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NRG4CAST

Deliverable D7.1

Validation methodology

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Executive Summary

This Deliverable provides description of the developed validation methodology including criteria and measures for validation. The deliverable identifies the detailed development goals for each pilot case. It will describe project expectations from each pilot case, as well as the method for measuring these expectations.

The validation methodologies described in this document are based on the following:

- The *International Performance Measurement & Verification Protocol IPMVP*[2], developed by the Efficiency Valuation Organization EVO. This protocol has been adapted in order to serve the NRG4CAST purposes.
- The *Uniform Methods Project: Methods for Determining Energy Efficiency Savings for Specific Measures*[3]. This report was published in April 2013 by the U.S. Department of Energy. It is a set of protocols for determining energy savings from energy efficiency measures. Deliverable 7.1 has used parts of this report for consultation purposes.
- The knowledge gained from the EU project *3e-HOUSES: Energy Efficient e-HOUSES*[4] and especially the deliverable "D1.2 Definition of methodologies"[5]
- The knowledge gained from the EU project *eSESH: Saving Energy in Social Housing with ICT*[6] and especially the deliverable "e-SESH ICT PSP methodology for energy saving measurement"[7].

[2] http://www.evo-world.org/index.php?option=com_content&view=article&id=272&Itemid=323&lang=en
[3] http://www.nrel.gov/docs/fy13osti/53827.pdf
[4] http://www.3ehouses.eu
[5] http://www.3ehouses.eu/sites/default/files/3e-HOUSES_-_Deliverable_1_2_Definition_of_Methodologies_v12Annex.pdf
[6] http://www.eSESH.eu
[7] http://esesh.eu/fileadmin/eSESH/download/documents/News/CIP_Common_deliverable_eSESH_2011.pdf

1 Introduction

This deliverable provides description of the NRG4CAST validation methodology developed by the project partners.

NRG4CAST validation methodology is based on the experience of European projects on implementation of ICT-based energy efficiency services in public buildings, social housing, street lighting and electrical vehicles. The second Chapter of the deliverable provides an overview of validation methodologies applied within the European projects on ICT for energy efficiency.

The Chapter 3 of the deliverable illustrates the NRG4CAST validation methodology which includes the methodology for Energy Efficiency Measures, Control group approach to behavioural changes, User acceptance evaluation, and methodology for evaluation of the NRG4CAST ICT solution.

In the framework of NRG4CAST project, the validation methodology will be applied for single pilot cases and for validation of the integrated pilot “Miren-FIR-CSI-IREN scenario” (ENVIGENCE-FIR-CSI-IREN). The Chapter 4 describes the methodology for validation of Energy Efficiency Measures in NTUA University Campus. The Chapter 5 is dedicated to the methodology for validation of energy consumption reduction within the CSI building and a set of public owned buildings in Turin. Chapter 6 provides the methodology for validation Energy saving of the District Heating network. Within the Chapter 7 the methodology for validation of energy prediction by the Smart Charging Algorithm is described. Furthermore the Chapter 8 provides the methodology for validation of energy consumption reduction at the Miren municipality.

Additionally primary version of methodology for validation of Integrated Miren-FIR-CSI-IREN Scenario is described within the Chapter 9. This methodology integrates the methodologies elaborated for the separate pilots involved in the project. NRG4CAST is aiming not only to compare different homes and households with each other but whole neighbourhoods, which are virtually combined. Therefore specific NRG4CAST methodology for virtual pilot validation will be provided in the next months based on wide European experience of modelling at the urban scale of sustainability.

2 An overview of validation methodologies applied within the European projects on energy efficiency

NRG4CAST validation methodology is based on the experience of European projects on implementation of ICT-based energy efficiency services in public buildings and social housing, street lighting and electrical vehicles. Referring to the subject of ICT-based energy efficiency services in public buildings and social housing, ICT-based energy efficiency services for street lighting and ICT-based energy efficiency services for electrical vehicles the following projects were taking in consideration:

- **SMARTSPACES**[8]**:** Deals with saving energy in public buildings by using ICT
- **BECA**[9]**:** (Balanced European Conservation Approach) ICT services for resource saving in social housing
- **eSESH**[6]**:** (Saving Energy in Social Housing with ICT) Deals with the achieving of a significant reduction of energy consumption in European social housing
- **3e-HOUSES**[4]**:** Deals with ICT technologies in order to provide energy efficiency in social housings
- **Lites**[10]: (Led-based intelligent street lighting for energy saving) Delivers an intelligent public street lighting service
- **BLISS**[11]**:** (Better Lighting in Sustainable Streets) Deals with a reduction in street lighting energy consumption
- **ESOLI**[12]: (Energy Saving Outdoor Lighting) Aims the increased awareness of intelligent street lighting and acceleration of the use of available technologies

The specific methodology for validation whole neighbourhoods which are virtually combined will be based on wide European experience of modelling at the urban scale of sustainability:

- HTB2 models (Alexander, 1996; Alexander DK (1996) HTB2 User's Manual, Welsh School of Architecture, Wales);
- Energy and Environmental Prediction (EEP) model (Jones P, 1997; Alexander DK, Jones PJ, Lannon S (1997) Energy Modelling of Building Estates. BEPAC Conference, Sustainable Building 136-140, Abingdon, England).

The validation methodology for NRG4CAST is mainly adopted from the eSESH and 3e-HOUSES methodology

2.1 Modified EVO International Performance Measurement & Verification Protocol

This ICT PSP project designs a common methodology for energy saving measurement which is taken as a starting point for NRG4CAST validation methodology to measure the energy savings in the building sector involved in the project.

The original basis for savings calculations within the mentioned above ICT-PSP projects are a modified version of the EVO International Performance Measurement & Verification Protocol (IPMVP). According to the EVO site[13] this protocol is the leading international standard in measurement and verification protocols and it defines concepts related to Energy and Water Savings, Improved Indoor Environmental Quality, Energy

[8] http://www.smartspaces.eu/S/home/
[9] http://www.beca-project.eu/
[10] http://www.lites-project.eu/
[11] http://www.bliss-streetlab.eu/
[12] http://www.esoli.org
[13] http://www.evo-world.org

Savings in New Construction, Energy Savings in Renewable Energy Technologies are defined within this protocol.

The methodological proposal for ICT PSP projects in the residential sector described within the Common Deliverable sets out from the IPMVP and adapts its provisions to the scale of energy consumption in the residential sector and to the different purpose of providing feedback on the success of attempts to save energy in that sector.

However, there are parameters such as demand response and avoided CO2 emissions which are not taken into account in the IPMVP protocol. To calculate the CO2 emission savings from energy use savings the overall consumption of electricity and of particular fuels for heating can be converted to CO2 using standard combustion coefficients for fuels and a coefficient for CO2 emission per kWh electricity generated based on the national mix of generation sources[7].

The IPMVP measurement and verification plan mainly focuses on meter installation, calibration and maintenance; data gathering and screening; development of computation methods and – if necessary – acceptable estimates; computation of measured data and reporting, quality assurance and third-party-verification of reports.

The IPMVP four options (A, B, C and D) for measurement and verification were analysed within the ICT PSP common deliverable on methodology for energy saving measurement. The Option C, Variable demand as a result of the ICT, is applicable to ICT PSP pilots with some adjustments. This Option doesn't assume constant energy demand, but it is based on the use of utility meters, whole building meters or sub meters to assess the energy performance of a total building. The whole facility baseline and reporting period (utility) meter data are to be analysed within this option[7].

2.2 Foundations of the ICT PSP approach for validation

The ICT PSP methodology is based on the following key terms such as dependent and (relevant) independent variables, and, for the before-after approach, the idea of baseline and reporting period.

Independent Variable: Characteristics of a building, its environment or use which affect energy consumption: weather (temperature, humidity), occupancy, dwelling size, heating system, etc. When reference is made to an independent variable, the implication is that it has an impact on demand[7].

Dependent Variable: Characteristics of a building or its use which is the target of an intervention. Here the main focus is (reduction in) energy consumption, which can be related to the scale of the intervention as number of tenants (kWh per person) or the size of the dwellings (kWh per square meter) [7].

2.2.1 Pre-post comparison

In before-after comparison, the actual energy saving caused by an Energy Saving Intervention (ESI) is estimated from the difference between consumption after the intervention and the consumption which would have taken place under the same demand conditions without the ESI. To estimate what consumption would have been without the ESI, consumption data prior the intervention is used. This is known as baseline data. An extended baseline is the projection of consumption before the intervention into the period after the intervention[7].

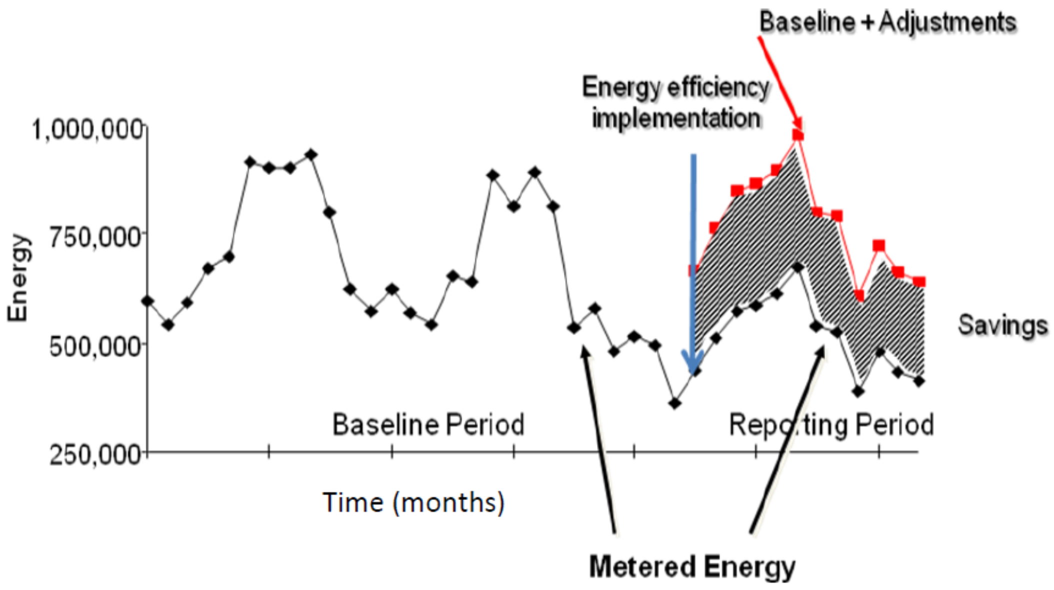


Figure 1- - Energy saving (Source: Common_deliverable_eSESH[7])

In order to measure energy savings, we need to estimate the "non-intervention" consumption (what would be the consumption in case there is no intervention on energy saving). For these estimations historical data on energy consumption is needed. The comparison of the energy consumption after the intervention with the baseline gives us the energy saving intervention result (Fig.2). The independent variable should be taken in consideration where possible with the reference to the model on energy use variations under the influence of independent variables developed within the ICT PSP Common deliverable[7].

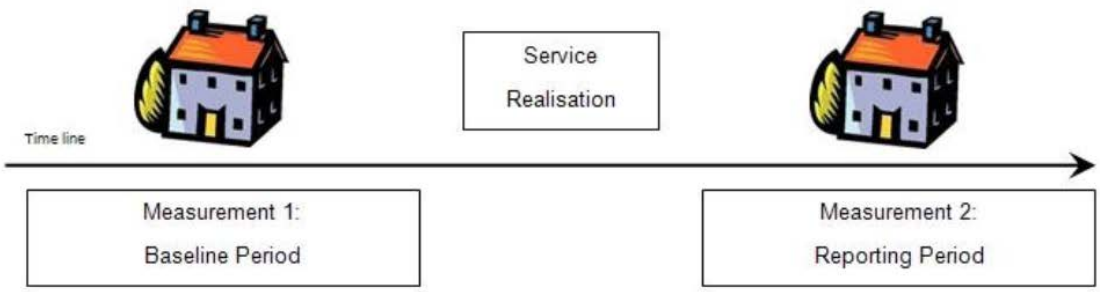


Figure 1- Before and after analysis of building[7]

2.2.2 Selection of reporting period

It is necessary to monitor persistence (increase or decrease) of energy savings in the time. The ICT PSP Common deliverable[7] following steps developed the following steps for this monitoring:

- In the short term, to compare each week to analyse if the energy savings are continuous over time after the energy saving intervention, especially if the savings depend on social behaviour;
- the long-term verification is of high importance in case the equipment renovations were performed[7]

2.2.3 Applying control group techniques

In the cases were historical data on energy consumption isn't available, another way for pre-post intervention comparison should be applied: control building approach (Fig.3).

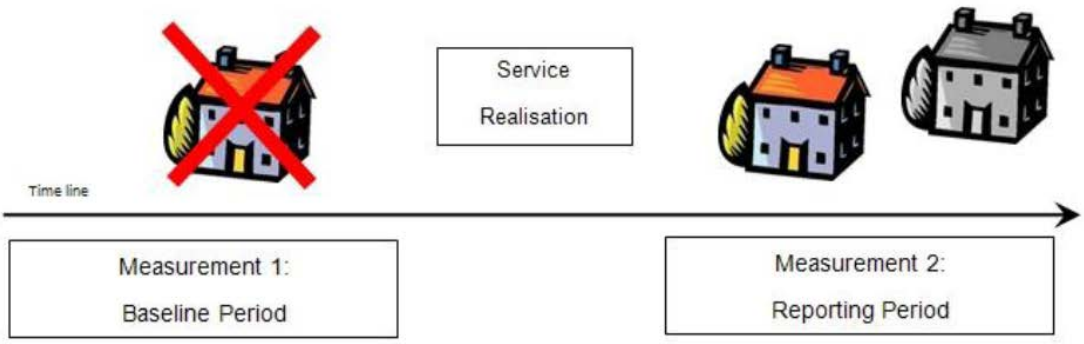


Figure 2- Control building design[7]

A control building has to be chosen. This building has the same characteristics (building typology, year of construction, building use) of the pilot building involved in the experiment. The independent variables have to be the same as well (at least these which are known). This method of estimation is advantageous as well, since the information about the 2 buildings is gathered at the same time.

3 NRG4CAST validation methodology

The aim of the NRG4CAST validation methodology is to provide a coherent method for calculating the energy savings, measured before and after the implementation of the NRG4CAST solutions. Validation is crucial for the detection of any deviation from the original plan and for the implementation of early corrective actions.

In the framework of NRG4CAST project, the validation methodology will be applied in the two case studies; the University Campus in Athens (NTUA) and the integrated Miren-Turin-Aachen-Reggio Emilia scenario, called “Miren-FIR-CSI IREN scenario” (ENVIGENCE-FIR-CSI-IREN).

This chapter provides a methodology for determining energy savings from the energy efficiency measures implemented in the NRG4CAST pilot cases. The developed methodology provides a straightforward method for evaluating energy savings for each implemented measure and for each pilot plant separately.

This report contains methodologies for the following pilot plants:

- University campus in Athens (NTUA),
- CSI headquarters building and group of historical buildings in Turin (CSI),
- Thermal energy plants for district heating and Iren buildings within it main headquarter (Campus Nubi)(Reggio Emilia),
- Electrical vehicles in Aachen (FIR),
- Municipality of Miren-Kostanjevica in Slovenia (ENVIGENCE),
- Integrated scenario Miren-Turin-Aachen-Reggio Emilia (“Miren-FIR-CSI-IREN”)

The methodologies concern the following energy efficiency measures:

- Energy consumption monitoring system (Athens, Turin)
- Energy and infrastructure management system (Miren-Kostanjevica)
- Thermal energy production and distribution (Reggio Emilia)
- Electrical vehicles charging management system (Aachen).

3.1 Methodology for Energy Efficiency Measures

The evaluation, measurement, and verification methods described here are based on the International Performance Measurement and Verification Protocol IPMVP[14]. The use of a common methodology to calculate the energy savings is expected to increase the credibility of the reported savings, thus the electric utilities, their regulators and other stakeholders will be given a greater level of confidence about the reported savings.

Energy savings result from the difference between the energy consumption that would have occurred had the measure not been implemented (baseline-period) and the consumption occurring after the retrofit (reporting-period). Energy calculations use the following fundamental equation:

Energy Savings = (Baseline-Period Energy Use – Reporting-Period Energy Use) ± Adjustments (eq. 1)

The adjustment term calibrates baseline or reporting use and demand to the same set of conditions. Common adjustments are changes in schedules, occupancy rates, weather, or other parameters that can change between baseline and reporting periods. Adjustments commonly apply to heating, ventilating, and air-conditioning (HVAC) measures, but less commonly to lighting measures, or are inherent in algorithms for calculating savings.

Apart from energy savings, there may be also savings in peak demand, which are expressed by the following equation:

Demand Savings = (Baseline-Period Demand – Reporting-Period Demand) ± Adjustments (eq. 2)

For each energy efficiency measure (EEM) undertaken, this document explains our proposal of methodology to calculate these savings, as follows.

3.1.1 Measure(s) Description

In the first section, the EEM is briefly described, such as whole-building retrofit, upgrade of HVAC heating ventilation and air conditioning equipment, upgrade of boilers and furnaces and/or installation of lighting controls.

3.1.2 IPMVP Option determination

For every EEM, there are four options to calculate the energy savings, according to the type of EEM implemented:

A Partially Measured Retrofit Isolation: Savings are determined by partial field measurement of the energy use of the system(s) to which an EEM was applied, separate from the energy use of the rest of the facility. Measurements may be either short-term or continuous.

B Retrofit Isolation: Savings are determined by field measurement of the energy use of the systems to which the EEM was applied, separate from the energy use of the rest of the facility. Short-term or continuous measurements are taken throughout the monitoring (post-EEM) period.

C Whole Facility: Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the monitoring (post-EEM) period.

D Calibrated Simulation: Savings are determined through simulation of the energy use of components or the whole facility. Simulation routines must be demonstrated to adequately model actual energy performance measured in the facility.

It is of crucial importance to choose the most appropriate option, according to the type of EEM implemented. This choice will further specify the calculation method and will finally determine the energy savings of the EEM.

[14] Energy Valuation Organization, International Performance Measurement and Verification Protocols, Concepts and Options for Determining Water and Energy Savings, Vol. 1, January 2012.

3.1.3 Measurement & Verification Plan

a) Boundaries identification

The boundaries of the savings determination have to be identified and all effects occurring beyond the boundaries should be described and estimated. Some examples of the boundaries of the savings determination are:

- The electricity/natural gas bills
- The energy use of a whole building
- The assumption that a boiler is associated only with fuel consumption and not electricity (auxiliary) consumption.
- The assumption that the installation of a more efficient lighting system does not decrease the air-conditioning load, since a building is closed during summer.

b) Baseline period data

This section describes the collection and record of the energy and operating data occurring during the baseline period. Baseline period is the time necessary to be representative of the operation of a building, before the implementation of an EEM (see following figure).

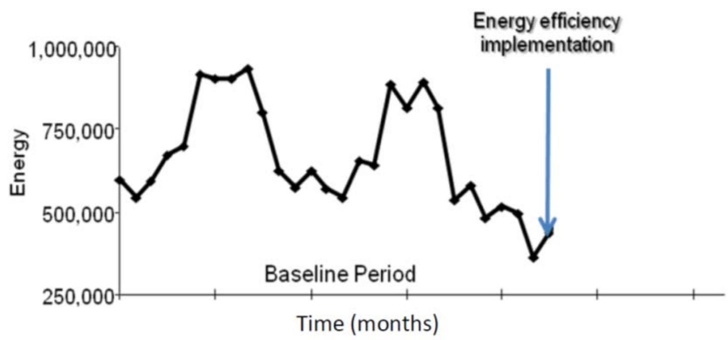


Figure 3: Baseline period[4]

The collection of consumption data occurring during the baseline period is necessary in order to be able to quantify the energy savings.

In reality though, the conditions change from one measurement period to another and therefore adjustments have to be done.

This data may be derived from a comprehensive energy audit and includes:

- energy consumption profiles
- occupancy type, density and periods
- space conditions (thermal comfort level and indoor air quality) for each operating period and season
- equipment list: technical specifications, location, condition, photos
- equipment operation: schedules, set points, actual temperatures/pressures, problems

The extent of the information to be recorded is determined by the boundaries of the savings determination. The baseline data documentation typically requires well documented audits and/or metering activities. In case of Options C and D, all building equipment and conditions should be documented.

c) Monitoring

The monitoring procedures should include a description of all metering points, period(s) of metering, meter characteristics, meter commissioning procedure, calibration process and method of dealing with lost data.

d) Commissioning

The commissioning procedures should include a description of the commissioning of the EEM, the inspection of the installed equipment and assurance of the correct system operation. Revised operating procedures to ensure that they conform to the initial scope of the EEM.

e) Reporting period data

The reporting period is the period after the implementation of the EEM during which energy savings are monitored. During the reporting period, the energy consumption is expected to be lower than it would have been, had the EEM not been implemented.

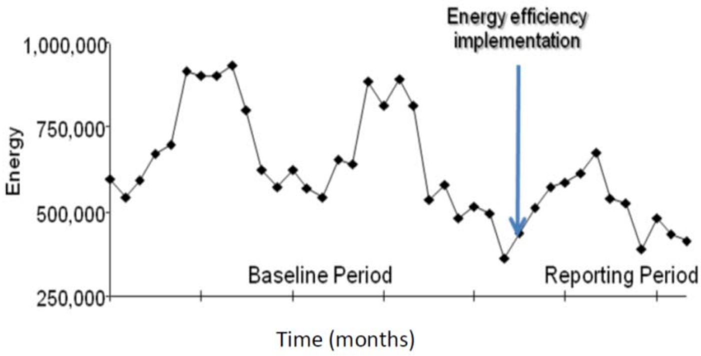


Figure 4: Baseline and reporting period[4]

f) Data analysis

This section is related to the data analysis procedures, algorithms and assumptions. For each mathematical model used, all of its terms and the range of independent variables over which it is valid should be defined.

The **independent variables** are the characteristics/environment/use of a building which affect energy consumption, such as weather conditions, occupancy, building size, type of heating/cooling system, etc. The independent variables affect the demand.

The **dependent variables** are the characteristics/environment/use of a building which is the target of an EEM. Here the main focus is (reduction in) energy consumption, which can be related to the scale of the intervention as number of tenants (kWh per person) or the size of the dwellings (kWh per square meter).

g) Quality assurance

Specification of quality assurance procedures.

h) Measurement accuracy

Quantification of the measurement accuracy during data capture and analysis.

3.2 Control group approach to behavioural changes

To create a reliable result in all measurements it is crucial to choose the right control groups. Those groups determine what measurements are compared to each other and therefore have a big impact on the quality and validation of the results. In the NRG4CAST project, two different kinds of groups are varied to achieve a solid foundation for the result. One is the object group, which varies the kind of object that is measured and one it the consumer group that varies the knowledge of the consumers.

3.2.1 Object groups

To vary the objects, two different approaches are proposed within the NRG4CAST project. As seen in Figure 5, the first is the "one-to-one comparison" and the second is the "before-after- comparison". Within the "one-to-one comparison", two equal objects need to be used. The equality needs to be ensured for at least the characteristics that are important for the measurement. For conducting a measurement, both objects have to be fitted with measurement equipment. Thereafter, one characteristic is changed in one object (e.g. some energy efficiency improvements are applied on a building). Since both objects have the same preconditions, the difference in the measurement derives from the change at one of the objects.

The "before-after comparison" is the time-regarding measurement. In this case, only one object is observed but over a certain period of time. The advantage is that no equal object is needed but the same one is used before and after a change. The time-dependency might lead to complications if external parameters (e.g. the weather) are changing during the measurement. Therefore, the data needs to be acquired and used with a certain diligence.

The two approaches do not need to be exclusively applied. In fact, using both at the same time does usually increase the amount of useful data. However sometimes it is not applicable for several reasons to apply both. For each measurement it needs to be decided what approach would result in the best data.

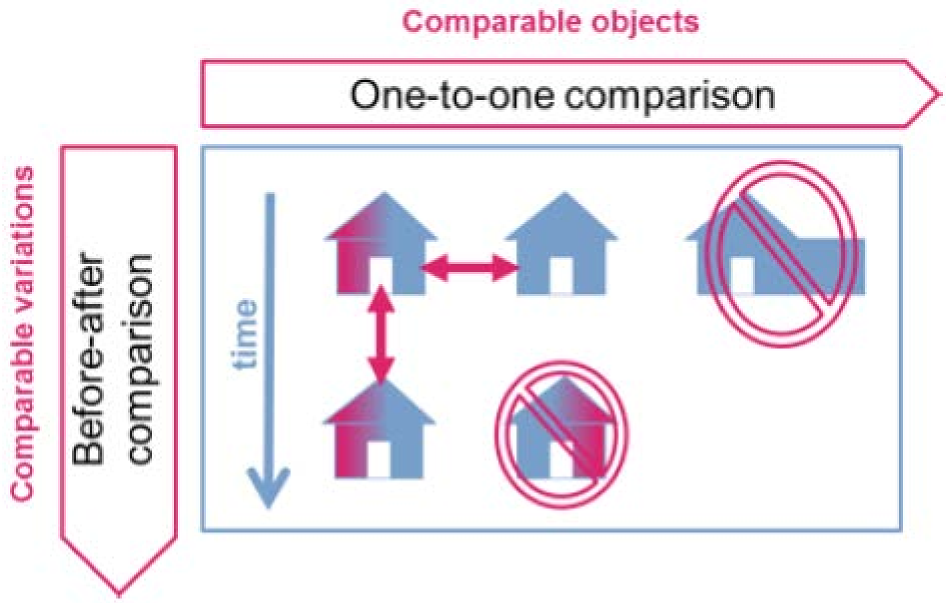


Figure 5: Two different comparison methods for objects (see DOW, Chapter 3.1.2)

3.2.2 Consumer Groups

Beside the object group, a second control group is used to acquire useful results. In this approach the customers are divided into three groups. To one, the information about their energy consumption is given within short periods of time (or even real time), to a second one the information is given regularly but after a longer period, whereas the third group will not receive information about their energy consumption and is not informed about the measurement at all. Using the results of this comparison, it can be determined how the knowledge of energy consumption has an impact on the users' behaviour.

3.3 User acceptance evaluation

Figure 6 displays the described approach. There are four parts of the acceptance evaluation that need to be individual for each use case (Preparation, Status Quo, Questionnaire I / II Part 1). Two parts can be used in all use cases (Questionnaire I / II Part 2+3).

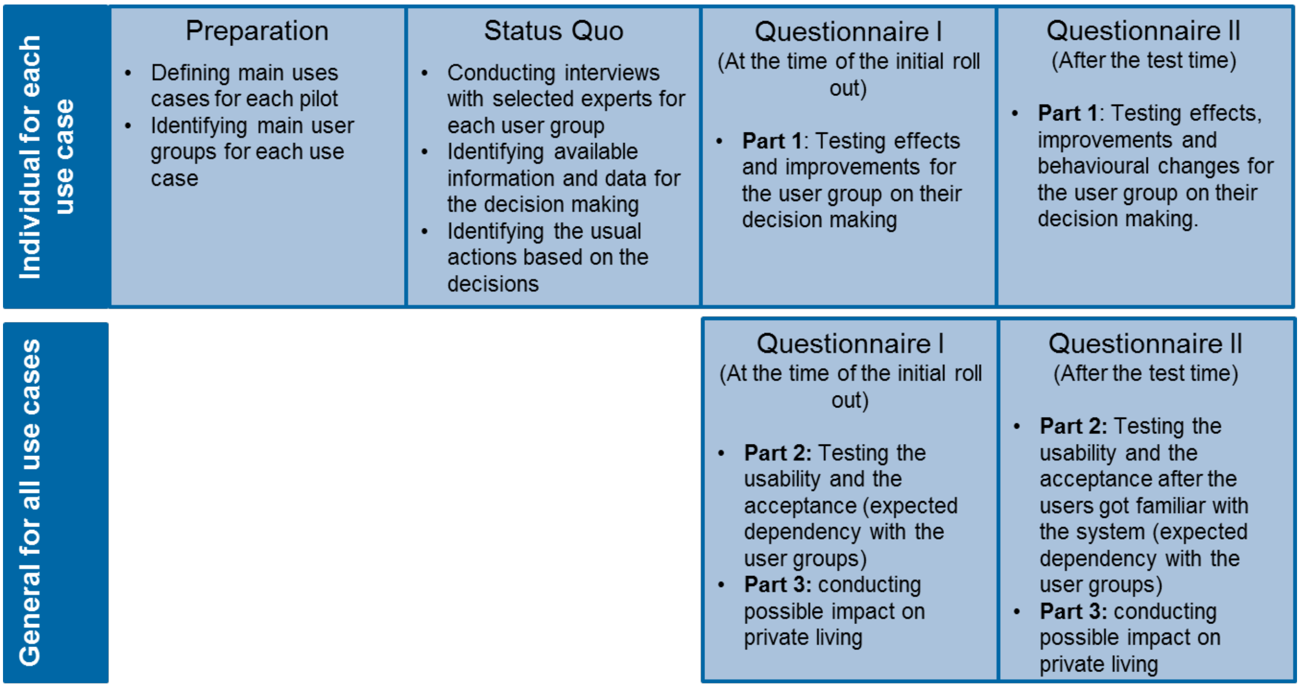


Figure 6: User acceptance evaluation approach

The user acceptance is validated with a set of questionnaires and interviews. For each pilot, main use cases are defined and the main user is identified ("Preparation" in Figure 6).

The interviews will be conducted to determine the status quo of the main users of each use case. Thereby, the available information and data for decisions is identified, as well as the variety of possible and usual actions based on the decisions ("Status quo" in Figure 6). If it is not possible to access a main user, a suitable expert can be interviewed.

The results provide a base for the questionnaires. The **time line for the questionnaires** is:

- The initial rollout for "Questionnaire I" (see Figure 6)
- Ca. 3 months after the initial roll out for "Questionnaire II" (see Figure 6).

This is done to identify the improvements and the behavioural change of the user groups with the information provided by the NRG4CAST prototype.

The three parts of the questionnaires are described below:

Part 1: A special questionnaire for each use case. This validates the information provided for the user group in the use case. This part of the questionnaire is unique for each use case in the pilots.

Part 2: A usability and acceptance test of the prototype. This is a general part for each questionnaire; it tests the users for usability of the ICT, regarding the specific use case.

Part 3: A general survey of the users' situation in its private home. Due to the fact that the private life is not included in the NRG4CAST scope, but the energy consumption at the individuals' homes is a significant factor. The possible effects of providing improved information of the users' individual consumption at home on the users' decision making will be tested over all user groups by a general third part included in the questionnaires.

The field tests of the pilot sites applications are to be planned and prepared in advance.

3.4 Methodology for Evaluation of the NRG4CAST ICT solution

3.4.1 Evaluation by Questionnaires and Interviews

NRG4CAST platform will be assessed both in terms of functional and non-functional aspects and according to the expected behaviour as defined in the requirements definition steps (WP1).

More specifically, the evaluation approach will consist of the following dimensions:

- Evaluation of the functionality of the system;
- Evaluation of non-functional aspects (performance, usability, etc.).

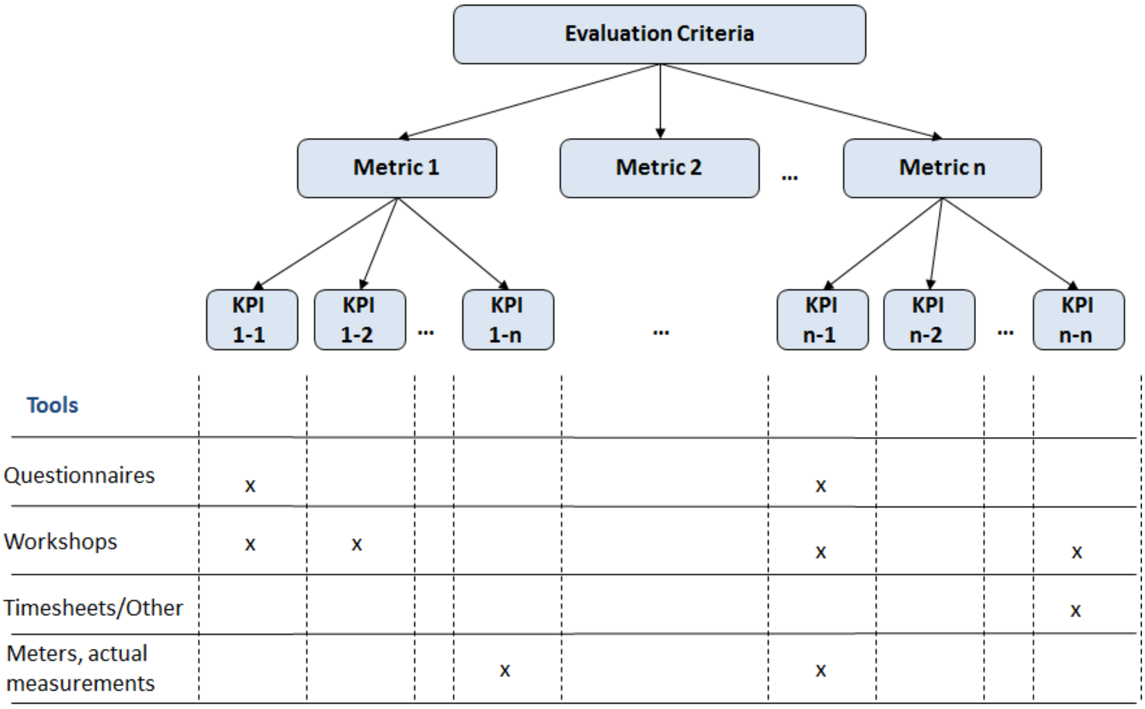


Figure 7: NRG4CAST platform evaluation approach

The evaluation will start with the definition of the criteria. Those represent basic expectations from the system. Examples of criteria are: performance, usability, fit for purpose, etc. As a second phase, the methodology will elaborate on those criteria in specific metrics, which specialize in detail the above-defined criteria. For each of those metrics a specific KPI that can either be measured in quantitative or qualitative approach will be defined. The table below presents specific criteria that will be tested from ICT point of view:

Table 1: Functional/ non-functional criteria of NRG4CAST evaluation

Criterion	Metric	KPI	Measurement Tool
Functionality	Functionality failures	No. of bugs found during the pilot operation	• Checklists
		Lack of functionality as stated in the requirements	• Checklists • Questionnaires • Workshops
Performance	Processing time for forecasting/ reporting	Processing time	• System logs

Criterion	Metric	KPI	Measurement Tool
Flexibility	Ease in changes/ adjustments	Users' satisfaction	• Questionnaire
		No. of complaints/ remarks	• Workshops
Usability	Level of difficulty to learn the system	Time needed to learn the system operation	• Timesheets
	Ease to understand	Users' satisfaction	• Questionnaire • Workshops
		No. of complaints about the system	• Workshops
	Simplicity/Ease to use	Users' satisfaction	• Questionnaire • Workshops
		No. of complaints about the system	• Workshops
Responsiveness	System responsiveness in user demands/ specific actions	Users' satisfaction	• Questionnaire • Workshops
		No. of complaints about the system	• Workshops

For each of the defined KPI specific tool(s) will be used for data collection. Depending on the KPI the consortium will use the following:

Quantitative tools:

They represent actual meters, system logs that can provide accurate measurements on a specific KPI. Examples of quantitative tools are provided in the sections for energy efficiency and predictions evaluations (e.g. sections 3.1 and 3.3). Besides them, some performance measurements of the system (response times, etc.) will be gathered through system files.

Qualitative tools:

The following tools will be used for the platform evaluation purpose:

- *User questionnaire:* Users will be asked to provide their input on specific functional/non-functional aspects of the platform. Those questions will represent the KPIs and the users will be asked to provide a satisfaction rate ranging from very low to very high (satisfaction). Besides that, the users will be asked to provide an importance level for each of the questions in order to understand which aspects of the system are of more importance for them. This will eventually define the necessary priorities for further corrections/improvements of the system.
- *Workshops:* Complement to the user questionnaires, the consortium will organize workshops during the pilot operations in order to have an open discussion and understand better the user feeling on the system behaviour. The workshops will be held with the key persons operating the system (representing different roles like: energy manager, administrator, driver, etc.) and the purpose will be to capture "unstructured" feedback from the users such as general complaints, areas of improvements, etc.

3.5 Goals and expectations for the pilot case (Development goals)

Goals and expectations need to be specified for the validation of the system functionality and for the evaluation of the system performance.

The objective of WP7 is to ensure that:

(1) the model will be developed in order to meet user needs and expectations (development goals),

(2) the model will be tested during pilot activities by follow a common methodology,

(3) relevant and feasible data will be collected in order to provide a robust evaluation of the NRG4CAST system.

The aim of the Pilot Tests is to apply and evaluate the NRG4CAST model, ensuring that the tests conducted in the two pilot sites return relevant and feasible data. It is important to assess the technical aspects of the system's performance, but also consider the user aspects e.g. ease of use, confidence in the system, willingness to have etc. Therefore, the Common Evaluation Framework (CEF) has been designed to encompass

The following schematic diagram represents the flow line underpinning the evaluation and validation framework to be implemented:

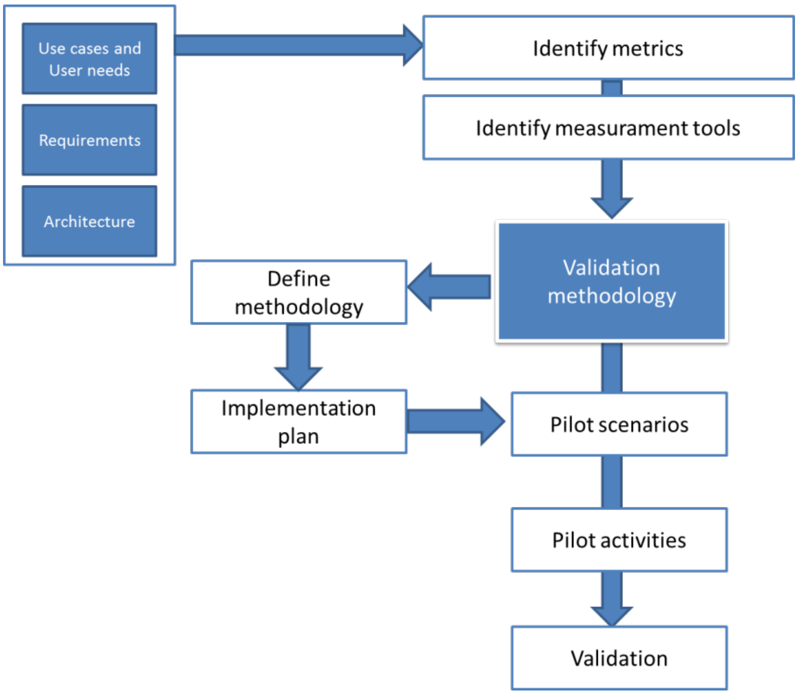


Figure 8: The validation framework

The initial user needs and expectations, use-cases and requirements will be defined in D1.2.

Needs and requirements will be used to derive the evaluation metrics (technical and non-technical). The Use Cases defined in WP1 can be applied to help defining metrics and requirements for both the non-technical and technical metrics, so will be used as the primary source of information.

After the identification of the various metrics, to be used to evaluate the NRG4CAST models, the next step in the flow line will be to identify the most appropriate tools that can be adopted for the measurement and analysis of both the technical and non-technical metrics, and of the related success criteria.

The validation methodology for calculating energy savings will be then transferred into the computational model and tested iteratively.

Validation will conclude with field tests of the case study applications which will demonstrate the benefit created for the target users.

3.6 Predictions

Predictions will be based on the results of the model-driven methods which will utilize statistical analysis and machine learning techniques. Predictions can be divided into two groups according to the nature of the output:

1. Regression (predicting continuous value of the observed phenomena – for example energy demand and energy consumption)
2. Classification (predicting discrete value of the observed phenomena – for example network failures and anomalies)

The system should be able to model complex energy network behaviour and predict energy demand and consumption for various time scales. The system should also be able to detect anomalies in the behaviour of the system. Description of work states the following demands for accuracy of the detection:

- The accuracy of calculated prediction for:
  - short time periods <2h is >80%
  - medium time period 2h < x < 1d is >60%
  - long term 1d < x < 1 week is > 40%
- The accuracy of detected anomalies should be at least 70%

We propose usage of standard measures for estimating accuracy of the methods. With the regression models we propose the sue of *mean absolute percentage error, which is defined as*

$$M = \frac{1}{N}\sum_{t=1}^{n}\left|\frac{A_t - P_t}{A_t}\right|,$$

where A_t is the real value of the data point at time *t* and P_t is the value of the prediction at that same time, *n* is number of tested data points.

In the second case we propose the usage of standard *accuracy* measure in pattern recognition/information retrieval, which is defined as

$$A = \frac{tp + tn}{tp + fp + tn + fn},$$

where *tp* stands for true positives, *tn* for true negatives, *fp* for false positives and *fn* for false negatives. With the classification problem the true events shall be defined by an expert user on a test dataset, for regression problems true values are already included in the dataset. (DoW page 60/160)

4 Methodology for validation of Energy Efficiency Measures in NTUA University Campus

4.1 Measure(s) description

The NTUA University Campus pilot case is related to the monitoring and breakdown of electricity and gas consumption in the Campus and the assessment of the thermal comfort level in a typical office. Monitoring involves the use of instrumentation to measure and record physical parameters. In the context of energy-efficiency evaluations, the purpose of this pilot case is:

- to monitor the energy consumption,
- to forecast the energy demands,
- to detect short term trends in energy prices through cost benefit analysis,
- to guide the NTUA Energy Management Commission towards energy reduction measures and decision making process and
- to reduce the energy consumption of the NTUA Campus by 2%.

This measure involves the installation of various sensors in the Campus buildings for monitoring the electricity consumption for cooling and lighting, the gas consumption for heating and the thermal comfort level in a typical administration office. The realisation of the NTUA University Campus pilot case includes the following energy monitoring activities:

- Installation of electricity sensors for all buildings in the Campus,
- Installation of sensors for measuring the thermal comfort level in an office in the Campus,
- Development of a data acquisition system to collect and integrate data from different network topologies and heterogeneous sources into the same architecture.

The phases of the NTUA pilot case are demonstrated in the following table.

Table 2: NTUA Pilot Operation and validation phases (see DoW B1.3.3.5)

Phases/Activities	Due Date	Expected results
Laboratory installation (produce raw data) – small sample in 1 building	M12	Consolidated data stream from integrated energy network
1st validation results	M14	
Initial rollout: Real life installation (5-7 buildings)	M24	Monitoring and basic analytics environment
2nd Validation results	M26	
Final Rollout: Mass installation (whole campus)	M34	Complete setup
Final validation results	M36	

This measure has not a direct impact on energy consumption, since the sensors installation does not automatically indicate the reduction of energy consumption. Instead, it has an indirect impact, stemming from the knowledge that every kWh of energy spent is monitored, is then compared with the state of the art and finally, published.

4.2 IPMVP Option determination

In this case, the estimation of the total savings requires a comprehensive method for capturing this combined effect. The recommended method is the consumption data analysis, which refers to the analysis of consumption data from utility billing records (billing analysis).

This method is consistent with the recommended International Performance Measurement and Verification Protocol (IPMVP) Option C, Whole Facility. Option C was designed in part to address evaluation conditions that occur with a whole-building retrofit program. The key reasons for using this method in the NTUA pilot case are:

- The goal of the EEM is improvement of whole-house performance
- Because multiple types of EEMs are implemented, the individual savings of each cannot be easily isolated because of interactive effects
- The expected savings are large enough to be discernible over natural variation in the consumption data, at least across the aggregate of program participants.
- Major non-program changes in energy consumption are either not expected or will be adequately controlled for in the analysis.

4.3 Measurement & Verification Plan

a) Boundaries identification

The boundaries of the savings determination for NTUA are the following:

- In most of the buildings, there is laboratory equipment of high electrical load that operate occasionally. Their energy consumption should be isolated from the building's energy consumption.
- The natural gas boilers are assumed to have only natural gas consumption and not electricity (auxiliary) consumption.
- The consumption of the natural gas boilers will be monitored through energy bills. The fuel use from the gas utility bills during 2011 was $3.8*10^6$ m^3 (at 2 bar) and $1.6*10^6$ m^3 (at 300mbar).
- In case of a strike, there is a possibility of schedule reforming, occupancy pattern change and energy consumption reduction.
- The energy measurements have to take into account the accuracy of the sensors.

b) Baseline period data

Energy measurements and possible savings are to be computed annually for the subsequent year using a measurement of the electrical load immediately after the installation of the EEM and on each anniversary thereafter. The baseline period represents the year immediately before the EEM installation, as shown below.

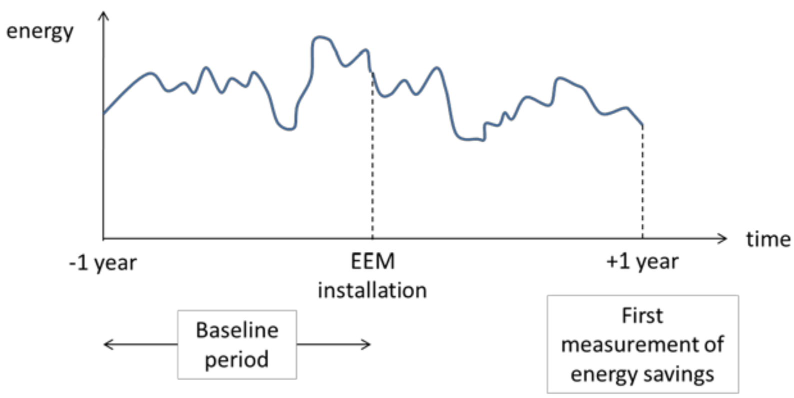


Figure 9: Energy savings measurement plan

The data from the baseline period (utility bills) have to be analysed, with the view to correlate the electricity and natural gas demand with weather, occupancy levels, solar radiation, etc. Multiple linear regressions can be performed on monthly energy use and demand, metering period and degree days (DD).

The electrical power readings on the base year and all future years will be made by the NTUA's appointed personnel. All data and analyses will be available for inspection.

c) Monitoring

The physical properties monitored under this EEM are the following:

Electric power

Electric power and energy is the most important physical property for energy savings evaluations. Since electric power is a direct measurement of the energy use of the NTUA load, it is the only measurement needed to determine savings between the base case and the measure implemented. The common unit of power is kilowatts (kW). The common unit of energy is kilowatt-hour (kWh). Other electrical measurements are voltage (V), current in amperes (A) and power factor (PF).

Temperature

Temperature is a parameter that is incorporated into the calculation of the thermal comfort level in a typical office in NTUA. The temperature sensors to be installed will monitor the dry bulb temperature of the room air.

Relative Humidity

The relative humidity of the air will be measured to determine the thermal comfort conditions in a typical office in NTUA. Relative humidity is a measure of the relative amount of water vapour in the air for a given condition, versus the capacity of the air to hold water vapour at that same condition.

Illuminance

Illuminance is the total luminous flux incident on a surface, per unit area. It is commonly measured in units of lux. Illuminance level will evaluate the amount of light in the work plane of the typical office in NTUA.

Normalising parameters

Additional physical properties will be collected and monitored with the view to normalize the energy consumption evaluation. Normalisation is required, since the specific conditions between the baseline and the post-implementation period is expected to differ. For the NTUA loads, typical meteorological year (TMY) weather data and occupancy levels will be used to normalize the energy consumption evaluation.

The basic characteristics of the monitoring equipment that will be installed in the NTUA premises for the scope of the project are listed below.

Electric power monitoring device

- Product functions: Measurements of voltage, current, active power, reactive power, pulse, frequency.
- Digital output, compliant with fast Ethernet, MODBUS TCP protocol.

Temperature and Relative Humidity sensors

- Measurement range: 0-100% RH, 0-50^{o}C
- Output 4-20 mA

Illuminance monitoring device

- Measurement range: 0-20000 lux
- Output 0-10 V

Central Data Handling Unit

It is the software for supporting the power management system. It collects and processes the measured data of all monitoring devices in the 23 substations of the NTUA Campus. It enables the data detected by the measuring devices to be read out, displayed, archived, monitored, graphed and processed in basic analyses, such as cost centre allocation, consumption comparison, and duration curve presentation. Data files are saved in .csv or .xls format.

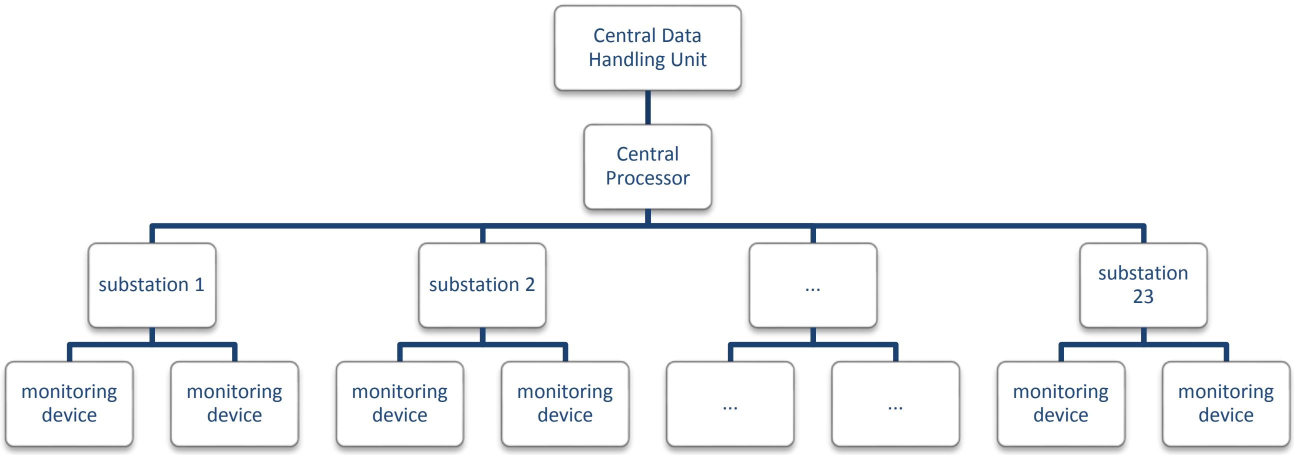


Figure 10: NTUA monitoring system configuration

The recording interval for the electricity meters that will be installed is chosen at 15 minutes, since this interval provides sufficient time resolution to capture the reaction of the load to the controlling conditions. The recording interval for the temperature, relative humidity and illuminance sensors that will be installed is chosen at 1 minute.

d) Commissioning

The commissioning procedures should include a description of the commissioning of the EEM, the inspection of the installed equipment and assurance of the correct system operation.

The operational test of each monitoring equipment, prior to its installation is crucial for an accurate monitoring process. As such, before installing each sensor, the technicians will test it to ensure it is working properly and making the intended measurement. These tests will include the following:

- If meter operates on batteries, are the batteries in good condition, and is there a backup set? Is the meter properly powered?
- Is the meter clock synchronized to local time zones?
- Are all the settings on the meter correct?
- Are sensors properly attached and in place?

e) Reporting period data

The post-retrofit period will use utility bills for the natural gas consumption and the sensors' measurements for the electricity consumption. The first report will be produced 1 year after the EEM installation.

f) Data analysis

The report will include data on energy consumption reduction. This reduction will be derived from the comparison of the baseline period and the post-retrofit period data that will have been correlated with variables, such as weather, occupancy levels, solar radiation, degree days etc. The report may use the following indicators on the energy consumption reduction.

Heating

- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)
- Energy consumption (saving) per degree-day KWh/HDD p.a. (Heating Degree Days)
- Primary Energy consumption (saving) per square meter (kWh$_{PE}$/m^2 p.a.)
- Share of renewable energy (%)

Cooling

- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)

- Energy consumption (saving) per degree-day KWh/CDD p.a. (Cooling Degree Days)
- Primary Energy consumption (saving) per square meter (kWh_{PE}/m^2 p.a.)
- Share of renewable energy (%)

Electricity

- Energy consumption (saving) per person (kWh/person p.a.)
- Energy consumption (saving) per square meter (kWh/m^2 p.a.)
- Primary Energy consumption (saving) per square meter (kWh_{PE}/m^2 p.a.)
- Share of renewable energy (%)

Avoided CO_2 emissions

- CO_2 avoided emissions ($kgCO_2$/p.a.) = energy savings (kWh/a) * emission factor ($kgCO_2$/kWh)

Economics

- Cost of consumption (saving) per person (€/person)
- Cost of consumption (saving) per square metre (€/m^2)
- Net present value of the investment per square metre (€/m^2)
- Return on investment (ROI) (%).

Buildings

- Thermal comfort
- Categorisation of buildings according to their energy consumption
- Identification of the cost-effective strategies to reduce the energy consumption of the most energy intensive buildings
- Forecasting of the consumption peaks.

g) Quality assurance

Data verification is a quality assurance procedure followed in NTUA pilot plant. Verification of the collected data is an essential aspect of ensuring an accurate monitoring process. The data verification practices that will be followed are:

- Data reviewing: This is done in order to verify that the data is complete and correct and to identify the readings that appear inappropriate.
- Data cross-checks: If the readings appear to be incorrect, cross-checks with other sensors will be conducted. Additionally, the assumptions that were made when planning the monitoring equipment will be checked.
- Equipment calibration: If the cross-checks do not validate the data, the equipment has to be calibrated in order to match with the other monitoring equipment. Alternatively, it should be checked whether the sensor needs replacement.
- Data collector: The responsibility for the data collection process will be assigned to a specific individual who will determine the design and structure of the monitoring process.
- Data verification: The retrieved data will be reviewed again for completeness and accuracy before its incorporation into the final analysis and reports.

h) Measurement accuracy

The accuracy of a measurement is proportional to the cost of the instrument and the installation method. Additionally, such factors as measurement location, monitoring duration and sampling interval also impact the accuracy of the results. For a given measurement or parameter, the necessary precision is an important consideration in the savings estimation. The accuracy of the monitoring devices to be installed at NTUA Campus is shown below.

Electric power monitoring device

Formula for relative total measurement inaccuracy

- for measured variable voltage: +/- 0.3 %
- for measured variable current: +/- 0.2 %
- for measured variable output: +/- 0.5 %

- for measured variable output factor: +/- 0.5 %
- for measured variable active energy: Class 0.5 according to IEC62053-22
- for measured variable reactive energy: Class 2 according to IEC61557-12 and IEC62053-23

Temperature and Relative Humidity sensors

Humidity Element:

- Accuracy at room temperature (20°C): ±2% RH, 0-95% RH
- Temperature effect: Less than 0.1% per degree C

Temperature Element:

- Time constant at 0°C to 50°C and 10-80%RH: Approx. 20 seconds in moving air
- Accuracy:
  - ± 0.8°C: 15°C to 35°C and
  - ± 1.0°C: -40°C to 15°C and 35°C to 60°C

Illuminance monitoring device

No data available.

4.4 Use Cases and Main User in NTUA pilot

The use cases of the NTUA pilot are the following:

- Streaming data integration and management

  This use case describes the improvement on the flow of information related to the energy consumption, correlated with variables such as weather, degree days, occupancy level, CO2 emissions and energy prices. The aim of this use case is to provide a more reliable and comprehensive method for the correlation of the information, as well as to provide coherent reports on the energy consumption of NTUA campus. The results of this use case will be used for resolving any energy related issues, for updating/amending the current energy strategy of the NTUA and for supporting the decision making on energy efficient or renewable energy systems installation.

- Real-time analysis, reasoning and network behaviour prediction

  This use case describes the improvement on the prediction of the energy consumption in NTUA. The improvement stems from the network monitoring, the anomaly detection, the route cause analysis, the trend detection, the planning and the optimisation. The aim of this use case is to provide a more reliable and accurate prediction on the NTUA's buildings energy consumption. The user would thus have the possibility to evaluate the energy efficiency measures, to accurately predict the energy consumption, to choose the most profitable utility provider (where possible) and to calculate more accurately the return of investment of a potential energy efficiency measure.

The main user of the NTUA pilot is the Energy Management Commission. The Commission, consisting of professors and engineers, has been appointed to detect the intensive energy consumption areas, to report the energy consumption of NTUA Campuses, to provide consultancy on the implementation of energy efficiency and renewable energy measures in NTUA and to take decisions on energy management issues.

4.5 Status quo

The status quo of the NTUA Campus could not be reported, since the administrative personnel of NTUA were on strike from September until the time of report writing (November 2012). The strike greatly affected the operation of the University, since lectures and exams were cancelled and there was limited access to the Campus. As such, initial interviews of the building users were impossible.

5 Methodology for validation of energy consumption reduction within the CSI building and a set of public owned buildings in Turin

5.1 Measure description

The CSI building and a set of public owned buildings in Turin are one of the parts of the city-like pilot scenario MIREN-FIR-CSI-IREN. The energy provider partner IREN will assure the data on district heating availability for the buildings involved. The building of CSI-Piemonte (Turin), where the main detailed experimentation will be performed, is a historic building and it isn't built considering energy saving issues. This building is a typical example for the historic public buildings in Turin.

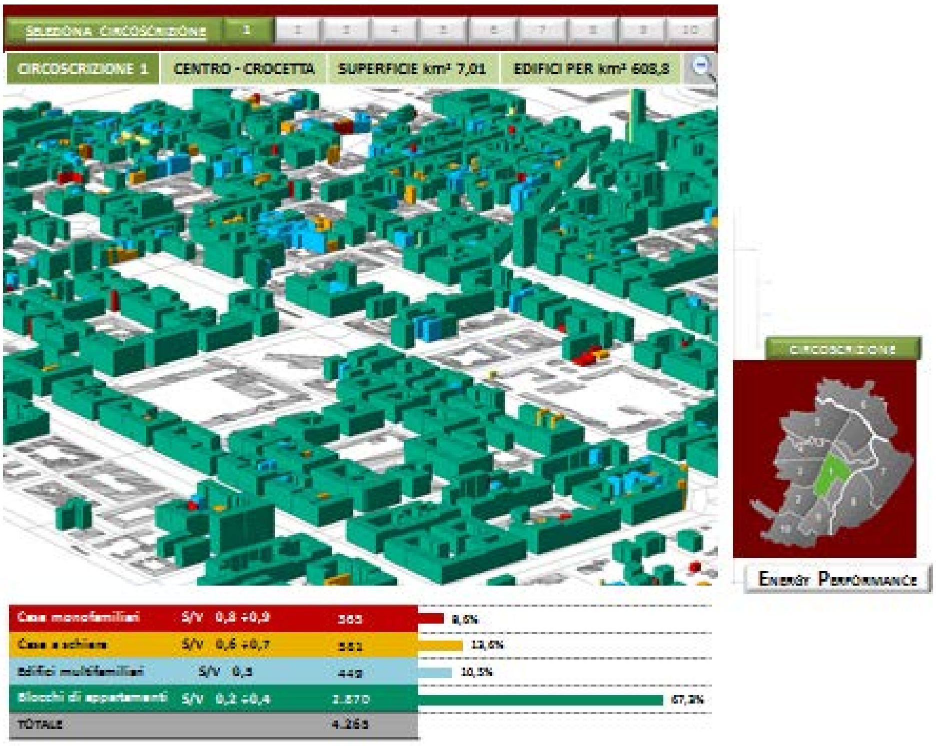


Figure 11 ENERCAD3D, The City of Turin

A number of public owned buildings are chosen based on the data availability on thermal energy consumption to be provided by IREN. Furthermore the data on electrical consumption is taken form the City of Turin database PITAMB. All the geometrical characteristics of buildings necessary to individuate the building typology are taken form the 3D Energy Cadastre ENERCAD3D developed by CSI-Piemonte (Fig. 12)

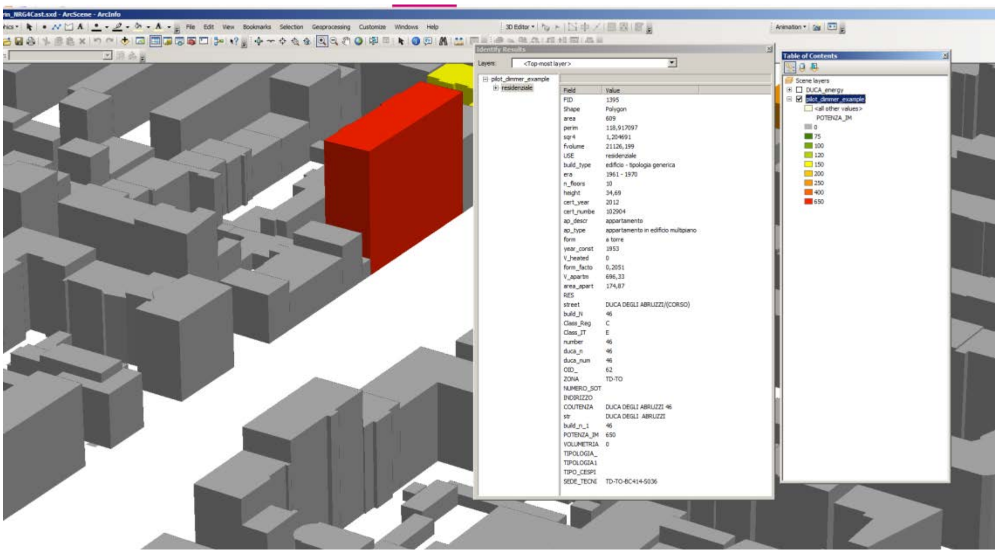


Figure 12 – 3D Energy Cadastre ENERCAD3D for The City of Turin developed by CSI-Piemonte

CSI pilot aims at the enhancement of energy efficiency and forecast energy consumption in historical buildings. Other important goals are as follows:

- to monitor the energy consumption
- to measure internal comfort and external parameters (temperature, humidity, etc.).
- to improve the accuracy and quality of electricity measuring and monitoring.
- to forecast energy demand
- to reduce energy consumption within the historical public owned buildings (CSI building, etc.)
- to detect the anomalies,
- route cause analysis,
- trend detection

This measure involves the use of various sensors already installed within the CSI building and installation of various sensors in some representative offices of the CSI building for monitoring the electricity consumption for cooling and lighting. Another sensor will be installed in order to estimate the gas consumption for heating and the thermal comfort level in the CSI building. The realisation of the CSI building pilot case (part of the MIREN-FIR-CSI-IREN pilot scenario) includes the following energy monitoring activities:

- Installation of electricity sensors within the representative offices of the CSI-building
- Installation of environment sensors like temperature and humidity within the representative offices of the CSI-building
- Elaboration of the data coming from 41 appliances already installed within the CSI Building in order to measure total electrical energy consumption of the building excluding energy used for Data Centre cooling
- Development of a data acquisition system to collect and integrate data from the 41 meters already installed within the building of CSI and for calculation of total electrical energy consumption
- Installation of Natural gas meters within the CSI building in order to measure gas consumption for heating
- Development of a data acquisition system to collect and integrate data from different network topologies and heterogeneous sources into the same architecture.

This measure has not a direct impact on energy consumption, since the sensors installation does not automatically indicate the reduction of energy consumption. The main goal is to monitor energy consumption in a very precise manner. The pilot is expected to carry out intensive data collection of energy usage. Currently the pilot sites have two levels of monitoring and energy management. There is the substation and the unit level counters. We require a much higher detail and dissection of energy related data. The intention in the CSI pilot is to monitor electrical current ex-post device with equipment between the plugs and energy consuming appliances and equipment as well as environment sensors like temperature and humidity.

Every kWh of energy spent will be monitored and compared with the state of the art (base line: historical data on electrical energy consumption is available within ION DataBase since June 2011. The data is gathered on 15 minute basis).

In the case of CSI pilot, an estimation of the total savings requires a comprehensive method for capturing this combined effect. The recommended method is the consumption data analysis, which refers to the analysis of consumption data from utility billing records (billing analysis). This method is consistent with the recommended International Performance Measurement and Verification Protocol (IPMVP) Option C, Whole Facility.

The data achieved by applying The ICT solution developed by NRG4CAST will be an input for the best cost optimal options for building retrofitting, for identifying the best solutions for energy recovering (e.g. the thermal energy from the data centre cooling could be used for the adjacent swimming pool through heat pumps); evaluating the use of renewable energies (e.g. thermal or photovoltaic solar collectors on the parking roofs and other available surfaces).

5.2 IPMVP Option determination

The recommended IPMVP method is Option C (Whole Facility), which was designed in part to address evaluation conditions that occur with a whole-building retrofit program. The key reasons for using this method are:

- The goal of the EEM is improvement of whole-house performance
- Because multiple types of EEMs are implemented, the individual savings of each cannot be easily isolated because of interactive effects
- The expected savings are large enough to be discernible over natural variation in the consumption data, at least across the aggregate of program participants.
- Major non-program changes in energy consumption are either not expected or will be adequately controlled for in the analysis.

5.3 Measurement & Verification Plan

a) Boundaries identification

The boundaries of the savings determination for the CSI building and a set of the public owned buildings in Turin are as follows:

- The energy consumption of the Data Centre should be isolated from the building's energy consumption.
- The electrical energy consumption of the public owned buildings in Turin will be monitored through energy bills (PITAMB database).
- The energy measurements have to take into account the accuracy of the sensors.

b) Baseline period data

Energy measurements and possible savings are to be computed annually for the subsequent year using a measurement of the electrical load upon the installation of the energy efficiency measure (EEM). For the CSI building the baseline period represents approximately 2 years before installation. For the buildings involved in the Turin pilot, the 1 year of historical data is available.

The baseline period information has to be analysed and correlated to such factors as weather conditions, occupancy levels, solar radiation, etc. Multiple linear regressions can be performed on monthly energy use and demand, metering period and degree days (DD).

c) Monitoring

The physical properties monitored under this EEM are the following (besides, other operating considerations are discussed, including where, when, and how often monitoring will be performed):

Electric power (kWh)

Electric power and energy is the most important physical property for energy savings evaluations. Since electric power is a direct measurement of the energy use of the CSI building load (excluding gas, district heating), this measurement is to be used to determine savings between the base case and the measure implemented. The common unit of power is kilowatts (kW). The common unit of energy is kilowatt-hour (kWh). Other electrical measurements are voltage (V), current in amperes (A) and power factor (PF).

Moreover, the data on electric energy use for public owned building chosen for the CSI pilot, will be derived from the City of Turin databases PITAMB.

Thermal energy (kWh)

Thermal energy meters will be installed within the CSI building in order to measure the gas consumption for building heating (Fig.16). The information on thermal energy consumption for public owned building chosen for the CSI pilot will be provided by project partner IREN.

Indoor Temperature (°C)

Temperature is a parameter (°C) incorporated into the calculation of the thermal comfort level in the typical office of CSI building. The temperature sensors to be installed will monitor the dry bulb temperature of the room air.

Relative Humidity (indoor Humidity, %)

The relative humidity of the air will be measured to determine the thermal comfort conditions in a typical office in CSI Building. Relative humidity is a measure of the relative amount of water vapour in the air for a given condition, versus the capacity of the air to hold water vapour at that same condition (indoor Humidity in %).

Luminosity (lux)

Luminosity is the total luminous flux incident on a surface, per unit area. It is commonly measured in units of lux. Luminosity level will evaluate the amount of light in the work plane of the typical office in the CSI building.

CO2 production (ppm)

Measurement of carbon dioxide gas will complete the monitoring of indoor air quality. An infrared gas sensor or chemical gas sensor will be chosen.

Normalising parameters

Additional physical properties will be collected and monitored with the view to normalize the energy consumption evaluation. Normalisation is required, since the specific conditions between the baseline and the post-implementation period is expected to differ. For the CSI building loads, typical meteorological year weather data and occupancy levels will be used to normalize the energy consumption evaluation.

Monitoring equipment

The basic characteristics of the monitoring equipment already existing or to be installed in the CSI building for the scope of the project are listed below.

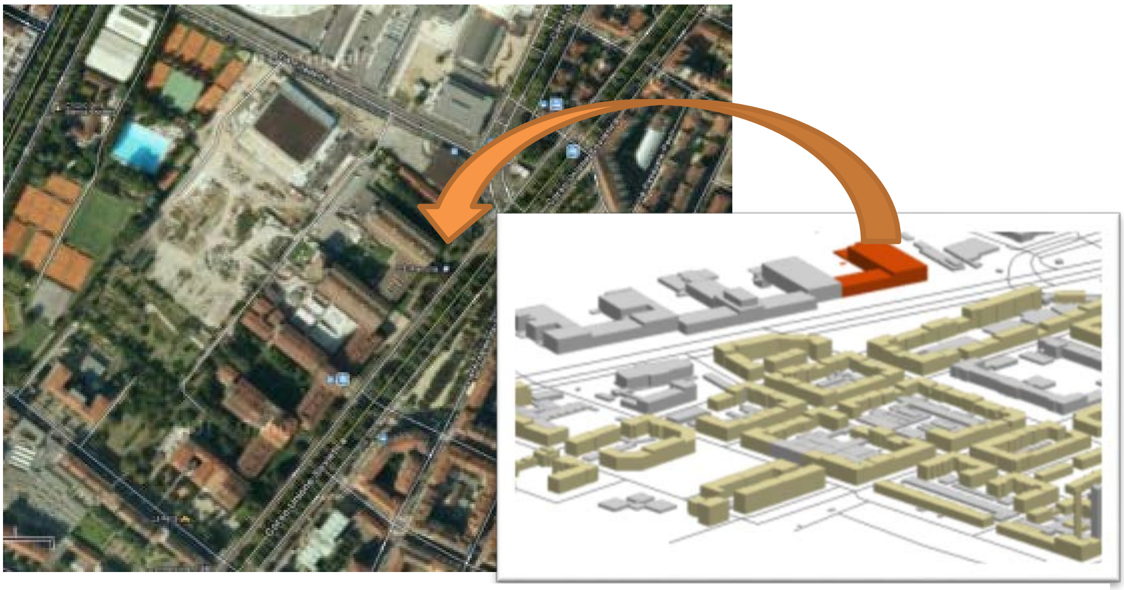


Figure 13: CSI-Piemonte company occupies a part of the building served by district heating system (Source: Google and CSI-Piemonte ENERCAD3D system)

Electrical Energy Consumption already existing monitoring devices

In the CSI building, real time data on electric energy consumption are monitored by 41 appliances installed on the switchboards of Data Centres, within the Power Centre of the substations and within the Power Centre of Data Centre. The measurements are managed through the software of Schneider Electric (PowerLogic ION Enterprice) which stock data into the SQL ION database. Moreover, the cooling energy generator is supported by 4 refrigeration units. Schneider Electric Software allows the monitoring of refrigerator electrical consumption as well. There is no data on thermal energy consumption. Historical data on electrical energy consumption is available within ION DataBase since June 2011. The data is gathered on 15 minute basis.

All the data on electrical energy consumption were migrated into another relational database provided by an existing web-based service QRS (the web based tool for energy consumption control and energy saving planning), with a record frequency of 15 minutes as well. Using ETL database process we could transfer proprietary internal data recorded by CSI building Energy Monitoring System into the relational database of QRS.

QRS is a system which allows municipalities for automatic loading and elaboration of energy bills, realisation of reports and graphs on consumption monitoring, gives suggestion for interventions, savings and makes energy consumption prediction. It is based on operational databases in Oracle 10g and Postgress 9.0.4, and specific applications as front-end developed in PHP.

In order to measure the *building electrical energy consumption*, the 2 intermediate calculations are to be performed.

Calculation 1. Building electrical energy consumption excluding Data Centre electrical energy consumption and electrical energy used for building cooling

The formula is following: (PILLER B_cab_bt_B_ARRIVO_TRAFO1 + PILLER B_cab_bt_B_ARRIVO_TRAFO2) – (PILLER B_cab_bt_B_Gruppi_Frigo1_2 + PILLER B_cab_bt_B_Alimentazione_Rete + CABINA_CED_QSM_B)

Sensors involved in this calculation are: (31+32) – (24+28+33)

- DB_SOURCES

  ID NUMBER: 31; Quantity 193

    - NAME: PILLER B_cab_bt_B_ARRIVO_TRAFO1>kWtot

  ID NUMBER: 32; Quantity 193

    - NAME: PILLER B_cab_bt_B_ARRIVO_TRAFO2>kWtot

  ID NUMBER: 33; Quantity 117

    - NAME: PILLER B_cab_bt_B_Gruppi_Frigo1_2>Real Power Tot

  ID NUMBER: 28; Quantity 193

    - NAME: PILLER B_cab_bt_B_Alimentazione_Rete>Real Power Tot

  ID NUMBER: 24; Quantity 193

    - NAME: CABINA_CED_QSM_B>Real Power Total

Calculation 2. Building electrical energy consumption including energy used for cooling, water heating and excluding Data Centre energy consumption

The following set of parameters was taken in consideration:

a) Central Refrigirator constant consumption
b) InstantCOP
c) Battery constant consumption UTA CED=33 kW
d) Engine constant consumption CED= 11kW
e) PILLER_B__CAB_bt_B.Gruppi_Frigo_3_4 = sensor 29
f) PILLER_B__CAB_bt_B.Gruppi_Frigo_1_2 = sensor 33
g) Energy consumption for cooling of Data Centre = (e+f)-((a+c)/b)+d → (29+33)-((3+constatnt value for battery consumption)/COP)+constant consumption
h) Building cooling and water heating= (e + f) – g → (29+33) – cooling Data Centre

In order to achieve overall electrical energy consumption of CSI building the Calculation 1 plus Calculation 2 is to be effectuated.

Electrical Energy Consumption monitoring devices to be installed

Our goal is to allow the CSI building managers through operations staff in the future to cut energy and maintenance costs without effecting the comfort or productivity of their employees. NRG4CAST system will track utilities and equipment conditions, and will help to analyse and improve electrical reliability.

Moreover NRG4CAST will give a possibility to forecast energy requirements. In the future we hope to be able to optimise multi-site contracts and accurately allocate or sub-bill costs, find and sustain energy savings, reduce emissions and meet “green” building standards in order to increase asset value.

The total budget foreseen by NRG4CAST for electricity meters acquisition is 1 100 Euro (2 Electricity meters, price per item: 550,0 Euro). Energy meter is to be installed at the office number 113 (CSI building).

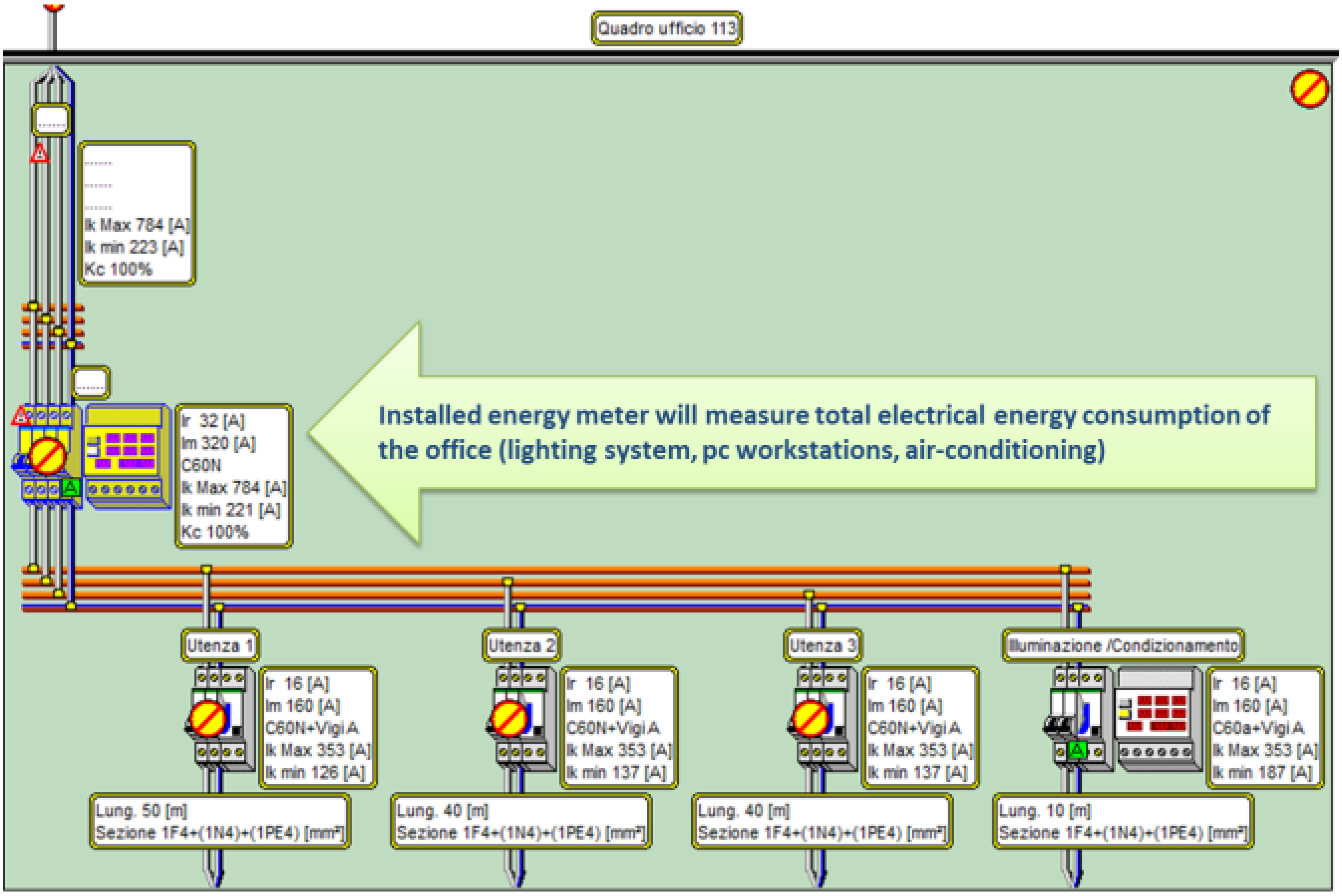


Figure 14- Electric system of the office 113 (CSI Building)

A number of basic energy meters by PowerLogic Schneider Electric were analysed. The table below shows the comparison of specifications between various iEM3000 sensors.

Specification guide	iEM3100 Range				
	iEM3100	iEM3110	iEM3115	iEM3150	iEM3155
Current (max.)Direct connected	63 A				
Meter constant LED	500/kWh				
Pulse output		Up to 1000p/ kWh			Up to 1000p/ kWh
Multi-tariff			4 tariffs		4 tariffs
Communication				Modbus via RS485	Modbus via RS485
DI/DO		0/1	2/0		1/1
MID (EN50470-3)		■	■		■
Network	1P+N, 3P, 3P+N				
Accuracy class	Class 1 (IEC 62053-21 and IEC61557-12) Class B (EN50470-3)				
Wiring capacity	16 mm²				
Display max.	LCD 99999999.9kWh				
Voltage (L-L)	3 x 100/173 Vac to 3 x 277/480 Vac (50/60 Hz)				
IP protection	IP40 front panel and IP20 casing				
Temperature	-25°C to 55°C (K55)				
Product size	10 steps of 9mm				
Overvoltage and measurement	Category III, Degree of pollution 2				
kWh	■	■	■	■	■
kVARh					■
Active power				■	■
Reactive power					■
Currents and voltages				■	■
Overload alarm					■
Hour counter					■

Table 3- Comparison of specifications between iEM3155 and other iEM3000

In order to measure the Energy consumption (kW) the Watt-hour meter iEM3155 is chosen. This is an advanced multi-tariff energy meter & electrical parameter plus RS485 comm port Direct connected 63 A A9MEM3155 (http://www.schneider-electric.com/site/home/index.cfm/ww/).

Direct connected up to 63 A

Connectivity advantages	
Programmable digital input	External tariff control signal (4 tariffs) Remote Reset partial counter External status like breaker status Collect WAGES pulses
Programmable digital output	kWh overload alarm (i EM3155/iEM5255) kWh pulses
Graphic LCD display	Scroll energies Current, voltage, power, date and time
Communication	Modbus RS485 with screw terminals allows connection to a daisy chain
Standards	
IEC standardsntegrated display	IEC 61557-12, IEC 61036, IEC 61010, IEC 62053-21/22 Class 1 and Class 0.5S, IEC 62053-23
MID	EN 50470-1/3

Figure 15: Watt-hour meter iEM3155, connectivity and standards

The Watt-hour meter iEM3155 is characterized by following functions and features:

- Direct measurement (up to 63 A): watt-hour meter with direct measurement input on a three-phase + neutral network (from 3 x 100 / 173 Va...3 x 277 / 480 Va) with partial metering and reset
- Active energy measurements
- Four quadrant energy
- Electrical measurements (I, V, P, etc.)
- instantaneous value (U, I, P ...) access by display and communication;
- Multi-tariff (internal clock) – up to 4 tariffs
- Multi-tariff (external control) -2
- Measurement display
- import / export energy measurement
- reactive energy measurement
- kW overload alarm
- 1 configurable digital output for metered pulses (kWh), alarm status
- 1 configurable digital input for partial meter reset, circuit breaker status
- MID 2004/22/EC compliance (legal metrology certification)
- Communication port: Modbus via RS-485 (Modbus is a protocol that uses serial communication lines. These serial lines connect a Modbus master to slave devices along a Modbus network. A Modbus master can support up to 247 slave devices on one serial communication network. Modbus RS-485 Indicates Values Using Differences in Voltage; Modbus RS-482 is the Modbus protocol variant that uses an RS-485 connection. This two-wire, multipoint connection communicates data by indicating values by sending different voltages across the two wires. These differences between these voltages are related to one and zero values, which make up the Modbus R2-485 communications.)
- Width (18 mm module in DIN Rail mounting) -5

Another option is to use the available in CSI energy meter HWg-PWR: M-Bus IP energy meter (SNMP, WEB). However this product has been already replaced in the market by a new version: HWg-PWR 3/12/25.

The HWg-PWR captures data from 3 external meters on the M-Bus and connects the data to IP. M-Bus data are available over Web (graphs), SNMP, Emails or Log files. With external M-Bus (EN 13757) meters it can be used for remote monitoring/metering of Electricity power, Heat, Water or Gas consumption. There are standard 3rd party M-Bus compatible meters on the market.

HWg-PWR reads data from external 3 M-Bus meters (EN 13757) and analyses them. Up to 30 metered values can be shown on the WEB by graphs or monitored over SNMP. The HWg-PWR M-Bus IP meter supports alarming through e-mail or SNMP traps whenever a defined value exceeds limit (current overload).

Features:

- Ethernet: RJ45 (10BASE-T)
- WEB: Embedded WEB server, graphs
- Data input: External M-Bus meters (EN 13757-2)
- M-Bus interface: Up to 3 meters (powered from HWg-PWR)

- M-Bus standards: EN 13757-2 (physical and link layer) & EN 13757-3 (application layer)
- Values limit: Up to 30 values from all meters
- Digital Inputs: 3 DI dry contact inputs
- Power: 230 V AC
- Housing: DIN rail montage

Indoor comfort / Environment sensors

The Indoor Temperature, Humidity, luminosity and CO2 production will be measured using the **Environmental Sensor SX30-485** (interface RS-485).

The sensor can be wired using standard LAN cables. In order to facilitate the realization of linear networks, the sensor SX30-485 is equipped with 2 RJ45 identical input /output connectors, so it is possible to connect sensors "chain".

In order to power the sensors RS485 and to facilitate their interoperability it is recommended to use an appropriate module JP1A. This Module is powered at 220V and has the following features:

- integrated power supply +12 VDC/0.5A enough to power up to 50 sensors in parallel terminals for connection of the RJ45 line with the PC;
- 10 RJ45 connectors for rapid connection of sensors SX30;
- available in two versions (linear or star topologies);
- ability to chain up to 5 modules (250 sensors);
- jumper for termination of the BUS (485) at the end of the line

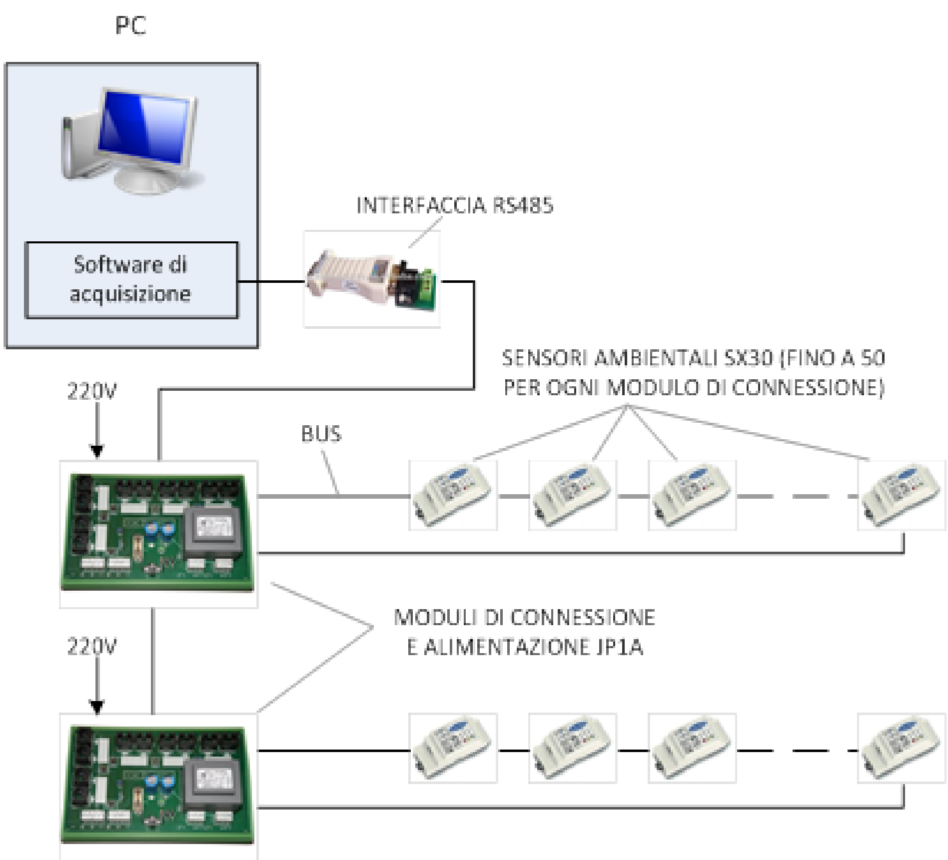


Figure 16 - An example of sensors scheme (RS485 interface)

Figure	Component
	Environmental Sensor
	Connection and power module JP1A
	Converter usb-485

Figure 17 - Sensors kit RS485

Main characteristics	SX30-485
Measurements	**Temperature, Humidity, luminosity and CO2 production**
Sensor dimensions	60mm w x 40mm height x 60mm
Material	polyethylene
T min /max for normal functioning	-20 a + 80 °C
Connections	n. 2 connectors RJ45
Level of internal protection	IP30
Interface type	RS485
Communication protocol	Modbus-RTU
Communication speed	9600 BAUD
Supply voltage	9 a 24 VDC
Consumption average	7 a 30 mA (depends on configuration)
Protection against reverse polarity	yes
Temperature sensor	
Measuring range	d-15 a +80 °C
resolution	0,1 °C
Accuracy	+/- 1% +/- 0,5 °C
Humidity sensor	
Measuring range	10 a 90 %
resolution	1%
Accuracy	+/- 5%
luminosity sensor	
Measuring range	0 a 20000 Lux
resolution	20 Lux
Accuracy	+/- 1% +/- 20 Lux
CO2 Sensor	
Measuring range	0 a 1000 ppm
Resolution	1 ppm
Accuracy	+/- 5% +/- 1 ppm

Table 4- Sensor main characteristics

d) Commissioning

The commissioning procedures should include a description of the commissioning of the EEM, the inspection of the installed equipment and assurance of the correct system operation. Revised operating procedures to ensure that they conform to the initial scope of the EEM.

The operational test of each monitoring equipment, prior to its installation is crucial for an accurate monitoring process. As such, before installing each sensor, the technicians will test it to ensure it is working properly and making the intended measurement. These tests will include the following:

- If meter operates on batteries, are the batteries in good condition, and is there a backup set? Is the meter properly powered?
- Is the meter clock synchronized to local time zones?
- Are all the settings on the meter correct?
- Are sensors properly attached and in place?

e) Reporting period data

The post-retrofit period will use utility bills for the electrical energy consumption and the data on thermal energy consumption provided by IREN for the Turin public owned buildings. The sensors' measurements for the electricity consumption and the sensors measurements for thermal energy consumption will be used for the CSI pilot building. The first report will be produced 1 year after the EEM installation.

f) Data analysis

This analysis will include report on data on energy consumption reduction. The reduction will be derived from the comparison of the baseline period and the post-retrofit period data (***the before-after approach*** will be applied for the validation of energy savings in the historical buildings in Turin). Correlation with independent variables is necessary. The following indicators on the energy consumption reduction will be used:

Heating:

Energy consumption (saving) per person (kWh/ person p.a.)

Energy consumption (saving) per square meter (kWh/m_2 p.a.)

Energy consumption (saving) per degree-day KWh/HDD p.a. (Heating Degree Days)

Primary Energy consumption (saving) per square meter (kWh_{PE}/m_2 p.a.)

Cooling (electrical energy):

Energy consumption (saving) per person (kWh/ person p.a.)

Energy consumption (saving) per square meter (kWh/m_2 p.a.)

Energy consumption (saving) per degree-day KWh/CDD p.a. (Cooling Degree Days)

Primary Energy consumption (saving) per square meter (kWh_{PE}/m_2 p.a.)

Electricity (lighting, workstations etc.):

Energy consumption (saving) per person (kWh/person p.a.)

Energy consumption (saving) per square meter (kWh/m_2 p.a.)

Primary Energy consumption (saving) per square meter (kWh_{PE}/m_2 p.a.)

Share of renewable energy (%)

Avoided CO_2 emissions

CO_2 avoided emissions ($kgCO_2/a$) = energy savings (kWh/a) * emission factor ($kgCO_2/kWh$)

Subjective "comfort" experienced by employees, residents of public owned houses etc.

Room air temperature (degrees C)

Relative humidity (%)

An economic perspective (return on an economic investment)
Cost of consumption (saving) per person (€/person)

Cost of consumption (saving) per square meter (€/m_2)
Net present value of the investment per square meter (€ / m_2)
Return on investment (%).
Public funding [%]: Share of public funding in the energy saving investment.

g) Duration of Measurement and Recording Interval

The CSI building and the Turin pilot public owned buildings monitored by its sensors. The recording interval is usually predetermined by the installed equipment. However, the measurement intervals are chosen within an appropriate time frame. The external data sources provide data on request or within limited intervals. The provided data is in higher resolution and provides a continuously data stream. Within useful limits the data is requested and updated. For example the information on electrical energy consumption and thermal energy consumption is to be acquired every 15 minutes for the CSI building. The data on thermal energy consumption for the Turin pilot public owned buildings will be provided on the 15 min basis, whereas the electric energy consumption information isn't of high resolution, this information is coming from the energy bills collected within the database PITAMB.

Even though the measurement is performed continuously, the evaluation will only be done to certain periods. This guarantees the comparability of the recording.

h) Quality assurance

Data verification is a quality assurance procedure followed in CSI pilot plant. Verification of the collected data is an essential aspect of ensuring an accurate monitoring process. The data verification practices that will be followed are:

- Data reviewing: This is done in order to verify that the data is complete and correct and to identify the readings that appear inappropriate.
- Data cross-checks: If the readings appear to be incorrect, cross-checks with other sensors will be conducted. Additionally, the assumptions that were made when planning the monitoring equipment will be checked.
- Equipment calibration: If the cross-checks do not validate the data, the equipment has to be calibrated in order to match with the other monitoring equipment. Alternatively, it should be checked whether the sensor needs replacement.
- Data collector: The responsibility for the data collection process will be assigned to a specific individual who will determine the design and structure of the monitoring process.

5.4 Use Cases and Main User in CSI pilot

The following subchapters provide an overview of the two use cases described by the CSI in the context of the energy positive buildings scenario.

Streaming data integration and management
This use case describes the improvement in the elaboration of the information flows related to the building energy consumption and the integration of environmental data such as humidity, temperature and CO2 production and energy prices. The aim is to provide a more reliable and comprehensive solution for data integration and to achieve complete information on energy consumption of building. This use case is the base

for setting up the politics on changing the employee / inhabitant's behaviour. Moreover it would be the base for decision making on retrofit.

The main user of this case would be the building energy manager, city manager/decision maker and employees/home owners.

Real-time analysis, reasoning and network behaviour prediction

This use case describes the improvement of prediction of building energy consumption. This improved prediction becomes a decision support system based on network monitoring, anomaly detection, route cause analysis, trend detection, planning and optimisation. The aim is to provide a more reliable and accurate prognosis on building energy consumption. This would allow the user to evaluate if the energy efficiency politic functions, what is the amount of energy needed for the next year, what is the price the building owner is expected to pay. As an example, on the base of this improved prediction the user can decide to change the energy provider. Improved confidence in prediction allows to energy saving and money saving.

The main user of this case would be the building energy manager, ESCO, Municipality authorities, the city manager.

5.5 Status quo

The test plan involved initial interviews followed by questionnaires, as described in chapter 3.3. The first part of the questionnaires varies according to the different use cases, whereas the second and third parts stay the same. The initial interviews are used to evaluate the status quo of a certain use case and provide a basis for the questionnaire. During the interviews, the task is to detect what information is required for certain decisions.

The interviews for the three CSI main users are described below:

What Information is required for a CSI employee (public sector employee/home owner)? Can you imagine using this system for evaluation of your own consumption?

- Information on overall electrical energy consumption
- Information on thermal energy consumption
- Information on electrical energy consumption divided by energy use such as cooling, water heating, electricity for work stations, electricity used for coffee machines, electricity for lighting
- Information on energy prices
- Information on energy consumption trend
- Information on Environmental parameters which influence the energy consumption
- The tips could recommend to switch devices
- The tips could be related to the consumer behaviour
- When the main load of energy consumption occurs
- Which device consumes more energy,
- How can I save energy and decrease electricity bills

What information are required for an Energy manager (CSI Energy Manager Dominique Fragale**)**
Example FIR

- Information on electrical energy consumption

- Tips on how to regulate energy consumption
- Tips on "where to intervene" with retrofit actions
- Do the energy efficiency/energy saving actions function
- Information on energy peaks
- Clear precise information on energy demand
- Prediction of faults

What information are required for the city manager/ESCO

- Where do I have to intervene (support to the decision making) at the city level
- Characterise building typologies at the city level (in terms of energy demand)
- Precise information on energy consumption
- Information on "energy behaviour of household /public employers"
- Information on return on an economic investment

6 Methodology for validation Energy saving of the District Heating network (IREN)

6.1 Measure description

Iren SpA is the thermal energy producer and distributor in the city of Reggio Emilia. In NRG4CAST and within the integrated pilot, Iren contributes by bringing the industrial needs and expertise of one of the main distributor of energy in Italy.

According to that, the pilot plant in Reggio Emilia will be focused on the improvement of energy efficient in the management of the District Heating (DH) network of Reggio Emilia, considering both the production and distribution of thermal energy.

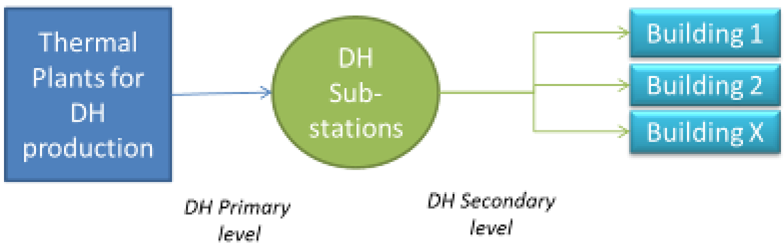
The pilot site will have two main target: the thermal power plants and the Iren buildings within the Iren campus, called “Campus Nubi”.

Particularly, the Iren pilot site activities in Reggio Emilia will be focused on **two main use-cases**:

(1) **District heating production forecasting:** The NRG4CAST model will foresee the total amount of thermal energy (MWh) requested by the DH network of the city of Reggio Emilia 2 days in advance, hour per hour, with respect to the outdoor temperature.

(2) **Energy consumption of District Heating in the Campus Nubi:** the forecasting model will be able to foresee and suggest the optimal water temperature to be provided to each building substation within the Campus Nubi in order to keep a pre-defined indoor temperature (e.g. 20°).

Iren pilot objectives are the following:



- to forecast total thermal energy demand of the city of Reggio Emilia according to the weather forecasts;
- to reduce energy consumption for District heating distribution;
- to measure internal comfort and external parameters (temperature, humidity, etc.);
- to improve the accuracy and quality of district heating measuring and monitoring;
- to detect alarms in the substations within the Campus Nubi.

The impact provided by the use of the forecasting model is:

- **UC1:** Possibility to predict, on the basis of the trends of the past years as well as on the correlation between the outdoor environmental conditions and the weather forecasts, the energy to be producing for supplying district heating to the city network;
- **UC1:** Possibility to determine in advance when to switch the various heat production plants on and how much energy to supply to the district heating network.
- **UC2:** By installing new regulators and new counters that are remotely read and controlled, it will be optimized the district heating service by more efficiently planning the supply of district heating on the network over time and according to the registered temperatures (indoor and outdoor).

The expected outcome from the usage of the forecasting model is:

- Better management of Thermal Power plants and of the district heating distribution network.

- Better energy efficiency in the distribution of the DH distribution service in terms of energy saving.

6.2 IPMVP Option determination

To validate the Energy Forecast model developed within the project in terms of (1) optimization of the district heating energetic production and of (2) the thermal energy consumption of the target buildings in the Campus Nubi, the **C Whole Facility will be used** *("Savings are determined by measuring energy use at the whole facility level. Short-term or continuous measurements are taken throughout the monitoring (post-EEM) period").*
The option C is the most viable option for Iren since, as an energy producer and distributor, Iren continuously monitors the production of its Thermal Power plants and it can rely on many sensors and measuring devices already installed in the Iren facilities (The campus Nubi) and additional specific sensors that will be installed for the purpose of the NRG4CAST project.
For facility level is intended the whole buildings within the Campus Nubi (including the substations and the indoor sensors) and the Thermal Energy power plants.
For short- term measurement is intended an hourly sampling of data and a daily transmission from the local devices to the server.

6.3 Measurement & Verification Plan

a) Baseline period data

The Baseline period is the time necessary to be representative of the operation of a building, before the implementation.
The identified baseline period identified that best suits the objective for district heating is the thermal season, which goes from October to April every year.
The validation of UC1 will be performed by comparing the predicted value and the effective value of the amount of energy requested by the DH network during the operational time.
The validation of UC2 will be performed by comparing the energy consumption of each substations within the Campus Nubi with and without the usage of the NRG4CAST model in 2012 and 2013.

b) Monitoring

In the following subchapters are described the properties of the two main use-cases identified for the Iren pilot site. The requirements and the tools used for the measurement are described. Finally, the proposed validation methodology is introduced.

UC1:

Concerning UC1, the monitoring equipment installed in the city Energy Pole that consists of a cogeneration plant, which produces thermal energy for the urban district heating network, allow to gather the listed measures described in the previous section. No interventions will be done.

Historical data are available in the period 15.10.2011 - 15.4. 2012, namely the thermal season.

Data concerning temperature, humidity and wind rate of the city of Reggio Emilia will be collected and made available from JSI via a web service.

UC2:

Concerning UC2, an important comparison has to be considered between the "as is" situation and the "to be" situation of the district heating (DH) distribution to the Campus Nubi.

Indeed, the existing status in terms of energy consumption monitoring (i.e. which application/metering systems are in use) is described as follows:

As-is situation for Iren UC2:

The current energy consumption measuring system of the Campus Nubi is made up of a district heating counter that records the energy supplied to the plant (in KWh).

A fixed-point temperature regulator regulates the flow temperature of the water. Operation hours are regulated by means of a clock which is set at the beginning of the heating season. The operator manually changes the time of switching on and off of the system. The setting of both operation times and water temperature is set by Iren according to the outdoor temperature.

In the Campus Nubi, each office is equipped with fan convectors on which the chosen room temperature is set. The heating water is supplied at a fixed temperature, ranging between 55 ° / 60 °, and the fan convector regulates the room temperature between 18 ° and 22 °.

Sensors/Devices: The current district heating counters are equipped with a temperature probe for both outgoing and ingoing water flaw temperature. They also measure the water volume in order to register the energy consumption. The temperature regulator is at “fixed point” and it requires that the temperature is manually set by the operator.

Registered measures:

- Outgoing water flaw temperature and volume (from the temperature regulator)
- Energy consumption (from the counter).

Communication protocol: C-Bus (for temperature regulators)

Counter and regulator: they are equipped with different protocols that do not communicate among each other.

To-Be situation for Iren UC2:
In order to achieve the objectives of monitoring, prediction and intervention on energy consumption related to district heating, Iren must be able to acquire new data in the Iren Campus Nubi. By doing that, Iren will:

1. Act on the temperature regulator by modulating and setting the temperature of the warm water flow to the radiators, depending on the information provided by the outdoor probe (placed outside the building) and the room indoor probe - (e.g. Water flow Temperature might be set at 60 ° from 7 am to 8.30 am in the morning in order to reach 20 ° eof room temperature, then water flow temperature can be lowered for the rest of the time, such as to maintain the temperature of 20°). The probes send an input signal and the temperature regulator reacts by changing the output, i.e. opening or closing the water control valve.
2. Possibility to detect the room temperature by means of the indoor probes that are to be installed in significant areas. The temperature regulator compares the temperature read by the external probe and the indoor probe to determine at what temperature to adjust the water to be sent in the pipes and heat that target environment.

c) Commissioning

The commissioning procedures include the inspection of the installed equipment and the assurance of the correct system operation, to ensure that they conform to the initial scope.
The operational test of each monitoring equipment, prior to its installation, is crucial for an accurate monitoring process and will be performed by the operators of the DH distribution network.

- If meter operates on batteries, are the batteries in good condition, and is there a backup set? Is the meter properly powered?
- Is the meter clock synchronized to local time zones?
- Are all the settings on the meter correct?
- Are sensors properly attached and in place?

d) Reporting period data

The reporting period will start at the beginning of the new thermal season, i.e. October of each year, and it will end up in April of the next year.

e) Data analysis

The measures that will be taken into account are the following:

For UC1:

- Outdoor temperature
- Wind rate
- Humidity
- DH total thermal production (MWh)

Use-case 1 (UC1)	Data sampling	Data source	Time period	File format
Historical data of DH production	Hour	PI	From 15/10 to 15/04 in 2012	.csv file
Current data of DH production	Hour	PI		.csv file
Outdoor temperature (historical)	Hour	ARPA	2012	.csv file
Wind rate (historical)	Hour	ARPA	2012	.csv file
Outdoor temperature (current data)	Hour	Web service	From 2013	tbd
Wind rate	Hour	Web service	From 2013	tbd
Humidity	Hour	Web service	From 2013	tbd

Factors influencing the estimation and forecasting of the total Thermal Energy to be produced are the following:

- **Dependant Variables:** Total amount of Thermal energy production (MWh)
  Independent variables: weather conditions, wind rate, humidity

For UC2:

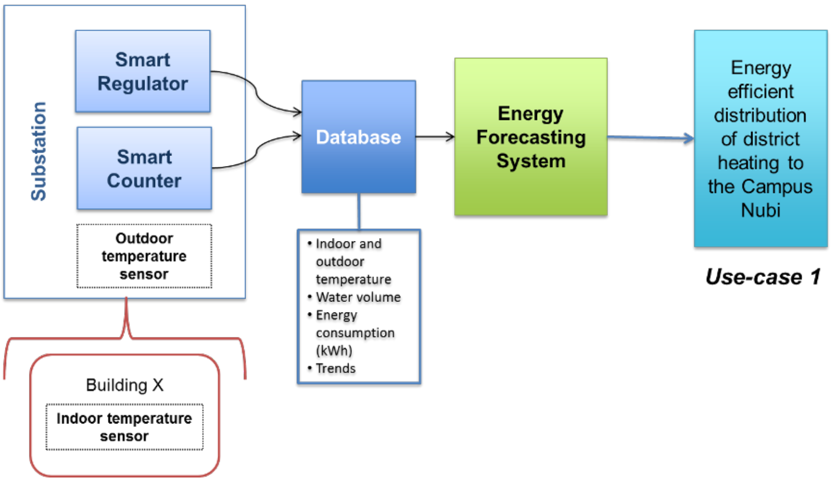
- Outdoor temperature
- Indoor temperature,
- Forward water temperature,
- Backward water temperature,
- Water flow rate,
- Energy consumption of each substation.
- Alarms from each substation

Data	Data sampling	Data source	Time period	File format
Current energy consumption of the buildings within the Campus Nubi	4/5 times a year	Coster XTT 608 SWC 701 Coster	From 2014	.csv file
Outdoor temperature	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file

Forward water temperature (secondary level)	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file
Backward water temperature	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file
Indoor temperature	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file
Water flow rate	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file
To-be-confirmed: Alarms from each substation (e.g. on a broken sensor or a wrong water temperature), including timestamp + type of alarm (ID)	1 Hour	Coster XTT 608 SWC 701 Coster	From 2014	.csv file

To sum up, concerning UC2, the parameters to be considered that influence the overall energy consumption of district heating at the level of each substations are:

- **Dependant Variables:** water flow rate, forward water temperature, backward water temperature, energy consumption of each substation.
- **Independent variables:** outdoor temperature, indoor temperature,



Measures are provided by sensors, regulators, counters, and probes installed in the facilities.

This measure has not a direct impact on energy consumption, since the sensors installation does not automatically indicate the reduction of energy consumption.

f) Quality assurance

The verification of the quality of the collected data is necessary in order to ensure the reliability of the NRG4CAST model.

The quality verification will be performed by the operators, for both use-case 1 and use-case 2, once a week. The activities performed will be: Data reviewing, Data cross-checks, Equipment calibration, Data collector, Data verification (as already described for NTUA pilot).

g) Measurement accuracy

The accuracy of the measurement depends on the accuracy of the data delivered by external sources (e.g. weather forecasts) as well as the information from the Iren smart meters. However, there is no possibility to ensure the accuracy of the information provided by the measuring sensors. The data quality of the sensors can be validated by operators by periodically comparing measurements, historical data and predicted data.

6.4 Use Cases and Main User in IREN pilot

The following subchapter provides an overview of the two use cases described by IREN in the context of Energy production and distribution.

Iren UC1

UC1 user: The operators of the District Heating production plant (the «Polo Energetico Cittadino 1»)

UC1 Goal in context: To support the planning of district heating production in order to define the thermal energy request of the city network 2 days in advance, with respect to the outdoor temperature

Trigger condition: Limited performance of current applications that have access to limited energy consumption information (no trends, no remote communication of real-time data) and few analytical results.

Use-case steps:

(1)Gathering of historical data (2011-2012) - existing process for Thermal energy production planning,

(2) Data sampling

(3) Data transmission

(4) Application of the NRG4CAST model for a certain operation time

(5) Validation of the NRG4CAST model by comparing the forecasted value of energy to be produced in advance of 2 days with the effective value of energy provided.

Success End Condition:

- Users have access to data elaborations;
- Users receive suggestions on correct interventions on production and network energy peaks;

Iren UC2:

The Campus Nubi is made up of 6 substations for heating and 1 substation for heating and hot water. The type of buildings involved are the following: warehouses, laboratories, offices and changing rooms.

The 6 substations provide with the DH service the following buildings:

- SST 5312: workshops heating and gas production, district heating offices and of offices and chemical laboratories.
- SST5319: offices and laboratories of electricians (Energetic class : D, Volumetry: 2783,82 m3)
- SST5320: Warehouse (Energetic class : C, Volumetry: 17457,88 m3)
- SST5310: office building and changing rooms (Energetic class: E, Volumetry: 4213,36 m3)
- SST5305: building H – offices (Glass and steel palace) – (Energetic class : F, Volumetry: 3145,03 m3)
- SST5318: Management Building (Energetic class : D, Volumetry: 7289,06 m3)

Figure 18: Map of the buildings location in the Campus Nubi

UC2 User: The **operators** of the District Heating provision of the Campus Nubi

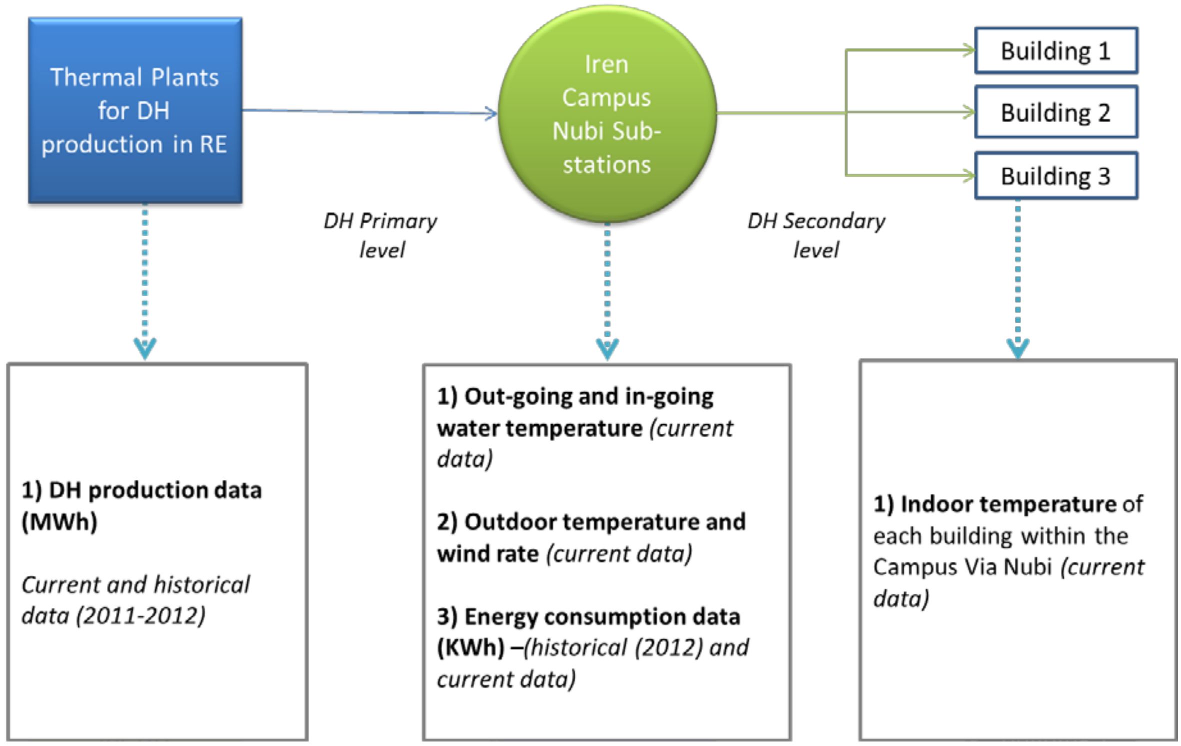
UC2 Goal in context: The main goal is to **remotely collect accurate data** on temperature, volumes and energy consumption of the Campus Nubi district heating provision, and to be able **to intervene, by following the recommendations of the Energy Forecast system**, on some target variables, in order to optimize the energy supply and prevent network defaults.

UC2 Trigger condition: The monitoring and regulating system is nowadays based on the operator's manual intervention. Temperature is set at a given threshold at the beginning of the thermal season and it is not easily modified according to the weather and contextual conditions. The monitoring and regulation of the district heating network distribution should be improved by means of the information provided by the forecasting system on the Campus consumption data, by correlating real-time data (indoor and outdoor temperature) with historical consumption data (in the last 2 years).

UC2 main steps:

(1) Install new sensors, regulators and counters;
(2) Interface the database and software in use with the Energy Forecast system
(3) Data sampling every hour
(4) Data transmission (once a day)
(5) Pilot activities: Usage of the Forecasting Model
(6) Validation of the energy saving by applying a before-after approach, assessing the energy consumption

UC2 Success End Condition: Energy consumption optimization of the Campus Nubi compared to the consumption data of the previous 2 years (2012-2011)



6.5 Status quo

The before-after comparison approach will be applied, by assessing and validating the NRG4CAST model compared to a baseline period and by assessing the user-acceptance of the system by means of a questionnaire. The "before-after" approach foresees the following steps:

(1) Identification of an **operational time** for the baseline that include all that possible variations of the independent variables, in both UC1 and UC2 , that are expected to be repeated in the future.

(2) Gather data for dependent variables and for all accessible independent variables baseline period;

(3) Perform a regression analysis to establish the coefficients for each independent variable;

(4) Identify the reporting period which is again long enough to capture all variation of immeasurable independent variables;

(5) Gather data for the energy consumption (dependent variable) and for all accessible independent variables (reporting period);

(6) Apply the coefficients estimated in the baseline to the reporting period, yielding the result: energy saving as the difference between estimated and measured consumption.

7 Methodology for validation of energy prediction by the Smart Charging Algorithm (SCA)

The electric vehicle data monitoring is done with by using the data collection platform established in project Oscar (open service cloud for the smart car). The data of the FIR vehicles and other vehicles is collected and provided by this open service cloud. Also external data, like weather, charging stations etc. is collected by this. This chapter describes details on the measurement as well as the validation methodology. Main use cases for the data are defined as well as the main user groups. This uses cases are the bases for the validation and the questionnaires described in the test plan.

The Smart Charging Algorithm and the data profiles have been described in detail in Chapter 3.4 in Deliverable D1.2.

7.1 Measure description

The purpose of this case is the evaluation and prognosis of energy consumption of electric vehicles. As seen in figure 1, the approach of the smart charging algorithm (SCA) can be described in 3 major steps: Real Time Tracking, Simple Prognosis and Advanced Prognosis. The fourth step, following the Advanced Prognosis, is not part of this project, but is mentioned here for reasons of completeness. In this fourth step the user is manipulated by incentives to change his behaviour e.g. selecting different charging stations or drive in a more economical way than he normally would do.

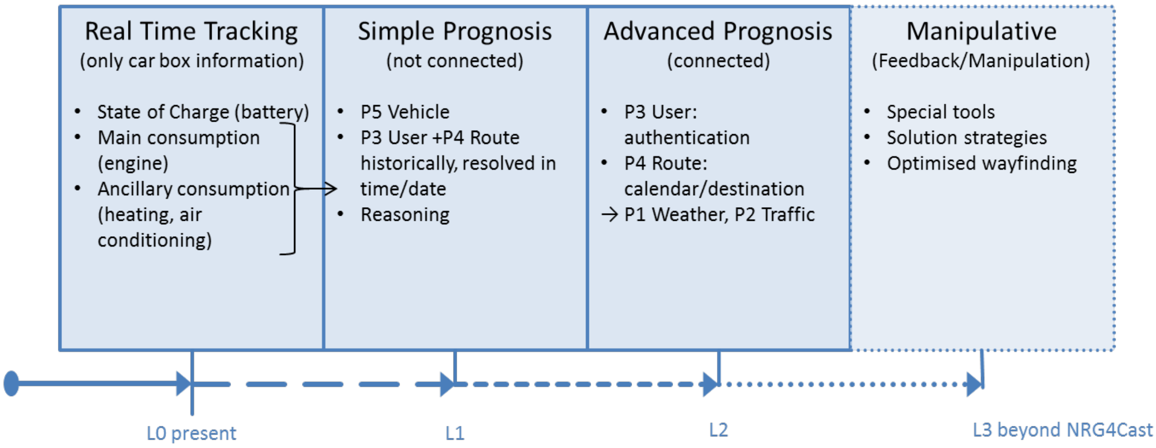


Figure 19: Itemisation of the Smart Charging Algorithm, SCA (compare with Deliverable 1.2 Chapter 3.4)

7.2 IPMVP Option determination

To validate the energy prediction within the electric vehicle scenario, the IPMVP option B (Retrofit Isolation: All Parameter Measurement) is used. Since the IPMVP option was designed for evaluating buildings, option B is usually hard to fulfil due to the high number of sensors that would be necessary to monitor a whole building. Choosing this option in the FIR scenario is possible due to the measurement architecture of the electric vehicle that already provides a comprehensive monitoring of energy use. The key reasons for using this method are:

- The comprehensive measurement can be performed since the measurement data can be accessed through the Oscar project and an expensive sensor implementation in the car is not applicable.
- This option allows more accurate and reliable results, consequently a dysfunction of sensors and invalid data can be determined easier
- Only one source of energy in an electric vehicle, therefore there is no interference with other measurements and all parameters can be measured

- The goal of the EEM is to improve the performance of the electric vehicle. Therefore, a rougher approach would not allow a breakdown of the energy to every vehicle.
- The measurement frequency for an electric vehicle is continuous (vehicle moves) with breaks (vehicle parks).

7.3 Measurement & Verification Plan

The following subchapters describe the properties of the electric vehicles that are monitored in this case. Furthermore, the requirements and technics used for the measurement are described. Finally, the proposed validation mechanism is introduced.

a) Boundaries identification

Since only one electric vehicle is available for performing the measurement, the "one-to-one comparison cannot be applied but the „before-after comparison" (see chapter 3.2). However, with the time-related monitoring of the electric vehicle the available data is sufficient for deriving reliable conclusions.

In order to apply the SCA it is required that all the information about the factors of influence on the energy consumption is available initially. Based on the historical data predictions are made. To ensure the quality of any predictions the accuracy of the measurement needs to be ensured. Being a data consumer with no direct influence on the measuring sensors (in the vehicle or external data sources) the verification of the data must be performed by testing and matching the provided data. Therefore a data verification method is proposed in the chapter g. – Quality assurance.

b) Baseline period data

In order to compare the electric vehicle before and after the usage of the SCA a baseline is required. The baseline serves as a basis to which other measurements can be compared to. However, to increase the comparability of measurements to the baseline, the same route as the one driven to measure the baseline should be used for each measurement. Apart from the direct comparison of the baseline to a measurement using the SCA there is also the possibility for a more general approach. For example, the improvements of finding appropriate charging stations. For this approach, the historical data measured during the Oscar project can be used.

c) Monitoring

Factors influencing the vehicle's energy consumption are collected and sorted to different data profiles. This data for these factors are measured by the vehicle sensors or are provided by external data sources. Based on the data history prognosis for the profiles can be made. Factors which take influence on the result (and are therefore monitored) during each of the steps are mentioned in their respective boxes in the image above. Particular parameters (P1-6) need to be examined more precisely and are therefore described below (see Figure 20 and compare Deliverable 1.2 Chapter 3.4).

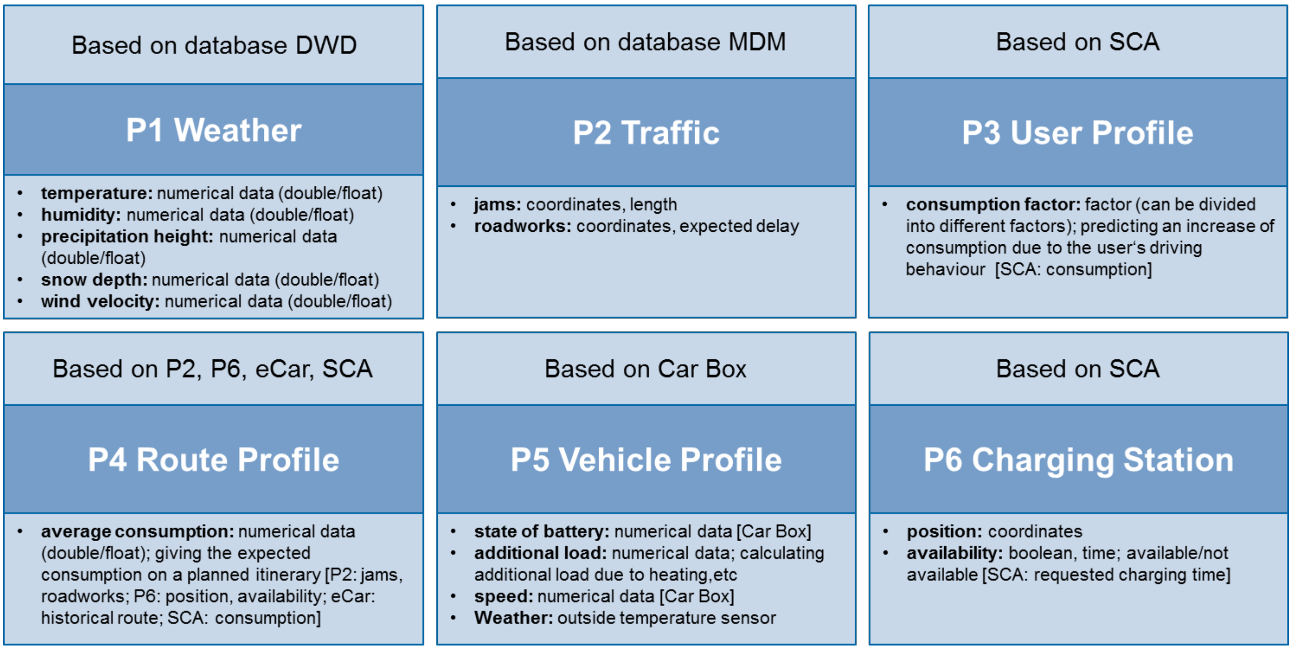


Figure 20: Details on the monitored parameters (DWD: German weather service, MDM: German traffic service)

The weather is the first parameter (P1). It is available in the form of numerical data of the temperature, humidity and precipitation. The temperature has to be taken into consideration concerning the strain on the battery because it influences the usage of the air conditioner as well as the temperature-related behaviour of the battery (especially at low temperatures). The humidity level influences the utilization of the air conditioner as well. The amount of precipitation determines the driving characteristic and also affects the usage of the vehicle lighting, thus influencing the battery load. Also factors like road icing and humidity have effects on traffic and driver behaviour and are considered in advanced prognosis (Level 2 SCA). The weather data is provided by the Deutscher Wetterdienst (DWD, German Weather Service).

The second factor is the traffic (P2), which is described by coordinates and lengths of traffic jams as well as the coordinates and the expected delay by roadwork. Information about available parking spaces near destination is also taken into account in form of coordinates. It is based on the Mobilitäts Daten Marktplatz (MDM, German traffic service) database.

User profiles are the third parameter (P3) which considers the driving behaviour of the user. The driving behaviour is determined by his way of driving accelerating, decelerating and information about speed limits, traffic lights, the amount of stop and yield signs (route information P4), bus stops and the weather (P1).

The route profile (P4) can be described in form of numerical data of the average consumption, which takes the traffic (P4) into account as well as the distance and the height profile. It is based on the information from open map data provided by several services, the measurements of the vehicles.

The vehicle profile (P5) is available in the form of numerical data of the car characteristics. Regenerative braking, the battery charge level and the car load are determining this factor. Also aging factors and changes are considered, e.g. the changes of the available energy, provided by the battery, over its lifetime. It is based on the measurements done by the vehicle itself.

The last factor, the charging station, (P6) is based on the data provided by the Charging stations in the project Smart Watts (LISY-Platform). If there is no data provided by the charging station, the vehicle measurements of charging processes is used instead. The positions of the charging stations are described by coordinates and the availability through Boolean variables and time information. Also the energy amount provided at a point of time and during the hole charging process is tracked.

Figure 21 display the used parameters and the influence on the SCA.

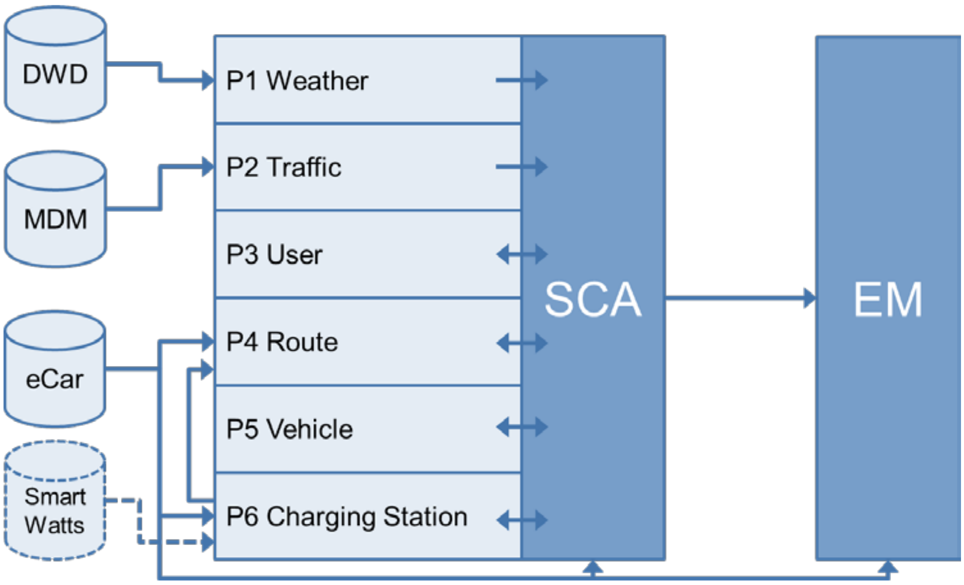


Figure 21: Details on the monitored parameters

Monitoring of the energy consumption, state of battery, driving speed or other vehicle related attributes are measured by the vehicles sensors and are delivered from the vehicle itself to the open service cloud. Other necessary information is being delivered by external sources like the MDM and the DWD.

d) Commissioning

Since the sensor equipment is already integrated in the electric vehicle, the commissioning in this case deals with the installation of the Smart Charging Algorithm. Once the software component is ready to implement, the electric vehicle be supplemented with the SCA. Once the software is running, a test of all functionalities needs to be performed to ensure the algorithms are working reliable. If an error was found during the initial check or the running tests an update needs to be applied. Accordingly, the users of the electric vehicle report every deviation from the standard behaviour of the software.

e) Reporting period data

The electric vehicles are continuously monitored by its sensors. The recording interval is usually predetermined by the installed equipment. However, it can be assumed that the measurement intervals are chosen within an appropriate time frame, since the gained sensor values are a crucial part of the fully functional vehicle. The external data sources provide data on request or within limited intervals. The provided data is in higher resolution and provides a continuously data stream. Within useful limits the data is requested and updated. For example the weather information can be acquired every 15 minutes, whereas the traffic information needs a higher resolution such as every 5 minutes.

Even though the measurement is performed continuously, the evaluation will only be done to certain periods. This guarantees the comparability of the recording. For example, a forecast for a certain scenario can be calculated. After the electric vehicle has performed the scenario, the prediction can be compared to the measurement during the performance.

f) Data analysis

There is certain expected Added Value to be facilitated by the data analysis. The risk of having insufficient car battery load can be reduced, but without a monetary cost prediction. Therefore the reliability increases which leads to a better satisfaction of the driver as well as the operator. Furthermore, the failure risk for the battery can be reduced, as the end of life can be predicted and hence replaced on time. A too early replacement can be avoided. In addition, a prediction of certain vehicle parameters can be calculated based on the earlier measurement. Afterwards, the prediction can be compared with the measurements done with the actual vehicle. The result of this comparison gives a feedback of the prediction quality.

Following indicators are recommended to contribute to the analysis:

Weather

- Temperature (consider heater, A/C, battery behaviour at low temp.)
- Humidity (consider A/C)
- Precipitation (different driving characteristics, lights)
- Traffic
- Traffic / congestion: Type (accident, construction site, traffic jam) and position (GPS), also data of begin and assumed date of end
- Available parking spaces near destination (avoid circling the block in search)

User

Behaviour Data influencing the energy consumption:

- Speed (km/h)
- Accelerating (m/s^2)
- Decelerating (m/s^2)
- Recuperation (Watt)
- Energy Consumption, e.g. use of lights, music, heating, (Boolean on/off and consumption in Watt)

Route information (depending on time and day)

- Elevation/Height profile: GPS data
- Distance: GPS data

Optional:

- Traffic Signs: Type and position (GPS) (Speed limits, Traffic lights, Stop-signs, etc.)

Vehicle Data/Car characteristics

- Charging state of Battery (watt, maximum capacity, minimum capacity, actual charging state)
- Battery quality (efficiency quotient for charging and vehicle power usage)
- Recuperation/Regenerative braking (efficiency quotient)
- Consumer map (engine, heating, other consumers, all values in Watt)
- Weight (passengers, load, in kg)

Charging Station data:

- Position (GPS)
- Type and list of available charging levels (Watt, list of charging types)
- State of usage (flag with in use, blocked, defect, free and estimated time of flag change)

g) Quality assurance

For the NRG4CAST project the quality assurance deals mainly with the data verification. In case of an electric vehicle, plenty of sensors are already installed. Because of the different types and specifics of the used vehicle no information about the sensors are available. Therefore the measurement quality, measurement range, blind spots and quality of the data cannot be evaluated. However, there are several steps to verify an acquired data set. In General, a plausibility check can be performed, to check whether the data set is complete or has gaps in it and to determine single unreasonable measurement values (see list below). This test can be performed by comparing the measured values with a typical or expected behaviour of this sensor. For example if the battery sensor indicates a low battery right after the battery was charged for quite some time. In this case the expected value differs from the measured, which could be an indicator for an invalid measurement (or a defect of the battery, which can be decided by analysing further data). If the data still appears to be incorrect, it might be an idea to perform a cross-check with different sensors. In case of an electric vehicle, this is usually a complicated endeavour. If more than one electric vehicle is available it usually takes less effort to recreate the scenario the other electric vehicle is in, to comprehend the measured data.

In addition to the mentioned plausibility check, several other indicators can be used to check for consistent data. The following points provide an overview of parameters divided into functional groups:

Direct comparison

- Same start and finish locations
- Driving instructions determined by driver vs. determined by algorithm
- Compare battery status / consumption and time elapsed at destination
- Repeat for different routes to possibly determine strengths / weaknesses
- Multiple drivers for every route to account for driving styles (without algorithm)

Long-term comparison (real life application)

- Use car every day over long period of time (to be able to average out differences in routes taken)
- Average consumption (e.g. kWh/km) and speed/pace (km/h, min/km)
- Differences in route and driving
- Multiple drivers to average out different driving styles (without algorithm)

Driver-acceptance

- Multiple drivers to test system for a period of time (~ week)
- Algorithm-“paternalism” may lead to defiant driving in everyday use

h) Measurement accuracy

The accuracy of the measurement depends on the accuracy of the data delivered by the external sources as well as the information from the electrical vehicle itself. There is no possibility to ensure the accuracy of the information provided by the measuring sensors from the project point of view. However, the data quality obtained by the sensors can be validated within certain thresholds by comparing measurements, historical data and predicted data. With more collected data, and therefore more data to compare, the validation quality improves. The data can be verified as described in the next chapter.

i) Reports

The reports of the electric vehicle scenario describe the changes of the behaviour after the SCA is applied. Therefore, one possible report method is to show the used energy with and without using the SCA in a graph. An expected result would be the decreased energy consumption when using the SCA. The comparison can be illustrated with a bar diagram.

7.4 Use Cases and Main User in FIR pilot

The following subchapters provide an overview of the three use cases described by the FIR in the context of the electric vehicle scenario. Within the NRG4CAST-Project a solid foundation for the use cases will be defined so it could be easily adopted. However, the actual implementation is out of scope.

1. **Optimized charging station distribution**

   This use case describes the application of an optimized distribution of charging stations. Therefore, the information basis should be provided. To gather information that can be used for optimising the charging station distribution, the electric cars can be monitored. Besides the position of a car, the time it is remaining at the same spot can be logged. If several cars stay close to a certain point for at least an hour the conclusion can be drawn that this point might be a decent location for a charging station.

The main user of this use case would be the provider of electric charging stations. The provider would be interested in providing as less charging station as necessary but as much as needed. Therefore, the outcome of this use case can make a valuable contribution to this decision.

2. Avoiding grid failure due to overconsumption

The use case describes the avoidance of grid failure due to overload. This could happen if too many electric vehicles are using charging stations that are connected to the same network node. To overcome a network failure the easiest approach would be to charge the vehicles sequentially. However, this would lead to the fact that vehicles would have to wait to get charged. To avoid that this use case describes an approach that allocate the electric vehicles to empty charging station that are close to the actual planned charging station. Therefore, the station occupation needs to be monitored, so station with a high and a low demand can be identified. Using this information, the vehicles can be rerouted to empty stations. However, it needs to be evaluated if users do accept the rerouting (and hence a parking spot further away from their destination) for charging without waiting. In addition, it can be tested whether the user could be convinced using incentives like cheaper charging or free parking.

The main user of this case would be an energy provider who is in charge for the network nodes. The focus of interest of the provider would be to charge as many vehicles as possible since every charging vehicle represents a paying customer. Consequently, the provider is interested in keeping the waiting line as short as possible. A rerouting of an electric vehicle to another charging station would increase its revenue, even if the provider would use incentives such as a lower charging fee.

3. Improved range prognosis

The use case describes the improvement of the range prognosis. The aim is to provide a more reliable and accurate range prediction. This would lead to more comfort for the driver and an improved use of the whole battery capacity. In addition, the break down due to insufficient battery capacity could be reduced.

The main user of this case would be the vehicle driver that would benefit from the improved range prognosis. In addition to the actual prognosis would lead to a more comfortable and more relaxed way of driving since the driver would not need to worry about the range accuracy.

7.5 Status quo

The test plan involved initial interviews followed by questionnaires, as described in chapter 3.3. The first part of the questionnaires varies according to the different use cases, whereas the second and third parts stay the same. The initial interviews are used to evaluated the status quo of a certain use case and provide a basis for the questionnaire. During the interviews, the task is to detect what information is required for certain decisions.

The interviews for the FIR main users are described below:

What information is required for a driver of an electric vehicle (Test driver within the Oscar Project)

- In general an information about the rage of an electric vehicle and if it is possible to reach a certain destination.
- Information about the influence factors of the range: i.e. Traffic information, Topography, Weather information, the current consumption of the other devices such as radio, air condition …
- A result could be to display the range according to the current and planned situation. In addition the vehicle could present hints to the user how the energy consumption might be reduced. The tips could on the one hand recommend switching of the devices such as radio etc., on the other hand to adapt the style of driving.

What information is required for a grid provider (M. Ferdowsi, EON Energy Research Centre and information within the "merge" project www.ev-merge.eu):

- Dump Charging (immediately charged after plugged in), if 10% of all vehicles would be electric and charge according to their normal driving habits, will lead to a peak demand increase of 6%-11%. Therefore the grid need handle that kind of additional load.
- Smart Charging (intelligent charging that can limit/stop/start charging according to certain parameters) will not lead to any peak increase but an increased demand of energy during the night hours. Therefore, no problem with the grid would be expected.
- As a result of the Dump Charging and Smart Charging effect, it would be interesting to see how many people would use a smart charging system and what would be the maximum additional expense they would accept?
- In addition, simulations show that the voltage drop caused by charging EVs can reach the allowed minimum. Especially the medium and low voltage transformations and feeder cables might be overloaded Therefore, it needs to be determined how many EVs are interested in charging at one certain node and would they accept a detour to another charging station?
- So far, no precaution systems are installed to ensure operating grid nodes. However there is still ongoing research to test such systems and to determine the threshold the system should intervene.

8 Methodology for validation of energy consumption reduction at the Miren municipality

The street light network data monitoring is done with by using the ELNM (Envigence Lighting Network Manager) platform. This chapter describes details on the working and measurement environment and the methodology for validating the consumption.

8.1 Measurement description

Each ELCN (device integrated in street light) every 0,2s measure the electricity consumption of the light. The internal controller does the necessary calculations and prepares each 6 minutes the report which is send to the management system (ELNM). The report consists of: last max. current measured value, last min. current measured value, average value, dimming profile, number of measurement. The ELNM use also the external environmental data (temperature, humidity, pressure) produced by ESN (sensor node). On the SW side we do the cleaning process on received reports (clean duplicates …).

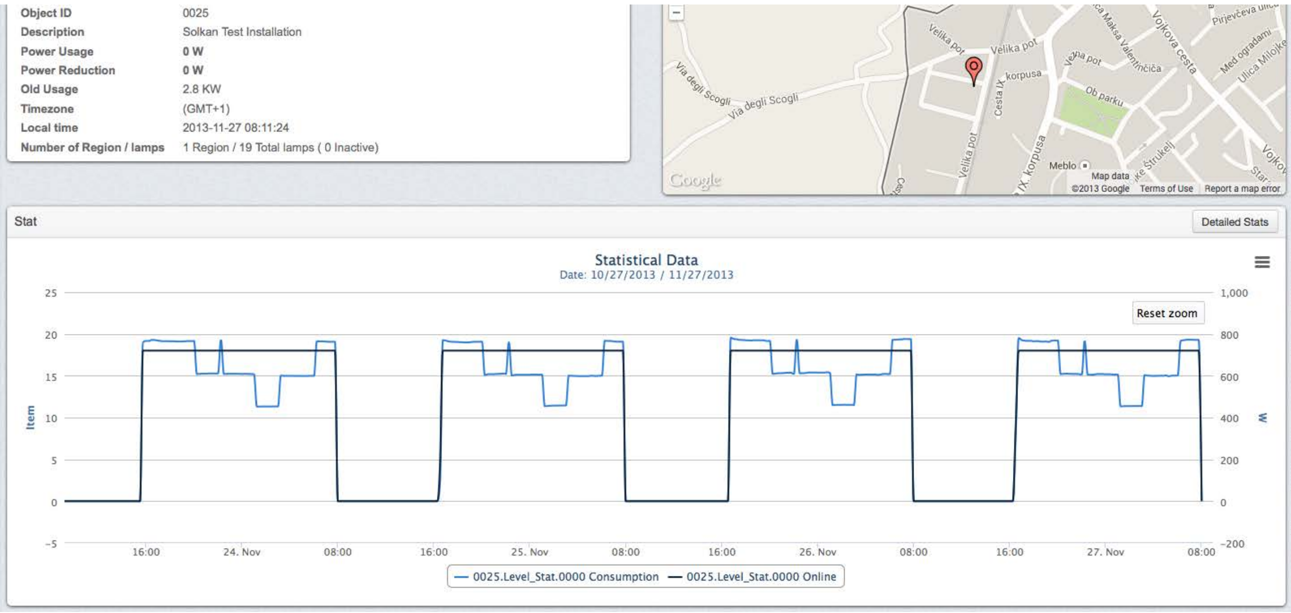


Figure 22: Monitoring the consumption on street lights

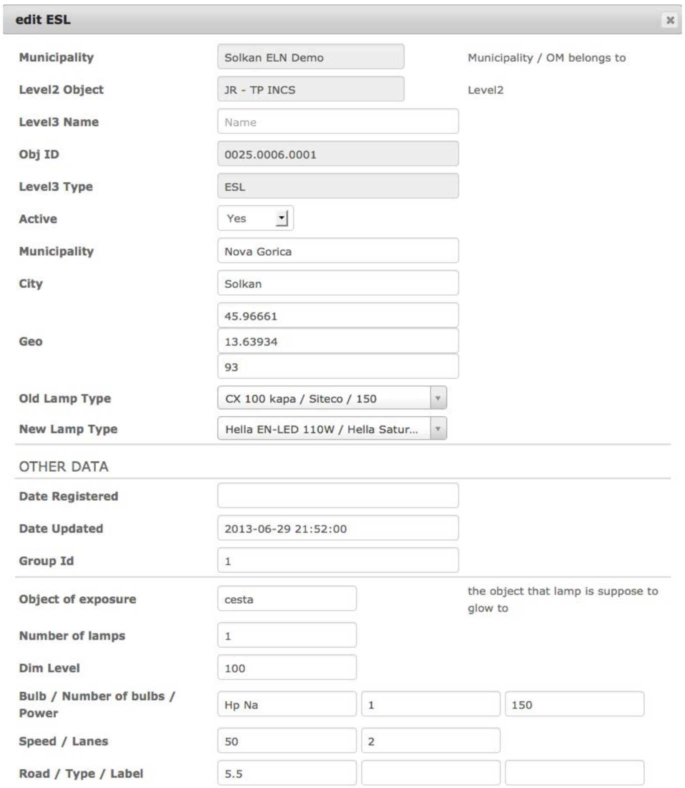
We don't use special equipment for do the measurement, we use the real installation on the field.

8.2 IPMVP Option determination

We use the IPMVP method Option C (Whole Facility), which was designed in part to address evaluation conditions that occur with a whole- lighting network retrofit program. The key reason for using this method is that the goal of the EEM is improvement of whole lighting network performance.

8.3 Measurement & Verification Plan

In this case we are monitoring the electricity consumption on each street light regarding the type of the street. Each type of the street has different terms and conditions regarding standardization. The application always checks if the light meets this requirements for level of lumens regarding standardization.



We use this data to do the verification

- Street information (depending on time and day)
    - Speed Limits
    - Traffic (heavy, middle, no traffic)
    - Type of street (ME1 – ME6, S1 – S6)

- Light/pillar characteristics
    - dimming levels
    - working hour
    - power factor
    - type of pillar
    - type of connection on power line
    - Switch on/off
- weather
    - clouds or fog
    - temperature
    - humidity
    - storm/lightning
- GPS position
    - Day in year dependence
    - Nearest power station - Type of power station

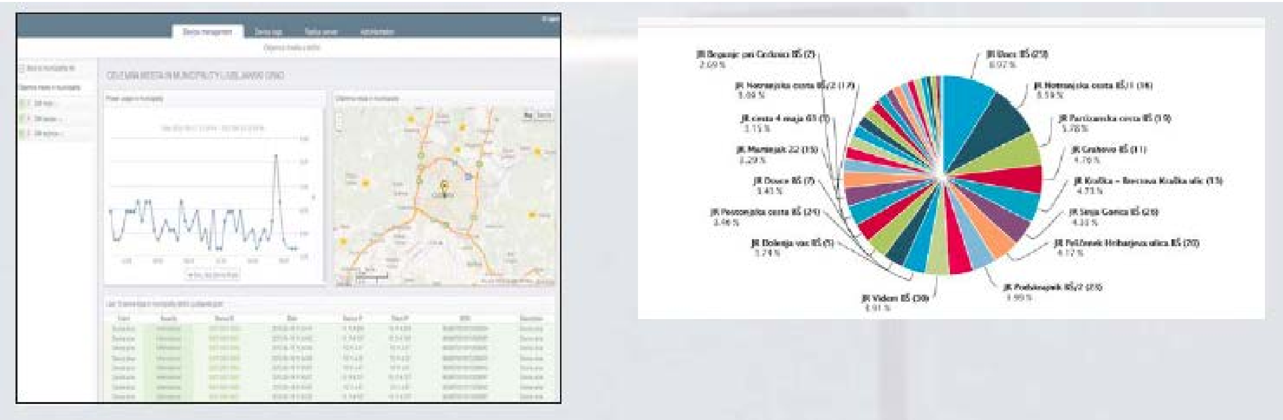
8.4 Use Cases and Main Users in Miren pilot

The use case for Miren case will be the optimisation methods in which we will predict the energy consumption for day, week, and month in advance. ELNM software is prepared to include the necessary tolls to do the automatic optimisation regarding on the previous data collections, weather conditions, street type and other collected data. For this purpose we will integrate the NRG4CAST toolkit into the ELNM software and we assume that we could get up to 15-20% additional savings on energy consumption on the whole lighting network.

The main users in Miren case are municipality energy manager. Energy manager need to do the monthly reports of the consumption on all of the energy consumption in municipality.

8.5 Status quo

Energy cost saving for Miren municipality. Every day system produces the report for energy consumption for each light, group of the light and for all light in municipality.



The system could also produce the predicting report regarding of use of different parameters. The system use three different comparisons.

- Direct comparison
  - Same type of light – different dimming level
  - Light with the same light output (LUX lumens)but different power consumption
  - Different switch on and off of light (depending on photo cell sensor)
  - Light with management system – light without management system
- Long-term comparison (real life application)
  - Old installation – new installation – energy consumption and maintenance costs
  - Average consumption (e.g. kWh/day/week/month/year)
  - Different scenarios
  - Reductions on maintenance - event maintenance (alarm)
- Determine payoff: consumption / cost reduction/cost of ownership

What is your experience of using an intelligent control system for street lighting in your municipality?

Costs for public lighting was reduced by more than 50%, with the installation of the control system, we save an additional 20% energy. With the optimisation and forecasting the consumption we can save an additional 10% of energy for public lighting. The Municipality of Miren Kostanjevica

9 Methodology for validation of Integrated Miren-FIR-CSI-IREN Scenario

9.1 Measure(s) description

This case integrates street lighting, building monitoring, electrical vehicle charging, district heating production and distribution, and traffic information system into a test region aspect. The data comes from the systems of Envigence (street lighting in Miren), CSI (CSI building and a set of public owned building in Turin, FIR at RWTH Aachen (smart charging, at the laboratory of FIR-RWTH), and IREN (district heating production plants and distribution network in Reggio Emilia) in order to monitor the energy behaviour in a broader topology network.

The goal is to integrate those different applications into the analytics functionality of NRG4CAST and produce result for a region level (even though some activities will be done in other location).

More particularly, the purpose of this integrated scenario is to make a laboratory test of NRG4CAST with different sources of (real life) information even though those are coming from different locations. Pilot operation and validation will follow the three-phase approach and will be adapted according to the table below:

Phases/Activities	Due date	Expected results
Laboratory installation (produce raw data) – small sample	M12	Consolidated data stream from integrated energy network
1st validation results	M14	
Initial rollout: Real life installation (1 full municipality/city)	M24	Monitoring and basic analytics environment
2nd Validation results	M26	
Final Rollout: Mass installation	M34	Complete setup
Final validation results	M36	

Figure 23: Integrated Pilot Operation and validation phases (see DoW B1.3.3.5)

9.2 IPMVP Option determination

Since the scenario is evaluated as a whole, the recommended IPMVP method for the integrated Miren-FIR-CSI-IREN Scenario is Option C (Whole Facility). The reasons for this approach are listed below:

- The integrated scenario aims for an improvement over all contribution parts
- The individual savings are described and analysed in the separate cases, therefore the focus of the integrated part is on the joint contribution.

9.3 Measurement & Verification Plan

The measurement and verification plan for the integrated scenario represents a combination of the individual pilots. For the individual measurement and verification plan of each pilot the according chapters provide detailed information (Miren: Chapter 8.3 , CSI: Chapter 5, FIR: Chapter 7.3, IREN: Chapter 6.3).

h) Boundaries identification

Since the integrated scenario is a combination of all four single scenarios, the boundaries of them also describe boundaries of the integrated scenario. In addition, there are boundaries regarding the comparison method. Due to the fact, that the combined scenario is only a virtual combination of several individual scenarios, it is not possible to create an equal construct that would allow a “one-to-one comparison”. Therefore, the “before-after comparison” needs to be applied.

i) Baseline period data

The baseline of the integrated scenario is a combination of the used baselines of each individual scenario. Due to the different kind of energy consumption (e.g. continuous with buildings but impulsive with electric vehicles), attention needs to be drawn at the time span in which the baseline is acquired. In fact, the characteristic of each baseline needs to be evaluated to find an appropriate measurement period that delivers a representative integrated baseline.

j) Monitoring

For each single scenario, a lot of different parameters such as electric power, temperature, etc. are acquired using several different measurement devices. A detailed description of those parameters and measurement devices is provided in the individual chapters. For the integrated scenario, the focus is set on the energy consumption. Therefore, the some of the monitored parameters need to be reduced or converted into the used energy.

k) Commissioning

The commissioning is part of the separate scenarios and not in control of the combined one. For example, the electric vehicle scenario is updating installing software and using already existing sensors, whereas the building cases install sensors and other equipment. Therefore, the commissioning, installation and assurance of the correct system is described in the according subchapters for every scenario.

l) Reporting period data

As described earlier, the reasonable reporting period differs for scenario to scenario. Therefore, each reporting period needs to be evaluated to determine an optimised reporting period for the integrated scenario.

m) Data analysis

The independent variables for every individual scenario are similar and do therefore also apply for the integrated scenario. They combine the parameters that affect the energy consumption such as weather conditions, occupancy, etc. The dependent variables are the ones that are measured. Since this project has the emphasis on energy consumption, those variables are closely related to the consumption. In addition to the direct consumption measurement (kWh), additional data such as consumption per person or the reduction can be recorded.

n) Quality assurance

A first quality assurance is performed in every individual scenario. However, an additional review can be performed after the combination to the integrated case. For this purpose, a plausibility check can be performed to validate the acquired data. For example, a too strong variation of energy consumption without an obvious reason or a heavy consumption incensement during the middle of the night.

o) Measurement accuracy

On the one hand, the accuracy of the overall measurement is as accurate as the most inexact measurement of all single scenarios. Consequently, the individual scenarios itself are trying to provide as accurate data as necessary. On the other hand, the aggregated energy consumption is naturally higher than the individual one and small error will not have such a big impact on the final result. As a result, a reasonable trade-off has to be found between high accuracy, performance and costs.

p) Reports

The report of the integrated scenario is focused on the overall improvement of the energy consumption, whereas a detailed description is provided by the individual scenarios. The main achievement is to consolidate the different results to one unified report that represents the energy consumption before and after the energy efficiency measure (EEM).

9.4 Use Cases and Main User

This use case describes the private housing. It is not included in one of the pilots. Nevertheless, can it be seen as a support for future user of the virtual city (Miren-FIR-CSI-IREN). For this use case the information system will not be developed or integrated. However, the information demand and interest of the user group should be evaluated. Within this project, no direct access to this user group is available. Therefore, the questionnaires are used to gather information about the private housing topic. It can be assumed that most of the participating users are responsible for their own private house or apartment regarding energy questions.

The private housing use case deals with the whole energy consumption of private houses and apartments. The entire energy consumption consists of heat (district heating, gas, oil...), power, etc. Instead of monitoring the consumption as a whole, the use case is about the consumption of one certain form of energy in one certain room at a certain time. This acquired data could be used as a decision basis for changing the users' behaviour or give the user the ability to choose an adequate energy provider according to its needs.

Thus, the main user for this use case would be every person who is responsible for the energy consumption in a house or apartment.

The other Use Cases and Main Users are summarized in the tables below and described in detail in the according chapters.

9.4.1 Use Cases

Use Case	Pilot plant objectives	Threshold	Performance indicator	Measure	Tool	Main User	Secondary User
IREN UC1	The forecasted value is correct with respect to the real value	5% of error rate	Comparison between the total amount of energy forecasted by the model 2 days in advance and the actual amount of energy provided	TBD	TBD	Thermal power plant operator	
IREN UC2	Energy consumption saving compared to the total amount of energy consumptio	2-3% saving	energy consumption (KWh)	Meter Logs	KWh meters	…	

	n of DH network of last year						
FIR UC1	Providing the information basis for an optimized charging station distribution	-	Expected usage of the planed charging infrastructure	Amount of vehicles with charging interest within a limited area	Advanced Prognosis within the SCA	Charging station provider	Vehicle Driver
FIR UC2	Avoiding of grid failure due to overconsumption	-	Avoidance of consumption peaks and inacceptable charging delays (<6h)	Predicted consumption compared to available energy amount per grid knot	Advanced Prognosis within the SCA	Grid provider	Vehicle Driver
FIR UC3	Improved range prognosis	-	Improved confidence in range prognosis	Improved driver mobility and range; less incidences of insufficient remaining capacity	Advanced Prognosis within the SCA	Vehicle driver	
CSI UC1	Streaming data integration and management	-	Improved and complete information on energy consumption		Data adapters /data integration	Energy manager, Employee/house owner	
CSI UC2	Real-time analysis, reasoning and network behaviour prediction	-	Improved confidence in prediction	Energy saving/ money saving	Energy demand prediction	Energy manager, City manager, Municipality authorities	

MIREN UC1	Energy consumption saving compared to the total amount of energy consumption of light network of last year	10% savings	Complete information on energy consumption and prediction	Meter logs	ELCN (light control node) and ELNM (management system	Facility / energy manager	Energy distributor/ provider

9.4.1 Main User

The following matrix showing the dependencies between user (P primary; S secondary) and use cases.

User / Use Case	Energy Provider	Energy Manager	Thermal power plant operator	Employee/ House owner	Charging Station Provider	Electric Vehicle User	City Manager/ Municipality Authority
IREN UC1			**P**				
IREN UC2			**P**				
FIR UC1					**P**	**S**	
FIR UC2	**P**					**S**	
FIR UC3						**P**	
CSI UC1		**P**		**P/S**			
CSI UC2		**P**		**S/P**			**P**
MIREN UC1	**S**	**P**					**P**

Conclusions

This document describes the theoretical background as well as the actual application of the validation methodology that is used in the NRG4CAST project. The document is structured to guide from a rough overview of methodologies to the very specific requirements of the scenarios. Consequently, the first chapter provides an overview over the methodologies within other European projects dealing with energy efficiency is given. Afterwards, the methodology is adjusted according to the specific NRG4CAST requirements. Finally, the validation methodology is given for every scenario in a separate chapter. Therefore, the NTUA validation methodology is given in chapter 4, the validation methodology adapter to the CSI scenario is described in chapter 5, the IREN methodology is described in chapter 6 the FIR methodology is described in chapter 7 and the Miren methodology is described in chapter 8. Eventually, the validation methodology for the integrated scenario is described in chapter 9 and consequently represents a combination of the individual validation methodologies.

As the validation methodology is adapted from other EU projects such as eSESH and 3e-HOUSES, one of the first steps is to choose an option from the IPMVP (International Performance Measurement and Verification Protocol) for every scenario. This is followed by the individual measurement and verification plan that differs according to the requirements of every scenario. The measurements of energy consumption in buildings do need another measurement setup and verification as the measurement of electric vehicles, for example. In a third step, the different use cases for each scenario are described as well as the main user. To determine the status quo, interviews have been conducted with the main users. The outcome of this interview is described in the last subchapter for every scenario and will be used as a basis for the questionnaires to evaluate the user acceptance of the NRG4CAST system.