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Deliverable D5.4

Situational awareness services

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Executive Summary

This Deliverable concludes the work package 5 Real-Time Decision Support and Reasoning. The report provides description of the situational awareness services developed based on the NRG4CAST monitoring and alerting, and forecast analytical services. The situational awareness GUI was integrated within the Report Management & Visualization and Real-time Visualization Components GUI.

The first part of the document introduces the situational awareness component main idea. We have analysed the importance of these services for the Energy Efficiency Directive and Energy Performance in Buildings adoption by the EU countries-partners of the project and examined the potential end-users feedback and suggestions on further developments.

The technical part of the Deliverable describes the situational awareness implementation process and progress made in the development of Event Processor and Rule Editor. We have also provided the description of particular energy problems and desired solutions characteristics that are relevant among the project pilots.

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Abbreviations

DSS Decision Support System

CBR Case-Based Reasoning

DSS Decision Support System

GUI Graphical User Interface

1 Introduction

Deliverable 5.4 introduces NRG4CAST complex situational awareness services built on the top of WP 5 outcomes. The outcomes of the monitoring and alerting services function as baseline for designing NRG4CAST situational awareness services. Furthermore, the situational awareness component acts as the base for NRG4CAST decision support system for energy efficient decision making.

Chapter 2 describes NRG4CAST situational awareness component in detail. This Chapter consists of an overall introduction into situational awareness services and describes the NRG4CAST situational awareness component main idea.

Furthermore, evidence of Situational awareness services' importance on an example of Energy Performance of Buildings Directive (2010/31/EU) and Energy Efficiency Directive (2012/27/EU) application is provided within the Subchapter 2.3.

During the project life a number of workshops and informal meetings were organised in order to gather the potential users' opinion on the NRG4CAST solution as a whole and Situational Awareness Services in particular. The Subchapter 2.3.1 provides the stakeholders' suggestions and feedback on Situational Awareness GUI.

Chapter 3 provides information on implementation of the Situational awareness services. Moreover, the Chapter 3 describes the recent changes within the Rule Editor and Event Processor. The description of NRG4CAST situational awareness services is provided in this Chapter as well. This description is common for all the project pilots and consists of an overview of particular energy problems and desired solutions characteristics.

2 NRG4CAST situational awareness component

2.1 Introduction into situational awareness services

Situational awareness involves being aware of what is happening in the vicinity, in order to understand how information, events, and one's own actions will impact goals and objectives, both immediately and in the near future. In decision making the situational awareness is a cognitive process defined as "the perception of elements in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future".

Situational awareness is especially important in domains where the information flow is high and poor decisions may lead to serious consequences. Having complete, accurate, and up-to-date situational awareness is essential where technological and situational complexity of the human decision-maker is a concern. Situational awareness has been recognized as a critical foundation for successful decision-making across a broad range of complex and dynamic energy systems. The fundamental definition of "situational awareness" is "understanding the current environment together with the context and being able to accurately anticipate future problems to enable operative actions." This allows operators to take right decisions and to provide effective solutions.

There are two different situational awareness approaches. The more traditional one is focused on user interface issues in displays and visualizations. The other approach to situational awareness research addresses not only the user interface design issues, but also the problem solving context, goals, assumptions, and expectations that affect human performance.

2.2 NRG4CAST situational awareness component main idea

One of the 3 year NRG4CAST project tasks is to develop complex situational awareness services based on meta-level reasoning approaches. NRG4CAST team has implemented situational awareness services for a number of project pilots and use case scenarios.

The situational awareness component is based on the user context and provides related information about the environment to be used in the reasoning process. The general domain knowledge provides explanations to the outcome of the reasoning process

The outcomes of the monitoring and alerting services function as baseline for designing NRG4CAST situational awareness services. NRG4CAST system assesses the situation with the information about the environment. This assessment includes understanding the information, comparing it with an individual user context. The model receives sensory data about the environment, interprets the data with respect to an individual user context, and then anticipates the future state of the environment.

The overall aim is to combine three distinct levels:

- perception
- comprehension
- projection

The situational awareness component outcomes act as the foundation for successful NRG4CAST energy efficient decision-making. Situational awareness services are used for the Decision Support System (DSS) which allows potential users to lower the energy use of a buildings, to optimize the lighting system of a town in terms of energy consumption, to distribute - in an efficient way - energy for district heating and charging stations by making the best use of the installed equipment. Also, the system could support users when making long-term decisions, such as making investments in new building equipment and selecting between energy tariffs. With such mechanisms in place, electric and district heating utility owners and operators can better detect anomalous conditions, take appropriate actions to remediate them, and investigate the chain of events that led to the anomalies.

We would like to point out, that there are many different kinds of useful products on the market for monitoring networks for possible security/economic/technical events. Nevertheless, these products tend to be imperfect once unusual requirements of control system networks come up. The NRG4CAST solution is based on the user opinion and personalised rules created by pilot-partners, which helps reduce the blind spots.

2.3 Situational awareness services importance

Furthermore, we would like to provide evidence for the importance of Situational awareness services on the example of the Energy Performance of Buildings Directive (2010/31/EU) and Energy Efficiency Directive (2012/27/EU) applications.

Currently, about 35% of the EU's buildings are over 50 years old. By improving the energy efficiency of buildings, we could reduce total EU energy consumption by 5% to 6% and lower CO2 emissions by about 5% (European Commission, 2015).

In April 2015 The European Commission has asked Italy, the Netherlands and Poland to take action and ensure that the Energy efficiency in buildings directive is fully transposed into national law. Under this Directive, Member States must establish and apply minimum energy performance requirements for new and existing buildings, ensure the certification of buildings energy performance, and require the ***regular inspection of heating and air conditioning systems***. The Directive had to be transposed by 9 July 2012.

The two NRG4CAST partners (CSI-Piemonte and IREN) are situated in Italy. This country has already received a reasoned opinion for failing to adopt any measures to transpose the Directive, in January and June 2013 respectively. Italy has adopted transposition measures in the meantime, but some of the provisions of the Directive still remain non-transposed. Since 2014 most Member States have complied with their transposition obligation and the only infringements remaining open are against Austria, Italy, the Netherlands, the Czech Republic, and Poland.

Furthermore, the Directive 2012/27/EU was transposed into Italian Decree 102/2014 in July 2014. Since then Public bodies should push for the market uptake of energy efficient products and services. Starting from the 2014, and until 2020 they will have to progressively reduce the energy consumed on their own premises. The emphasis is given on energy savings for consumers. Large Enterprises and energy-intensive enterprises starting from the 5 December 2015 shall carry out energy audits or implement an energy management system. Buildings requalification and retrofit for public property also became high priority. Moreover, The Directive requires:

- widespread application of cost-effective technological innovations such as smart meters,
- up-to-date information about their energy consumption, or billing based on actual consumption to enable customers to regulate their energy use,
- empowerment of final customers regarding access to metering and billing information of their individual energy consumption, etc.

The real-time management, analytics, and forecasting services for energy distribution networks in urban/rural communities developed within the NRG4CAST project are completely in line with the Directive. The software module pipeline providing prediction and the decision support system acts as the basis for building assessment and audit. The flows of data in real time, reinforced by energy consumption prediction, allow for detailed analysis of critical elements of the buildings, offices, public lighting system, power stations, and district heating distribution. E.g. new suggestions on retrofit through the decision support system could be based on detailed buildings analysis.

Additionally, the weather forecast integrated within the NRG4CAST system plays an important role in the energy efficiency on the various pilot sites of the NRG4Cast project. Correlation of this data with cooling and heating systems flexible systems provided a possibility to manage cooling systems *ad hoc* and to program heating systems in advance.

Furthermore, the situational awareness service is a solid base for "what-if" analysis and scenarios, creation of *ad hoc* alerts, and design of DSS.

2.3.1 Feedback gathered during the meetings with the stakeholders

A number of workshops, formal and informal discussions were organised in order to gather users' feedback on Report Management and Visualization GUI, Real time Visualisation GUI and Situational Awareness GUI importance and usability. The city's decision makers and stakeholders, energy providers, facility managers, and building owners provided their opinion during these meetings. The following information/functions appear of high interest of the participants-NRG4CAST end users:

- geospatial capabilities for visualisation of geospatial data patterns
- a notification to be visualised once energy consumption is too high for the particular building, district, area etc.
- a tool to highlight expected high electricity consumption for the next week (due to high temperatures etc.)
- a tool for estimation of the consumption for the next week and an amount of money to be paid next week
- an option to highlight technical problems, whether there is a gap in the data flow, etc.
- possibility to translate energy consumption into "monetary"
- a tool for building assessment decision support, for example: "my building is the one with energy performance class G and I spend certain amount of money for energy. In the case, my building reaches energy performance class A, I would pay much less. How much would I pay?"
- capability to compare weekly energy consumption time series and to highlight anomalies
- capability to compare energy consumption during the same day during different years and to highlight anomalies
- Possibility to calculate energy consumption per person in the case of buildings energy consumption (the presence factor plays a very important role).

The direct debate with the target users also resulted in overall suggestions for NRG4CAST future developments after the project ends. Situational awareness services 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 investment in technologies, given a set of input parameters that describe technologies and the tariffs used to buy and sell energy. The DSS would generate a number of scenarios, each describing a possible future development of the parameters. The system would then determine the best strategic decisions for the day, considering the possible future scenarios. The results could allow for technology investments. Moreover the system would evaluate possible modifications within the technology and retrofit actions, alongside the monetary and emission effect of these changes would be calculated.

Advanced DSS logic (even though, it isn't not a subject of NRG4CAST project, situational awareness services would act as a base for such a DSS):

- I know the problems faced in the past

- The user can insert values for various parameters
- Using Complex event processing, I 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

3 Situational awareness services implementation

The NRG4CAST situational awareness services are based on meta-level reasoning approaches. Development of these services on the top of WP 5 outcomes is the final task of the work package. The WP5 provides the underlining environment of the project in terms of predicting energy demand on several network granularity levels (municipality, city, single building, university campus, household, and energy service provider). 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.
NRG4CAST monitoring and alerting services are described in detail in the Deliverable 4.2 (T. Hubina et al., 2014).

NRG4CAST system components are described in detail within the Deliverable 6.4 (T.Hubina et al., 2014). From the logical point of view, NRG4CAST system consists of the three macro blocks (see Figure 1):

- Real time data and monitoring database (core of the NRG4CAST system);
- Analytical Platform, in particular the Forecast Engine provides prediction of energy consumption, trend of the energy prices and system performance;
- Complex Event Processing Engine provides alerting on anomalies within the system , weather forecast and energy consumption

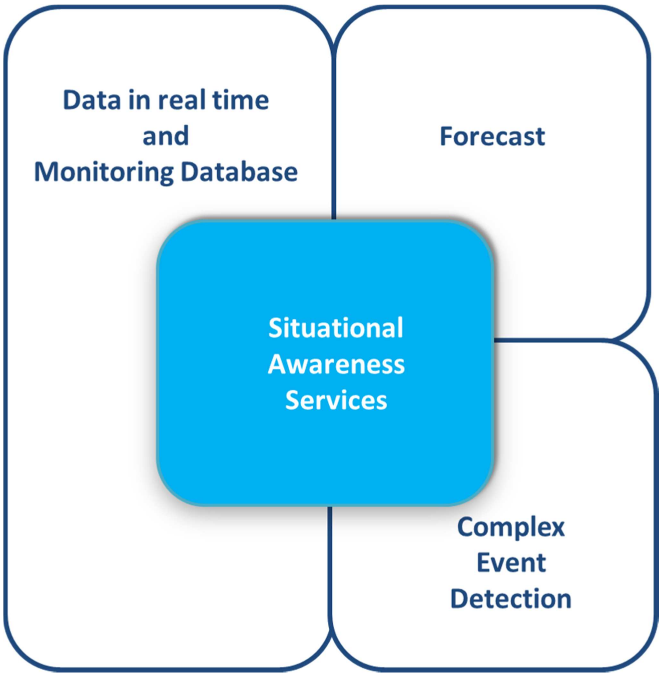

Figure 1 - Situational Awareness environment (high-level, logical view)

The Report Management & Visualization and Real-time Visualization Components GUI receives input from these three parts of the NRG4CAST system. The GUI modules, such as a map with geo-referenced data, upper panels top boxes with real time data, and a set of predefined reports allow users to receive an immediate and overall information on pilot.

The situational awareness GUI has been integrated within the Report Management & Visualization and Real-time Visualization Components GUI. These GUI offers all the functionalities needed for the situational awareness GUI:

- receives the data from the NRG4CAST components,
- integrates, enhances and displays various data streams,
- analyses the system behaviour
- compares current and predicted measurements
- offers an assessment of the prediction quality and reliability.

Moreover, the possibility for visualization of alerts in real time, together with a set of historical alarms is fundamental for Situational Awareness GUI. The dynamic configuration of the Report Management & Visualization and Real-time Visualization Components (for details see the Deliverable 6.4, ANNEX 2. Report Management & Visualization and Real-time Visualization Components configuration, (T.Hubina et al., 2014)) was integrated with the configuration of Situational Awareness services.

Continuous interaction with the final user has provided important ideas for NRG4CAST basic and advanced situation awareness service development:

- change within the Report Management & Visualization and Real-time Visualisation GUI. The top boxes referred to the whole pilot and representing current and predicted measurement will be coloured according to certain rules. An alert message and icon will appear;
- the savings predefined reports calculated in Kw/h will be translated into “monetary” savings (in the case of fixed energy costs, Italian example);
- certain rules will be applied on real time data in order to highlight high energy consumption;
- an alert will appear once there is a gap within the data flow, or the data within the real time visualisation GUI isn’t shown in real time;
- energy consumption forecast will be provided for one week in advance, as in the case of Turin pilot, CSI building;
- there will be a possibility to analyse a set of sensors by performing mathematical equations;
- possibility to apply Event/Alert processing application on predicted data will be evaluated;
- possibility to create prediction models based on sums of sensors (aggregates) will be considered.

3.1 Event Processor recent work

Recently it was desired to improve the Event Processor, as described in the Deliverable 4.1 (A. Moraru et al., 2014), to also include predictions and a way to compare them to other predictions, values, and normal sensors. Additionally we would like to compare predictions “in the future” – at the time predictions come into the system/the time at which we are predicting the sensor.

This proved to be quite an issue with the current configuration, as the Esper event processor engine, described in detail in the Deliverable 4.1 (A. Moraru et al., 2014), only allows the data to enter the stream at its system time. Therefore we cannot have different times for the prediction and sensor streams and it is not possible to compare them “in the future”.

Currently we circumvent this problem by delaying predictions until the time of the prediction and then insert them into the stream. This way we can compare all the desired sensors in real time (versus current measurements/values).

3.2 Rule Editor expanded

This chapter describes an extension of the previous work on a GUI developed for Event Processor editing. For the basics please refer to Chapter 6.2 -GUI (A. Moraru et al., 2014)
URL(s): http://demo3.nrg4cast.org/en/PILOT/rule-editor.html

Available options for **PILOT** are:

- **reggio_emilia**
- **nubi**
- **turin**
- **miren**
- **fir**
- **ntua**
- **epex**
- **csi**
- **iren**

Since there have been a few changes to the Event Processor we also adapted the GUI. We added a new sublevel to the rule (severity) levels:

- Notice
- Warning
- Alarm

Namely the user must choose whether the rule best fits into the following categories:

- Environment
- Technical
- Economic
- Energy

The message that will show when a rule is triggered is now arbitrary. We have added password protection for rule deletion, so only authorised persons can delete rules. Anyone can still create them though.

The most significant enhancement to the Rule Editor introduces a new atom (see Figure 2) that enables the user to input any equation using both sensors and predictions of the sensors (and of course basic operands "/", "*", "+", "-"). It is also possible to input brackets ("(", ")"). During input a basic check of operation feasibility is performed and the action is not allowed if it would lead to an invalid equation. It is still possible to (intentionally) produce invalid equations. In this case the user will be alerted of this when the Esper (EsperTech Inc., 2015) tries to parse the equation.

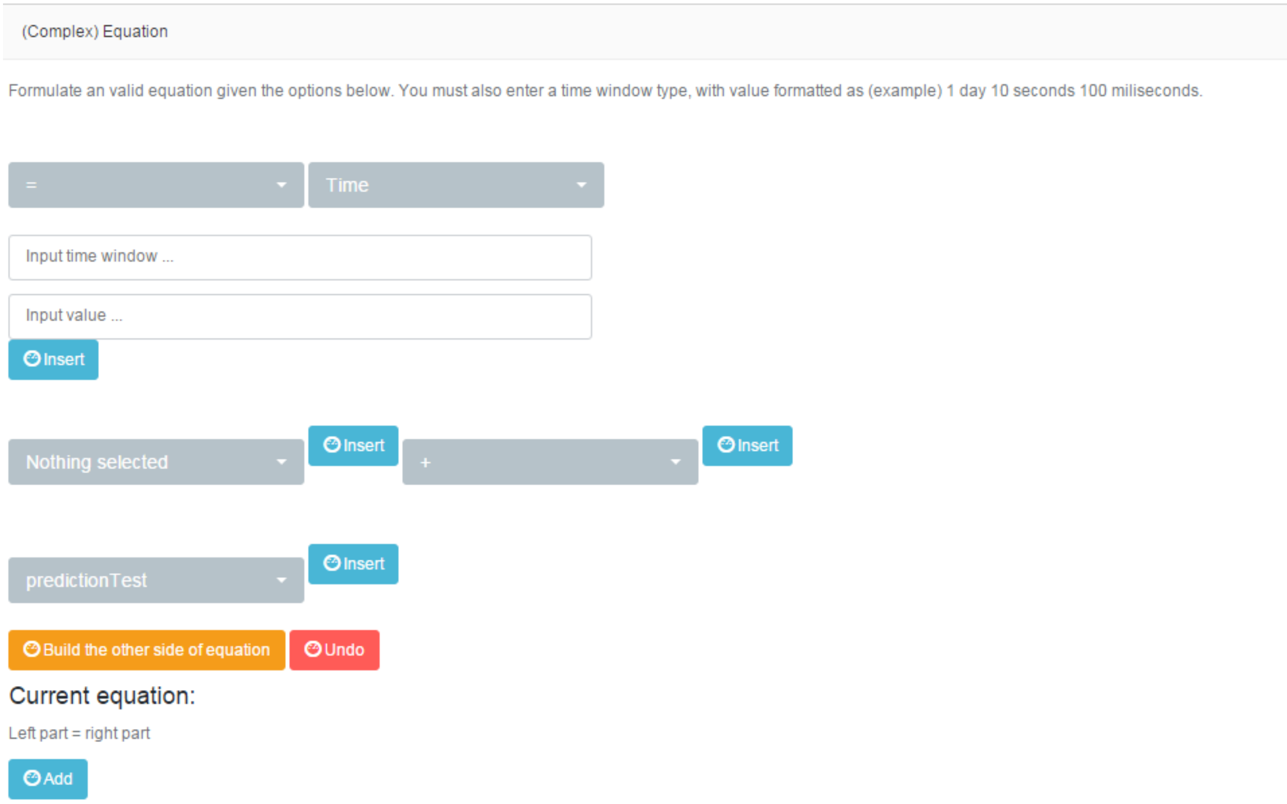

Figure 2 - The new Equation builder

The first thing you want to do is imagine which equation you would like to input. Than you select the appropriate comparator ("=", "!=", "<", ">") and as with the other atoms input the desired time window (for details see Deliverable D4.1, Chapter 6.2.3 – Creating rules, (A. Moraru et al., 2014).

Now you go ahead with building the actual equation. A visualisation of the current state of the equation will be displayed at all times in the "Current equation" section.

You can alternate between build the left/right side of the equation or undo the most recent step (can be done in succession – you can undo multiple steps) using the appropriate buttons. It is only possible to build the equation linearly – meaning it is only possible to insert something to the end of the side of the equation. The equation side has to start with a value, sensor, or a prediction sensor and then alternate between basic operands and the objects described above. To insert the desired object just select (input) it in the appropriate box and click the insert button next to the box.

It is also possible to insert brackets "(" and ")" and some basic checking if the insert is valid is done, but invalid equations can still be produced at this stage. Further checking is completed when the rule is translated and sent to the Event Processor service (A. Moraru et al., 2014).

See Figure 3 for an example of a built equation. This atom effectively replaces the previous atoms. But they are still included in the GUI as they are simpler to navigate and should be used if they are adequate for the users' needs.

Translation to EPL code is now a bit more complicated, as we have to build the atom code more carefully and we also have to expand the preamble to accommodate inclusion of predictions, but the resulting code has very similar structure as before – just with (usually) longer descriptions for equation atoms.

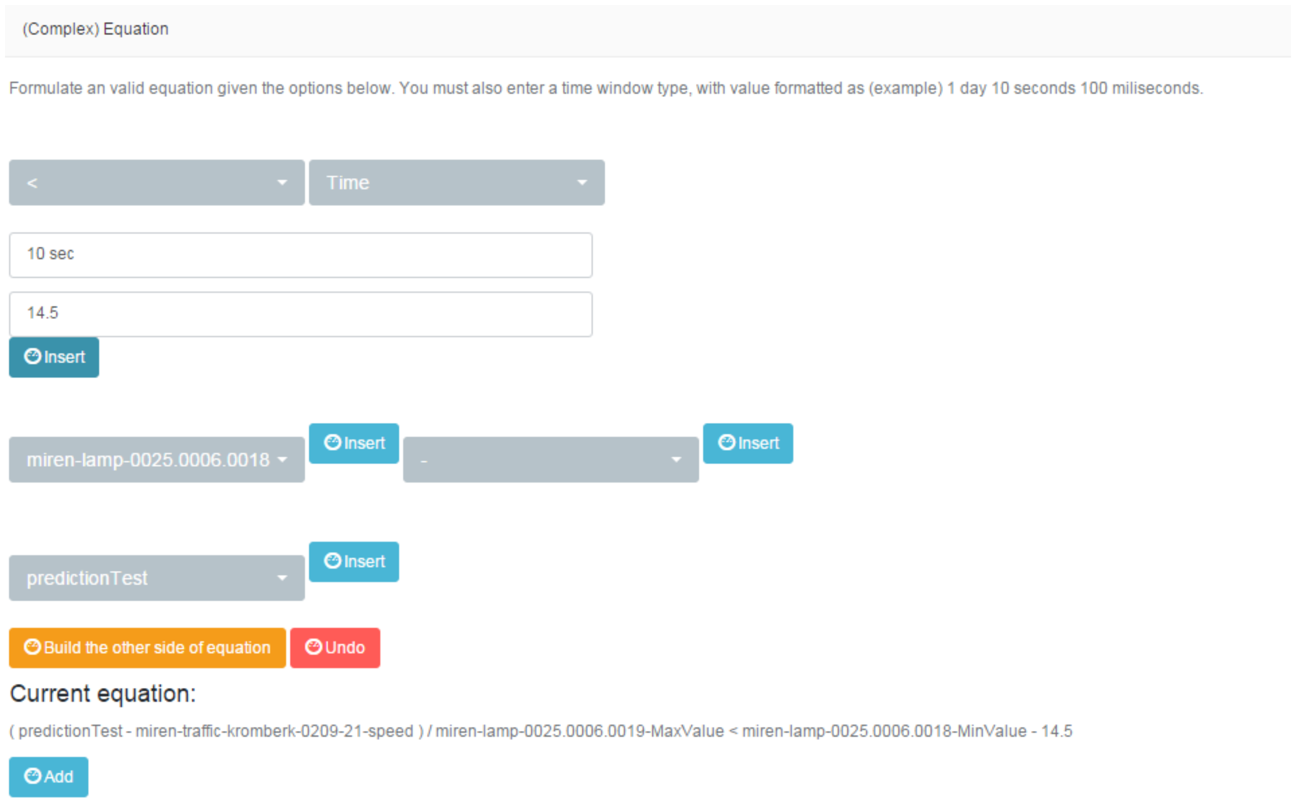

Figure 3 - An example with a built equation

3.3 NRG4CAST situational awareness services description

The description of particular energy problems and desired solutions characteristics that are relevant among the project pilots are provided below. Situational Awareness GUI integrated within the Report Management & Visualization and Real-time Visualisation GUI is available at the url: http://energia.sistemapiemonte.it/nrg4cast/login/start.do.

3.3.1 Current versus predicted energy consumption

The aim is to 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. Only the sensors with the predictions available are included in this part of the application. The user can select a sensor id and the operators for matching or math.

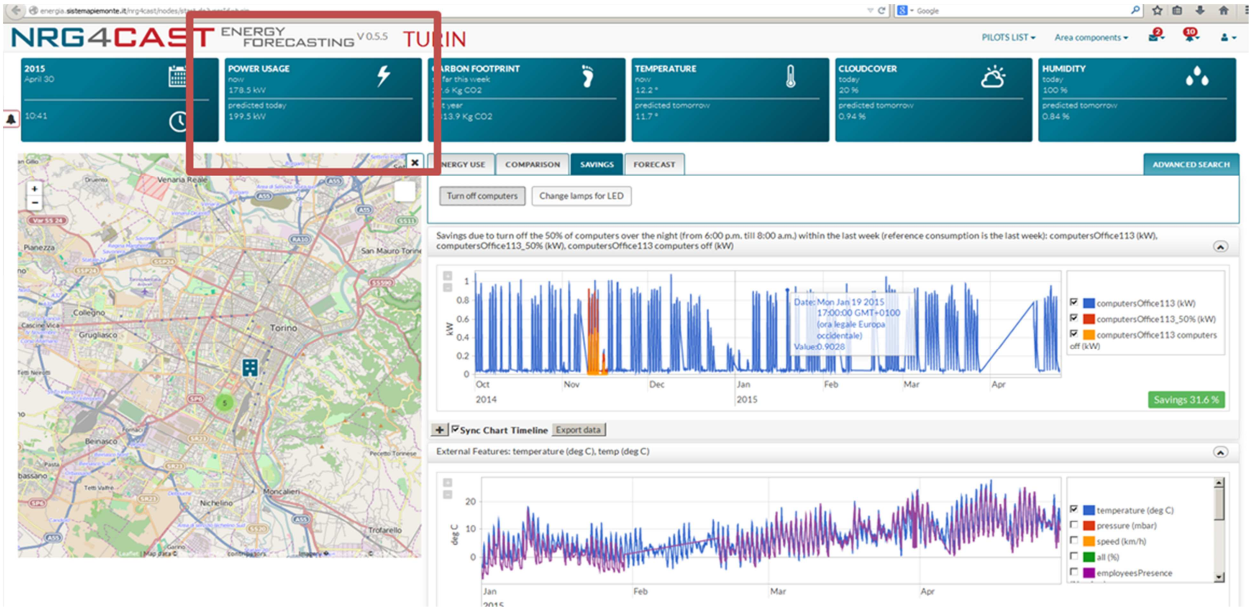

Figure 4 - Energy usage now and predicted for tomorrow upper panel integrated with the situational awareness service (Report Management & Visualization and Real-time Visualization GUI)

The JSON configuration of Situational awareness GUI upper panel alert is provided below (Turin pilot, CSI building example):


```
{
        "id": "panel4",
        "title": "POWER USAGE",
        "label": "now",
        "display": "true",
        "usealarms": "true",
        "sensors": [
          {
            "type": "simple-property",
            "sensorId": "turin-building-CSI_BUILDING-buildingtotalconsumption",
            "uom": "kW",
            "property": "last-measurement",
            "time": "Time",
            "service": "currentAggregatesServerUrl",
            "source": "/api/n-get-current-aggregates",
            "format": "###.#"
          }
        ]
      },


{
        "id": "panel8",
        "title": "TEMPERATURE",
        "label": "now",
        "display": true,
        "usealarms": "true",
        "sensors": [
          {
            "type": "simple-property",
            "sensorId": "OWM-Turin-Italy-OWM-temp",
            "uom": "C",
            "property": "last-measurement",
            "time": "Time",
            "service": "currentAggregatesServerUrl",
```

```
                "source": "/api/n-get-current-aggregates",
                "format": "###.#"
            }
        ]
    },
```

Examples:

- Verify when sensor buildingtotatalconsumption value > 370 kW

- Verify when the datacentercooling predicted value > 140 KW for 3 h during the next week

- Within the Advanced search the user is able to verify if there will be any single sensor/node/consumption centre alert in the future.

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. In the case of an automatic system, the “predicted alert” will appear spontaneously.

3.3.2 Analysis of weather forecast

Weather forecast is vitally important for decision making regarding energy efficiency actions. The detection of anomalous weather conditions allows for accurate actions in case of heating and cooling facilities. The possibility to analyse the weather forecast and to create rules for NRG4CAST weather sensors allows for situation awareness services for building and lighting system managers.

Analysing the historical and predicted temperature and cloud cover, we created an alert announcing high temperatures and high percentage of cloud cover, which could lead to additional costs for cooling and lighting (Figure 5, Figure 6).

Figure 5 - NRG4CAST Situational Awareness GUI, high temperatures alert

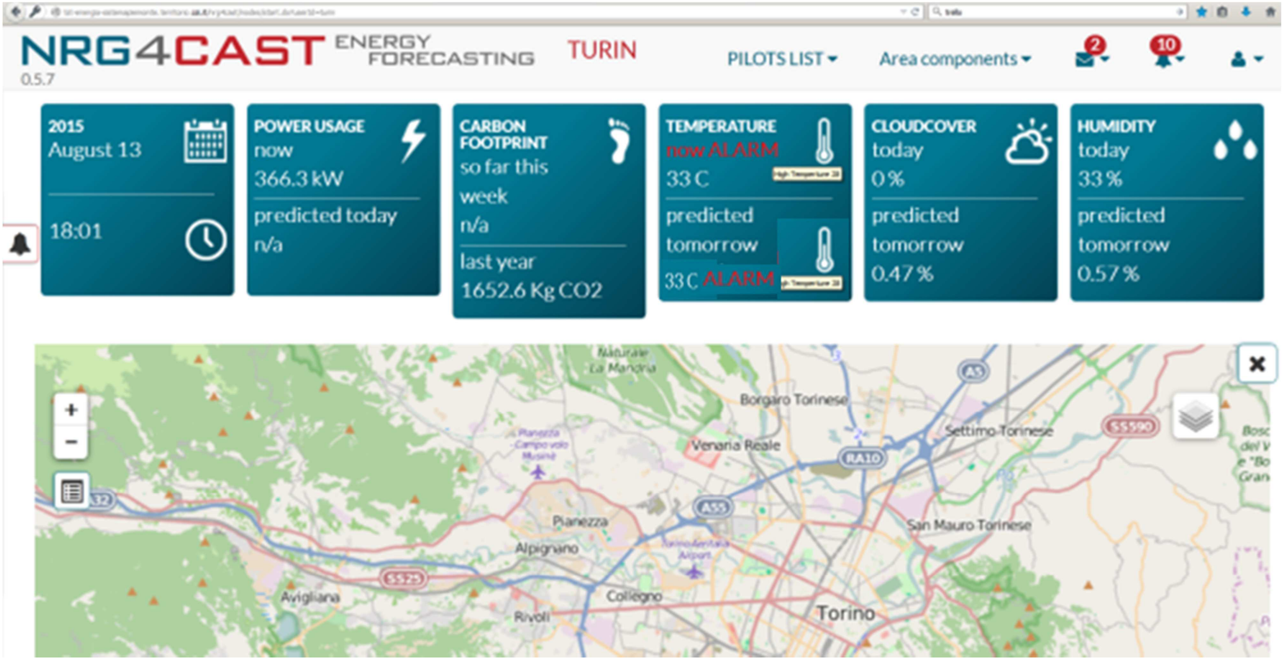

Figure 6 - NRG4CAST Situational Awareness GUI, high temperatures alert, an alert and an explanation example (GUI is a work in progress)

3.3.3 Complex rules to be applied on historical and current data

To allow analysis of the complex consumption centres (such as towns, districts, university campuses) we will need to make more complex queries, so some basic math operators such as "+","-","/","*", etc. were added to the Rule Editor GUI. This way we can, for example, sum more sensors in order to analyse the consumption centre overall energy consumption.

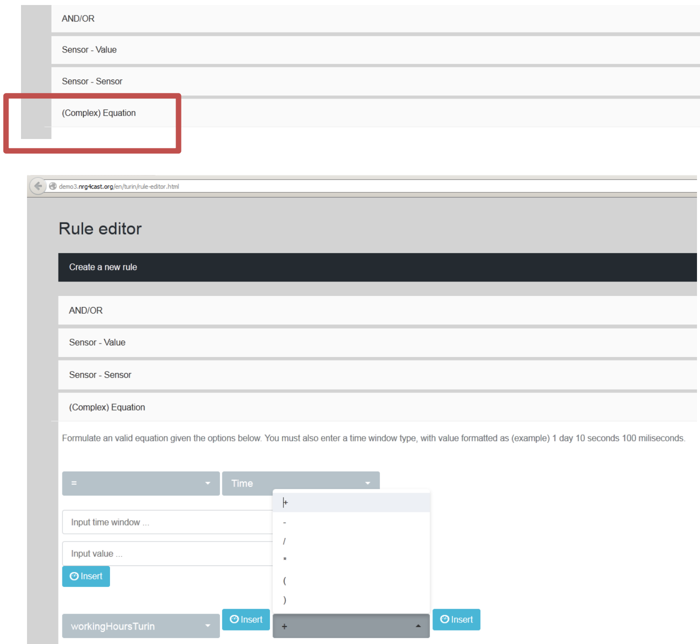

Figure 7 - Complex Equation Editor

3.3.4 Analysis of energy prices

The main idea is to integrate energy price analysis and prediction within the Situational Awareness GUI.

Within the NRG4CAST project German energy market has been analysed. Furthermore, a link between Situational awareness services GUI of FIR Smart Charging Algorithm German pilot and the prototype could be established. We could develop *ad hoc* services such as spot-get-energy-price. Based on the set of parameters (predefined concept, related keywords etc.), the user can automatically view all the worldwide information related to the pilot. Using this solution, we could give an answer on questions such as "There is a pick of energy price in Germany, what is happening in the world? What is the correlation with the world news and the main events?"

3.3.5 Gaps in the data flow

Situational awareness GUI will alert the user of technical problems within the data flow. An alert will appear once there is a gap in the data flow.

Within the upper panels of the NRG4CAST Real time visualisation GUI, the data is visualised in real time. Once the data doesn't relate to the actual current date, an alert will appear within the Situational Awareness GUI.

A possible Rule for Alert: actual time stamp = value time stamp. Another Rule possibility could be:
the sensor Buildingtotalconsumption - doesn't send the measurements for the last 3 hours (Turin pilot, CSI building example).

3.3.6 Integration of situational awareness services within the Forecast set of predefined reports

The aim is to allow for a possibility to verify reliability of the energy consumption forecast.

We will add "current consumption sensor" within the Forecast predefined report Energy Use Tomorrow (predicted use of energy for today and tomorrow). A green colour icon will appear while the forecast and current values are within the reliable range. An alert notice (red coloured icon) will appear once there is a difference between the current and the predicted value.

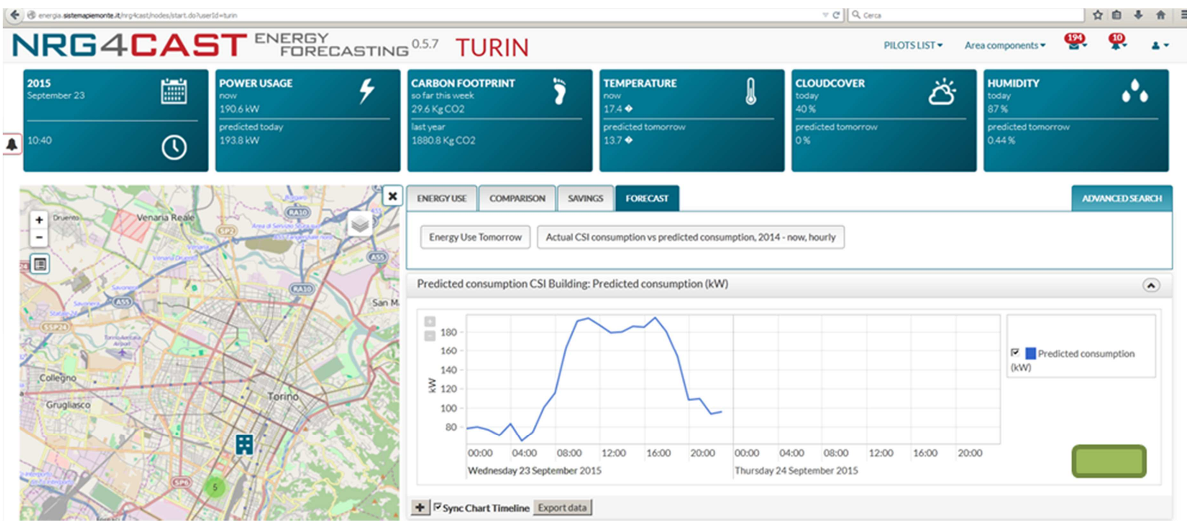

Figure 8 - Report Management & Visualization and Real-time Visualization GUI, Forecast predefined reports, integration with the Situation Awareness GUI

4 Conclusions

Situational awareness services created on the solid base of predictions and alert services are fundamental for the NRG4CAST Decision Support System. At the moment situational awareness GUI allows for anomaly awareness, shows “monetary” savings, and highlights high energy consumption and anomalously high temperatures. It is possible to analyse the energy consumption of an overall complex consumption centre, such as University Campus, the city, and municipality area.

The user environment was analysed in deep in order to create the NRG4CAST situational awareness services. The solution’s services and GUI were developed based on the end-user recommendations and NRG4CAST pilot’s needs. The direct debate with the target users during the workshops and informal meetings also resulted in overall suggestions for NRG4CAST future developments after the project ends.

The developed situational awareness services are a solid base for a long term optimisation DSS, which could be a subject for a new project on ICT and energy efficiency. The services are perfectly in line with the Energy Performance of Buildings Directive (2010/31/EU) and Energy Efficiency Directive (2012/27/EU) and allow for detailed energy performance assessment of the buildings, offices, and analysis of public lighting systems, transformers and charging stations for electrical vehicles, and district heating distribution.

One of our concerns is that using the NRG4CAST CEP engine Esper we are able to compare predictions versus current measurements, but we can’t use any future predictions. Some of the rules created within the Rule Editor could be applied on predicted data. It could be a set of predefined rules that work also for forecasts. An interaction with the rules system would allow for a possibility to check for the alerts “ to be”.

By generating alerts using predicted data the system would send an alert on high consumption in the future or other anomaly situations related to energy management and energy efficiency to the user. This kind of alert on predicted data would allow the user to modify the energy management system and to be ready for any anomaly in advance.

However, for this reason, a separate service would need to be developed. To get the desired functionality we would have to develop a different event processor with the ability to insert data with a certain timestamp. The engine should then be able to compare predictions to other predictions and values (combined with normal operations of course). Currently we bypass this problem by delaying predictions until the time of the prediction and then insert them into the stream. This way we can compare all the desired sensors in real time.

References

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