ICT solutions for monitoring and evaluation of energy savings in novel refurbishment buildings under iNSPiRe project.

Speakers:

Macía Andrés¹; Corredera Alvaro¹; Sanz Roberto¹; Fedrizzi Roberto²; Mabboni Tizziano³; Besana Francesco³.

¹ Fundación CARTIF, Boecillo-Valladolid
² EURAC, Bolzano, Italy
³ Gruppo Industriale TOSONI, Villafranca di Verona, Italy

Abstract: The project iNSPiRe aims at conceiving, developing and demonstrating Systemic Renovation Packages, through the innovative integration of envelope technologies, energy generation (including Renewable energys systems (RES) integration), energy distribution, lighting and comfort management systems into deep energy renovation of buildings, both in the residential and tertiary sectors. With the systemic renovation packages it will be reached an overall Primary Energy consumption of the building lower than 50 kWh/m²/year.

The main objective of this paper is the definition of the monitoring systems in the three demo buildings which require methodologies and strategies to assess the energy savings and performance of iNSPiRe buildings, as well as to implement an innovative system for the integrated management of the building’s energy fluxes. For achieving this objective it has developed a methodology which cover the next issues: Definition of meters and sensors required for building monitoring, definition of the interfaces for data collection from both sensors and management hardware, development of the distributed monitoring network and definition of a baseline to be used as a reference for the calculation of the energy savings following the exploitation of assessed technologies and smart management of the building.

Building, Energy, Monitoring, Inspire

Introduction

According to the Renewable Heating and Cooling European technology Platform (1), currently most of the energy consumption in Europe is due to heating and cooling used for domestic, tertiary and industrial purposes: low temperature heat in the domestic and tertiary sector accounts for almost 60% share (around 4,000 TWh/y overall consumption). Again, heat accounts for 86% of the final energy in the residential sector, 76% in the commerce and services. This energy is largely produced by directly burning fossil fuels with a negative environmental impact.

Over the last 20 years electricity consumption in European non-residential buildings has increased by a remarkable 74% (2). This is compatible with technological advances over the decades: cooling demand contributes mostly to this figure and it is alarming due to the huge
foreseen rise in the next 10 to 20 years. The cooling demand in the non-residential sector is foreseen to increase by around 3 times the actual values (around 400 TWh/y in 2020). The same trend is predicted in the residential sector; even though the absolute values are rather lower (1).

Furthermore, lighting is among the highest end-use categories in the tertiary sector, being evaluated in about 160 TWh/y at present for the entire EU (3). The utilization of smart ICT systems for the control of lighting and replacement of conventional artificial lighting systems with energy saving models and the exploitation of daylight could contribute to the strong reduction of such a value.

Monitoring systems in buildings collect and gather data of systems integrated within a home/building through the Information and Communication Technologies (ICT). Such systems allow decentralizing the monitoring (local and remote) thanks to a number of devices.

The project iNSPiRE aims at conceiving, developing and demonstrating systemic packages for deep energy renovation of buildings, both in the residential sector (demosite located in Madrid and Ludwigsburg) and tertiary sector (demosite placed in Verona). The systemic renovation packages will make use of innovative envelope technologies, energy generation systems integrating a large amount of RES and energy distribution, lighting and comfort management systems. The optimal integration of such systems will lead to a synergic effect on primary energy savings (as well as a reduction of CO₂ emissions), assuring at the same time enhancing comfort conditions to the users. To surveillance of these energy savings it has defined and implemented a monitoring system for each demo building which is described on this paper.

**Demo Building Description**

On this section architectural characteristics of iNSPiRe demo buildings (Ludwigsburg, Madrid and Verona) and their energy consumption profile are defined.

**Ludwigsburg demo building:** The building was built in the early 70’s, includes 3 flats on 3 stories. The total living area is about 280 m². The building is nearly in the original status; only the façade has been renovated in the 80’s with 5 cm outside insulation. The roof and floor is not insulated and the windows are old style double glazed and not air tight. The technical status is also nearly original, with a 25 years old oil burner and radiators for heat distribution. The fresh water tubing is corroded and needs to be refurbished in the near future. The current final energy consumption of the building for heating is about 180 kWh/m²y (HDD =3500). An average 20 kWh/m²y final energy consumption for domestic hot water preparation was estimated. No cooling devices are currently installed.

**Madrid demo building:** The building has 20 dwellings (60m² gross area per dwelling) on 5 stories and is composed by 2 linear blocks linked through the staircase. EMVS owns 3 of these flats. The façade is made of 24 cm brick wall without any insulation. The windows are built with aluminum frame and simple glass. The roof is built with asbestos-cement boards
without any insulation. Individual heating systems (electric, gas or none) are setup in the dwellings. The electric and lighting systems have to be completely renovated. The current final energy consumption of the building for heating is about 140 kWh/m²y (HDD = 2100). An average 20 kWh/m²y final energy consumption for domestic hot water preparation was estimated. No cooling devices are currently installed despite the large summer loads. The building will be completely renovated by means of one of the Systemic Renovation Packages assessed. In this second case, only the energy generation kits will be used, while the remaining part of the renovation will be executed with conventional techniques.

Verona demo building: The building is GIT’s headquarter, located in Villafranca di Verona (Italy). It was constructed in the 90’s without taking into consideration any special energy concept as it was usual in that period. The section interested by the renovation (330 m²) is a small two stories wing in the south-west side of the building which includes part of entrance hall, the reception, some administrative offices and meeting rooms. The wing was selected as a minimum representative portion allowing the monitoring of the building’s performance after renovation. The external façade (facing south and north-east), covers approximately 210 square meters over the two levels. It is a mullion and transom curtain walls with extruded aluminum painted. The ground floor is characterized by typical modules of 2170x4460 mm, with a vision area consisting in single glazed windows. The first floor has modules of 2170x3900 mm with opening and fixed windows (2x2170x900 mm): Heating and cooling are distributed by conventional fan coils. The current final energy consumption of the building for heating is about 170 kWh/m²y (computed from the gas bill, HDD = 2500). The total electricity consumption for cooling, ventilation and lighting is about 167 kWh/m²y (computed from the electricity bill, appliances are also included).

Definition of monitoring systems
Roughly speaking, a monitoring system is composed of sensors, gateways and data acquisition system. These components are included in a network, which can have different architectures. Monitoring system architecture specifies the connection between different components of the installation: sensors, actuators and controllers.
The monitoring system to be installed and commissioned is aimed to analyze the behavior of the building in terms of energy as well as the comfort and behavior of the users of building. In this respect, a thorough study of the building conditions and systems is needed, in order to set the parameters to be monitored.

Each indicator needs two types of data: Static data such as building geometry (air volume, area, façade) and Dynamic data such as energy consumption, temperatures, flows. Recording frequency has to be defined for these data, and it usually depends on project goals (yearly, monthly, daily or time series). Also it exists a dependence in indirect data derived from measurements which are considered dynamic.

After the identification of these data and considering buildings and facilities, location of the meters is determined, taken into account their needs of measure in the schematic diagram and other criteria such as: Applicability of the measurement; Needs of local visualization, maintenance Optimization of sensor position, etc.

The use of diverse wired and types of networks makes possible the existence of different parameters as the complexity of cabling, speed of transmission, vulnerability, network management, rate of malfunctions, etc. Main architectures are centralized, decentralized, distributed and hybrid/mixed.

The partitioning of the energy fluxes within the building allows an accurate distinction of the energy carriers, the systems and the different loads inside the building. The delivered energy carriers include in general fossil, district and electrical energies (gas, oil, biomass, district heat, district cooling, and electricity) as well as environmental energy (soil, ground water, extract air, waste heat and solar radiation). The consumed energy inside the building represents the loads occurring in the zones including the circuits, i.e. heating, domestic hot water, cooling, lighting and other electrical uses. The systems provide the energy need and - if
necessary - include a transformation process. The media to be measured define the type of the required sensors, i.e. calorimetric counters (heat/cold meter) or electrical meter.

A flow diagram and the documentation of the building is the starting point to illustrate the sensor location, connections and communication. The flow diagram (imagen 2) shows energy flows and parameters that are monitored and where the sensors are located in a dwelling. The building documentation further specifies the exact location and interconnections of the sensors. Additionally, the monitoring system overview should specify the logic behind the installation of each sensor (which parameters is being monitored and why; what is the expected outcome from the analysis). The commissioning phase provides an opportunity to further evaluate the monitoring strategy and help to identify if corrective measures are needed (e.g. additional sensor, change of sensor position).

**Imagen 2. Schematic of a general flows and parameters monitored.**

**Variable to be Monitored**
A standard set of monitoring devices for the three demo sites has been selected in order to speed up the design and the installation phase. Indoor comfort, weather conditions and thermal/electrical consumptions have to be assessed in order to produce a monthly report for functional areas, to schedule an action plan and optimize with a fine-tuning the control systems of the thermal/electric existing plants.

**Indoor comfort**
ELTACO FCO2TF63 series is a wireless indoor sensor which measures CO₂, relative humidity and temperature. A wireless technology has been selected in order to reduce as much as possible the interference for the occupants due to the installation. For this reason a wireless base station is needed in order to get signals from the comfort sensor and transfer it
to a gateway via LON protocol. A Wireless Transceiver produced by Thermokon has been selected for this purpose. In the residential demo case, one receiver per dwelling has been installed in order to acquire data from a set of indoor comfort sensors. In the office building, one receiver was sufficient.

**Thermal and electricity consumption**
The thermal consumptions are due to heating loads and domestic hot water preparation purposes. The thermal energy flows monitoring requires a heat meter installed along the pipelines. A Multical 602 produced by Kamstrup is an all-purpose energy calculator for heat together with a pulsed flow sensor and with 2 wired temperature sensors. This meter saves energy data on a yearly, monthly, daily and hourly basis, which provides the operations manager with a complete performance analysis. The meter can be fitted with LON communication. The Countis series electricity meter by Socomec is the modular active energy meter selected for the three demo cases. The pulse output is gathered by a LON pulse memory module that redirects the information into the LON-network.

**Weather conditions**
Outdoor temperature, relative humidity and direct and diffuse solar radiation are assessed through a Warema weather station. A Warema sensor is used to record temperature and humidity, while two Deltaohm pyranometers are used to gather diffuse and total solar radiation. The weather station is connected to a Warema Lonse III (LON sensor unit), enabling the integration into the LON-network.

**Commnnication and Architecture**
An open system with LonWorks communication protocols has been selected for the three demo sites. This decision takes into account the need to have a decentralized architecture, end-to-end, which allows to distribute the intelligence between sensors installed. As displayed in imagen 3, the LON network consists generally of several branches, one branch per each functional area (i.e. dwelling or office), plus one for the weather station. For this reason an L-Switch XP by Loytec has to be installed due to the system decentralization. For the management of all the data within the LonWorks network an iLON Smart Server manufactured by Echelon has been mounted. Finally a 3G modem sends all the data to a monitoring server.
Monitoring and Management Software

After the sensor definition, architecture and protocol communication have to be defined through a management software.

The software defined in iNSPiRe project is FarEcho system which gives a cloud service that can be via a web address and a login access. Starting from the data collected, an energy analysis with an hourly, daily and monthly base can be exploited. In imagen 4, an example of electricity daily data is reported.

Imagen 3. General architecture of the monitoring systems

Imagen 4. Electricity consumption profile.
Apart from the energy and comfort data analysis, the software allows setting and monitoring alarms associated with the alert thresholds. Each alarm is configured according to a class, allowing managing the behavior of the system in a simplified way, managing notice to the relevant professionals (e.g. maintenance, energy manager and administrator).

**Conclusions.**

Within framework of iNSPiRe project, a monitoring system for the three demo building has been defined, which has taken into account the energy flux, weather conditions and indoor conditions.

Furthermore, it has implemented a management software FAR-ECHO system which gives a cloud service, data acquisition, storage, control and analysis data. Then Far-ECHO generates automatically a report with consumptions on an annual, monthly or daily profile according to the needs of the user.

**References.**

2. BPJE, (2011) Europe’s Buildings Under the Microsoft, public report,