognosis

Primary actor

The driver triggers the process by the usage of the electrical vehicle and the smart charging algorithm within the vehicle calculates energy consumption and range.

Goal in context

The simple prognosis is a further specialization of the Real-Time-Tracking (RTT) and thus relies on its functions. The RTT is the basic prediction of range and operates in the same way as the mileage prediction in nowadays cars. By tracking the constant specific energy consumption (primary and secondary energy use) and calculating the average per distance and knowing the battery's state of charge a first fundamental prediction can be made.

The simple prognosis takes these findings one step further. The hardware installed inside of the vehicles is capable of saving historical data. This data is defined in the "Simple Prognosis Requirements". With this historical data the vehicle can make assumptions on the driver, the terrain within the vehicle's area of operation, the average and typical routes, typical weather and traffic conditions and driving habits. The L1-Level of the SCA shall then be able to make a rather accurate prediction of energy consumption that can be extracted from the historical data. Real time environmental changes (e.g. traffic jams, unforeseen weather conditions, etc.) can of course not yet be factored in.

Use case steps

- Installation of sensors in cars or interpretation of the provided data by the car's controlling systems
- Collection of data
- Virtualisation of the data for adaption in other regional context
- Exploration of correlations
- Exploration of ways to classify drivers out of historical data
- Exploration of measures for improvement on energy consumption and charging

Frequency

Depending on car usage

Trigger condition

- Start of vehicle
- Stop of vehicle
- Use of vehicle

Success end condition

The energy consumption on tours and the range of the vehicle can be predicted resulting from the historical data collected by the energy monitor

3.4.2.3 Use Case 3. Advanced Prognosis

Primary actor

The driver triggers the process by the usage of the electrical vehicle and the smart charging algorithm within the vehicle calculates energy consumption and range.

Goal in context

The advanced prognosis on the L2-Level of the SCA will be even more accurate. Additionally to the L1-Level it will know the precise destination and the driver (this includes the driver's driving profile and habits). In some cases the calendar entries can also be loaded into the system so that the SCA knows all consecutive destinations. This information gives the SCA the opportunity to plan the expected energy consumption on routes and possibly for a longer time span as well. In this case it can also optimise the recharging process and possibly be higher prioritised once connected to the grid.

By also giving the SCA access to real time data on traffic and weather conditions, the prognosis can be even more accurate.

The SCA shall also be able to differentiate the current traffic conditions. I.e. in the case of heavy commuting and stop-and-go-traffic the SCA can identify this specific situation and not make assumptions on the driver's usual driving habit. This makes future prognoses more accurate.

Use case steps

- Collection of data
- Exploration of correlations not yet considered within the simple prognosis
- Exploration of ways to classify drivers when precise driver is known and historical data can be clearly related to the corresponding drivers
- Exploration of measures for improvement on energy consumption and charging

Frequency

Depending on car usage

Trigger condition

By start of car

Success end condition

Energy consumption on tours and the range of the vehicle can be predicted resulting from the historical data collected by the energy monitor as well as real time information on traffic and weather condition, the driver's precise destination and driving habits.

3.4.3 User Requirements

The requirements are split up in two sorts of requirements, functional and non-functional requirements. The functional requirements are describing the necessities which have to be provided for the NRG4Cast algorithms (EM, SCA, etc.) to work properly. In addition, there are non-functional requirements which ensure simple usability.

3.4.3.1 Functional Requirements

Requirement code	Description	Level	User importance
FIR_MFC_1	**Miren-FIR-CSI Scenario**	**Functional**	**2.6**
FIR_MFC_1.1	Knowledge of energy consumption of street lighting. In order for a smart integration and interaction between the different types of energy consumers the knowledge of each participating energy user's electricity need is essential. Modulating the energy need of street lighting will depend on the traffic intensity and the season, hence day light time.	Functional	3
FIR_MFC_1.2	Knowledge of energy consumption of buildings. The modulation of energy consumption by buildings will have many variables to be factored in. They depend on weather and climate conditions, as well as user habits and building specific parameters. Otherwise virtual buildings can't be integrated within the Miren-FIR-CSI Scenario.	Functional	3
FIR_MFC_1.3	Logical fusion of different types of energy consumptions within buildings (i.e. heat vs. electricity) and possibility of integration into NRG4Cast. It is to be evaluated in which ways both forms of energy depend on each other and if they are both capable of being integrated into NRG4Cast. This affects the quality of the knowledge of energy consumption and the quality of the prognosis	Functional	2
FIR_MFC_1.4	Prediction of point in time and duration of energy consumption by buildings and street lighting. For the best possible improvement on energy efficiency and to avoid grid failures it is necessary to predict the point in time and duration of energy extraction from the grid by buildings and street lighting. This is a basic enabler for controlling the best possible interaction between different consumers and a possible adaption.	Functional	3
FIR_MFC_1.5	Predicted amount of energy needed from grid at destination point (grid node). The same is the case for the extracted amount of energy by the electrical vehicles at their destination point. Only with this knowledge the extraction of energy can be adapted and controlled to meet the grid's capacity, enable an interaction between all consumers in the most efficient way and prevent grid failures by early intervention of the grid structure.	Functional	2
FIR_ MFC _1.6	Grid topology; grid node of the specified energy consumptions. In order to adapt and control the interaction of different energy consumers involved within the distributed area of one grid node in an efficient way not exceeding the grid's capacity, it is necessary to obtain knowledge of the grid's topology and capacity itself	Functional	3
FIR_ MFC _1.7	Knowledge of relevant local criteria for driver's behaviour. To implement virtual electrical vehicles in the municipality of Miren, it is necessary to know about regional factors influencing the behaviour of vehicle drivers, e.g. height topology, typical distances between residential areas and industrial areas or other working places like public buildings and town centres, or shopping centres.	Functional	2
FIR_ SP _2	**Simple Prognosis**	**Functional**	**2.3**
FIR_ **SP** _2.1	Knowledge of type and state of the vehicle and average	Functional	3

	consumption. Depending on the type of the vehicle and its state the energy consumption will vary. With growing age and the wearing out of components the specific energy consumption will increase. The energy consumption will also depend on the different components used for the vehicle (e.g. kinds of tires). For a reliable prediction of the average consumption these factors are necessary.		
FIR_ **SP** _2.2	Knowledge of battery health. With each charging cycle the battery's health will diminish. To predict the current amount of energy left at a certain charging state and hence the range of the battery, knowledge of the overall battery health is necessary.	Functional	2
FIR_ **SP** _2.3	Knowledge of state of battery charge. To be able to predict the amount of electrical energy still available in the vehicle's battery and thus the maximum possible travel distance, it is necessary to know the state of battery charge.	Functional	3
FIR_ **SP** _2.4	Knowledge of routes of specific vehicle from historical data. It is possible to predict the probable distance a specific vehicle will travel at a specific time and date, by collecting data every time the vehicle is moved and saving the distances travelled itemised by time and weekday. With this information the Smart Charging Algorithm can predict the probable amount of energy needed from the typical vehicle behaviour.	Functional	2
FIR_ **SP** _2.5	Knowledge of driver habits of specific vehicle from historical data: Even this information can be gathered by collecting historical data of the considered vehicle. The SCA can collect information of every tour regarding how energy efficient the driver's behaviour was and save this information itemised by time and weekday. So even if there are several different drivers using the same vehicle, the vehicle can predict who of them will probably use the car at what time of the week, hence predict the average energy consumption due to the driver's behaviour.	Functional	3
FIR_ **SP** _2.6	Knowledge of average terrain in specific vehicle's area of operation. The knowledge if a vehicle is situated in an area with a lot of hills and mountains or rather in a plane area gives the possibility of predicting the consequent average energy consumption due to the height profile to the Smart Charging Algorithm.	Functional	2
FIR_ **SP** _2.7	Knowledge of overall traffic situation in vehicle's area of operation from historical data. Analysing the acceleration and braking performance itemised by time and day of the week allows the SCA to reason on the time-depending traffic situation in the vehicle's region and on the vehicle typical itineraries and therefore predict a probable increase of energy consumption.	Functional	2
FIR_ **SP** _2.8	Reasonable basic evaluation of current driving manner by traffic. If one finds typical stop and go driving behaviour, thus constantly alternating change of acceleration and braking at low speed, it is possible to reason on the traffic conditions and to distinguish this driving behaviour due to the traffic situation from the driver-specific behaviour.	Functional	2
FIR_ **SP** _2.9	Basic knowledge of typical weather situations in vehicle's area of operation from historical data: The Smart Charging Algorithm can save the changes to energy consumption per month of the year e.g. due to rain, snow or very windy conditions, hence give a prediction on the probable increase of energy consumption regarding the current month. This kind of reasoning and analysing needs more time to work properly than the other predictions above, because more than one cycle of seasons to pass is needed.	Functional	2
FIR_ AP _3	**Advanced Prognosis**	**Functional**	**2.4**
FIR_ **AP** _3.1	Knowledge of specific driver and corresponding driving	Functional	2

	habits. By authentication of the driver's identity at the beginning of the tour through an interface or registration tool, the Smart Charging Algorithm can reason on the specific driving habits of this driver by collecting data of accelerating and braking behaviour and the resulting increase or decrease of energy consumption compared to an average consumption every time this driver is in the car		
FIR_ **AP** _3.2	Knowledge of specific driver and corresponding typical routes. By authentication of the driver's identity, the Smart Charging Algorithm knows the typical routes and behaviour of a driver and can reason on where the driver will probably go.	Functional	2
FIR_ **AP** _3.3	Knowledge of specific destination. In the beginning of a tour the driver can insert his destination in an interface or similar tool, so the Smart Charging Algorithm knows the route to be driven, hence predict the energy consumption regarding all known parameters like topology, weather and traffic conditions on this itinerary.	Functional	3
FIR_ **AP** _3.4	Knowledge of destination resulting from calendar entries. The access of the Smart Charging Algorithm to time and location of the calendar entries of the vehicle's typical user allows a prediction on the itinerary to be driven and gives the Algorithm the possibility to prepare the car (for example heating it, without stressing the cars battery) and knowing how much energy is needed at the probable end of charging time, so for example the Algorithm can optimise the charging according to the energy prizes. It the scheduling for the car usage provides the possibilities, at times of high energy prizes the energy which won't be used or can be replenished within this or the next time slot, without affecting the usage, can be sold and be utilized by the grid.	Functional	2
FIR_ **AP** _3.5	Knowledge of traffic situation on specific route. Gathering information from databases, like the mobility data marketplace (MDM) or the traffic sensors of the street lighting in Miren, the Smart Charging Algorithm can calculate the increase of energy consumption due to traffic jams, if it knows the itinerary and routes to be driven.	Functional	3
FIR_ **AP** _3.6	Reasonable evaluation of current driving manner by traffic situation. By taking the current traffic situation on the route into consideration, it is possible to distinguish the consequent acceleration and braking behaviour from the driver-specific behaviour to achieve a better analysis of the driver's consumption behaviour.	Functional	2
FIR_ **AP** _3.7	Knowledge of weather situation and impact on traffic situation and driving manner. Taking into consideration the weather data prognosis for the vehicles area of operation, gives the opportunity to predict the resulting change of the typical energy consumption due to changing traffic situations and driving manners. E.g under rainy conditions it is probable that the driver will reduce his speed, but also the energy consumption will increase, because of the changing transmission from tyres to street.	Functional	3
FIR_ **AP** _3.8	Knowledge of typical routes from historical data of the vehicle's area of operation. Using the typical route profiles from vehicles operating in the same area as the considered vehicle, can help to predict the destination of the vehicle and hence predicting the amount of energy needed for this route and at the destination point.	Functional	2

Table 8 Functional Requirements for FIR scenario

3.4.3.2 Non - functional Requirements

Requirement code	Description	Level	User importance
FIR_FrameConditions_1	**Miren-FIR-CSI Scenario**	**Non - Functional**	**1**
FIR_FrameConditions_1.1	Backup system for essential energy consumers if system should fail (e.g. prevent street lights from going dark). There should be a backup system for essential infrastructure and buildings (e.g. street lightning, hospitals, etc.) installed that they can rely on in the case of system failure	Non - Functional	1
FIR_FrameConditions_2	**Simple Prognosis**	**Non - Functional**	**2.7**
FIR_FrameConditions_2.1	Price for hardware as low as possible. Price for essential hardware should be kept as low as possible, thus enabling car makers to participate on a broad basis and facilitating the market implementation and dissemination. If the surcharge is to be paid for by the consumers, it should be even lower so that a amortization of the extra cost can be achieved as soon as possible.	Non - Functional	3
FIR_FrameConditions_2.2	Misuse of saved data must be prevented. For users to participate it is essential to prevent the misuse of saved and personal data. This must also be communicated clearly to build up the trust of the users.	Non - Functional	2
FIR_FrameConditions_2.3	Installed systems must be easy to use. To avoid user frustration and a broad participation the installed systems should be as easy to use as possible.	Non - Functional	3

Table 9 Non - Functional Requirements for FIR scenario

3.4.3.3 Application mapping and constrains

At the point of the composition of this document, the development of the mapping and constraints within the Miren-FIR-CSI case can’t be reproduced in a correct and complete map.

4 NRG4Cast system preliminary Requirements

The preliminary user requirements for each pilot scenario were analysed and integrated into unique list of NRG4Cast system user requirements. The preliminary requirements gathered from each single pilot scenario (MIREN, CSI, NTUA) and virtual pilot site (MIREN-FIR-CSI) are organised taking into account the description as well as the user importance and the user need. Requirements that describe similar functionalities are generalised and merged, producing the System Requirements, which covers all of the functionalities expressed.

The NRG4Cast system preliminary requirements classified into categories with an integrated rating are presented within the table below.

Requirement number	Requirement Code	Description	Level	User importance
1	**FIR_MFC_1.1**	Knowledge of energy consumption of street lighting. In order for a smart integration and interaction between the different types of energy consumers the knowledge of each participating energy user's electricity need is essential. Modulating the energy need of street lighting will depend on the traffic intensity and the season, hence day light time.	Functional	3
2	**FIR_MFC_1.2**	Knowledge of energy consumption of buildings. The modulation of energy consumption by buildings will have many variables to be factored in. They depend on weather and climate conditions, as well as user habits and building specific parameters. Otherwise virtual buildings can't be integrated within the Miren-FIR-CSI Scenario.	Functional	3
3	**FIR_MFC_1.4**	Prediction of point in time and duration of energy consumption by buildings and street lighting. For the best possible improvement on energy efficiency and to avoid grid failures it is necessary to predict the point in time and duration of energy extraction from the grid by buildings and street lighting. This is a basic enabler for controlling the best possible interaction between different consumers and a possible adaption.	Functional	3
4	**FIR_MFC_1.5**	Predicted amount of energy needed from grid at destination point (grid node). The same is the case for the extracted amount of energy by the electrical vehicles at their destination point. Only with this knowledge the extraction of energy can be adapted and controlled to meet the grid's capacity, enable an interaction between all consumers in the most efficient way and prevent grid failures by early intervention of the grid structure.	Functional	2
5	**FIR_ MFC _1.6**	Grid topology; grid node of the specified energy consumptions. In order to adapt and control the interaction of different energy consumers involved within the distributed area of one grid node in an efficient way not exceeding the grid's capacity, it is necessary to obtain knowledge of the grid's topology and capacity itself	Functional	3
6	**FIR_ MFC _1.7**	Knowledge of relevant local criteria for driver's behaviour. To implement virtual electrical vehicles in the municipality of Miren, it is necessary to know about regional factors influencing the behaviour of vehicle drivers, e.g. height topology, typical distances between residential areas and industrial areas or other working places like public buildings and town centres, or shopping centres.	Functional	2
7	**FIR_ SP _2.1**	Knowledge of type and state of the vehicle and average consumption (Simple Prognosis.). Depending on the type of the vehicle and its state the energy consumption will vary. With growing age and the wearing out of components the specific energy consumption will increase. The energy consumption will also depend on the different components used for the vehicle (e.g. kinds of tires). For a reliable prediction of the average consumption these factors are necessary.	Functional	3
8	**FIR_ SP _2.2**	Knowledge of battery health (Simple Prognosis.). With each charging cycle the battery's health will diminish. To predict the current amount of energy left at a certain charging state and hence the range of the battery, knowledge of the overall battery health is necessary.	Functional	2
9	**FIR_ SP _2.3**	Knowledge of state of battery charge (Simple Prognosis). To be able to predict the amount of electrical energy still available in the vehicle's battery and thus the maximum possible travel distance, it is necessary to know the state of battery charge.	Functional	3
10	**FIR_ SP _2.4**	Knowledge of routes of specific vehicle from historical data	Functional	2

		(Simple Prognosis). It is possible to predict the probable distance a specific vehicle will travel at a specific time and date, by collecting data every time the vehicle is moved and saving the distances travelled itemised by time and weekday. With this information the Smart Charging Algorithm can predict the probable amount of energy needed from the typical vehicle behaviour.		
11	**FIR_ SP _2.5**	Knowledge of driver habits of specific vehicle (Simple Prognosis) from historical data: Even this information can be gathered by collecting historical data of the considered vehicle. The SCA can collect information of every tour regarding how energy efficient the driver's behaviour was and save this information itemised by time and weekday. So even if there are several different drivers using the same vehicle, the vehicle can predict who of them will probably use the car at what time of the week, hence predict the average energy consumption due to the driver's behaviour.	Functional	3
12	**FIR_ SP _2.6**	Knowledge of average terrain in specific vehicle's area of operation (Simple Prognosis). The knowledge if a vehicle is situated in an area with a lot of hills and mountains or rather in a plane area gives the possibility of predicting the consequent average energy consumption due to the height profile to the Smart Charging Algorithm.	Functional	2
13	**FIR_ SP _2.7**	Knowledge of overall traffic situation in vehicle's area (Simple Prognosis) of operation from historical data. Analysing the acceleration and braking performance itemised by time and day of the week allows the SCA to reason on the time-depending traffic situation in the vehicle's region and on the vehicle typical itineraries and therefore predict a probable increase of energy consumption.	Functional	2
14	**FIR_ SP _2.8**	Reasonable basic evaluation of current driving manner by traffic (Simple Prognosis). If one finds typical stop and go driving behaviour, thus constantly alternating change of acceleration and braking at low speed, it is possible to reason on the traffic conditions and to distinguish this driving behaviour due to the traffic situation from the driver-specific behaviour.	Functional	2
15	**FIR_ SP _2.9**	Basic knowledge of typical weather situations in vehicle's area of operation (Simple Prognosis) from historical data: The Smart Charging Algorithm can save the changes to energy consumption per month of the year e.g. due to rain, snow or very windy conditions, hence give a prediction on the probable increase of energy consumption regarding the current month. This kind of reasoning and analysing needs more time to work properly than the other predictions above, because more than one cycle of seasons to pass is needed.	Functional	2
16	**FIR_ AP _3.1**	Knowledge of specific driver and corresponding driving habits (Advanced Prognosis). By authentication of the driver's identity at the beginning of the tour through an interface or registration tool, the Smart Charging Algorithm can reason on the specific driving habits of this driver by collecting data of accelerating and braking behaviour and the resulting increase or decrease of energy consumption compared to an average consumption every time this driver is in the car	Functional	2
17	**FIR_ AP _3.2**	Knowledge of specific driver and corresponding typical routes (Advanced Prognosis). By authentication of the driver's identity, the Smart Charging Algorithm knows the typical routes and behaviour of a driver and can reason on where the driver will probably go.	Functional	2
18	**FIR_ AP _3.3**	Knowledge of specific destination (Advanced Prognosis). In the beginning of a tour the driver can insert his destination	Functional	3

		in an interface or similar tool, so the Smart Charging Algorithm knows the route to be driven, hence predict the energy consumption regarding all known parameters like topology, weather and traffic conditions on this itinerary.		
19	**FIR_ AP _3.4**	Knowledge of destination resulting from calendar entries (Advanced Prognosis). The access of the Smart Charging Algorithm to time and location of the calendar entries of the vehicle's typical user allows a prediction on the itinerary to be driven and gives the Algorithm the possibility to prepare the car (for example heating it, without stressing the cars battery) and knowing how much energy is needed at the probable end of charging time, so for example the Algorithm can optimise the charging according to the energy prizes. It the scheduling for the car usage provides the possibilities, at times of high energy prizes the energy which won't be used or can be replenished within this or the next time slot, without affecting the usage, can be sold and be utilized by the grid.	Functional	2
20	**FIR_ AP _3.5**	Knowledge of traffic situation on specific route (Advanced Prognosis). Gathering information from databases, like the mobility data marketplace (MDM) or the traffic sensors of the street lighting in Miren, the Smart Charging Algorithm can calculate the increase of energy consumption due to traffic jams, if it knows the itinerary and routes to be driven.	Functional	3
21	**FIR_ AP _3.6**	Reasonable evaluation of current driving manner by traffic situation (Advanced Prognosis). By taking the current traffic situation on the route into consideration, it is possible to distinguish the consequent acceleration and braking behavior from the driver-specific behavior to achieve a better analysis of the driver's consumption behavior.	Functional	2
22	**FIR_ AP _3.7**	Knowledge of weather situation and impact on traffic situation and driving manner (Advanced Prognosis). Taking into consideration the weather data prognosis for the vehicles area of operation, gives the opportunity to predict the resulting change of the typical energy consumption due to changing traffic situations and driving manners. E.g under rainy conditions it is probable that the driver will reduce his speed, but also the energy consumption will increase, because of the changing transmission from tyres to street.	Functional	3
23	**FIR_ AP _3.8**	Knowledge of typical routes from historical data of the vehicle's area of operation (Advanced Prognosis). Using the typical route profiles from vehicles operating in the same area as the considered vehicle, can help to predict the destination of the vehicle and hence predicting the amount of energy needed for this route and at the destination point.	Functional	2
24	**CSI_FReq1.3**	Measurement of thermal energy consumption for heating the whole building and for hot water production in real time.	Functional	3
25	**CSI_FReq1.4** **NTUA.FunReq.2**	Measurement cooling energy consumption for the entire building	Functional	3
26	**CSI_FReq1.5**	Recording of thermal comfort parameters and energy quality in selected building space typologies	Functional	3
27	**CSI_FReq2.1** **NTUA.FunReq.1**	Development of an open source interface to register new devices and sensors	Functional	3
28	**CSI_FReq2.2** **ENV_Freq.32**	Profile definition to access the devices and sensor network platform that can act as a hardware extension to identify users	Functional	3
29	**CSI_FReq2.3** **NTUA.FunReq.4**	Acquisition, the capture and the connection of multimodal data coming from different network topologies and heterogeneous sources	Functional	3

30	**CSI_FReq3.1** **NTUA.FunReq.7**	Statistical analysis based on real-time monitoring data of electric, thermal and cooling energy consumption in order to trace energy consumption of the entire building	Functional	3
31	**CSI_FReq3.2** **ENV_Freq2.1**	Provision of technology for network failure prediction	Functional	3
32	**CSI_FReq3.3** **NTUA.FunReq.16** **ENV_Freq2.2**	Elaboration of simulating and predicting models for energy demand prediction	Functional	3
33	**CSI_FReq3.4**	Final evaluation of the accuracy of results	Functional	3
34	**CSI_FReq4.1** **ENV_Freq3.1** **ENV_Freq4.1**	Integration of already existing web-based systems in order to include revised data streaming. Upgrade of a EE Monitor platform in which energy consumption data of virtual infrastructures and correlates parameters are interconnected in real-time	Functional	2
35	**CSI_FReq4.3** **ENV.Freq.34**	On-line publication of detailed reports on real-time building energy consumption, predicting scenarios and energy saving suggestions	Functional	2
36	**CSI_FReq5.2** **ENV_Freq4.2**	Real-time analysis, reasoning and network behavior prediction to identify future patterns of energy demand, and arrange energy saving action plans	Functional	3
37	**ENV_FReq1.1** **CSI_FReq1.1**	Identification of the lowest price to buy new devices and sensors that gather information on energy consumption and improve the quantity, quality and accuracy of the entire energy data of buildings	Functional	2
38	**ENV_FReq1.3** **CSI_FReq1.6**	Measurements of local environmental conditions	Functional	3
39	**ENV_Freq2.1**	Technology for self-generated rules	Functional	3
40	**ENV_Freq3.3** **CSI_FReq.34**	Final evaluation of the accuracy of results	Functional	3
41	**ENV_Freq3.3** **NTUAFunReq.6**	"Order before use" visualisation model. The user should have an interface thought which will define the information sources to be integrated with NRG4Cast	Functional	3
42	**ENV_Freq4.3** **FIR_MFC_1.4**	On-line publication of virtual pilot site results through web-based high technology services.	Functional	3
43	**ENV_NFReq1.1**	Frequency of Data Acquisition: Electric energy consumption data for street lights will be gathered and shown every 15min, as well as minimum response frequency.	Non Functional	3
44	**ENV_NFReq1.2** **CSI_NFReq1.4**	Frequency of Data Acquisition: Environmental data, weather and in –door comfort will be gathered and shown every 1 hour, as well as minimum response frequency.	Non Functional	3
45	**NTUA.NonFunReq.7**	The user will be able to define the frequency of retrieving measurements from each sensor/ information source	Non Functional	3
46	**NTUA.NonFunReq.11**	The user will be able to define the frequency under which the overall map of the campus will be refreshed with new metrics (from sensors)	Non Functional	1
47	**ENV_NFReq2.1** **FIR_MFC_1.3** **CSI_NFReq.4**	Data Storage efficiency: The data integration solution should be as fast and flexible as possible. Logical fusion of different types of energy consumptions within buildings (i.e. heat vs. electricity) and possibility of integration into NRG4Cast. It is to be evaluated in which ways both forms of energy depend on each other and if they are both capable of being integrated into NRG4Cast. This affects the quality of the knowledge of energy	Non Functional	2

		consumption and the quality of the prognosis		
48	**ENV_NFReq4.1 CSI_NFReq4.1 NTUA.NonFunReq.1 NTUA.NonFunReq.3**	System appearance: the interface should be as simple as possible. It should as user-friendly as possible. There should be explanatory text in all cells/columns, "User Guide", "Help" section, "Contents" and "Glossary".	Non-Functional	2
49	**CSI_NFReq1.1**	Frequency of Data Acquisition: Thermal energy consumption data for heating and for hot water production will be gathered and shown every 15min, as well as minimum response frequency.	Non Functional	3
50	**CSI_NFReq1.2**	Frequency of Data Acquisition: Energy consumption data for cooling the entire building will be gathered and shown every 15min, as well as minimum response frequency.	Non Functional	3
51	**CSI_NFReq2.2 ENV_NFReq2.2**	Data Storage Interoperability: The data integration solution should interconnect different systems which use different programming languages, operating platforms, and data formats.	Non Functional	3
52	**CSI_NFReq2.3 ENV_NFReq2.3**	Open source Capability: Aggregate and store the information securely and privately on behalf of the data owner	Non Functional	3
53	**CSI_NFReq2.4 ENV_NFReq2.4**	Data Storage modifiability: The data integration solution should be vigilant of changes in the applications it connects	Non Functional	2
54	**CSI_NFReq3.1 ENV_NFReq3.1 NTUA.NonFunReq.6**	System usability: The system will be used by researches and technical operators	Non Functional	2
55	**CSI_NFReq4.2 ENV_NFReq4.2 NTUA.NonFunReq.9**	System maintenance: The system should be able to update automatically when the PC is connected to the internet. If faults appear, they should be automatically sent to the software developers for immediate correction. Backup of data should be performed on a daily basis enabling the recovery of data .	Non-Functional	2
56	**CSI_NFReq4.3 ENV.NonFunReq4 3**	System usability: The system will be visualised on-line by all the enabled end-users	Non-Functional	3
57	**FIR_FrameConditions_1.1**	Backup system for essential energy consumers if system should fail (e.g. prevent street lights from going dark). There should be a backup system for essential infrastructure and buildings (e.g. street lightning, hospitals, etc.) installed that they can rely on in the case of system failure	Non - Functional	1
58	**FIR_FrameConditions_2.1**	Price for hardware as low as possible. Price for essential hardware should be kept as low as possible, thus enabling car makers to participate on a broad basis and facilitating the market implementation and dissemination. If the surcharge is to be paid for by the consumers, it should be even lower so that a amortization of the extra cost can be achieved as soon as possible.	Non - Functional	3
59	**FIR_FrameConditions_2.2**	Misuse of saved data must be prevented. For users to participate it is essential to prevent the misuse of saved and personal data. \	Non - Functional	2
60	**FIR_FrameConditions_2.3 NTUA.NonFunReq.9**	Installed systems must be easy to use. To avoid user frustration and a broad participation the installed systems should be as easy to use as possible.	Non - Functional	3
61	**NTUA.FunReq.9**	The users will be able to view the campus in a map	Functional	3

		illustrating also a summary of each sensor		
62	**NTUA.NonFunReq.4 ENV_NFReq3.2 CSI_NFReq3.2**	System performance: minimum response time, but whenever this is not possible, a window should appear that informs the user about the time needed to perform the task. The accuracy of measurements/data should also be present.	Non-Functional	2
63	**NTUA.NonFunReq.5**	System operation: The software will be installed on a PC with Microsoft Windows Server 2003 or newer, Core i3 processor, 2.5 GHz speed, memory DDR3 4 GB and 500 MB capacity. The PC will be installed in an office in the Mechanical Engineering School in NTUA campus and will have internet access through Ethernet cable.	Non-Functional	3
64	**NTUA.NonFunReq.8**	The system should operate in the following languages: English, Greek, Slovenian, German, Italian	Non-Functional	2
65	**NTUA.NonFunReq.11**	Software driver to install the software in another pc in case the first one crashes.	Non-Functional	3
66	**NTUA.NonFunReq.12**	System security: The data should be accessible only to authorised users in NTUA campus	Non-Functional	3
67	**NTUA.FunReq.1**	Manually register sensors	Functional	3
68	**NTUA.FunReq.2**	NRG4Cast creates by default an *NRG4Cast Administrator*	Functional	3
69	**NTUA.FunReq.3**	The *NRG4Cast* Administrator will be able to create a new role	Functional	3
70	**NTUA.FunReq.4**	The *NRG4Cast* Administrator will be able to assign rights to a role	Functional	3
71	**NTUA.FunReq.5**	The *NRG4Cast Administrator* will be able to create a new user	Functional	3
72	**NTUA.FunReq.8**	The users will be able to view the area of interest in a map illustrating also the sensor locations	Functional	3
73	**NTUA.FunReq.15**	The user will be able to define the frequency on which produced reports are refreshed	Functional	2
74	**NTUA.FunReq.2**	System appearance in accordance with the Contents; for uniformity, the order of information seen on the screen should be equal to the order of the Contents.	Functional	1
75	**NTUA.FunReq.10**	The user will be able to view 3d plan of office in case of thermal comfort summary		
76	**NTUA.NonFunReq.10**	There should be a system log file that will assist in failure/bugs handling.	Non-Functional	3
77	**NTUA.FunReq.13**	The user will be able to export reports in different formats	Functional	2
78	**NTUA.FunReq.14**	The user will be able to share reports with other actors/roles	Functional	2
79	**NTUA.FunReq.15**	The user will be able to define the frequency on which produced reports are refreshed	Functional	2

Table 10 The NRG4Cast system preliminary requirements

References

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