Digital Transformation in Energy Transition

# Digital Transformation in Energy Transition

Guglielmina Mutani, Serena Galati
*Department. of Energy, R3C lab*
*Politecnico di Torino*
Torino, Italy
guglielmina.mutani@polito.it

Giuseppe Maria Perfetto
*Solar Design Studio*
Torino, Italy
info@solardesign.it

Francesco Paolo Lamacchia
*Network Edifici a Consumo Zero Association*
Matera, Italy
lamacchiafp@yahoo.it

***Abstract* — The emergence of the Internet of Things, which enables the connection of almost every building-element to the Internet, provides a huge and appealing amount of data to the Smart Building and Smart City ecosystem. These data also create value by enriching the offer and quality of applications designed for optimal management of energy efficiency. The topic of energy saving has also been evaluated for 119 buildings managed by the Territorial Agency for the House (ATC) in 9 districts of Turin. All the useful information, concerning the sample of buildings analyzed, were collected; in particular, its characteristics: the envelope, the technological systems and the type of use. By gathering the energy consumption data for 4 heating seasons, the energy signature has been represented for each building in order to analyze its thermal behavior and to identify operating anomalies. Finally, with a cost-optimal analysis, the most effective energy efficiency measures were identified. A comparative study of energy consumption is also started on other similar typological houses, new buildings ended two years ago with high energy standard certification, and located in south of Italy at different latitude from Turin. The apartments are part of three public buildings classified in Italy like social housing or low income people's houses, managed from the regional office named 'ARCA Sud Salento' (Regional Agency for House and Dwelling). This study shows how using monitoring devices and where in the internal spaces of buildings, equipped directly by display on the wall in each apartment so that each household could have the possibility to control their use at the same time of the operating, to be influenced by that visualization and to be pushed to modify his behavior for energy saving purposes. These devices will lead the household to virtuous behaviors in the energy use at home.**

***Keywords — Digital Efficiency; measurement campaign; dynamic characteristics; Energy Transition; Digital Transformation.***

## I. Introduction

The continuous technological revolutions and the economic expansion of the developing countries lead to a growing demand for energy availability. The abundant amount of energy at relatively low costs of the twentieth century has met this need, suggesting that it can consume energy almost without limits.

However, the environmental degradation in which we live today is proof of how this relationship between man and nature, based on the indiscriminate exploitation of resources, is no longer sustainable.

The theme of energy management, the rational use of energy and the reduction of emissions take on increasing weight over the years. The residential building sector plays a key role in achieving energy efficiency goals. The stock of buildings existing in European countries is responsible for about 40% of energy consumption and, of these, 63% is composed of residential buildings.

Furthermore, the building stock consists mainly of "older" buildings: if we consider the Italian case, about 2/3 of the built heritage belongs to a construction period before the law 373/76 on the containment of energy consumption.

In this framework, the instrument of energy diagnosis is inserted: a preliminary analysis aimed at promoting an energy requalification of the existing building heritage. Its task is to evaluate the transformation, distribution and consumption of energy within a structure, to investigate the causes of possible waste and to define possible technological improvement or management interventions.

## II. Public housing of Territorial Agency for the House (ATC)

### A. *Objective of the study*

The analysis of the energy behavior of a building was born from the need to conduct sustainable developments aimed at reducing energy consumption. The study undertaken, focused on the recovery of the existing, deals with studying social housing buildings that belong to the ATC building heritage. ATC (Agenzia Territoriale per la Casa di Torino - Territorial Agency for the House of Turin) is a public institution whose purpose is to provide, administer and manage cheap apartments for the low-income population (Figure 1).

The objective of the study is to analyze the thermal behavior of the buildings, of which the geometric and thermos-physical characteristics and the real consumption data for heating of the last seasons are known, and to develop a redevelopment plan aimed at energy and economic savings. The analyzed sample consists of 119 buildings located in Turin, built between 1910 and 1980. The buildings vary in volume from 700 to 40,000 m$^3$ and the total annual heating expenditure is around 2,300,000 €/year.

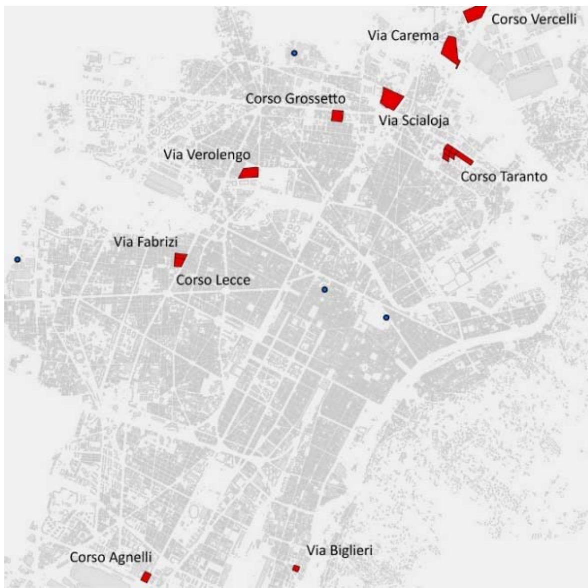


Fig. 1. Mapp of the buildings of the ATC public building stock (in red). The blue points identify the available weather stations.

## *B. Characteristics of buildings*

Through the use of GIS tools, the buildings have been mapped and an energy register has been built, which shows, in specific databases, the main reference data for the thermal analysis of the building such as geometric characteristics, thermo-physical characteristics, characteristics system, energy consumption (Table 1) [1]. For details on the type of construction, in the absence of other information, reference was made to the UNI TR 11552 drawing up a classification based on the age of construction [2].

About 70% of the buildings have a heated usable area of less than 1.500 $m^2$, the residual building fluctuates between 2.000 and 3.500 $m^2$. In three isolated cases, the value exceeds 6.000 $m^2$. More than half of the buildings analyzed have a high dispersing surface, to which corresponds a high heat exchange and a high demand for thermal energy. Only a third of them have a dispersing area of less than 1,000 $m^2$. This results in high surface to volume ratios, around 60% of buildings have a value greater than 0.6 $m^2/m^3$.

The buildings analyzed have two types of different installations: part of the buildings is served by district heating (around 15%); the remaining part has centralized heating systems for heating only or heating and DHW production and uses methane as an energy carrier.

TABLE I. CHARACTERISTICS OF THE BUILDINGS

| **Buildings** | ***n. buildings*** | ***Period of construction*** | ***Net surface $m^2$*** | ***S/V $m^2/m^3$*** | ***Uop $W/m^2/K$*** | ***Uw $W/m^2/K$*** | ***$\eta_{gl}$*** |
|---|---|---|---|---|---|---|---|
| Via Verolengo | 7 | 1910 | 8.900 | 0,62 | 1,520 | 2,762 | 0,863 |
| Corso Lecce | 12 | 1925 | 15.000 | 0,58 | 1,499 | 3,034 | 0,788 |
| Corso Vercelli | 15 | 1925 | 11.300 | 0,75 | 1,332 | 2,496 | 0,568 |
| Via Fabrizi | 10 | 1925 | 11.100 | 0,57 | 1,499 | 3,034 | 0,788 |
| Corso Agnelli | 24 | 1927 | 8.700 | 0,75 | 1,273 | 2,723 | 0,799 |
| Corso Grosseto – Via Sospello | 16 | 1930 | 32.900 | 0,43 | 1,273 | 2,723 | 0,799 |
| Via Biglieri | 8 | 1939 | 7.100 | 0,71 | 1,210 | 3,112 | 0,931 |
| Corso Taranto | 16 | 1967 | 56.000 | 0,52 | 1,115 | 1,912 | 0,894 |
| Via Scialoja | 1 | 1978 | 6.000 | 0,53 | 1,431 | 4,826 | 0,837 |
| Via Carema | 1 | 1983 | 6.900 | 0,68 | 0,680 | 3,210 | 0,504 |
| Via Ivrea | 1 | 1983 | 12.000 | 0,67 | 0,630 | 3,210 | 0,432 |

## *C. Analysis of consumption data*

Energy consumptions for space heating (H) and domestic hot water (DHW) have been collected for at least two heating seasons and compared with climate conditions [3] with the heating degree days (HDD at 20°C) detected by the stations meteorological data of Torino Reiss Romoli and Torino Via della Consolata. Referring to the Regional Law DGR 43-11965 of 2009, the buildings can be classified in the energy classes F and G. Only three residential complexes have slightly higher energy efficiency and fall within the energy classes D and E. The average monthly consumption was calculated for each building, considering consumption in each heating season normalized for the heating degree days 'HDD' (Table 2). Subsequently, specific consumptions were calculated, normalizing the average consumption data for a reference parameter, to release energy consumption from the building geometric characteristics. Starting from these last data, the energy signatures of the individual buildings have been obtained, which are useful for performing a comparison of consumption based on the energy behavior of the building. Based on this comparison, two buildings type have been selected, on which to build a thermal model. For each thermal model built, improvements were made to make the building more energy-efficient.

TABLE II. ENERGY CONSUMPTION DATA (MWH/YEAR)

| **Buildings** | ***2011-12*** | ***2012-13*** | ***2013-14*** | ***2014-15*** | ***HDD 11-12*** | ***HDD 12-13*** | ***HDD 13-14*** | ***HDD 14-15*** |
|---|---|---|---|---|---|---|---|---|
| Via Verolengo | - | - | 1.684 | 1.742 | 2.221 | 2.348 | 1.962 | 2.007 |
| Corso Lecce | 1.597 | 2.290 | 1.324 | 1.473 | 2.221 | 2.348 | 1.962 | 2.007 |
| Corso Vercelli | - | - | 1.614 | 1.627 | 2356 | 2489 | 2092 | 2129 |
| Via Fabrizi | 1.313 | 2.772 | 1.825 | 1.275 | 2.221 | 2.348 | 1.962 | 2.007 |
| Corso Agnelli | - | - | 1.251 | 1.051 | 2.221 | 2.348 | 1.962 | 2.007 |
| Corso Grosseto – Via Sospello | - | 4.315 | 3.580 | 3.841 | 2356 | 2489 | 2092 | 2129 |
| Via Biglieri | - | 1.142 | 1.064 | 1.084 | 2.221 | 2.348 | 1.962 | 2.007 |
| Corso Taranto | - | - | 3.861 | 3.282 | 2.221 | 2.348 | 1.962 | 2.007 |
| Via Scialoja | - | 774 | 697 | 745 | 2356 | 2489 | 2092 | 2129 |
| Via Carema | - | 706 | 600 | 561 | 2356 | 2489 | 2092 | 2129 |
| Via Ivrea | - | 1.161 | 890 | 997 | 2356 | 2489 | 2092 | 2129 |

## *D. Evaluations and intervention plan*

For each improvement operation an estimate was drawn up which summarizes the main costs for the implementation of the intervention and a simple return time was defined for the investment that considers the cost of the interventions and the annual economic savings.

Following the Cost Optimal methodology, the final energy consumption of each scenario, the energy savings in percentage terms and the total cost of the intervention were evaluated [4]. Based on these parameters, the most economically and energetically efficient interventions were identified and simulations were carried out on the ATC building stock to propose a intervention plan for energy retrofit of buildings.

The analyses of retrofit interventions and economic evaluations of Corso Vercelli and Via Sospello areas were described in Figures 2, 3, 4 and 5.

### *Retrofit interventions in Corso Vercelli*

The histograms in Figures 2 and 3 describe the achievable annual energy savings, expressed in MWh, and the costs of each investment for each intervention.

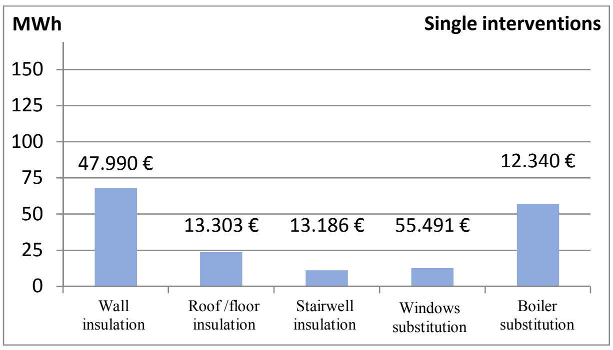


Fig. 2. Energy savings and costs of single interventions: corso Vercelli.

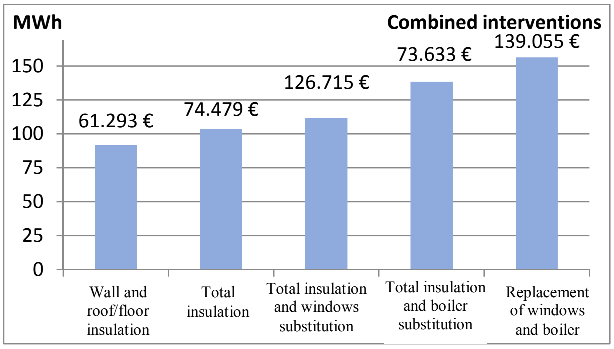


Fig. 3. Energy savings and costs of combined interventions: corso Vercelli.

*Retrofit interventions in via Sospello*

As for the previous analysis, the graphs in Figures 4 and 5 show the annual energy savings for each retrofit scenario and the relative cost of the intervention.

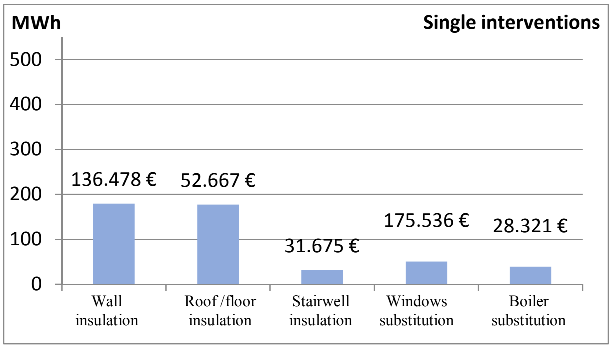


Fig. 4. Energy savings and costs of single interventions: via Sospello.

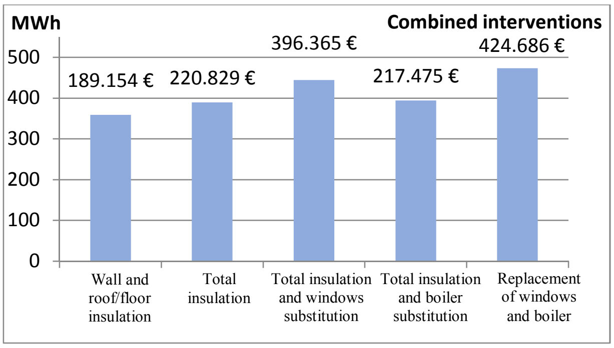


Fig. 5. Energy savings and costs of combined interventions: via Sospello.

*Cost optimal analysis*

The identification of an effective intervention from the energy point of view does not always correspond to an optimal intervention, from other points of view, for the building in question.

The optimal cost is a parameter that, considering different levels of energy efficiency and different intervention cost levels, identifies one or more scenarios that can be achieved with a view to greater energy savings with the lowest economic investment.

The global cost of each scenario is represented graphically with a diagram, on which the specific global cost, expressed in €/m$^2$, and in the abscissa the corresponding primary energy, expressed in kWh/m$^2$.

The curve that interpolates the values is called the cost curve and the area below the curve includes all the cost levels. The scenario, or scenarios, with the lower overall cost represent the optimal economic level to be considered in the improvements to be implemented on the building.

The specific global costs and the $EP_{gl}$ global energy performance index allow to obtain the graphic of the optimal cost, which identifies the most suitable improvement interventions to adopt, based on energy and economic savings. The cost optimal curve is represented by a parabolic function, but has a trend that present its minimum on the most economically and energetically efficient interventions (Figure 6).

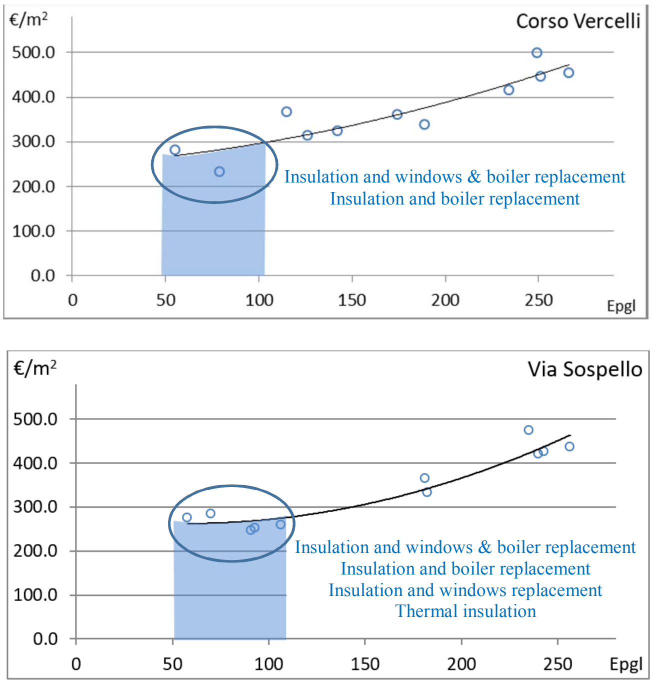


Fig. 6. Cost optimal analyses.

Considering the interventions that represent the optimal economic levels, graphs of comparison between the current state and the post-intervention state are created to highlight the percentage of annual energy savings obtainable (Figures 7-8).

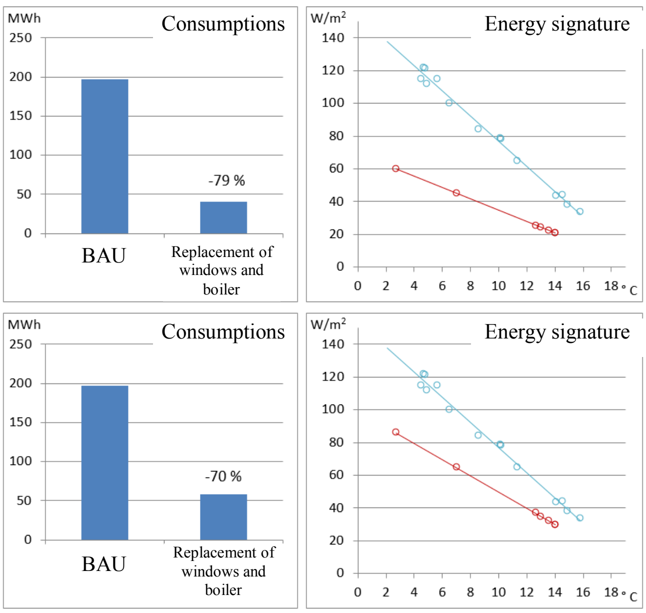


Fig. 7. Post intervention energy savings in % and variation of the building's energy signature: corso Vercelli.

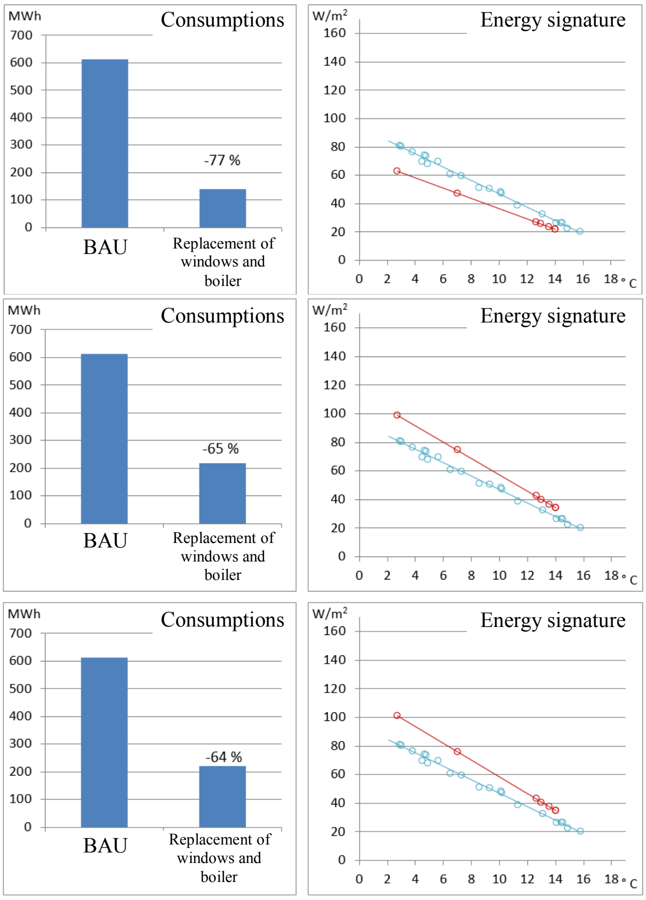


Fig. 8. Post intervention energy savings in % and variation of the building's energy signature: via Sospello.

To identify the critical buildings that need intervention, the sample was analyzed simultaneously according to consumption and according to specific consumption, through graphical analysis of the quadrant method (Figure 9).

The simulation of an intervention plan has an intervention with a constant time interval and can follow strategies that take into account:

- specific thermal consumption, intervening first on buildings that have the highest value;
- of the shortest return time, operating the interventions that fall in less time;
- the lower intervention cost, considering the cheaper interventions.

If we analyze buildings with priority interventions (buildings in quadrant I) and economic flows during a calculation period of 30 years, we obtain a graph that describes the trend:

- negative flows are represented by intervention costs, every three years (in red);
- positive flows are instead made up of economic savings on annual heating costs, deriving from energy efficiency measures (in green).

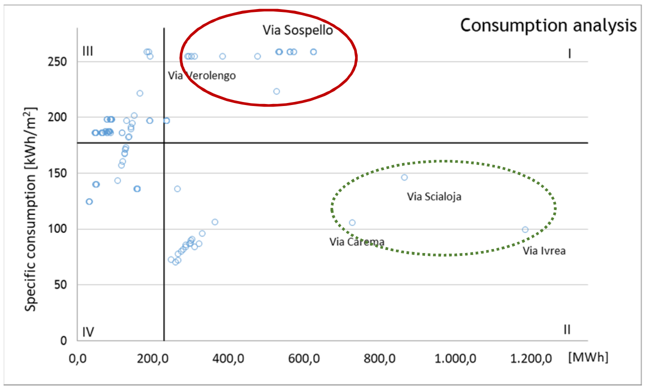


Fig. 9. Quadrant method to evaluate the priority of retrofit interventions.

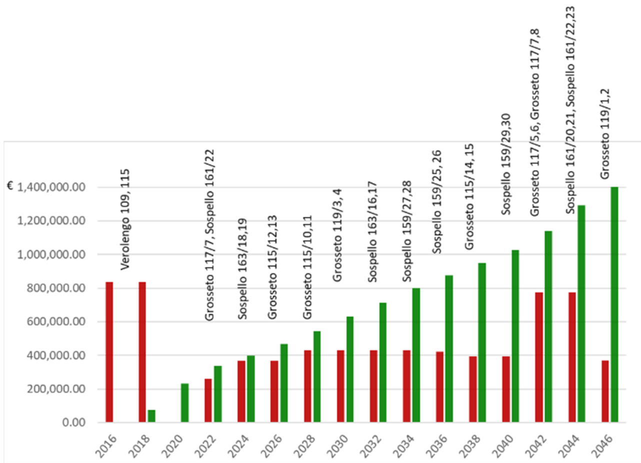


Fig. 10. Economic program of investments on the buildings stock of ATC (in red the costs of interventions; in green the economic savings on annual space heating costs without economic incentives after retrofit interventions).

From the simulations, it emerges that the economic saving generated by the interventions represents a continuous and growing cash flow over the years; in a numerous buildings stock, that need retrofit interventions, annual energy savings can be reinvested for further interventions (Figure 10). The choice on the order of priority of the interventions depends on the cost-optimal analysis. Well-planned retrofit interventions and constant monitoring, combined with a study of the lifestyle of the population that uses the buildings, represent a solid basis for sustainable development.

## III. Public Residential Buildings in Maglie (LE) - IT

### *A. Aim of the intervention program*

ARCA SUD Salento wants to keep all the results on how the household is influenced by living in high energy efficiency houses. According to UE and IEA, the behavior of the household linked to optimal use of technology and to a cultural mind change, could reach an energy gain from 5% to 20% [5].

The aim of the intervention for environmental and energy monitoring are:

1) to increase the awareness and the knowledge of people that lives in that buildings;
2) to improve the management and the maintenance of public residential buildings;
3) to raise a new social regeneration at urban scale

The actions tackled during the program of intervention are based on an information and training phase on the meaning of energy efficiency. Then a monitoring campaign of energy consumption will be carried out [6].

The following analysis is applied on public residential buildings in Maglie (LE), in Figure 11.

Fig. 11. New Buildings and their location.

## B. *Technical features of the buildings*

High performance materials by the use of wood fiber panels inside the envelope, high quality and energy performance windows, solar thermal plant, PV plant on the roof top, reuse and recover of raining water [7].

## C. *Monitoring campaign*

Monitoring testing phase is directly engaged inside apartments of the buildings by using sensors.

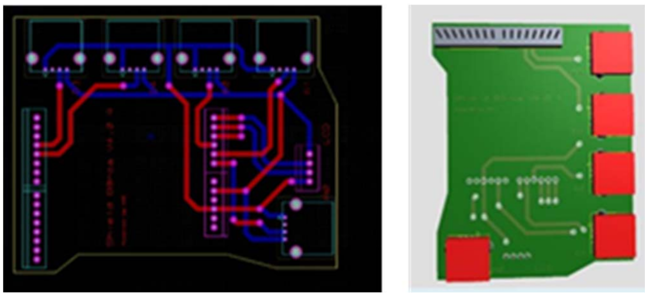

Fig. 12. Sensor board connecting Indoor Temperature & Humidity sensor

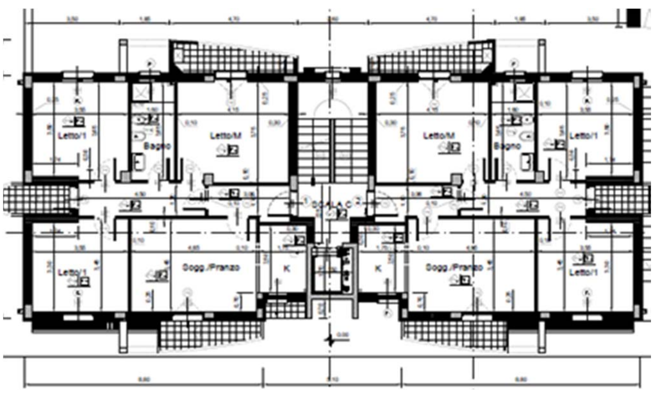

Fig. 13. Plant of the apartments and position of sensors.

The board represented in Figure 12 has been designed to guest two sensors, one for temperature and the other one for humidity, along with three analogic sensors (two by contact for transmittance by means of temperature and another one like fleximeter). To this board has been introduced the interface to a LCD display. The sensor board type B instead is equal to type a but it performs also energy consumptions by detecting the current on the wire. The monitoring results could have a positive influence on the behavior of the household and could give all energy needs amount. Collected data shall provide provisional target of maintenance and management costs during its life cycle [8].

# IV. Artificial Intelligence and Energy Efficiency

The energy efficiency of the built environment is strictly dependent on the possibility of having free supplies and renewable energy on site.

The management of renewables and in particular of solar energy, due to its random nature, is inherently complex as it is not a programmable source. The theme is the idea of an intelligent agent.

In the most common definition, Artificial Intelligence (IA) is the study of agents who receive perceptions from the environment and perform actions. Each agent implements a function that matches perceptual sequences and actions; the use of AI to manage the dynamic thermal equilibrium process signals the beginning of a new era in building management. Instead of relying on human engineers, this approach uses AI algorithms to holistically optimize all the equipment within an all-variable flow HVAC system (chillers, fans, pumps, etc.). These algorithms use the least amount of power required to maintain occupant comfort levels with control set points being automatically calculated based on real-time building load information inputs and the weather conditions prevailing outside of the building. The result is a global thermal load management strategy for a building instead of one focused on managing equipment.

A thermostat is a control element in HVAC systems which sense a temperature of an environment so that a temperature is maintained near set point. The sensor technology still changes, from 1883 when the first electric room thermostat was invented until today, but the principle of operation is always the same - two output states: on/off. However, the classic thermostat, which works as reflex automat, is an intelligent agent, IA. In artificial intelligence, AI, intelligent agent is an autonomous system that performs action without immediate presence of humans. IA is capable to carry out tasks on behalf of users, i.e. a Thermostat or a Simple reflex agent [9]

The ability to control physical devices over the internet and monitor sensor values with live feed from anywhere in the world gives us that simplicity, transparency, efficiency and security that is required in both home and industrial automation that our present system lacks [10, 11, 12].

There is a similarity between the computer program and IA. Namely, IA can be described as an abstract functional system and one of the basic problems in the field of designing agent-oriented system is finding an appropriate programming language platform. Various agent-oriented programming languages have been proposed, but no language has become mainstream yet.

Considering all the devices that have the function of regulating energy supplies to maintain indoor comfort conditions and achieving maximum possible efficiency, it is clear the potential to equip the entire system with an IA with a weather interface that includes external variations and adopts the right measures to anticipate energy management measures with significant savings.

In addition to researching the language of interaction between the control system and the device, the challenge is the sudden application to the built environment to obtain substantial savings in terms of $CO_2$ not emitted

## V. CONCLUSIONS

The analysis of energy consumption, climatic data and real use profiles of reference buildings allow to obtain models able to simulate the real operating conditions of these buildings and to be able to extend the results obtained on a larger building park, to simulate energy efficiency scenarios on a larger scale.

The energy diagnoses, the energy signatures, the quadrant method and the cost-optimal analyses illustrate the current state of art for the evaluation on the energy uses of a building stock, suggesting the most effective actions for reducing energy needs, assessing their technical and economic feasibility.

For a more sustainable development, the presented methodology could be integrated with the use of the available renewable energy technologies for the space heating, space cooling and domestic hot water uses.

The creation of an energy database is an important tool to identify the most sustainable retrofits' solutions considering a large building stock; it is important that this database has an interactive and real-time dialogue with available digital tools such as IA and its opportunities.

In future work the monitoring data will be analyzed. To date, the results of the measures are not yet available.


## ACKNOWLEDGMENT

Special thanks should be given to ATC (Agenzia Territoriale per la Casa di Torino - Territorial Agency for the House of Turin) and 'Arca Sud Salento' for the valuable support on this project.


## REFERENCES


[1] Mutani G., Casalengo M., Ramassotto A. (2018). The effect of roof-integrated solar technologies on the energy performance of public buildings. The case study of the City of Turin (IT), INTELEC® 2018 - International Telecommunications Energy Conference Proceedings, Torino(IT), October 7th-11th 2018, DOI 10.1109/INTLEC.2018.8612398.

[2] Mutani G., Mezzano S., Suffiotti V. (2014). Analisi sul consumo di energia termica per gli edifici scolastici della Provincia di Torino - Analysis on consumption of thermal energy for educational buildings in the Province of Turin", Journal: NEO EUBIOS, vol. 48, June 2014, pp 15-26, ISSN 1825-5515

[3] Delmastro C., Mutani G., Perassi S. (2016). In Use Monitoring of Public Buildings. Case Study in North Italy, International Journal of Heat and Technology, Vol. 34, Special Issue 2, October 2016, pp S266-S276, ISSN 0392-8764, DOI 10.18280/ijht.34S212

[4] Mutani G., Cornaglia M., Berto M. (2018). Improving energy sustainability for public buildings in Italian mountain communities, Heliyon, Volume 4, Issue 5, May 2018, DOI 10.1016/j.heliyon.2018.e00628.

[5] Lamacchia F.P., Perfetto G., Roccasalva G., Raimondo L. (2018). A Regional Energy Efficiency Strategy: integrated sustainable design process by adopting BIM, innovative energy solutions and dynamic energy analyses for a Hotel within the Historical Village of Sant'Angelo Le Fratte (PZ), Italy, Published in IEE CANDO EPE 2018, Budapest, Hungary, Obuda University, November 2018.

[6] Lamacchia F.P. and Perfetto G. (2016). Strategies for Energy Transition: from the national policies to technical and economic issues of a building's energy refurbishment, XIth Óbuda ENergy Conference - OENCO 2016 Zero Energy Building 2016, Óbuda University, November 8th 2016.

[7] Lamacchia F.P. and Perfetto G. (2014). Nearly Zero Energy Buildings (nZEB)'s Design in South Europe - Mediterranean Climate, European Energy Day by EU during Sustainable Energy Week, 23rd-27th June 2014. EUSEW, Workshop on Energy Related-Issues Targeted to Professional Engineers, Architects and Technicians, held in Matera, Italy, June 27th 2014.

[8] Perfetto G. (2010) BIPV Building Integration Photovoltaics Systems: Technical & Architectural Issues. The Master Builder n. 10.

[9] Radić Milica D., Petković Dejan M.. Improving Building Energy Efficiency using distribuited Artificial Intelligence, UDC 620.92:621.1.018 DOI 10.7562/SE2013.3.01.06

[10] Chatterjee A. Artificial Intelligence based IoT Automation: Controlling devices with Google and Facebook, International Research Journal of Engineering and Technology (IRJET), Volume 5, Issue 4, e-ISSN: 2395-0056, April 2018, pp 1437-1442.

[11] Martino M., Mutani G., Pastorelli M., Embedding final users in energy saving programs, INTELEC International Telecommunications Energy Conference, Osaka, Japan; 18th-22nd October 2015; Volume 2016, September 2016, ISSN 02750473, ISBN 978-147996582-3, DOI 10.1109/INTLEC.2015.7572274.

[12] Martino M., Mutani G., Pastorelli M., Miceli M.R., Smart energy users: ICT instruments for the consumer awareness, INTELEC International Telecommunications Energy Conference, Osaka, Japan, 18th-22nd October 2015; Volume 2016, September 2016, ISSN 02750473, ISBN 978-147996582-3, DOI 10.1109/INTLEC.2015.7572271.