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SMART REGENERATION OF PUBLIC UTILITY BUILDINGS

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Abstract

Energy renovation is instrumental for reaching the EU 2020 goals and smart districts are integral parts for the development of Smart Cities in the near future. At building scale, every structure runs differently and energy consumption profiles depends not only on climatic locations and technological quality of buildings, but also on occupancy levels and different types of public utility buildings (school, healthcare and homes for the elderly, office, university).

A new smart regeneration approach will represent the central focus beyond a simple technological concept of Smart Building, where the buildings should be seen as part of a larger system of energy networks and whose diffusion within the city could be linked with the concept of urban energy network and physical “nodes”.

Currently, good practices and projects aim to promote the adoption of the key technology and to identify and remove barriers to deployment. Still today, approaches to record non-residential assets in a comparable structure have not been successfully implemented yet and data are fairly poor.

An integrated approach is proficient to reveal the performance of the innovation, its technical requirement, as well as prerequisite required in terms of existing infrastructures, technical expertise, regulatory requirements and financial costs involved.

An ongoing research from the PDTA Dept. is promoting a set of exemplary of public utility buildings and a portfolio of material, industrialized systems, smart and energy equipment solutions to be used in refurbishment projects, in order to stimulate a whole vision of the smart efficient buildings and different scenarios according to the boundaries of a smart district level in Rome Municipality.

Keywords:

Interactive nodes; systemic approach; Building Energy Management Systems; set of technical solutions

1 INTRODUCTION

A large number of studies and surveys at the EU level and Eurostat data show that the existing European building stock requires urgent adaptation to current and future needs. More than 40% of the energy consumption in Europe is due to heating, ventilation and air conditioning and lighting operations within buildings. The non-residential building sector is characterized by a large number of different building types, each with specific functional, morphological and structural characteristics and parameters. In addition, the buildings differ on account of their age, the construction materials used in the corresponding periods and their technical equipment.

In the recent past some approaches have been made to reflect the current situation in terms of available information, but also in terms of finding appropriate ways to structure a non-residential building typology. Due to the poor availability of data so far, there is a great need for further research. Therefore, understanding energy use in the non-residential sector is complex as end-uses such as heating, ventilation, cooling, lighting, IT equipment and appliances vary greatly from one

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building category to another. Utility buildings, according to existing building and construction standards, have to be partly renovated (building envelope, HVAC) approximately every 20 years, and completely retrofitted approximately every 35 years [1]. A large portion of the existing utility building stock in the EU was built after the Second WW and mainly during the 60-ies and 70-ies. The renewal of this stock to meet energy standards and face climate issues – based on more efficient processes and zero or nearly zero emission – represents the next perspective for cities [2]. A sensible management of energy in these buildings can achieve major savings in the energy use (and thus, also cost) and in the reduction of greenhouse emissions.

Nowadays this is no more a vision but a concrete challenge for governments, associations, stakeholders and policy makers at all levels, and represents currently a priority for G20, World Bank and OECD agenda. According to the EPBD (Directive 2010/31/EU), all new buildings shall be nearly zero-energy buildings by the 31st of December 2020, and 2 years earlier for buildings occupied and owned by public authorities. Public authorities should set the example by renovating each year 3 % of central government buildings with insufficient energy performances, as required by the Energy Efficiency Directive (EED, 2012/27/EU). This requirement is complemented by the EED obligation for Member States to put in place longer-term renovation strategies. The implementation of the EPBD is supported by a set of European standards, dealing with the thermal performance of buildings and building components, ventilation, light and lighting, heating systems, building automation, controls and building management.

Buildings could be transformed from purely demand driven electricity consumers to interactive partners with a potential to store thermal energy [3]. The concepts of the Smart City and Smart Grid provide one of the possible solutions that could make historic, consolidated cities more efficient and sustainable, encouraging reflection, ideas, research and projects to regenerate this kind of environment with a focus on smart services [4]. A multi technology perspective, combined with energy management, will make existing energy systems of urban areas more intelligent, where decentralized energy generations and highly interconnected urban infrastructures are in place, buildings become physical interactive nodes of a larger Smart Grid which calls for an upgrade of building models in the direction of Smart Buildings, for a transition from single buildings to Smart Objects [5].

2 METHOD

The goal of this ongoing study is to design a roadmap for the retrofit of the existing public utility building stock, through the analysis of case studies of major significance in terms of building characteristics and period of construction.

According to the World Energy Outlook 2015 this study puts itself forward as a methodological approach to the widespread problems of saving energy, in which the construction sector is a fundamental element. Furthermore, Smart Cities and Communities Initiative highlights the importance of intelligent energy management systems in cities in order to achieve massive reductions of greenhouse gas emissions by 2020, and the integration of renewable energy sources as outlined in the 20-20-20 targets and in the European Energy Roadmap 2050 [6]. The Energy Roadmap 2050 considers that the high “energy efficiency potential in new and existing buildings is key” to reach a sustainable energy future in the EU, contributing significantly to the reduction of energy demand, the security of energy supply and the increase of competitiveness [7]. The Roadmap to a Resource Efficient Europe identifies the buildings among the three key sectors responsible for 70% to 80% of all environmental impacts [8]. In 2011 a survey on buildings' gross floor space in the EU27 revealed that this floor space totals approximately 30,500 sq km. 25% of this floor space are made up by non-residential buildings of which 28% consist of retail buildings, 23% of offices (the largest part are public buildings) and 28% are pure public buildings such as schools 17%, hospitals 7% and sports facilities 4%. The majority of these buildings are not owned by the national governments but by local authorities such as cities, urban communities, Lander, provinces, regions and others. When a Private property represents the ownership entity, usually these local authorities provide a subvention for their construction and maintenance [9]. The development and use of intelligent solutions based on ICT could promote efficiency, connectivity and the integration of urban infrastructures and systems at two distinct levels: building/district - district/city (IEA 2014. Energy Technology Perspectives-ETP). The City of Rome is trying to come into line, culturally and strategically, with European standards of environmental health and energy savings.

The City of Rome is divided into 19 municipalities (district), each with its own administration and management. The 2nd District (II Municipio) is one with the most relevant urban area to verify the theoretical background of the research as well as to the verification of prerequisites for regeneration strategy choice. The 2nd District evinces a high concentration of structures for basic and university education, advanced

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research and healthcare services, but also relevant buildings for public and private services and several student housings [10].

According the peculiar concentration of this type of buildings of such strategic functions makes it possible to an effective simulation of the potential effects of a series of interrelated renovation actions, both at a building scale and at local level. The District dimension, the building concentration and a good associative structure and participative characterization of this territory can finally facilitate the involvement of potential users for the growth of the smart community at a district level, increasing the benefits of the social inclusion in each renewal action on buildings.

These buildings are strategic case studies because they are representative for dimensional cubature, for their constructive characteristics and for the chronological distribution of their construction in order to conduct an analysis of substantial statistical significance. An operation carried out on building complexes with similar characteristics will allow us to direct a large part of the interventions on the entire stock, focusing immediately on the causes of the problems of degradation and inefficiency and the most effective lines of action to take.

The recognition of the consistency of the existing building stock and the subsequent selection of the buildings that are representative of general conditions make it possible to compare results and draw from them intervention guidelines that are applicable to almost all of the public utility building stock. Many energy efficient measures and technologies in retrofit processes can be developed to improve building energy performance for the lighting, window, HVAC, insulation system etc. These include replacing/converting LED, CFL and T8 tubes for lighting systems, VFD chiller system, VAV boxes, conversion of hot water boiler etc. for HVAC system, and mechanical systems such as variable flow primary/secondary systems. Smart lighting technology, which is combined smart LED lights and wisdom lamp holders, hardware and software, can bring more than 30% of energy saving in library and school buildings.

Smart, innovative, intelligent and energy-efficient buildings are concepts that have characterized recent academic literature as the recent funded projects under the 7thFP (Joint initiative EeB-PPP). In this context "Smart Buildings" can be defined as attractive for citizens and investors, as based on an alliance between economic innovation, environmental sustainability, social and cultural development and open governance, in line with the European Strategy 2020 and the EERA (European Energy Research Alliance) Joint Program Initiative on Smart cities.

According to a typology approach, the non-residential categories had been firstly defined (12 major categories each including a certain number of specific subtypes, see Table 1), and then the ones with special consideration to the main relevance in the district and/or due to their quantitative relevance were chosen among the others. An analysis of selected buildings from the research initiative shows that in some buildings, there is no distinct daily time profile for the electricity consumed for heating and cooling, whilst in other buildings, night setbacks or fixed operating times lead to very characteristic daily electricity consumption profiles for heating and cooling [11].

Category	**Function**
Education Buildings	Schools, Kindergartens, Universities
Housing for elderly	Residential buildings for the third age
Office and Administration Buildings	Banks, Insurance-buildings, Government buildings, Official buildings
Factory Buildings	Large-scale enterprises, Manufacturing buildings
Workshop Buildings	Craft, Trade
Health Buildings	Hospitals, Polyclinics
Retail and Trade Buildings	Shopping Centre, Food, Non-Food
Warehouses	Central Warehouses, Shipping Depots
Sports Halls	Private, School and College Sports, Indoor Centres
Indoor Swimm. Pools	Leisure Pools, Small Indoor Swimming Pools
Cultural Buildings	Operas, Theatres, Concert Halls, Cinemas, Exhibition Buildings
Accommodation Buildings	Hotels, detached Restaurants

Table 1: Typological categories for non-residential buildings.

Efforts to increase the rate and depth of renovation will stimulate at the same time the market uptake of highly efficient and renewable technologies and construction techniques that can deliver the expected increase of the actual energy performance of buildings.

Different new design approach for building energy management systems (e.g. Modelica) which are an object oriented description language, these methods create a simulation model of the entire building, including the technical equipment, weather and occupancy.

In this context, the typologies for the support of industrialized modular retrofit of existing types of social housing and of existing types of school buildings can serve as a model for the development of a typology handbook for

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industrialized modular retrofit of public utility buildings. Renovating public buildings in the traditional (and thus lengthy) way as used for home dwellings, would mean moving entire user populations for the time of the retrofitting process, which is hardly feasible and certainly very expensive (costs of twice moving and re-housing). For this reason, the vision is to transform the retrofitting construction sector from the current craft and resource-based construction towards an innovative, high-tech, energy efficient industrialized sector. In this project, new retrofit solutions in planning, design, technology, construction, operation and use of buildings are investigated and will be evaluated.

In a modular retrofit system concept, industrialized craftsmen, within a temperate indoor working climate, produce the new facade and roof components in factories, safely and under much better working conditions than at the construction site. The components (modules) are pre-fitted with heating, cooling and ventilation ducts and service ducts for energy and data transport and are then transported to the site and mounted on site with cranes, within a very short period (days instead of weeks / months).

3 RESULTS

The ongoing investigation led to the identification of the dimensional characteristics of a large part of buildings (mainly school buildings), information on electrical and heat consumption over the previous three years, inspections for the examination and direct verification of data, as well as providing a detailed survey and thermographic and thermos physical surveys useful for the characterisation of the building envelope in terms of thermal performance.

Energy management systems will be able to reduce the energy consumption in buildings. This enables informed decisions about the investment and operating costs, energy savings and comfort to be made at an early stage. The use of simulation based verification and optimisation methods dramatically simplifies the complex design process for trades panning energy management.

When planning a retrofit, multiple performance strategies and actions have to be considered. For this reason, a decision support methodology will be used to select the most appropriate retrofit strategy/actions. The simulation-based retrofit design process consists of three phases: (i) Analysis of existing conditions, (ii) Development of retrofit strategies/actions (+evaluation), (iii) Implementation of retrofit strategies/actions.

The specifications for the building management system will also derive from the requirements for the building behaviour defined from the user profiles and the possibilities offered by the building services technology. The states of the building services technology and their temporal development will be described using a so called state machine which responds to changing sensor values in the building and, based on parameterised functions, determines suitable regulating variables for the respective building services technology. These assignments can be changed during simulations across the year in order to optimise the defined quality criteria.

At the same time, the share of renewable energies in a grid of energy-efficient interactive Buildings, with electricity based technologies for heating and cooling (e.g. heat pumps, compression chillers, CHP plants) will contribute to relieving the electricity system and reducing the demand for electrical storages and energy conversion processes by shifting the electricity consumption for heating and cooling temporarily, using technical storages and the mass of the building to store the energy as heat or cold.

This will enable surplus solar and wind power to be used and stored with a high efficiency as heating and cooling energy. Control and energy management concepts will be necessary to ensure that buildings interact favourably with a dynamic power grid and assume a more active role as part of the energy system.

Some important activities are now going to be sufficiently anticipated, in order to ensure the overall energy performance of the buildings and the grid simulations. For these reasons, considerable work on energy performance monitoring, socio-economic studies, E-GIS and software design have to be carried out in parallel, making the renovation project not only a building construction project but also providing a holistic approach to integrate rational use of energy at a neighbourhood scale.

Actually a renovation project at district scale included an important task on the monitoring of the global performances of the buildings such as energy consumption, comfort criteria and quality of renewable energy systems. Monitoring techniques serve to assess the actual and the post-renovation performance of the buildings. Monitoring activities are classified in terms of stakeholders involved, technologies and feedbacks to actors, based on past experiences, in order to provide guidance on the choice of a particular solution.

As no actual standard exists for such large scale monitoring activity, a reflection on the methodologies is needed to highlight the strong/weak points of each of them depending on the initial objectives of the monitoring.

The program represents a unique opportunity of the demonstration project (scale of the project, strong political commitment) to innovate and enhance existing energy policies and practices at local level by: transforming project experience

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into municipal policy, regulation and best practices, thus ensuring immediate replication of the results, proposing evolution for regional and national policies and regulations, making the lessons available to others via the development of policy guidance notes thus facilitating the adoption and use of this innovation by other municipalities and urban planners.

The academic implication of the PDTA Department in the project as promotor proves to be highly beneficial. It provides credibility and legitimacy to the project actions, while taking one step forward the internal reflection regarding the leading role of the university for the development of sustainable urbanism and energy efficiency.

Last but not least, the replicability of this activity also demands a highly mechanization degree since tele-control and monitoring systems advance very quickly.

4 DISCUSSION

The greatest challenge in the renovation market is to find new solutions for an existing situation (built structure and its use). An advanced retrofit strategy aims at establishing a holistic building strategy for the entire, remaining life cycle of the building. The ultimate option in the building strategy is to construct a new building in replacement.

Since the non-residential buildings exist in all communities (e.g. there are more than 370.000 school buildings alone in the EU) the set of technical solutions would be applicable in all cities and regions throughout the EU for all those non-residential buildings that have a structure which allows modular retrofit [12].

The aim of the research program is to evaluate the implications of different critical parameters for reaching the EU2020 energy renovation goals, starting from the lack of a consolidated classification regarding different type of utility buildings such as schools, universities, healthcare and administration buildings [13]. On the other hand, the aim is to overcome also technological and knowledge barriers alongside the transition towards the smart building diffusion, as well as to share the good practices across several national and international contexts. The technology of modular retrofit of existing housing is in full development however the solutions cannot be transposed automatically to utility buildings because of several factors and barriers that impede the diffusion of the industrialized mass retrofit market for utility buildings.

5 CONCLUSIONS

An urgent need for adaptation and transfer of these industrialized technologies towards utility buildings is required and for the creation of the instruments for master planning and stakeholder involvement for adequate retrofit and use of public utility building stock.

The following steps have to be implemented in the future to create a non-residential buildings typology tool:

(i) Create, based on different available sources, database for non-residential buildings
(ii) Analysis of data to build up the typology, relevant tool
(iii) Create final building matrix for defined buildings category

By promoting and thus increasing the use of these smart technologies in the utility building renovation market, demand will rise creating more offer of automated, industrialized production, leading to prices dropping towards or even below the existing price level for traditional renovation.

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