NRG4CAST
FP7-2012-NMP-ENV-ENERGY-ICT-EeB
Contract no.: 600074
www.nrg4cast.org

NRG4CAST

Deliverable D7.5

Validation of final rollout

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Reviewers:	Irene Koronaki NTUA; Steffen Nienke, FIR
Deliverable Nature:	Report (R)
Dissemination Level: (Confidentiality)[1]	Public (PU)
Contractual Delivery Date:	November 2015
Actual Delivery Date:	November 2015
Suggested Readers:	Energy monitoring/forecasting software developers, municipalities' energy management commissions, city managers, public sector decision makers, providers of electric charging stations, energy providers
Version:	1.0
Keywords:	System validation, Agile methodology, pilot, energy savings

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Executive Summary

This Deliverable concludes the 3 years of the NRG4CAST Toolkit development process which conforms to the agile iterative approach. The software development process has been organized along three main phases, lasting one year each, which resulted in the delivery of the Data Stream Integration prototype (1st year), the Real-time Monitoring Integration prototype (2nd year) and the Final Integrated NRG4CAST Toolkit (3rd year). Validation methodology is based on the repeated validation phases within the iterative and incremental development process of the NRG4CAST.

This report provides an overview on the validation of the final rollout of each pilot case. The validation of the laboratory installation has been done in deliverable 7.3. Furthermore the validation of the initial rollout has been described within the deliverable 7.4. This deliverable results in a verification of the successful installed systems for each use case and ensures the success of the NRG4Cast platform as a whole.

Every pilot scenario is described in one chapter. These are further divided into subchapters, that represent brief description of the installation, results of the functional validation and energy savings validation.

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Abbreviations

GUI Graphical User Interface

DSS Decision Support System

CAS Central Authentication Service

SQL Structured Query Language

API Application Programming Interface

1 Introduction

The deliverable 7.5 describes the NRG4CAST toolkit final rollout validation based on the agile iterative approach. Each validation phase has focused on a) the incremental installation of the components of the NRG4CAST system which have been developed at the specific point of time to the different pilot cases; b) on the preparation of the pilots; and c) on the execution of the validation and testing activities with the direct involvement of the pilot users and stakeholders.

The Chapter 2 introduces Agile methodology and the process of validation of the system functionalities applied in the NRG4CAST project.

The Chapter 3 describes NRG4CAST toolkit functionalities and NRG4CAST web application GUI. NRG4CAST toolkit gives user a possibility to monitor and analyse historical, real-time and predicted "energy related" data coming related to NRG4CAST objects, consumption centres, nodes and sensors, metadata, and data related to external features. Furthermore the NRG4CAST toolkit GUI presents all the possible options and functions at a single click, and highlights the most important ones. GUI has a user-friendly interface, shows error messages and provides as flexible as possible data visualisation solution.

The Chapters 4,5,6,7 and 8 provide validation results for 6 different pilots from Germany, Italy, Slovenia and Greece. The main focus is district heating (Reggio Emilia and Nubi pilots), electrical energy consumption in public buildings (Turin pilot) and University Campus (NTUA, Athens), public lighting (Miren pilot) and charging stations for electrical vehicles (FIR pilot).

For each pilot we provide a brief description of the installation (more detailed information has been provided within the Deliverable 7.4), results of the functional validation, energy savings validation and stakeholder validation including suggestions for further developments and follow up projects where possible.

Chapter 9 introduces the idea of integrated pilot. A virtual consumption centre configuration functionality has been implemented in order to support the integrated city scenario which combines energy consumption data from sensors belonging to different isolated pilots.

Finally Chapter 10 provides the results of the system level software tests with a scope to perform the validation of the NR4CAST system as a whole.

2 Agile methodology and validation of the system functionalities

The NRG4CAST project has followed the Agile development process in order to deliver the final integrated NRG4CAST Toolkit since the software development process has been organized along three main phases, lasting one year each, which resulted in the delivery of the Data Stream Integration prototype (1st year), the Real-time Monitoring Integration prototype (2nd year) and the Final Integrated NRG4CAST Toolkit (3rd year). Figure 1 highlights the repeated validation phases within the iterative and incremental development process of the NRG4CAST.

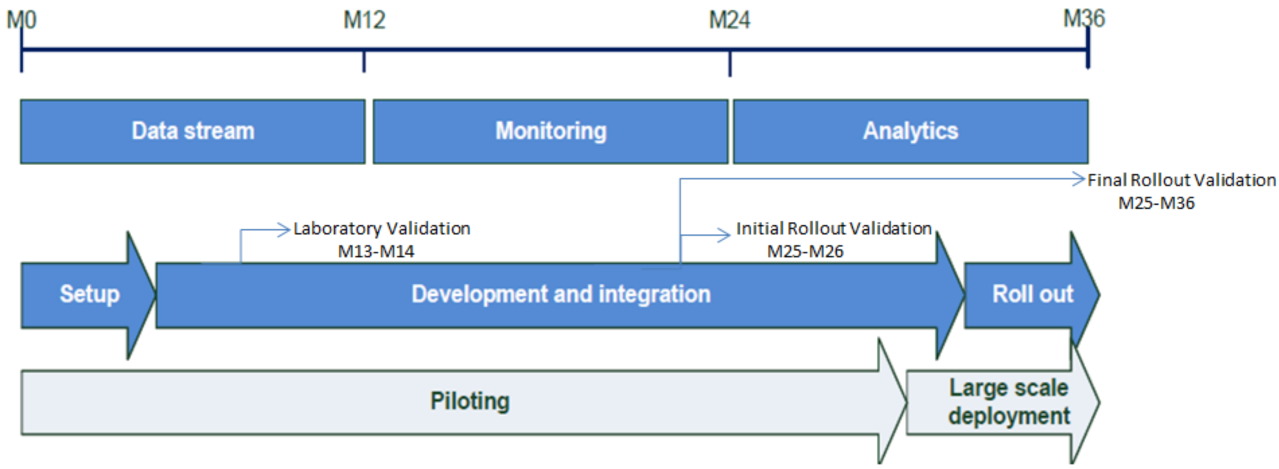

Figure 1: NRG4CAST iterative development and validation process (adapted/modified from [1])

Each validation phase has focused on a) the incremental installation of the components of the NRG4CAST system which have been developed at the specific point of time to the different pilot cases; b) on the preparation of the pilots; and c) on the execution of the validation and testing activities with the direct involvement of the pilot users and stakeholders.

In this context, it has been possible on the one hand to resolve bugs and bottlenecks related with the performance of the software and on the other hand to collect valuable input for necessary improvements on the provided functionalities and the user interface, requests for specific reporting, monitoring and forecasting services and make decisions about the evolution of the NRG4CAST prototype.

Specifically, each validation phase consisted of the following stages (Figure 2)

1. Software testing on the unit, integration and system levels (depicted as functional and internal test).
2. Installation to the pilot cases (depicted as prototype online for user test).
3. Validation by pilot users and stakeholders (depicted as validation by pilot partners)..
4. Requests for improvements and further development (depicted as request for further developments).

It is therefore evident that the development and validation methodology conforms to the agile iterative approach.

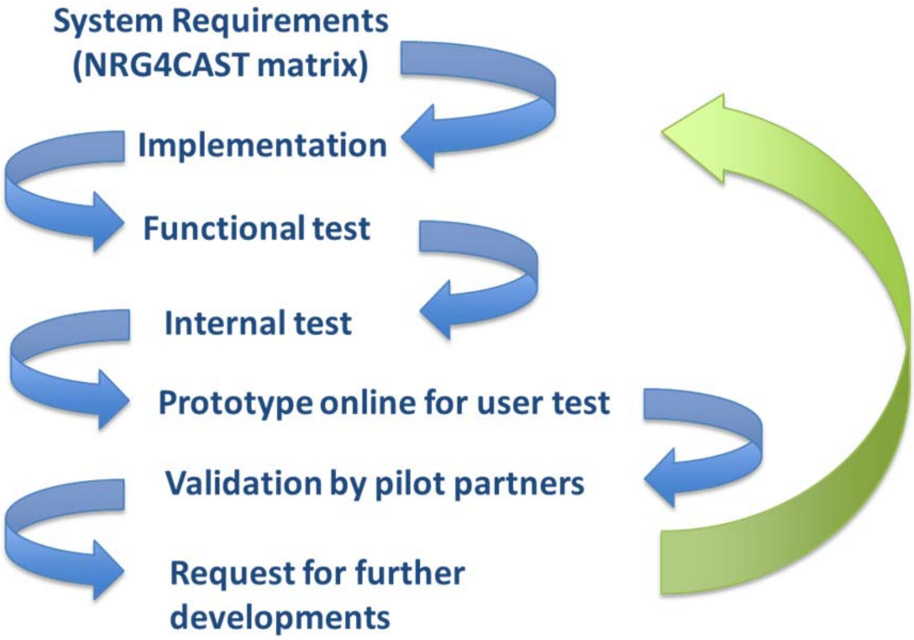

Figure 2: NRG4CAST validation phase flow

3 Description of the NRG4CAST toolkit

The NRG4CAST toolkit (**http://energia.sistemapiemonte.it/nrg4cast/login/start.do**) gives user a possibility to monitor and analyse historical, real-time and predicted "energy related" data coming related to NRG4CAST objects, consumption centres, nodes and sensors, metadata, and data related to external features. The NRG4CAST toolkit GUI presents all the possible options and functions at a single click, and highlights the most important ones. GUI has a user-friendly interface, shows error messages and provides as flexible as possible data visualisation solution.

NRG4CAST system analyses 6 different pilots from four countries. The main focus is district heating, energy consumption in public buildings and University Campus, public lighting and charging stations for electrical vehicles. Moreover, we've implemented a virtual consumption centre configuration functionality in order to support the integrated city scenario which combines energy consumption data from sensors belonging to different isolated pilots.

The front end web application of the NRG4CAST project uses the Central Authentication Service (CAS), a single sign-on protocol for the web. It allows user to access a multiple applications providing user id and password just once. Once authenticated by any of the NRG4CAST Toolkit components, the user will have access to other system components secured with this permission. If login is successful, the user will be automatically redirected to the NRG4CAST welcome page. All the applications associated to this certain user id, role id and task id are listed under the "Available applications" menu (Figure Figure 3).

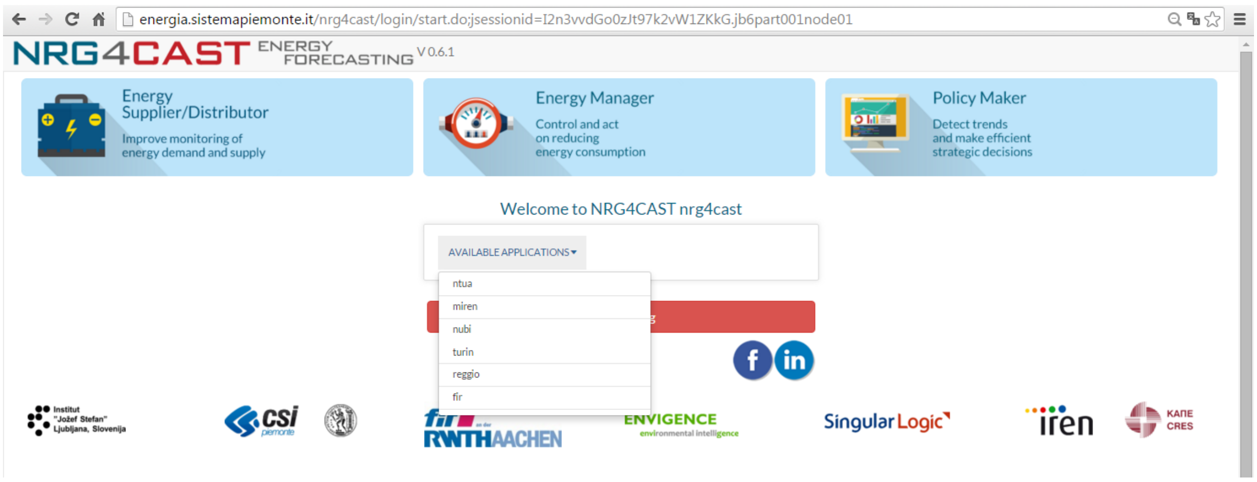

Figure 3: NRG4CAST Toolkit welcome page, available applications for the "super user" profile

Based on the roles, the web application allows or doesn't allow certain functions. In particular, basic and advanced users and associated roles have been created for each pilot. *Basic user* (guest) provides users with the rights necessary to operate all the GUI functions except for an Advanced Search (Figure 4). Furthermore, *Advanced user* (manager) has an access for all the basic and advanced GUI functionalities including Advanced Search and SQL query tool. Both base and advanced users are allowed to operate only within the pilot of competence.

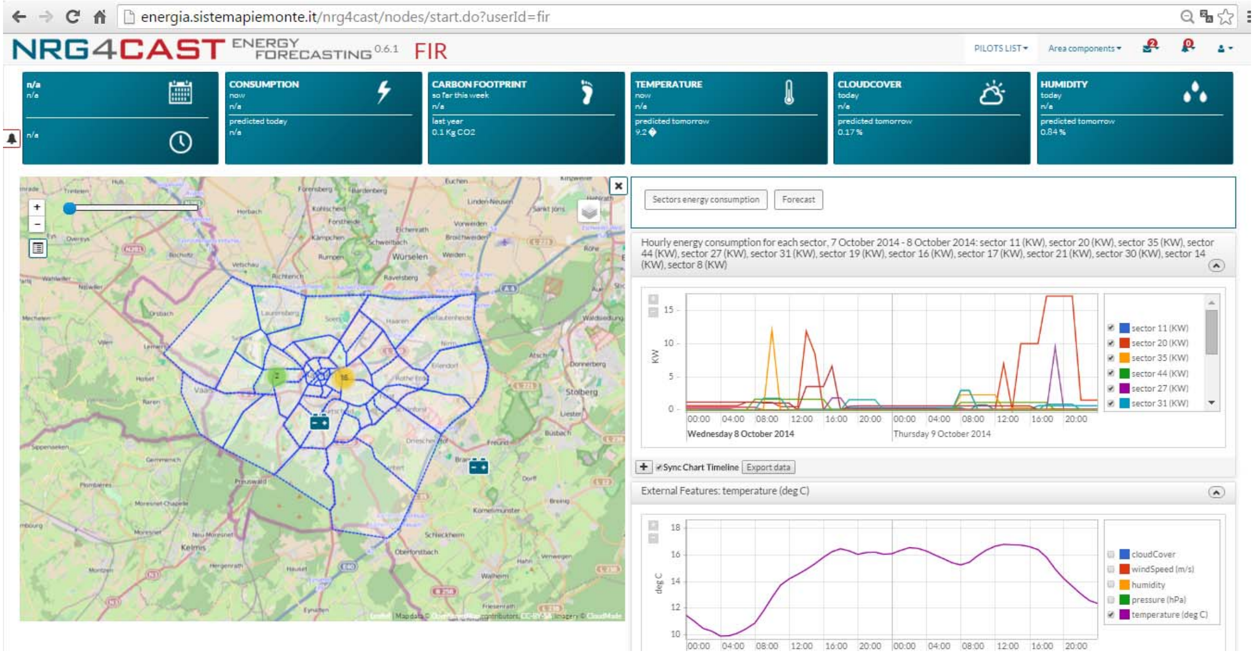

Figure 4: Report Management & Visualization and Real time Visualization GUI, basic user fir-guest (all the GUI functions except for the Advanced Search and SQL query tool

The prototype front page is designed as a dashboard. The top boxes are referred to the whole pilot and represent current and predicted measurements such as actual and predicted energy consumption, carbon footprint, temperature, cloud cover and humidity.

At the left side of the prototype there is a map with a zoom on the area of interest (chosen pilot site). All the geo-referenced objects are shown on the map (Figure 5). By clicking on the object, the user visualises all the information related to the object and sensors installed (metadata, location, selected sensors last measurements).

Figure 5: Georeferenced objects visualised on the map, NTUA pilot example

Each pilot contains a set of predefined reports on actual and predicted energy consumption and possible savings in kW/h. These reports provide visual representation of energy consumption trend within a certain timeframe. Once report diagram appears at the screen, there is a possibility to compare energy consumption, energy usage and thermal energy production with a number of parameters such as temperature, pressure, humidity, wind speed, wind direction, cloud cover, precipitation, visibility, people presence at the building, circulation of vehicles etc. Moreover user can visualize multiple data series (by unchecking Sync Graph Timeline) and compare them to each other. It's possible to export reports in tabular format.

Furthermore, an advanced search option is available for an expert user. There is a possibility for hierarchical search (Figure 6) where user navigates trough the project data structure and selects consumption centres, nodes and sensors to be visualised on the graph and analysed. All the chosen data can be exported in tabular format.

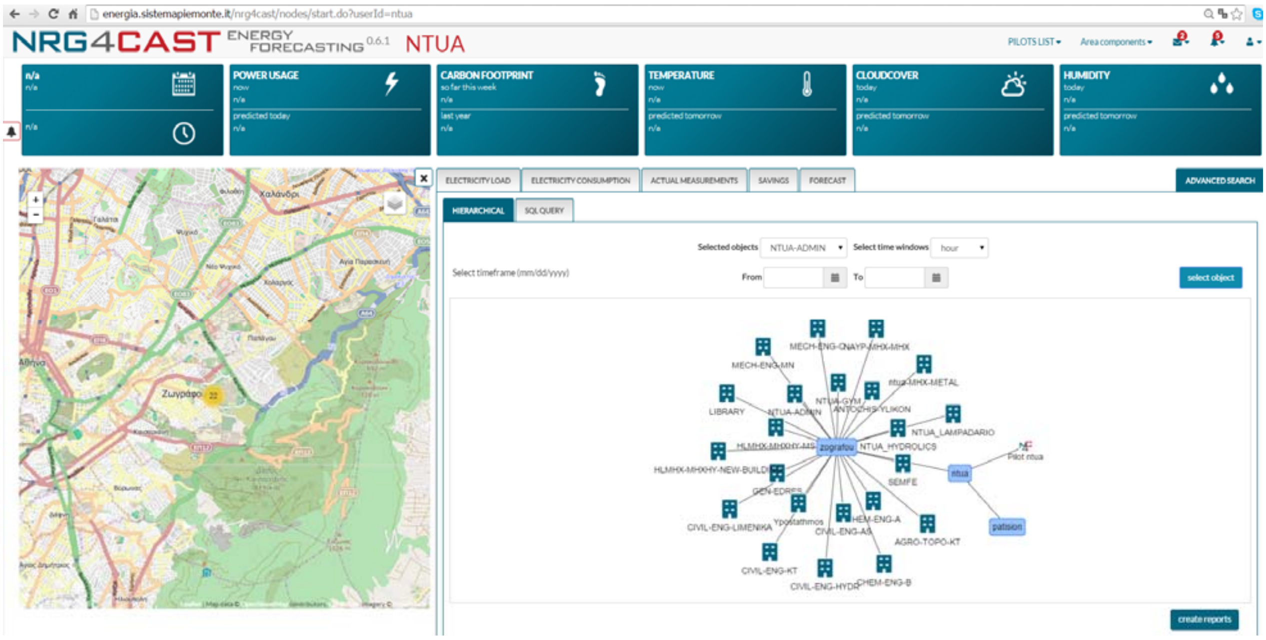

Figure 6: Hierarchical search tool, NTUA pilot example, objects visualisation

Additional advanced search option is an SQL query (Figure 7). For example, the NRG4CAST monitoring database can be queried regarding summed consumption for all the objects, which are part of a certain consumption centre.

The central data repository integrating all the data residing in the NRG4CAST Toolkit is the Monitoring database. The Monitoring database is queried by the Monitoring component either in the case of pre-defined reports or in the case of the creation of on-the-fly complex SQL queries which can yield very useful results. For example, the total consumption of all the objects in a consumption centre or in a pilot may be calculated and presented on a time series through the appropriate SQL command.

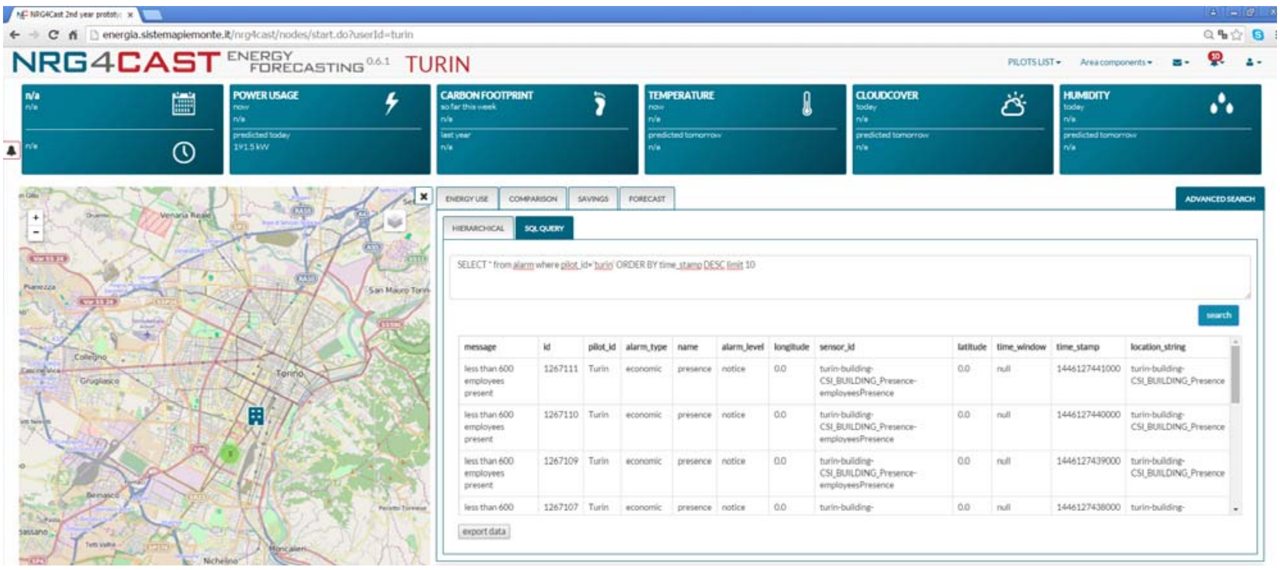

Figure 7: Advanced search SQL query tool, direct connection with the NRG4CAST monitoring database

A number of APIs and services were implemented in order to connect NRG4CAST components. Besides, the connection to the external systems developed by partner such as Rule Editor, Sensor register and Root Cause Analysis Component is effectuated via http link within the NRG4CAST web application.

The real time alerting is now available within the NRG4CAST web application (Figure 8). The NRG4CAST alarms were classified as follows:

- technical alerts (broken sensors, no data etc.)
- economic alerts
- environmental alerts
- energy alerts.

Moreover, an alarm level concept has been introduced to classify alerts as a notice, warning, or alarm. Each alert is referred to a certain object. All the alerts are geo-referenced and are visualised on the map in real time (Figure 9).

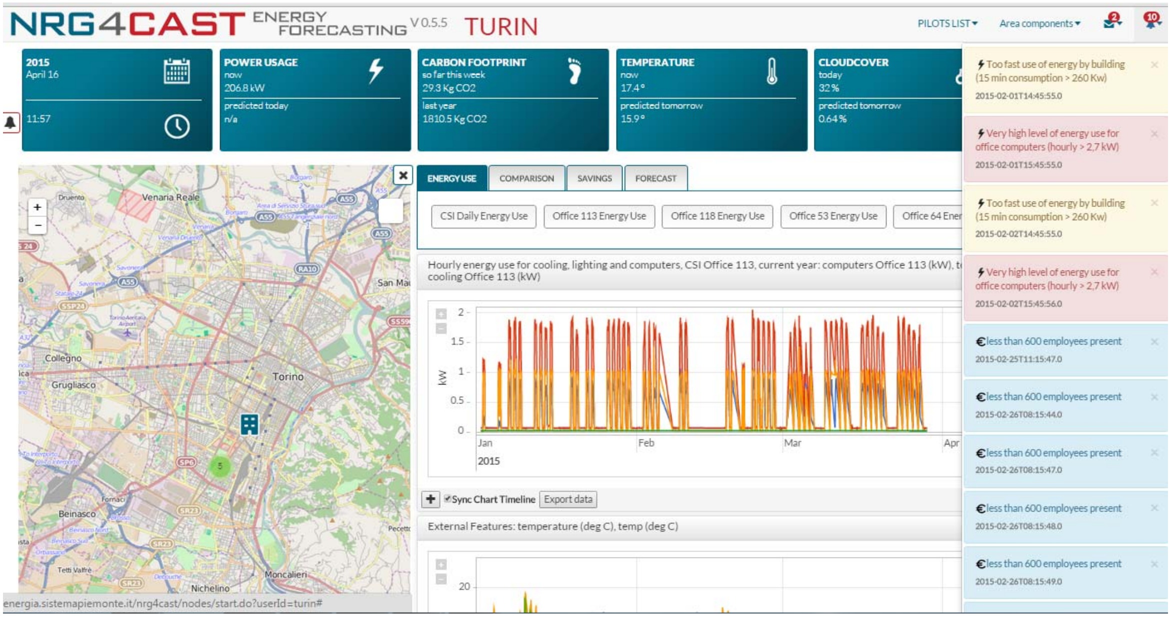

Figure 8: Visualisation of alerts in real time, Turin pilot

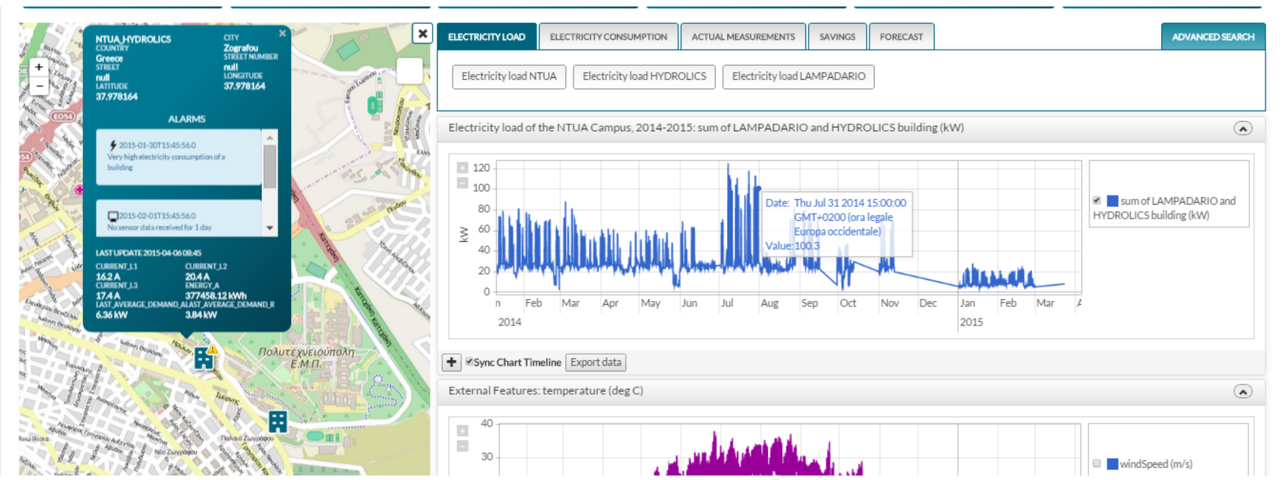

Figure 9: Georeferenced alerts in real time, NTUA pilot example

It is possible to view the system historical alerts within the left corner of the GUI (Figure 10).

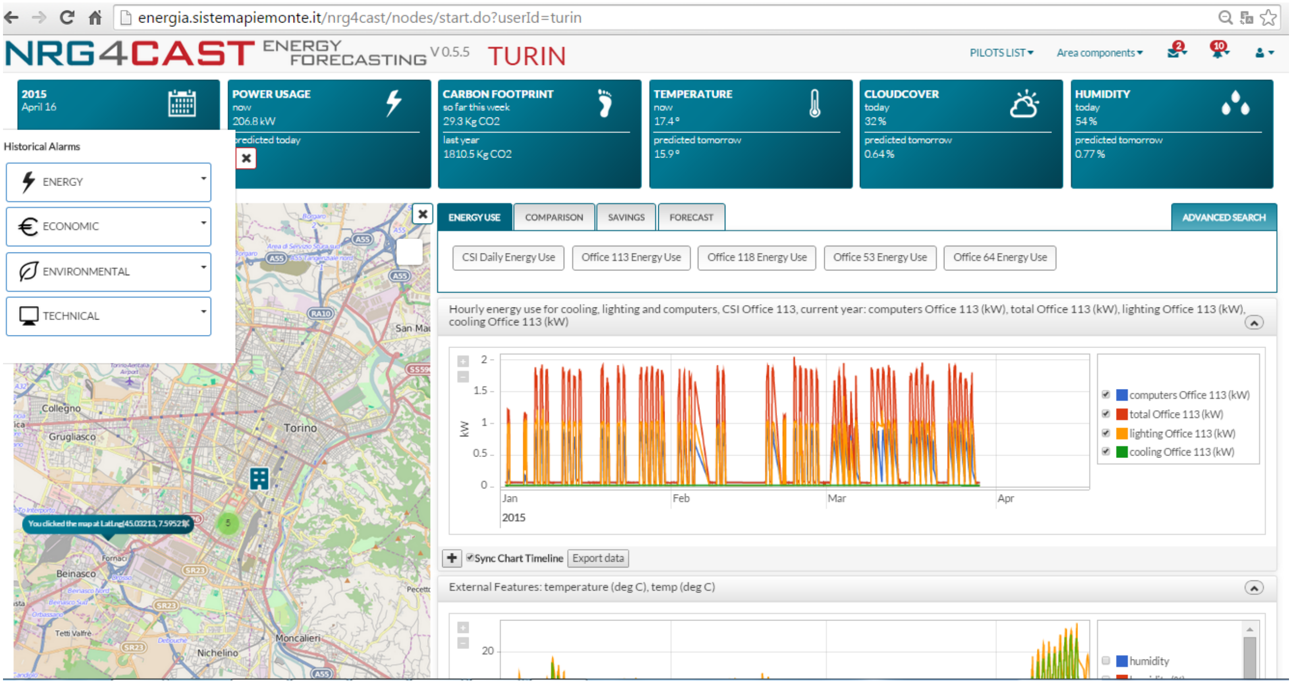

Figure 10: NRG4CAST Toolkit, Turin Pilot, visualisation of historical alerts

In addition, NRG4CAST team has implemented situational awareness services for a number of project pilots and use-case scenarios. This component is based on the user context and provides related information about the environment to be used in the reasoning process. The NRG4CAST Toolkit utilizes general domain knowledge in order to produce explanations with regard to the results of the reasoning process. Further, personalized rules and user input constitute the basis for the NRG4CAST Toolkit situational awareness services.

In particular, the NRG4CAST situational awareness services have been designed on the baseline of the monitoring and alerting services. The situation is assessed by the NRG4CAST Toolkit through the utilization of sensor information about the environment. The assessment process entails the comparison of an individual user context with the environmental sensory information. Sensory data are inputted to the model which interprets them with regard to an individual user context. The future state of the environment is then anticipated by the model.

The situational awareness services are built on top of the monitoring and alerting services and are closely connected to basic real-time decision support and reasoning environment of the project. The situational awareness GUI allows for anomaly awareness, shows “monetary” savings, and highlights high energy consumption and anomalously high temperatures (Figure 11). It is possible to analyse the energy consumption of an overall complex consumption centre, such as an University Campus, a city, and a municipality area. The situational awareness GUI has been integrated within the NRG4CAST web application GUI.

Figure 11: NRG4CAST Situational Awareness GUI, high temperatures alert

4 FIR Pilot. Smart Charging Algorithm for electric vehicles

Due to the rising number of electric vehicles within urban areas, the aim of the FIR pilot is to tackle the problems due to a grid overload. Therefore, it is necessary to offer the grid provider information on how much energy is needed at what specific time at what area in a city. Deriving from this knowledge the grid provider could provide vehicle owner with an optimal location to charge its vehicle. To motivate vehicle users to charge at a different charging station than the actual desired one, the grid provider could, for example, offer a discount on a nearby station. An extract of the charging stations in Aachen is displayed in Figure 12.

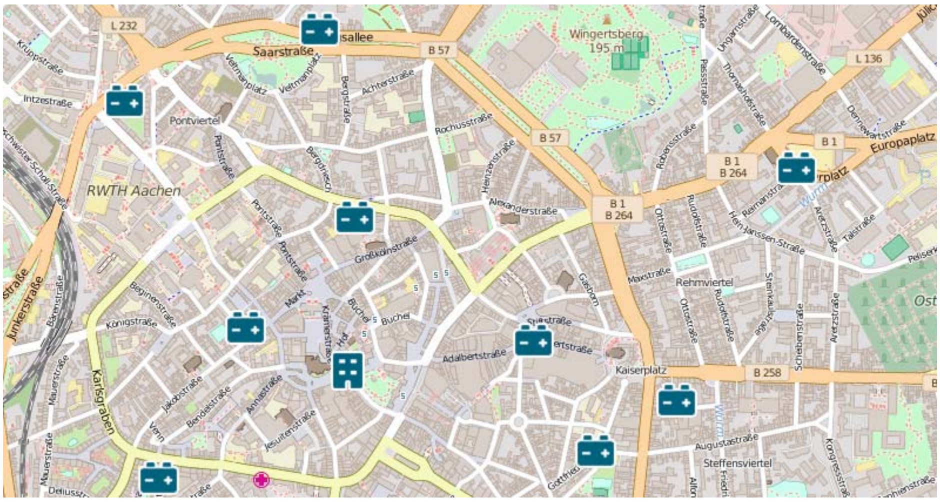

Figure 12: Charging stations (battery icons) within the inner city of Aachen

4.1 Brief description of installation

Each city is divided into certain areas that are supplied by one transformer. Each transformer converts the medium voltage level to a low voltage level to supply households and other end customers. An exemplary distribution of areas is display in Figure 13. The actual allocation of this areas is a secret to each grid provider.

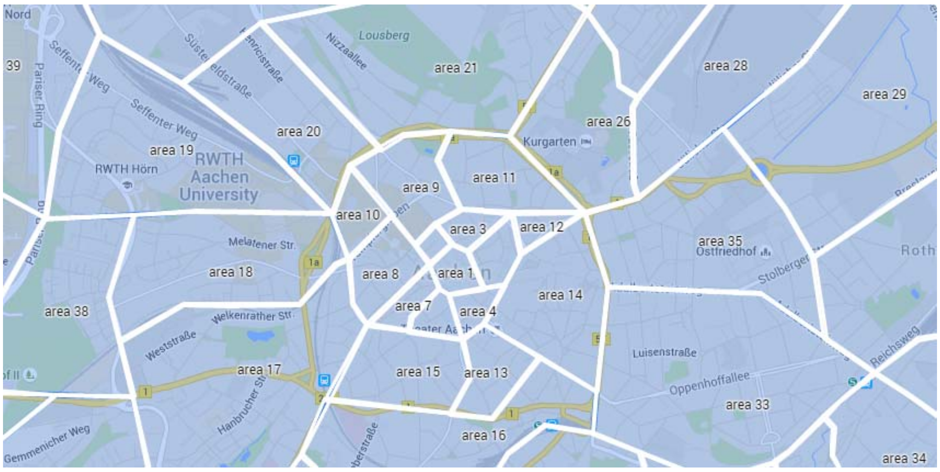

Figure 13: Different areas of energy supply in Aachen (exemplary depiction)

The initial idea for the FIR pilot was to use car2cloud boxes that would transfer the battery state as well as the current location to the NRG4Cast platform. Thereby, it would have been possible to determine when vehicles users charge their vehicles at what location. Consequently, an estimate of the needed amount of energy would have been possible. It was planned to develop the infrastructure for the car2cloud box within the national German research Project "O(SC)²ar - Open Service Cloud for the Smart Car". However, the developed box faced some technical problems regarding the stability of the data connection (for more details, please refer to Deliverable 7.4, chapter 5).

Therefore, a new way was found to predict the needed energy without endangering the FIR pilot outcome. Instead of monitoring the vehicles, the found solution focuses on the data that is acquired by the charging stations in Aachen. Deriving from that, it is possible to see when a car is charged and how much energy is needed. The drawback of this approach is that vehicles, that are charged at home will not be monitored, but the advantage of this approach is that all kind of vehicles are monitored, even though they are not fitted with a car2cloud box. Furthermore, this approach also grants a solution, that is easier to intergrade in a wider range of stakeholders. The only data that needs to be collected can be obtained by the charging station provider. Tough negotiations with the vehicles companies to get access to the data streams are not necessary.

In the NRG4Cast case, a data set was provided by the smartlab Gmbh, as a charging station provider within the Aachen area. The data is collected by the LISY ("Ladesäulen-Informations-System") platform as seen in Figure 14. This platform was originally only used to administrate the accounting information of the charging station users. For example to charge users for the used energy. As a side-effect, the platform also needs to collect the information about the time and amount of charged energy. Since the position of a charging station is fixed, all three needed parameters for the desired prediction are known.

Since the platform is operated by the smartlab GmbH, that is not part of the NRG4Cast consortium, it is not possible to have a direct access to the platform. Therefore, the basic data validation is also not done by the NRG4Cast consortium. However, since the data stream contains sensitive information regarding accounting issues, it can be assumed that the data is checked and valid. For a future use of the NRG4Cast platform, it is ensured, that other charging station providers and grid provider can easily intergrade a data live stream.

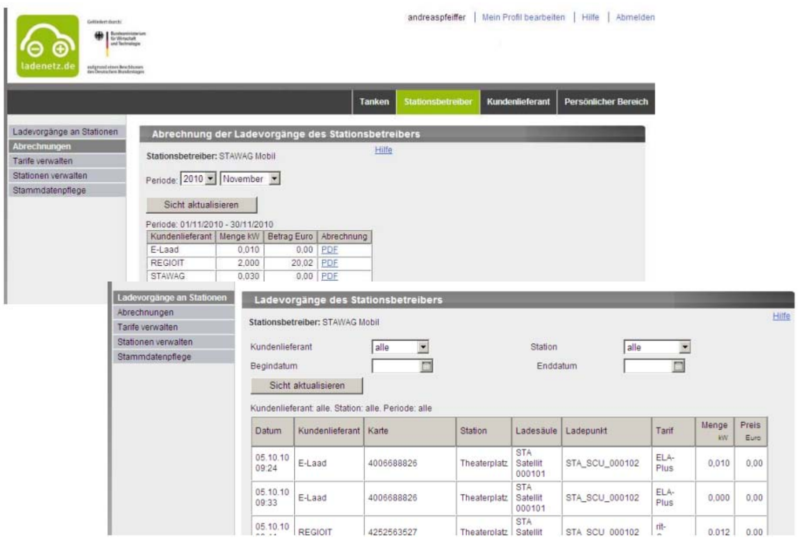

Figure 14: The LISY platform that is used to collect the charging station data

4.2 Functional validation

The two main functions, the FIR pilot wanted to tackle are the avoidance of grid failure due to overload and the evaluation of charging station locations. Those functions will be evaluated in the following chapters.

4.2.1 Avoidance of grid failure

As described above, one of the main goals for the grid provider is to avoid grid failure due to a high number of electric vehicles that are charging simultaneously and lead to an overload of the transformers. In addition, enough energy needs to be provided. If it is possible for the energy provider to plan ahead the energy production, this can be done more cost efficient than just an spontaneous reaction of an increasing and decreasing energy demand. Therefore, it is a crucial information for the grid provider as well as for the energy provider how the energy consumption will be during the next days. In almost every case it is enough to get a prediction that states the energy demand one day ahead, since it offers enough time to react. In addition, the prediction of the renewable energy sources works reliable and it would therefore be possible to consider the renewable energy sources.

This one day prediction of the energy demand was the aimed functionality for the FIR pilot within the NRG4Cast platform. This is realised within the platform by a map that displays the different sectors across Aachen. On the top left of this map, there is a slider that can be used to switch trough different time steps of the predicted day. The different areas in the map are coloured according to the energy demand in this area at the selected time (see Figure 16).

An example is display in the three pictures of Figure 15. On the first picture, area 20 is selected and the NRG4Cast tool displays the predicted energy demand at a certain time. The second image represents the same spot one hour later. The value of the energy demand is decreased and also the colour of the area is less dark. On the last picture, the demand is zero and therefore, the colour of the area is transparent.

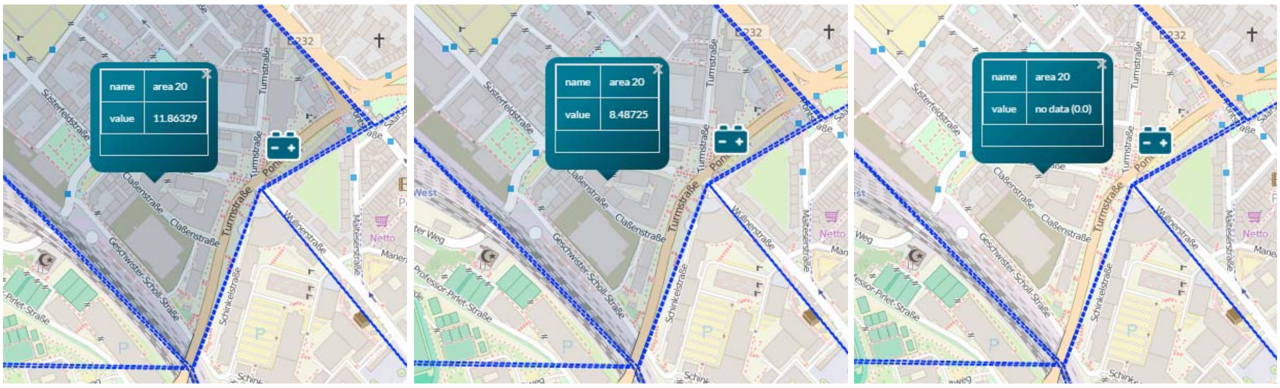

Figure 15: Energy demand prediction of a certain sector in Aachen

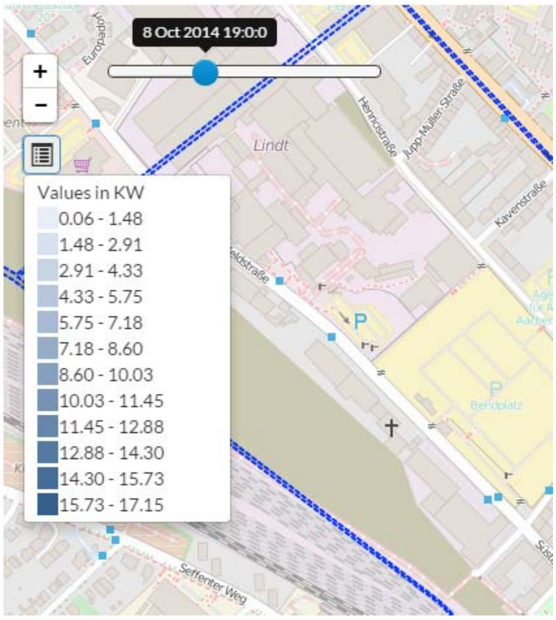

Figure 16: Slider to flip through the predictions and legend hat explains the KW according to the colour

By displaying the energy demand of each area and also having a visual support by the coloured maps, the grid provider as well as the energy provider can easily receive the needed information. By using this information, the stakeholder can ensure a stable energy supply even if the number of electric vehicles will increase dramatically as it was expected, for example, in Germany (see Figure 18).

4.2.2 Charging station location evaluation

As a second use case, the FIR pilot within the NRG4Cast platform could be used to determine if a charging station is placed at the right spot. Charging station provider usually face the problem, that they can just assume that a location is feasible for a charging station, since there are no reliable statistics on energy demands for electric cars broken down to certain areas of cities. By monitoring the charging stations with the NRG4Cast platform, the charging station provider can determine which stations are used frequently and which stations are only used by very few vehicles (see Figure 17). They can also determine in what areas the energy dement is high in general. Those areas can be fitted with a higher number of charging stations, whereas in an areas with a low energy demand, charging stations can be removed.

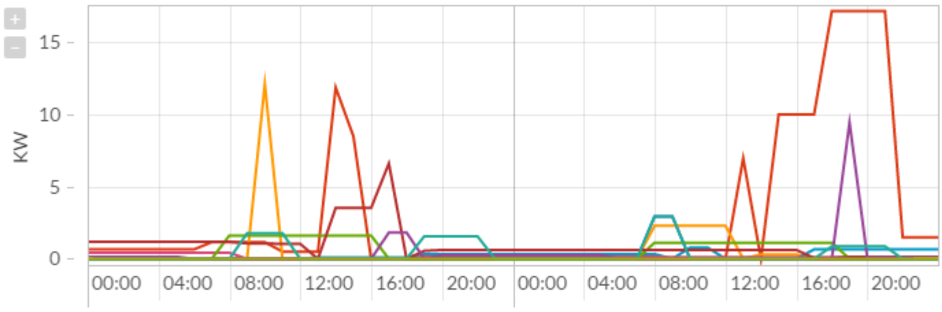

Figure 17: Detailed view of the current energy consumption (current day) and the prediction (next day). Each colour represents one charging station

The biggest issue in validating the FIR pilot, is the, already mentioned, low amount of actual electric vehicles within Aachen. During the proposal of the project, the predicted number of electric vehicles today was significantly higher than the actual number. Figure 18 displays the estimated amount of electric vehicles in Germany (blue line) compared to the actual amount (red line). As it can easily be determined, there is a large gab between those states in 2015. Therefore, the effects of electric vehicles on the energy grid are very minor and hard to measure.

Despite those facts, the German government is still convinced to archive the goal of 1million electric vehicles till 2020. If the penetration of electric vehicles will take large steps towards the proposed goal in the future, the NRG4Cast solution will win more and more significance, as it was proposed to have already at the end of the project.

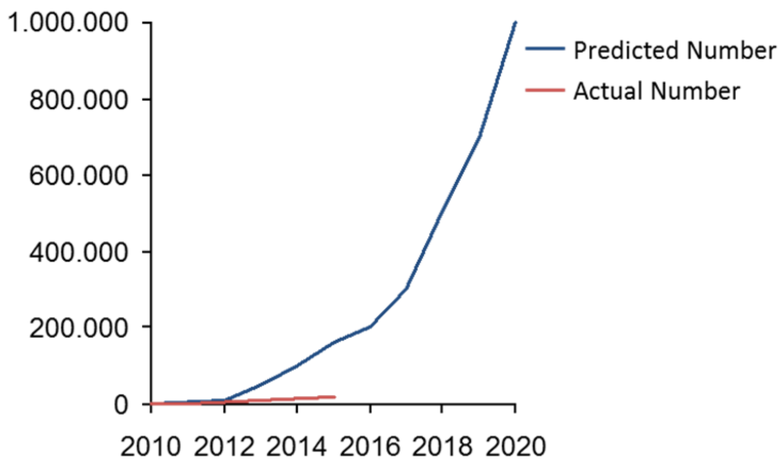

Figure 18: Prediction and actual development of the amount of electric vehicles in German

4.3 Stakeholder validation

The charging station provider is monitoring a exponential grow of energy demand generated by charging vehicles as it is displayed in Figure 19. This validates the progress that is stated in Figure 18 but also displays that the consumption would be even higher when the actual penetration of electric vehicles would be as high as predicted. However, it gets more and more relevant for the energy provider to receive predictions on energy demands. The stated paragraphs above are confirmed by the stakeholder. Therefore it will be even more important in future to see whether a charging station location is paying of or not as well as determining the grid load on a low voltage level to e.g. extend the transformer or other parts of the infrastructure.

For the future, it would also help the stakeholders to enhance the NRG4Cast platform by the following additional functionalities:

1. To improve the placement of charging stations even further, it would be helpful to obtain a long range prediction of the energy demand too. This does not need to be on such a detailed level as it is in the current state. However it would be helpful to get obtain a trend of the demand development in each sector.
2. For a follow-up project, an addition to the current state could help to add another benefit to the grid stability. Since the prediction right now determines when, where and how much energy is consumed, and relatively easy extension would be the prediction of when, where and how much energy is stored within vehicles. Therefore, this energy storage could be used to flatten energy demand peeks. Obviously, this needs to be done with the vehicle owners agreement. By elaborating how this bidirectional charging and discharging can be done, without neglect the human factor, this could be an further enhancement to the grid stability building up on the NRG4Cast platform.

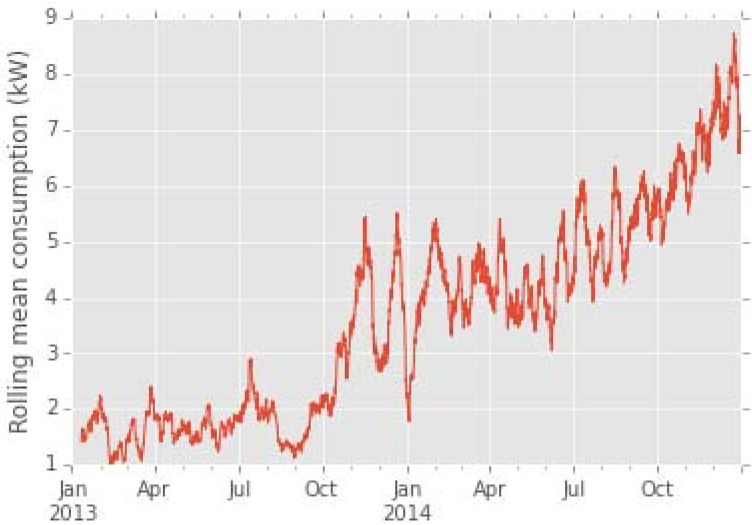

Figure 19: Energy consumption generated by charging stations during 2 years

5 Reggio Emilia pilots

5.1 Brief description of installation

IREN produces and distributes thermal energy within the Reggio Emilia region in Italy. Therefore, the pilot scenario deals with the **energy efficiency of the district heating network.** This rise in efficiency can be obtained on the **production side as well as on the distribution side.**

Therefore, the pilot scenario also aims at two targets: **the thermal power plants**, on the production side, **and the buildings within the Campus Nubi (the IREN campus),** on the distribution side:

- UC1: **District heating production forecasting**
- UC2: **District heating water temperature forecasting** in the Campus Nubi in order to keep a fixed room temperature

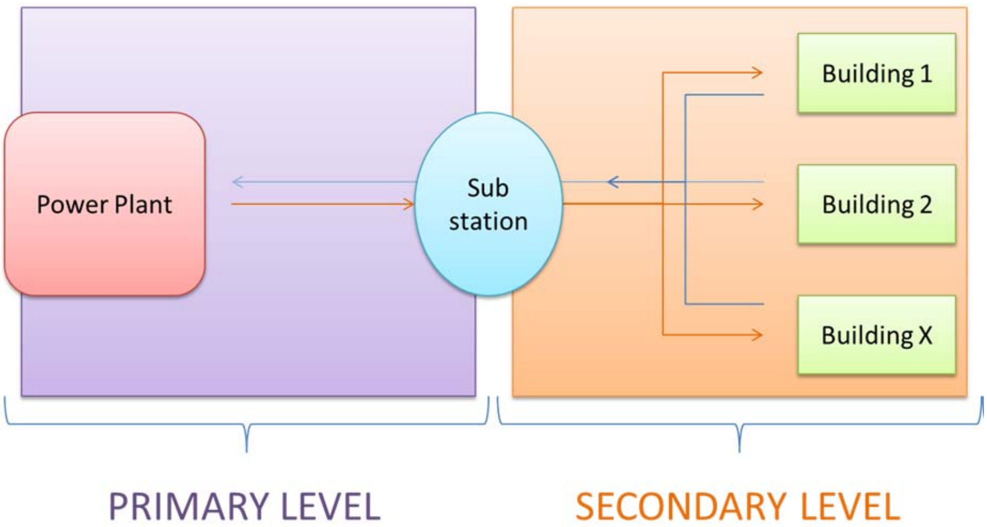

Figure 20: Use cases 1 and 2 of the Reggio Emilia pilot affect respectively primary and secondary DH network levels (adapted/modified from [5])

Data are collected from 5 Thermal Energy production plants in Reggio Emilia and 6 thermal substations that distribute DH to the offices, warehouses, and laboratories in the Iren Headquarter, called Campus Nubi, in Reggio Emilia:

- Data are uploaded on an hourly basis (granularity) and a .csv file is uploaded once a day on the IREN ftp server since January 2014;
- Historical data (2012/2013) have been provided;
- Data are integrated into the NRG4CAST platform;
- Early stage analysis, already available for historical data, has given results which are consistent with the DH network characteristics;
- Determinants and other control covariates are available as well (outdoor temperature, wind rate, humidity).

Within the Reggio Emilia pilot a further issue was investigated: the forecasting model of the optimal water temperature of the secondary level to be provided to each substation within the Campus Nubi station in order to keep a pre-defined indoor temperature (e.g. 20°) in the target buildings.

The Campus Nubi pilot in Reggio Emilia City let to reach interesting and forefront results in the domain of the forecasting models. The experimental aim of Campus Nubi pilot was to investigate the possibilities to find an alternative way to get data instead of installing sensors, devices and equipment's.

During the Campus Nubi pilot an Add-On Functionality (AOF) was deployed. It does not require new sensors but only information coming from the network and its sub-systems. The information is computed in an algorithm and the results provide an added-value in terms of cost reduction and production start.

In Campus Nubi pilot an algorithm to derive the heating energy consumption data was implemented, in order to avoid the installation of new sensors.

Concerning the thermal energy prediction the computation is really simple, as elicited in the following figure.

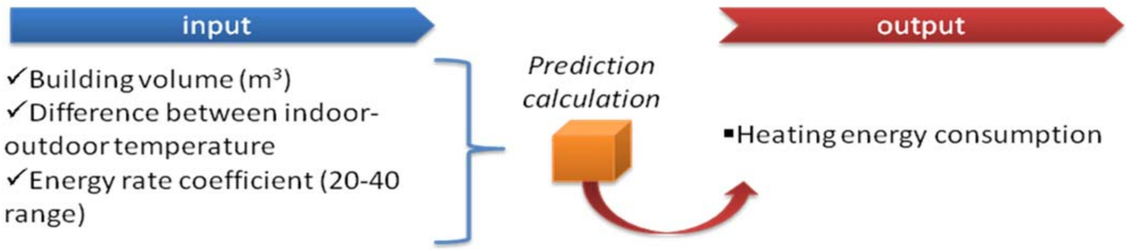

Figure 21: Input and output for thermal energy prediction (adapted/modified from [4])

The goal of the prediction model for energy consumption as it is already stated within the Deliverable 5.2[4] is as follows:

- to providing energy consumption estimation, allowing in this way to use the NRG4CAST forecasting tool without adding extra sensors to the current energy network.
- to contribute in in improvement of the efficiency of the thermal energy production taking into account the Adaptive Thermal Comfort Standard (for details about the Adaptive Thermal Comfort Standard please refer to D5.2).

Data provided to the forecasting model are:

- Current energy consumption of the buildings within the Campus Nubi (derived)
- Outdoor temperature
- Secondary forward water temperature
- Primary return water temperature
- Alerts from each substation (e.g. on a broken sensor or a wrong water temperature), including timestamp + type of alarm (ID)
- Indoor temperature
- SST and Building coordinates and volume
- Determinants and other control covariates are available as well (outdoor temperature, wind rate, humidity).

The current energy consumption is obtained through the following formula [4]:

Heating energy consumption (W) = Building volume (m^3) x indoor - outdoor temperature difference (C°) x Energy rate coefficient (range between 20 and 40) (1)

Or shortly:

$$P = V * (T2-T1) * c \tag{2}$$

5.2 Functional validation

NRG4cast platform is able now to provide the following forecasts:

- Thermal forecasts (thermal production and water temperature)
- Temperature
- Cloud cover and humidity

The major functional validation was related to the setting of the energy rate coefficient, needed to calculate the heating energy consumption. Up to now the only way to establish it is through heuristics and personal experience of thermal engineers.

In order to define the energy rate coefficient and verify the range relevance (from 20 to 40), we've created a baseline using historical heating energy consumption of the CSI building (Turin), internal and external temperature (November and December 2014; January, February, March and April 2015)

The main results are shown in the table below:

Table 1: Historical data about heating energy consumption and internal and external temperature of the CSI buildings in Turin (adapted/modified from [4])

Months/year	Values of average W consumption	Difference of average int-ext temp.	Coefficient mean
January 2015	81,02722153	19,27510316	30,86425873
February 2015	87,92931946	18,36489732	34,03624457
March 2015	62,22476712	11,24178096	57,77191618
April 2015	35,09756237	8,109869394	35,42931987
November 2014	50,37157982	10,90405519	34,73028813
December 2014	71,04368578	15,81385047	34,3293136
Total	**65,57107551**	**14,15409675**	**38,11481955**

Considering these results, we decided to set the energy rate coefficient to 38.

In the following some examples of the functionalities of the forecasting tool for the Reggio Emilia pilots.

Figure 22: Forecast overview on the top of the page: thermal, temperature, cloud cover and humidity forecasts

Figure 23: thermal production of the Reggio Emilia plant

Figure 24: Thermal forecast for the Reggio Emilia plant

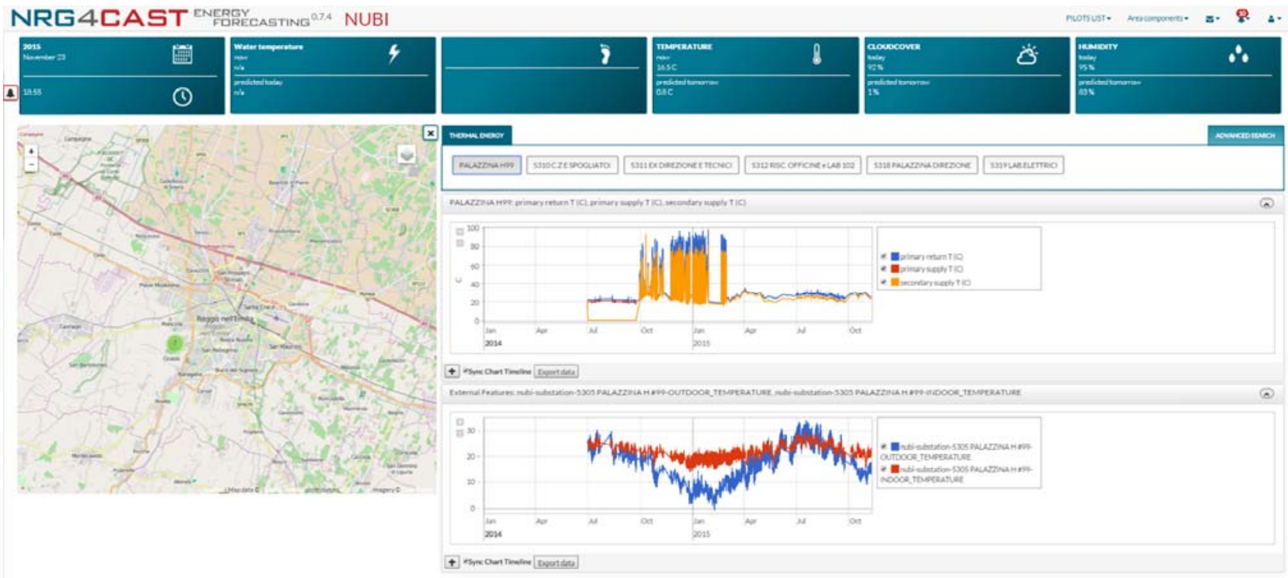

Figure 25: Water forecast functionalities for the Campus Nubi plant

5.3 Stakeholder validation

Stakeholders agreed that operating both at the consumption and at the production stages of the energy chain, NRG4CAST tool will help in reducing building energy consumes, contributing to the energy and climate goals set by EU (20% energy savings by 2020) thus leading to significant environmental benefits.

For the future, stakeholders interested in a follow-up project identified the following features:

- The combination of the forecasting models with a domotic tool, for example an energy storage system;
- The implementation of an "on demand- data benchmark" function in compliance with specific needs expressed by end users;
- The portability of the forecasting service on mobile devices through a dedicated App, as well as its integration in decision support systems.

6 Turin Pilot

6.1 Brief description of installation

Turin pilot objective is an energy efficiency in public owned buildings in Turin, Italy. The main goal is to use the NRG4CAST toolkit for energy consumption control, saving planning and reduction of energy consumption.

The consumption of the CSI building has been analysed in detail. The building total consumption monitoring is effectuated as following:

- building total energy consumption except energy used for cooling
- energy consumption used for cooling of Data Center
- energy used for building cooling
- building Total energy consumption (no Data Center)
- thermal energy consumption

The total offices consumption monitoring is based on the 4 pilot offices (typical CSI office):

- energy used for office cooling
- energy consumed by workstations
- energy used for lighting.

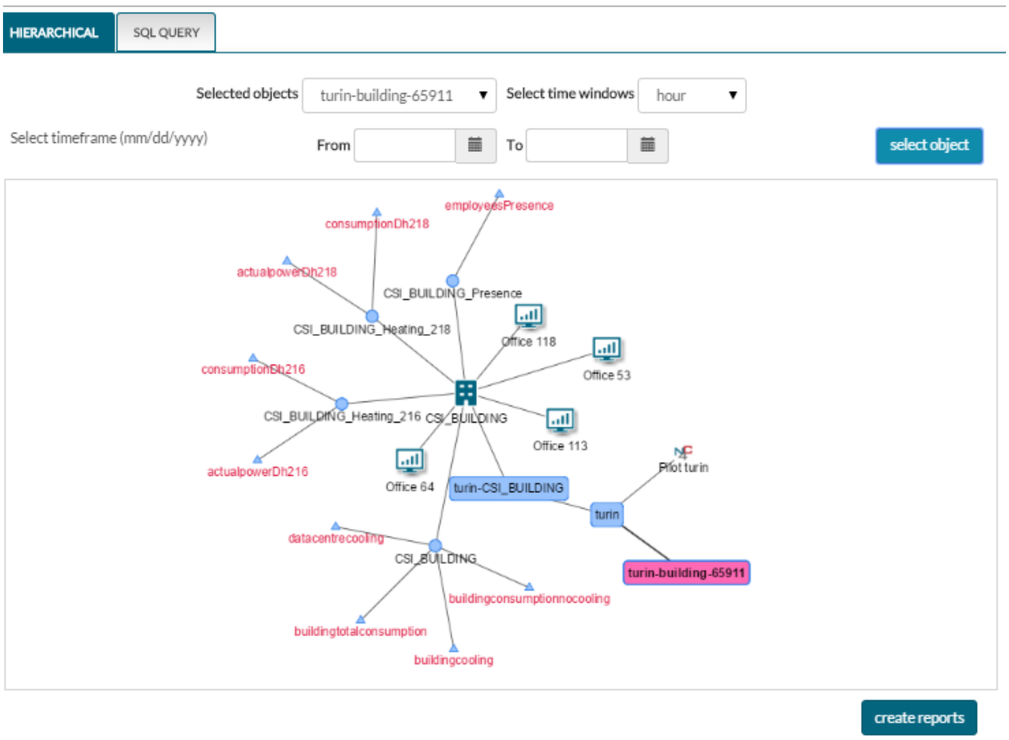

Figure 26: Hierarchical search tool, CSI building installation hierarchical structure

6.2 Functional validation

The main functionalities requested by Turin pilot can be summarized as following:

- tools for improvement of the accuracy and quality of energy consumption measuring and monitoring such as predefined reports, advanced search and comparison tools

- energy consumption and weather forecasting
- possibility for anomalies detection and awareness in real time

All these functionalities were validated during the 3 year of the project applying the methodology described within the Chapter 2:

- the set of predefined reports developed for Turin pilot gives a possibility for very accurate visualization of energy consumption on 15 minute basis. There is a possibility to compare energy consumption with people presence within the building, weather parameters etc.

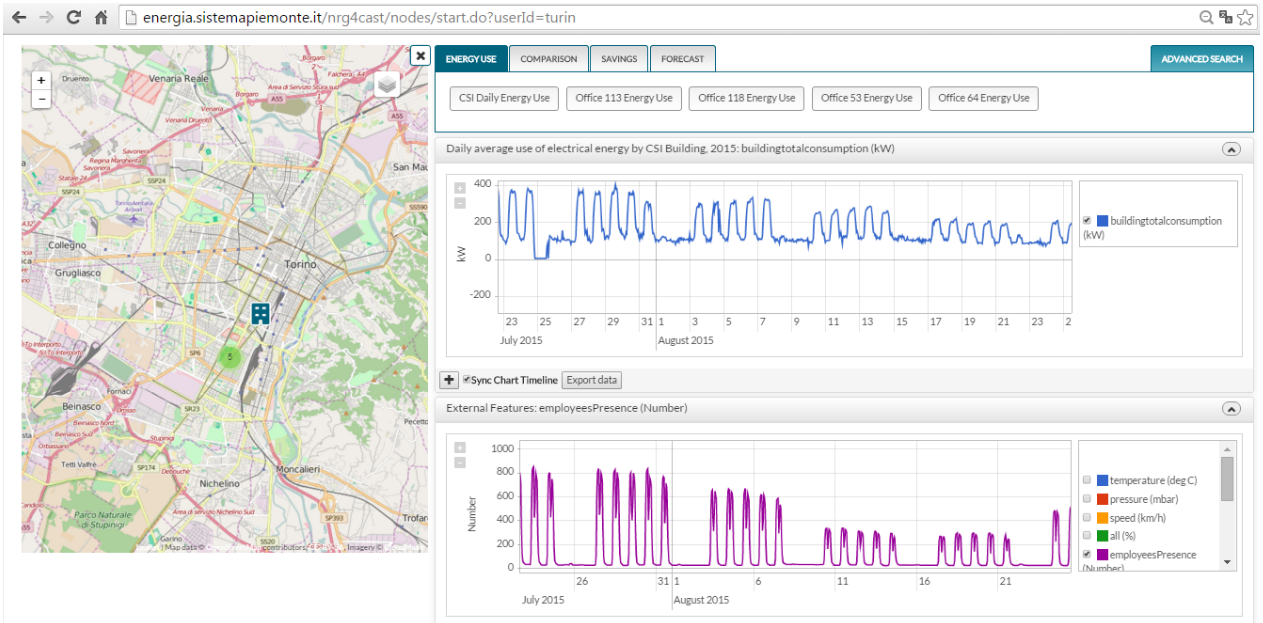

Figure 27: NRG4CAST toolkit, total electrical energy consumption vs building occupancy, CSI building

- results of the savings achieved after the CSI energy efficiency awareness campaign, can be visualised within the group of savings reports
- forecast for the Turin pilot is available

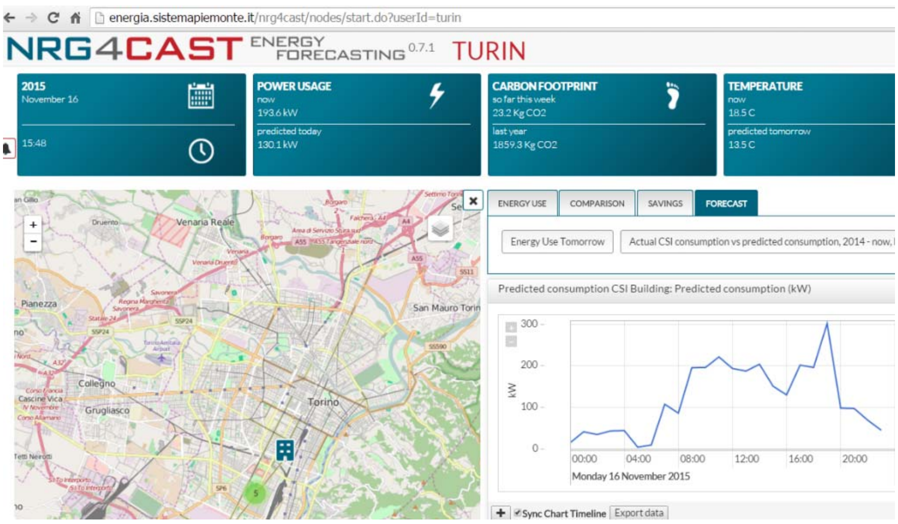

Figure 28: One day energy consumption forecast available for Turin pilot, CSI building

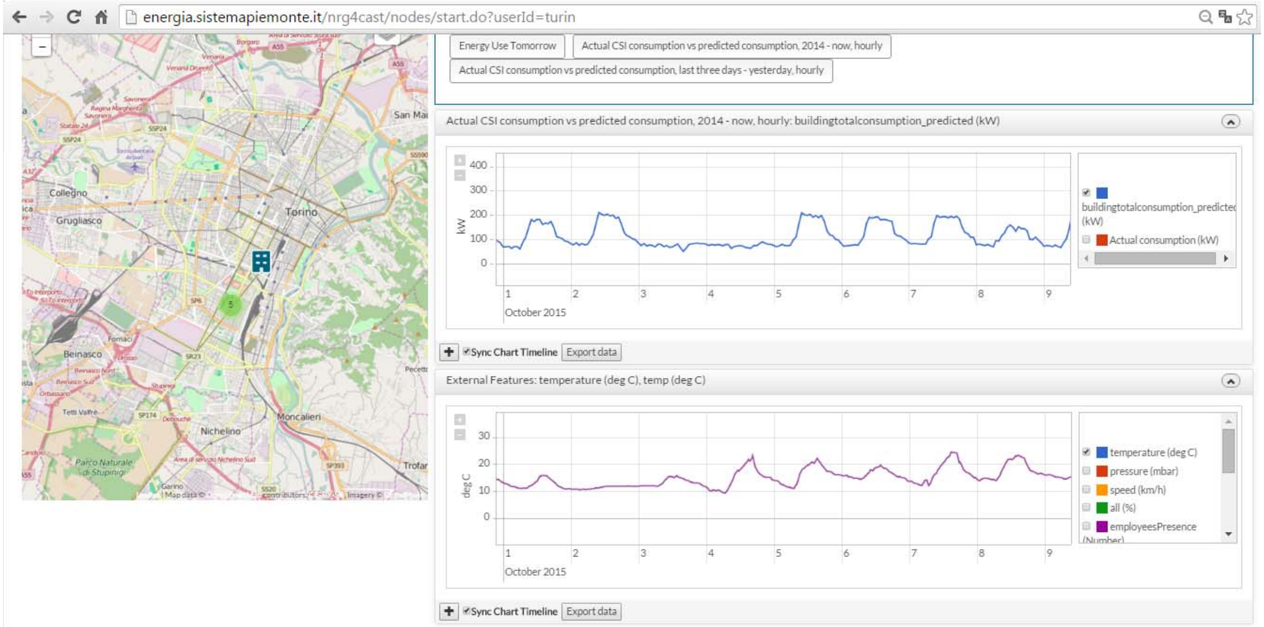

Figure 29: NRG4CAST toolkit, CSI building total energy consumption prediction, actual and historic data

- situational awareness services built on top of the monitoring and alerting services are available for the Turin case (see Figure 11). For Turin pilot the situational awareness GUI allows for anomaly awareness. It highlights high energy consumption and anomalously high temperatures. Please refer to the deliverable 5.4 for more details [3].

6.3 Energy savings validation

Conditions to be taken in consideration during the validation

- the cost of KW=0.16 € (CSI building, Turin, Italy)
- Data centre consumption (cooling and overall electrical energy consumption) operation is not included in the analysis
- In the 2013-2014 CSI directorate has decided to bring all the stuff to the CSI Head Quarters (pilot building) and leave all the additional buildings. In 2014 the growth in electricity demand was significant because of high employees presence in the building
- the graph and polynomial trend line (Figure 30) highlight the savings CSI achieved following the awareness campaign energy efficiency actions at the end of the 2014 – first half of 2015.

The Awareness Campaign and the possibility to use NRG4CAST toolkit to monitor energy consumption in real time, to compare energy consumption measurement with the external data stream and to forecast energy demand lead to the 27 percent energy savings.

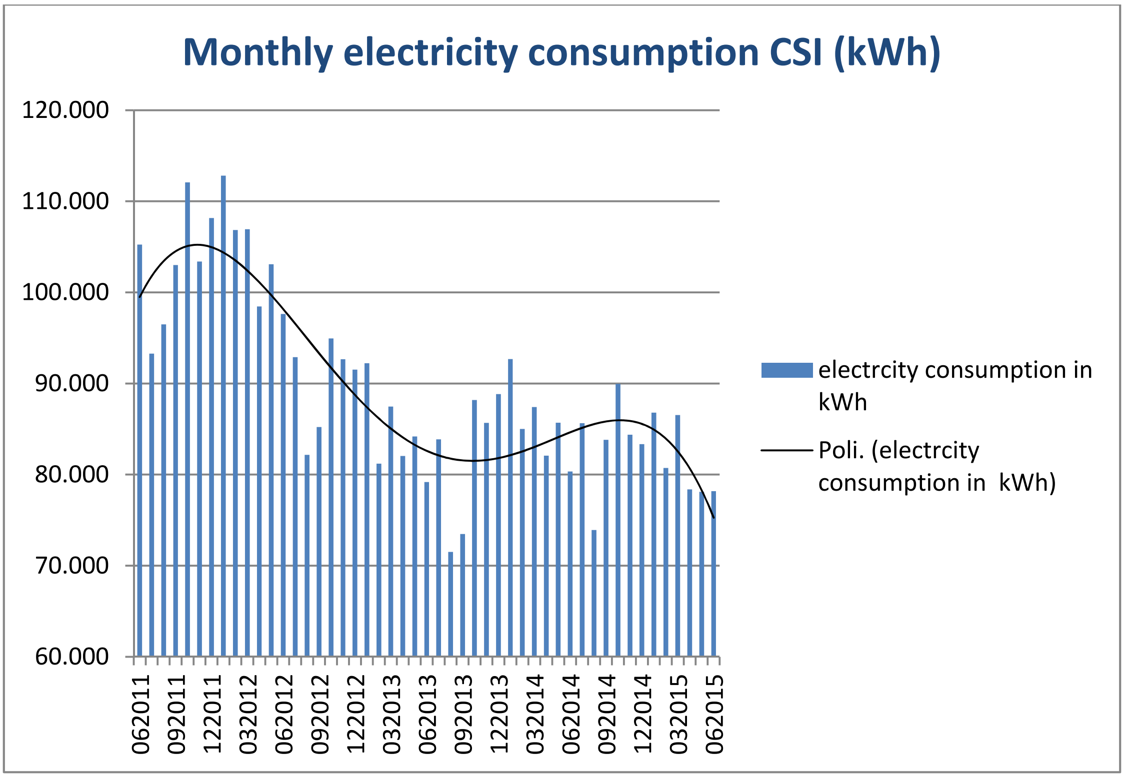

Figure 30: Monthly electricity consumption, CSI building, Turin, Italy

	Period	Sum	Total Costs	Number of employees	Annual energy consumption /employee (KWh)	Annual Energy cost/ employee (EUR)
NRG4Cast	Oct 14 - Jul 15	746.442	119.431	1.225	609	97
Previous year	Oct 13 - Jul 14	775.924	124.148	930	834	133

Table 2: Results from reference periods (Electricity)
(Oct 14 - Jul 15 vs. Oct 13 - Jul 14)

	Projected costs (Oct 14-Jun 15)
Without NRG4Cast	**163.528**
With NRG4Cast	**119.431**
Savings	**44.097**
% of savings	**27%**

Table 3: Validation result, CSI building, savings in Euro and percentage

6.4 Stakeholder validation

A number of workshops were organised in order to gather stakeholders' feedback on NRG4CAST tool importance and usability. The city's decision makers and stakeholders, energy providers, facility managers, and building owners provided their opinion during these meetings.

Stakeholders have shown a high interest in the NRG4CAST geospatial capabilities for visualisation of data patterns and notifications to be visualised once energy consumption is too high for the particular building, district, area etc. The weather and energy consumption forecast gives a possibility to highlight expected high electricity consumption which allows for energy saving actions planning. NRG4CAST user can estimate energy consumption and an amount of money to be paid, thus to translate energy consumption into "monetary". The NRG4CAST solution is based on the user opinion and personalised rules created by pilot-partners. This solution is flexible and ready for a prompt response on even unusual requirements, which is a

Furthermore the stakeholders provided suggestions for NRG4CAST future developments. NRG4CAST achievements could become the base for a long term optimisation DSS, subject of the eventual evolution and logical continuation of the NRG4CAST project. This DSS would suggest a strategy for the energy efficiency actions and investment in technologies, given a set of input parameters that describe technologies and the tariffs used to buy and sell energy. Ideally, this kind of system would propose strategic decisions/solutions (energy saving actions, retrofit actions along with the monetary and emission effect, for the day, week , month.

7 Miren pilot: lights as a service

7.1 Brief description of installation

With installation of the smart electronic on the street lights and use of NRG4CAST analytics tolls in municipality Miren – Kostanjevica we want to achieve more than 50% savings on electricity bill.

From the start point to monitor energy consumption in real time, to detect the anomalies on the network in real time and to forecast energy demand we upgrade the Light as a service model to more sophisticated with which we could deeply understand consumptions, trends and also events which influence on the electricity consumption.

With this final validation we want to validate the deployment processes, real savings and technical requirements for mass deployment of the electronics and NRG4CAST street lights tools. For additional savings, we take in the observation predicted information, moon phases and traffic flow.

7.2 Functional validation

For the functional validation we compare the results coming out from Envigence backend and from NRG4CAST frontend.

Results:

- all the data were the same
- predicted values were validated
- the alarms from the system were OK

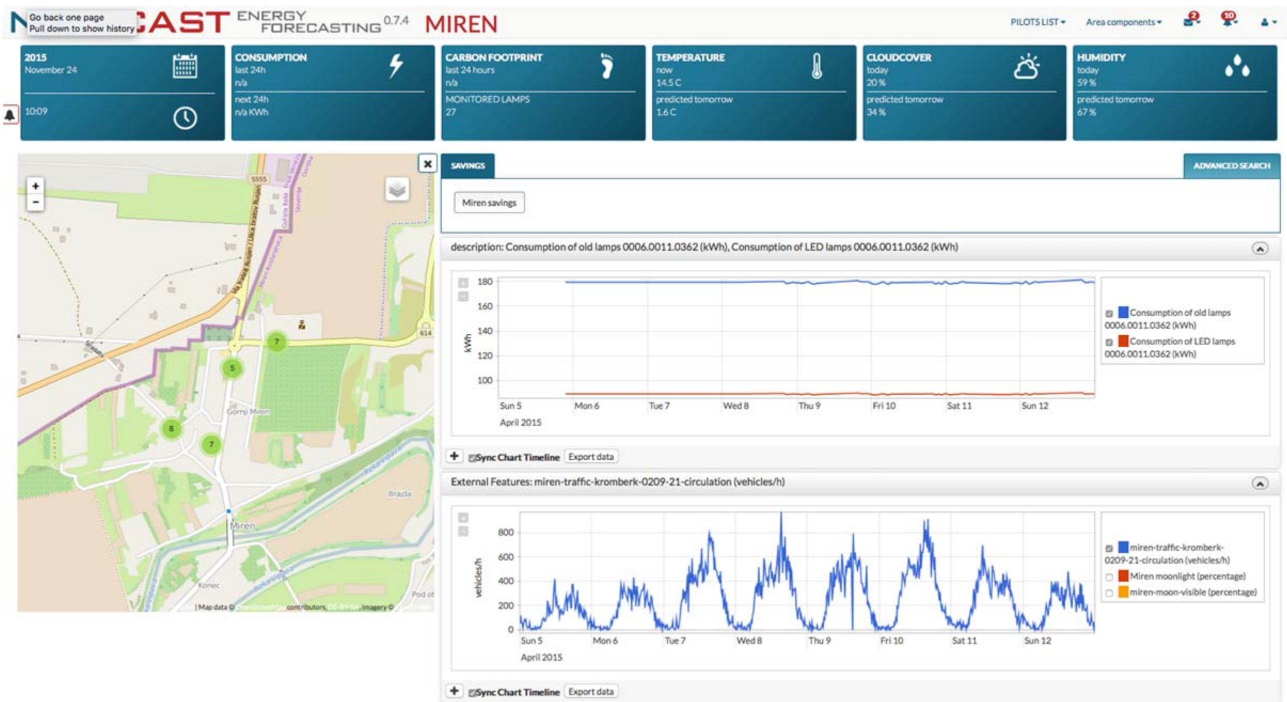

Figure 31: : NRG4CAST tool – Miren case

Figure 32: NRG4CAST tool – consumption, traffic, moon data

7.3 Energy savings validation

By implementing measurements from the mass sensor installation the final calculation schema was defined and validated against the targeted energy savings.

We validated the consumption in three phases.

1. phase: replacement of old street lights with new lights (classic or LED) – planed up to 50% savings

2. phase: added electronics for dimming the lights and central management system- additional up to 20% on "as is" situation - manually

3. phase: NRG4CAST tools consumption forecasting/predicting - additional 15 - 20% on "as is" situation

The resoults from the three phases energy savings validation.

	Old system	New lamps	LiaaS	LiaaS + NRG4CAST
investment per light		216	267,85	272,85
operational costs	5	5	2,16	2,76
maintenance costs	20	10	6,55	6,25
electricity consumption in kWh for 12 months	639.166,67	414.406,78	333.050,85	269.491,53
electricity costs per light per year	76,7	48,9	39,3	31,8
operationa & maintenece costs for 1 Y	101.700,00	63.900,00	48.010,00	40.810,00
TCO - 10Y	1.017.000,00	855.000,00	747.950,00	680.950,00
profit		162.000,00	269.050,00	336.050,00
% electricity and maintenance savings		37%	53%	59,87%

Table 4: Miren pilot, the results from the three phases energy savings validation

We can conclude that the impact of the NRG4CAST tools on the energy bill for electricity consumption of street lights can be up to 7%. With a total simulated calculation on the entire municipality, use of the NRG4CAST tools can save additional 7 euros per light per year.

8 NTUA pilot

8.1 Brief description of installation (pilot)

8.1.1. Introduction

NTUA is divided into nine academic Schools. The personnel of the nine Faculties include more than 700 people as academic staff, 140 scientific assistants and 260 administrative and technical staff. The total number of NTUA employees is about 1350. The total number of undergraduate students is about 8500 and the graduate students 1500. NTUA campus is comprised by 64 buildings of 256.000 m2 with labs, lecture rooms, offices, a library, restaurants and sports facilities. More specific, there exist a library building, two administration buildings (only with offices), two restaurants, a sports facilities building, several buildings with only lecture rooms, lab buildings and buildings with combination of lecture rooms, offices and labs.

The main idea behind the installation of the NRG4CAST tool in NTUA Campus was to assist the Energy Management Commission in taking decisions regarding the energy management strategy for NTUA Campus. The NRG4CAST tool is therefore expected to provide useful information regarding not only the distribution of the energy consumption across the campus but also information about decision support energy management solutions. This information will be also very useful for other public buildings (offices, schools, gyms).

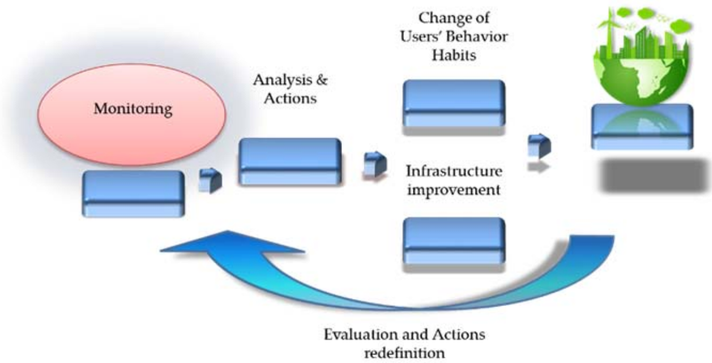

Figure 33: NTUA's scope

The NTUA University Campus pilot case included the following activities:

- Installation of electricity sensors for all buildings in the Campus:
    - 34 electricity meters SIEMENS SENTRON PAC3200, PAC3100
    - 16 electricity meters Schneider Electric PM3250
- Installation of sensors for measuring the thermal comfort level in an office in the Campus:
    - 4 temperature sensors & relative humidity sensors (KIMO TH210-BNDI-150)
    - 4 lux meters Vernier LS-BTA
- Installation of a central PC unit and a Building Energy Management system to collect, store and visualize all sensors data.
- Installation of a 42' monitor in a central spot inside the Rector's Building, showing the instantaneous energy consumption of all NTUA buildings, for dissemination purposes.
- Installation of other necessary electrical components: 50 power inverters, 22 analogue to digital converters for the connection of the electricity sensors to the Ethernet network, 2 PLCs with wireless

connection, 1 analogue to digital converter for the connection of the thermal comfort sensors to the Ethernet network.

The whole installation was completed by the end of January 2015. From January to March we were fine tuning the sensors and since then all data are available. Figure 34 shows the topography of all installed sensors and controllers.

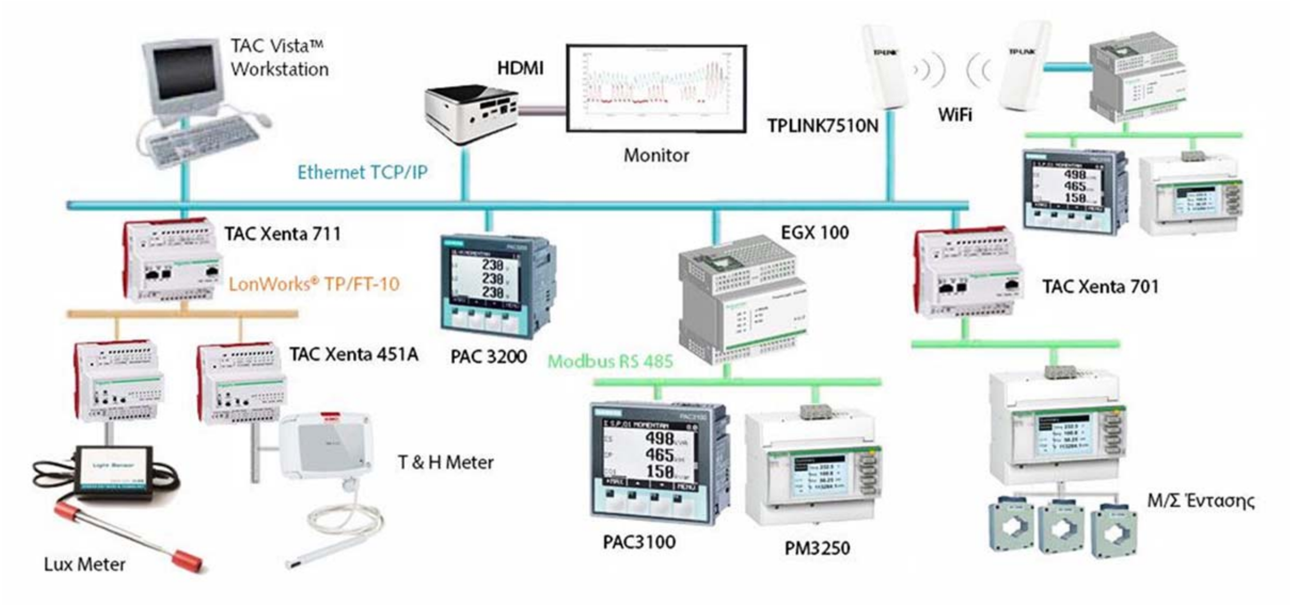

Figure 34: NTUA's campus installation topology

While the NTUA's buildings integration into the NRG4Cast toolkit is shown in Figure 35 .

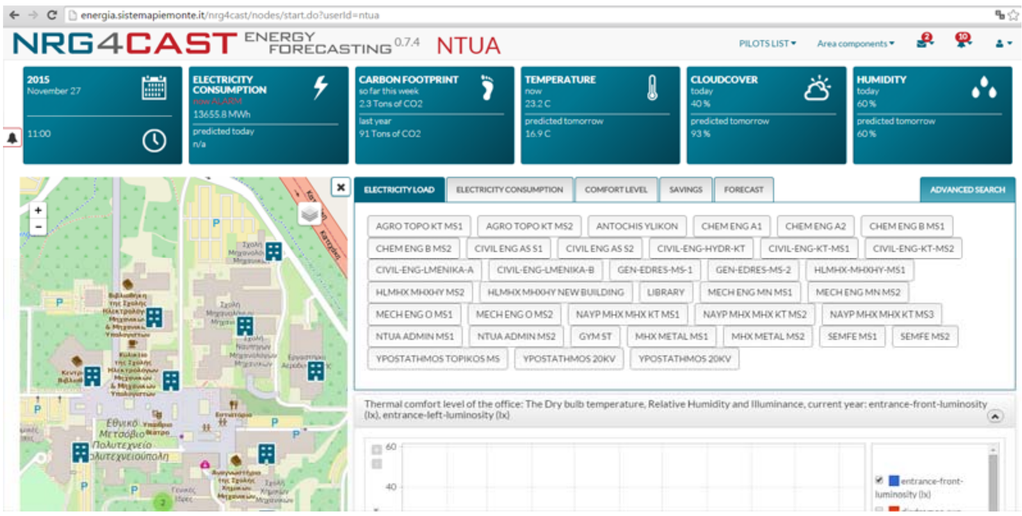

Figure 35: NTUA buildings installation into NRG4Cast Toolkit

8.2 Functional validation

The main functionalities requested by NTUA pilot can be summarized as following:

- Tools for the energy savings potential for group of buildings of relative use
- Energy consumption and weather forecasts for the whole campus and for group of buildings with offices
- Thermal Comfort evaluation through the psychrometric chart visualization

All these functionalities were validated during the 3 year.

8.3 Energy savings validation

During the validation period the following scenarios-actions were decided:

- Scenario 1: Lighting Schedule according to daylighting
  Lecture Rooms Building (2000 m2) May

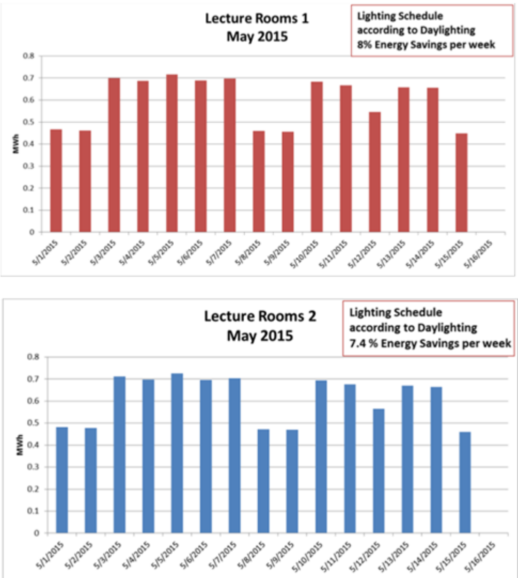

Figure 36: NTUA's Campus Energy Saving Scenario 1

- Scenario 2: Awareness Energy Savings Campaign –
  Turn off Computers and printers Administration Office Building (2500m2) July

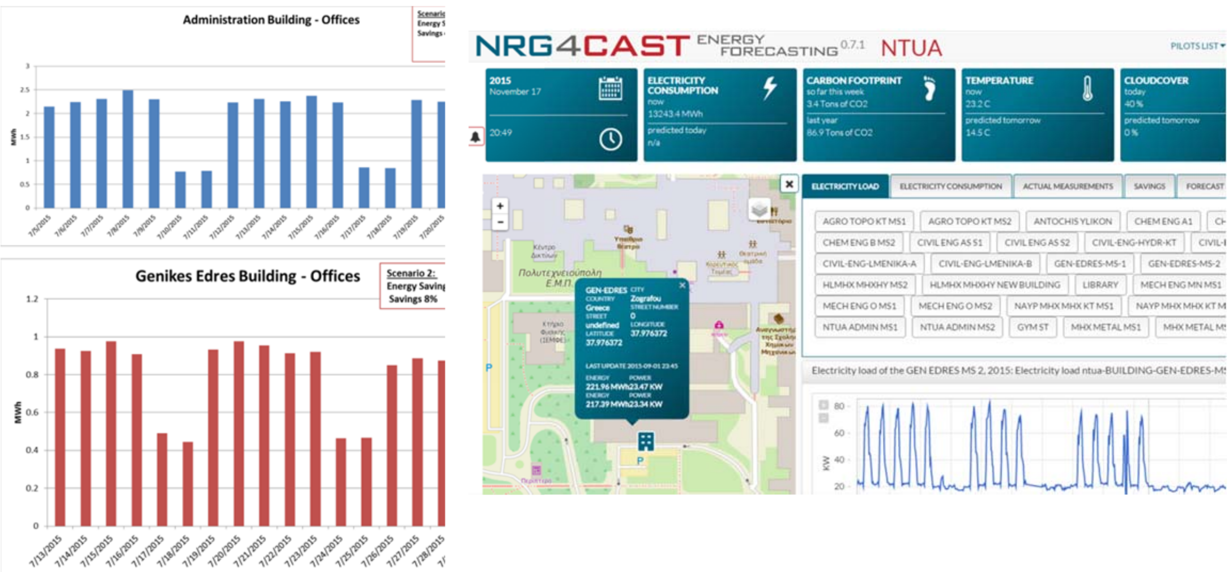

Figure 37: NTUA's Campus Energy Saving Scenario 2

- Scenario 3: Changing schedule of Lecture Rooms
  2 Lecture Rooms Buildings (3400 m2) September

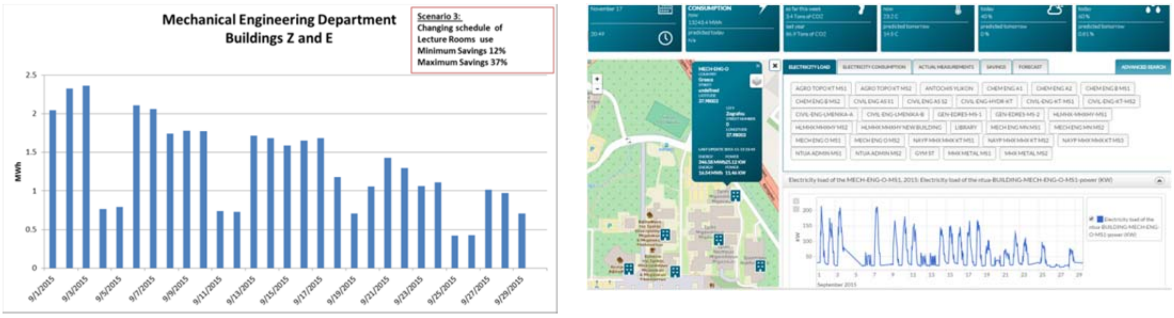

Figure 38: NTUA's Campus Energy Saving Scenario 3

- Scenario 4: Night Cooling
  Laboratory Building (14000 m3) July

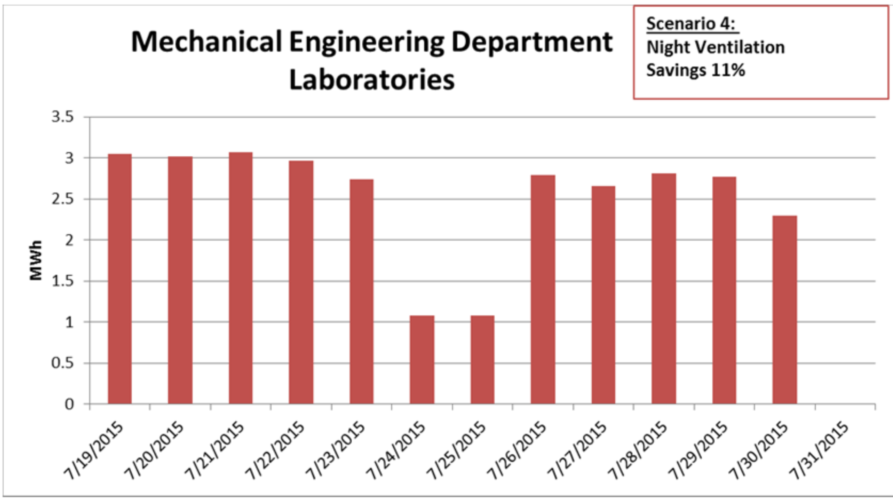

Figure 39: NTUA's Campus Energy Saving Scenario 4

The overall energy consumption per month for the whole campus before and after NRG4Cast is given in Figure 40.

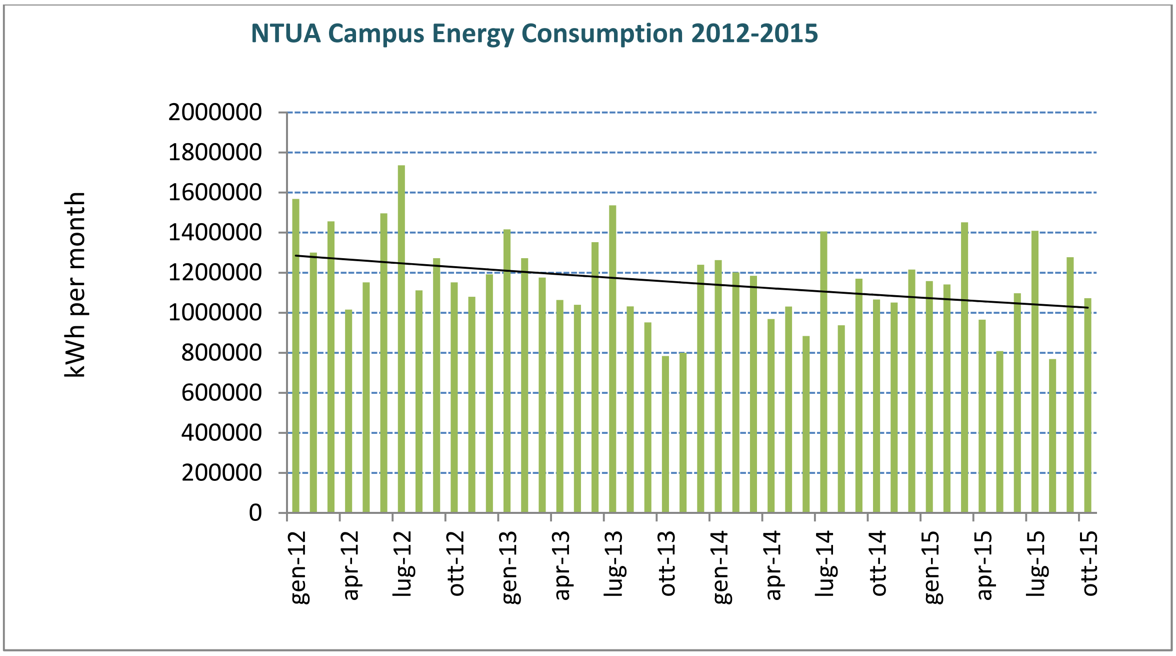

Figure 40: NTUA's Campus monthly energy consumption

According to the recorded data there has a total energy consumption reduction of up to 16.7% although the number of students has been increased by 20% (approximately 1800 students). The initial estimation of 2% energy savings for the whole campus has been overlapped.

Table 5 shows the monthly energy consumption from 2012 to October 2015.

	before NRG4CAST				during NRG4CAST					
	2009	2010	2011	2012	2013		2014		2015	
	consumption kWh	consumption kWh	consumption kWh	consumption kWh	consumption kWh	difference with 2012, %	consumption kWh	difference with 2012, %	consumption kWh	difference with 2012, %
Jan	1,680,000	1,728,000	1,608,000	1,568,000	1,416,000	-9.7%	1,262,860	-19.5%	1,158,453	-26.1%
Feb	1,440,000	1,284,000	1,424,000	1,300,000	1,272,000	-2.2%	1,201,228	-7.6%	1,141,021	-12.2%
Mar	1,494,000	1,188,000	1,520,000	1,456,000	1,176,000	-19.2%	1,184,065	-18.7%	1,351,547	-7.2%
Apr	1,092,000	1,158,000	1,184,000	1,016,000	1,064,000	4.7%	968,486	-4.7%	965,192	-5.0%
May	1,548,000	1,368,000	1,168,000	1,152,000	1,040,000	-9.7%	1,030,826	-10.5%	808,804	-29.8%
Jun	1,920,000	1,638,000	1,320,000	1,496,000	1,352,000	-9.6%	883,534	-40.9%	1,097,668	-26.6%
Jul	1,560,000	1,528,600	1,704,000	1,736,000	1,536,000	-11.5%	1,405,768	-19.0%	1,408,939	-18.8%
Aug	1,446,000	1,512,000	1,152,000	1,112,000	1,032,000	-7.2%	937,117	-15.7%	769,065	-30.8%
Sep	1,356,000	1,384,000	1,312,000	1,272,000	952,000	-25.2%	1,170,330	-8.0%	1,276,895	0.4%
Oct	1,350,000	1,296,000	1,128,000	1,152,000	784,000	-31.9%	1,066,283	-7.4%	1,072,440	-6.9%
Nov	1,368,000	1,168,000	1,416,000	1,080,000	800,000	-25.9%	1,050,985	-2.7%		
Dec	1,284,000	760,000	1,344,000	1,192,000	1,240,000	4.0%	1,215,300	2.0%		
sum from Jan-Oct	**14,886,000**	**14,084,600**	**13,520,000**	**13,260,000**	**11,624,000**	**-12.3%**	**11,110,497**	**-16.2%**	**11,050,024**	**-16.7%**

Table 5: Electrical Energy Consumption of NTUA Campus from 2012 to 2015

While Table 6 shows the final annual energy consumption per employee and student.

	Period	Energy Consumption kWh	no of employees	no of students	Annual energy consumption /employee+student (KWh)
NRG4Cast	Jan 15 - Oct 15	11,050,024	1.150	10300	965
2012	Jan 12 - Oct 12	13,260,000	1350	8500	1346

Table 6: Annual energy consumption per employee and student

Thus the annual energy consumption per employee and student has been decreased by 28% since 2012..

8.4 Stakeholder validation

Stakeholders like ESCO companies, equipment and energy providers were very interested in the NRG4CAST tool as they realized the energy saving potential for public office buildings and public schools leading to significant financial and environmental benefits.

For the future, stakeholders interested in a follow-up project identified the following features:

- The combination of the forecasting models with National Energy Codes for better evaluation of Buildings' Certification;
- The use of different tariffs through Demand Response Programs affecting the demand response of buildings by changing the load profile leading to less energy.

9 Integrated pilot

NRG4CAST system analyses 6 different pilots from four countries. The main focus is district heating, electrical energy consumption in public buildings and University Campus, public lighting and charging stations for electrical vehicles. Moreover, we've implemented a virtual consumption centre configuration functionality in order to support the integrated city scenario which combines energy consumption data from sensors belonging to different isolated pilots.

The initial idea for the integrated pilot was to test car batteries as a useful storage for electric energy. Integrated prototype should in this case be able to show total consumption per different type of consumer (charging station, lamps, buildings) and show overall consumption and detect, where there is too big or too low consumption.

For example – if total consumption is bigger than 2-times the average or lover than half the average, than this should be an opportunity to make some changes in the system. This could be an incentive to give lower prices for filling up car batteries.

Car batteries could act as a storage of energy and could then be used to lower the demand of electricity from the grid in case of peaks (for example in the morning). Even though the information about car batteries weren't included into the NRG4CAST, the reasoning above has been recognised as good tool for decision makers. A virtual consumption centre configuration implemented ad hoc for integrated pilot, includes different objects such as buildings, lights and charging stations (Figure 41). The solution proves that NRG4CAST system is ready to manage a number of diverse objects in the context of integrated pilot. The user can view the integrated pilot hierarchical structure using advanced search hierarchal function. A set of predefined reports gives a possibility to monitor total energy consumption per different type of consumer.

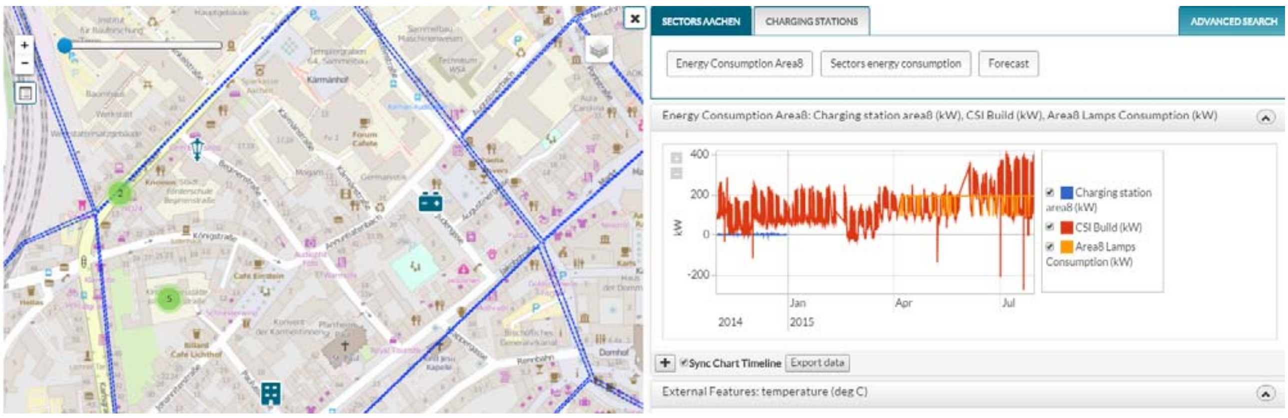

Figure 41: Sector 8, predefined report and a set of geo-referenced objects included in the integrated pilot, such as buildings, public lighting and charging stations

10 Software testing

Erroneously Deliverable D6.2 reported that the V-model software testing methodology was followed in the project. This is not correct since Unit, Integration and System tests [1] have been thoroughly repeated and extended in the 3rd iteration of the development of the NRG4CAST Toolkit. Further in the 3rd year of the project non-functional testing has encompassed an aspect which was omitted in Deliverable D6.2, i.e. security testing, since the infrastructure for the Authentication and Authorization of the users to the NRG4CAST Toolkit has been developed during this iteration of the development.

In the following sections, only System level software tests which have not been executed at the end of year 2 will be reported due to the focus and scope of this deliverable report on the validation of the NR4CAST system as a whole.

10.1 System Test Cases

As described in Deliverable D6.2 Test cases correspond to the relevant Use Cases and are further subdivided into subcases according to the requirements. Detailed information about the test cases may be found in Deliverable D6.2 [1].

10.1.1 Register new customer

Test subcase UC-RC-01: Create a new customer **Fulfils the requirements: SR-RC-01, SR-SC-02 and SR-RC-04**				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Create new customer	Create new customer form with auto increment ID, dropdown menu for company, municipality, person, project, etc. selection, input group for responsible person name, surname, address, email, dropdown menu for assign to an operator and checkboxes for service selection	No such functionality is provided. The installation of the Toolkit to a pilot case is a very complex procedure which cannot be done in an automated way.	N/A	

Test subcase UC-RC-02: Assign customized service to entity/user **Fulfils the requirements: SR-RC-02 and SR-RC-03**				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Assign exact service to customer	Edit customer form, the same as create new customer	No such functionality is provided.	N/A	

10.1.2 System Configuration

Test subcase UC-SC-04: Roles management **Fulfils the requirements: SR-SC-08 and SR-SC-09**				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Create/modify/delete roles	Manage access rights to different actions/ information types for new roles created. Modify access rights, delete a role.	Manage access rights to different actions/ information types for new roles created. Modify access rights, delete a role.	PASS	User & Role Management

Test subcase UC-SC-05: User management

Fulfils the requirements: SR-SC-10				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Create user	Add new user form with input group for name, surname, email, username, password, confirm password, comment and dropdown menu for role selection	A new user with all relevant data is created	PASS	User & Role Management
Modify user	Edit user form, similar to add new user form, with blocked role dropdown menu if not admin	The details of a user are edited	PASS	User & Role Management
Delete user	Delete user form with delete and cancel button only if admin	A user is deleted	PASS	User & Role Management

Test subcase UC-SC-06: Assign roles to user Fulfils the requirements: SR-SC-10 and SR-EM-39				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Assign role to different user	Open add new user form or edit user form and change role from dropdown menu	Role is assigned to a user	PASS	User & Role Management

Test subcase UC-SC-08: Initial data migration from information source (historical data) Fulfils the requirements: SR-SC-12, SR-SC-13 and SR-EM-34				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Edit imported data	Edit form, where all imported data can be modified	No such functionality is provided. Sensor data are huge in volume and it is not possible to edit them through a form	N/A	

Test subcase UC-SC-11: Define rules for energy monitoring and use of alternative source (e.g. photovoltaic) Fulfils the requirements: SR-SC-08, SR-SC-09, SR-SC-10 and SR-SC-17				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Define rules for energy monitoring and use of alternative source (e.g. photovoltaic)	the user can insert values for various parameters; using Complex event processing, we know the forecast of the consumption to be faced The system helps me to understand what should the user do in order to assure money savings	Advanced DSS isn't not a subject of NRG4CAST project, situational awareness services would act as a base for such a DSS	N/A	Monitoring GUI

10.1.3 Energy Management / Reporting & Monitoring

Test subcase UC-EM-03: Produce reports Fulfils the requirements: SR-SC-14, SR-EM-07, SR-EM-08, SR-EM-10, SR-EM-12, SR-EM-13, SR-EM-18, SR-EM-19, SR-EM-24, SR-EM-25, SR-EM-29, SR-EM-32, SR-EM-33, SR-EM-34, SR-EM-35, SR-EM-36, SR-EM-37, SR-EM-43, SR-EM-44, SR-EM-45, SR-EM-46, SR-EM-48 and SR-EM-49

ACTION	EXPECTED RESULT	ACTUAL RESULT	PASS/FAIL	COMPONENT
Check report structure	Report form with different parameters selection, like date and time from-to, charts, table, text, detailed information, maintenance, consumption, errors, anomaly, etc.	A set of predefined reports, advanced search, visualisation of hierarchical structure of the installation	PASS	Monitoring GUI

10.1.4 Energy Management / Alerts & Predictions

Test subcase UC-EM-06: Request a prognosis/forecasting Fulfils the requirements: SR-EM-30, SR-EM-46 and SR-EM-47				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
-compare current energy consumption of the consumption centre with the predicted consumption	The new Rule Editor Prediction part ("equations" section) allows creation of rules based on current consumption sensors and predicted consumption sensors. As an example: the weather forecast announces high temperatures next week. Using Advanced search the user will be able to check the sensor network for alerts. The “predicted alert” will appear spontaneously	This functionality has been provided	PASS	Monitoring GUI, Situational Awareness GUI, Rule Editor

Test subcase UC-EM-08: Manage the energy consumption and bookkeeping Fulfils the requirements: SR-EM-27 and SR-EM-28				
ACTION	**EXPECTED RESULT**	**ACTUAL RESULT**	**PASS/FAIL**	**COMPONENT**
Complex rules to be applied on historical and current data Analysis of energy prices	Analysis of energy prices; Analysis of historical, current and predicted data;	possibility to use reports and check the problems faced in the past; the user can insert values for various parameters; using Complex event processing, we know the forecast of the problems/anomalies to be faced ; The system helps me to understand what should I do in order to prevent future problems	PASS	Monitoring GUI, Situational Awareness GUI,

11 Conclusions

This deliverable results in a verification of the successful installed systems for each use case and ensures the success of the NRG4Cast platform as a whole. The final rollout of the large scale installation has required constant validation and testing and active participation of stakeholder community and other interested parties. As a result we provide a the report for each pilot and the NRG4CAST system as a whole.

In the FIR case, Germany, it's evident that in the future, the penetration of electric vehicles will take large steps towards the proposed goal of 1million electric vehicles till 2020. The NRG4Cast solution will win more and more significance, as it was proposed to have already at the end of the project. It gets more and more relevant for the energy provider to receive predictions on energy demands.

The Italian case of district heating (Reggio Emilia and Nubi pilots) confirms that operating both at the consumption and at the production stages of the energy chain, NRG4CAST tool can help in reducing building energy consumes, contributing to the energy and climate goals set by EU (20% energy savings by 2020) thus leading to significant environmental benefits.

Furthermore, the public owned building case in Turin has shown that the Awareness Campaign and the possibility to use NRG4CAST toolkit to monitor energy consumption in real time, to compare energy consumption measurement with the external data stream and to forecast energy demand lead to the 27 percent energy savings.

Greek stakeholders such as ESCO companies, equipment and energy providers were very interested in the NRG4CAST tool as they realized the energy saving potential for public office buildings and public schools leading to significant financial and environmental benefits. NTUA Campus (Athens, Greece) has recorded a total energy consumption reduction of up to 16.7% although the number of students has been increased by 20%. The annual energy consumption per employee and student has been decreased by 28% since 2012.

As for the Slovenia case of public lighting (Miren pilot), we came up to the conclusion that the impact of the NRG4CAST tools on the energy bill for electricity consumption of street lights can be up to 7%. With a total simulated calculation on the entire municipality, use of the NRG4CAST tools can save additional 7 euros per light per year.

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