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# European initiatives towards improving the energy efficiency in existing and historic buildings

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**Abstract**

Increasing the building sector's energy efficiency while reducing $CO_2$ emissions, constitute the main challenge that most European cities need to tackle. In Europe the building sector is responsible for nearly 40% of the total energy consumption. Considering the slow rates of constructing new buildings, a lot of attention needs to be paid to the already existing building stock. This paper presents some of the major projects carried out in Europe and their achievements regarding the integration of innovative technologies and use of different sources of renewable energy in existing buildings. Special attention has been paid to projects targeting historic buildings, since their significant cultural and historic values make their refurbishment and retrofitting process more complex.


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## 1. Introduction

The building sector is responsible for nearly 40% of the total energy consumption in Europe [1]. By combining technological and material advances and promoting the use of renewable energy sources, the European Union (EU) is attempting to reach the "20-20-20 climate goals": 20% increased use of renewables, 20% reduction in greenhouse gas emissions and 20% increase in energy efficiency, by year 2020. Currently the EU-27 counts with 160 million buildings, one-quarter of them built between 1970 and 1990; in France and the Netherlands more than 35% are from this period, reaching up to 45% in countries like Finland [2]. Also more than 40% of the residential buildings have been constructed before the 1960s in a worse way than buildings from earlier decades [3]. Considering that new buildings represent only 1-1.5% of the building stock [4], in order to achieve substantial impact in terms of energy savings and greenhouse gas (GHG) reduction, renovation and retrofitting of existing buildings become a very


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important challange. Although the large variety of existing buildings does not allow to have a unique retrofitting approach, in the EU, the Building Directive 2010/31/EU includes the major aspects of renovation of existing buildings and the technical elements and/or systems of retrofitting [1].
An important group within the existing stock is formed by historic and heritage buildings. This building group is mainly characterized by bioclimatic design, durable construction materials and resilient architecture that is usually needs to be preserved in order to maintain the cultural values. It has been estimated that in the EU-27, the buildings stock built before 1919 represents 14.3% of the total [5]. Therefore, improving the energy efficiency of this group of buildings represents an important challenge that need the attention of policy makers, researchers and other actors.
The paper presents the objectives and results of different initiatives that aim at improving the energy efficiency of historic buildings, throughout Europe. In some cases, projects including existing, but not necessarily historic buildings have also been included due to their importance and/or use of state of the art technologies/RES.

## 2. Methods

This study is based on information collected from several projects carried out throughout European countries, with different climate and cultural conditions, all of them having in common the use of innovative technological solutions for increasing the energy efficiency and use of renewable energy sources (RES) in existing and with historic value buildings. The main information regarding each project will be described, considering partners, energy saving data, RES contribution and $CO_2$ emission reduction.
It is important to mention that in this paper, historic buildings are considered to be the buildings important from a History point of view. To be classified as historic, buildings must have sufficient age, a high degree of physical integrity and historical significance, attributes described in detail by [3]. In many cases the protection measures included in heritage laws exceed the limits of the buildings' identity conservation, making some of the innovative refurbishment and retrofitting techniques unfeasible for this group.

## 3. Projects description

NEW4OLD

The aim of the project was to refurbish and retrofit a 140 years old building (the Renewable Energy House) located in Brussels, as well as the creation of a network of light-house Renewable Energy Houses that would serve as focal points for sustainable energy policy discussion in different EU Member States, contributing in this way to the commercialization of RES among others [6]. It is considered to be a perfect showcase for the integration of innovative renewable energy technologies in old heritage buildings. Two main objectives were pursued: reduction of the energy demand for HVAC with 50% and covering the entire demand with 100% RES. The project finalized in 2010 and counted with the following partners: European Renewable Energy Council, Global Renewable Energy and Conservation Trust, 3E Engineering, Institute for Sustainable Technologies (Austria), the Institute for Thermodynamics and Thermal Engineering (Stuttgart, Germany), National University of Ireland and the National and Kapodistrian University of Athens, Greece.
Some of the energy efficiency measures include insulation of façade and roof: façade with 15 cm of Expanded Polystyrene; roof with 15 cm mineral wool; windows were replaced with new ones, with k-value 1.5 W/m$^2$K; sun protective windows for roof glazing with a solar factor of g=0.35. The efficiency

of the mechanical ventilation system was improved by using a heat recovery wheel (85% efficiency) and ventilation system controls (occupancy and $CO_2$ sensors). T5 fluorescent lamps were installed with electronic ballasts and highly efficient reflectors. The renewable energy technologies applied, include a pellet heating system (2 biomass wood boilers, 85kW + 15 kW to be combined with a 3kW Stirling engine). Geothermal heating and cooling systems were installed: 4 geothermal energy loops (115m deep) exploited by a 24 kW ground source heart pump in winter and used as a cooling tower by a thermally driven cooling machine in summer. Advanced monitoring system was included in order to allow remote actions. Electricity was produced using PV (3 kWp); 7 mono-crystalline modules were installed on the roof; 6 thin-film modules on the windows; 3 polycrystalline modules; 4 thin-film modules; and 3 mono-crystalline modules including an innovative roof-mounting system.

EFFESUS

The project investigates the energy efficiency of European historic urban districts and developing technologies and systems for its improvement [7]. Historic urban districts are defined as a significant group of old buildings built before 1945 and representative of the period of their construction or history and not necessarily protected by heritage legislation. Several cities from Spain, Sweden, Budapest, Turkey, Italy, Germany and UK are participating in the project in order to represent different European areas, buildings from different periods and built with different materials, municipalities' commitment to support case studies and different levels of heritage protection. The project is planned to finalize in 2016. Seven study cases are included in the project, where three types of interventions will be carried out:
**urban** (implementation of new and existing technologies at urban district level, such as smart grids, PV and energy storage); **building** (application of new and existing products and systems at building level, as for instance, insulating mortars and coatings, aerogel insulation, traditional passive solutions, improved indoor climate control systems, and secondary glazing/windows); and **study**, including the analysis of existing municipal documents and data to prepare a building stock model and validate the DSS software tool.

3ENCULT

3ENCULT finalized in March 2014, and had as the main objective to bridge the gap between conservation of historic buildings and climate protection in an interdisciplinary way. Eight case studies were included in the project with the aim of demonstrating and verifying solutions that are applicable to the majority of European built heritage in urban areas [8]. Based on the developed solutions and proposed approach, 3ENCULT provided some innovative technologies and materials for refurbishment of buildings. All interventions took into account the genuine aspects of these buildings and maintained their heritage features. Thus, some of the most noteworthy solutions and developed products are: new or enhanced products (**interior insulation, windows, lighting, ventilation and solar integration**), implementation of **RES** (PV cells and biomass boilers), development of energy efficient heritage compatible window and **wireless monitoring** for a control strategy, such as; room temperature and occupancy pattern for the improvement of the comfort of the cooling systems, redistribution of the lighting systems with a switch off control strategy for empty rooms. Also a handbook with design guidelines and a pool of technical solutions for planners, guides for & involvement of local governments was developed.

RENERPATH

RENERPATH is an energy efficiency research project for historic buildings. The project aims to develop a new methodology to evaluate buildings' energy efficiency through non-invasive techniques and for decision support processes regarding their refurbishment [9]. The main objectives of the project are: analyze energy needs in heritage buildings; study and develop materials used in energy refurbishment (Solar Tyles, Ceramic masonry block); identify actions to improve the energy demand; and assess the starting point of a new method to certificate the heritage buildings based on different energy aspects. The techniques to evaluate the energy efficiency in the heritage buildings can be summarized as: sketch up modelling, laser scanning modelling, photographic modelling and thermography modelling.

RESSEEPE

The project started in July 2013, and aims at technically advance, adapt, demonstrate and assess a number of innovative retrofit technologies, achieving at least 50% reductions in the energy consumption [10]. Some of the innovative technologies and materials that will be integrated in the retrofitting process are: **envelope retrofitting**: ventilated facades, aerogel-based Superinsulating mortar, wooden insulating wall panel and VIP panel; **integration of RES**: PV energy and thermal collectors; **energy storage systems**: thermal storage and PCMs; **nanotechnologies and smart materials**: EC/PV windows; **ICT**: strategies at building and district level; intelligent building controls: HVAC systems. The previously mentioned technologies will be validated in different demo-sites in UK, Sweden and Spain. Some of the countries involved in the project are: Germany, France, Switzerland, Spain, Slovenia, UK, Sweden, Italy, Greece and Austria. The estimated impact targeted by the project includes 60% reduction of $CO_2$ emissions (48.15 kg/m$^2$ year and 63% reduction of energy consumption (66 kWh/m$^2$ year), with expected return on investment of 7.6 years. One of the project's work packages includes the development of a new thermal energy storage systems based on conductive or isolating materials in combination with phase change materials (PCM). PCM latent hear cool energy storage from using water chillers, will be used without the need for any modifications [11].

LIFE-INSU-SHELL

The project's main goal is the development of new elements for façades construction thus reducing partly the 5% of the total annual $CO_2$ emissions worldwide generated by the production of cement. The new elements are based on the technology of textile reinforced concrete (TRC), where the steel reinforcement is replaced with alkali-resistant fiberglass.
The new technology allows the reduction in use of concrete with 70%; $CO_2$ emission reduction with 50% (approx. 80kg/m$^2$) if compared to similar elements of ferroconcrete; heating cost reduction by integration of a layer of thermal insulation and improvement of the element's energy balance; additional energy and fuel costs savings due to the transportation and installation by the lower weight of the material in comparison to conventional ferroconcrete applications; the energy footprint for the façade system will decrease with 45% (from 1823 MJ/m$^2$ to 1026 MJ/m$^2$) [12].
The technology was implemented in Aachen (Germany), where with a total area of 1200 m$^2$, the construction project saved approximately 420 ton of $CO_2$ compared to a conventional reinforced concrete. The dissemination of the project's results has raised the interest of other stakeholders, and there is already a neighbouring building planned to have a similar façade.

PIME's

PIME'S is one of the many projects within the EU CONCERTO initiative, which demonstrates implemented examples of innovative technologies that are ready for application; the use of renewable energy sources for cities; energy efficiency measures; sustainable building and district development, among others. The PIME'S started in 2012, and its main activities include research and technological development, demonstration and dissemination in order to maximize the effect of the measures undertaken. The project goals are the implementation of large scale solar thermal and associated heat storage; the application of intelligent energy management through microgrids and the development of new Energy Service Company models by increased ownership of the inhabitants. The involved countries are Spain, Norway and Hungary. Some of the technologies/measures that will be tested are: installation of heat pumps that will use sewage water as a heat and cool source; glazing windows; double skin façade; green roofs; microgrid that will control the supply and demand side and thereby the efficient use of energy sources; building integrated PV; energy storage systems; and others [13].

Table 1 summarizes the main technologies and materials that have contributed to these projects being among the most significant ones in the building renovation area.

Table 1. Main technologies and materials used in the discussed projects

| Project title | Technologies | Materials |
|---|---|---|
| **NEW4OLD** | Efficient mechanical ventilation system; Highly efficient lighting systems<br><br>**RES:** Pellet heating system; Solar thermal system and absorption cooling system; Geothermal heating and cooling system; Electricity production: PV panels; Advanced monitoring system | **Insulation of the façade and roof:**<br>Façade: 15 cm of EPS (Expanded Polystyrene); Roof: 15 cm of mineral wool; Replace of the windows with new windows with k-value 1,5 W/m2K; Addition of highly efficient windows in front of the existing single glazed windows resulting in a triple-glazing (total k-value 1,3 W/m2K); Sun protective windows for roof glazing with a solar factor of g = 0,35 |
| **EFESSUS** | GIS (Geographic Information System); Window upgrade measures and integration of intelligent indoor climate solutions | New thermal insulating mortars for use as plaster and render; Aerogel insulation products for use in cavities behind existing wall finishes; Radiant reflective coatings for exterior application |
| **3ENCULT** | Interior insulation; Windows; Lighting (high efficiency lighting solutions); Ventilation (a wall integrated ventilation and heat recovery system); Wireless sensor network for monitoring<br><br>**RES:** Solar Thermal; PV | New models of Foam glass and aerogel panels for insulation (High performance capillary active internal insulation); Wooden Frames (a new heritage compatible highly efficient window); Thermal insulation mortars; Windows adapted to the historic buildings features Solar glazing windows |
| **RENERPATH** | Sketch Up modelling; Laser scanning Modelling; Photographic Modelling; Thermographic Modelling | Solar Tiles; Ceramic masonry block |
| **RESSEPE** | Integration of RES: PV Energy, Thermal Collectors; Energy Storage Systems: Thermal storage and Phase Change Material (PCMs); Nanotechnologies and smart materials: EC/PV Windows; ICT: Strategies at building and district level; Intelligent Building Controls: HVAC systems. | Envelope Retrofitting: Ventilated Facades, Aerogel-based<br><br>Super insulating mortar, Wooden Insulating Wall Panel and VIP Panel. |
| **LIFE-INSU-SHELL** | Textile Reinforced Concrete (TRC) | Insulating foam core (PUR) 150 mm; Textile reinforcement (AR-glass, 2x1200/ 1200 tex (0°/90°), 2D-warp-knit fabric ) |
| **PIME's** | High efficiency solar thermal systems; Energy storage system; Natural ventilation; Building Integrated Photovoltaic; Poly-generation | Lumber rooms under roofing; Low transmittance enclosure; High insulation thickness; Low emissivity glazing; Air tight, thermal break window frames |

## 4. Conclusions

Historic districts play an important role in the European cities: firstly, they are the trademark of their cities, contributing with great economic and tourist values. Secondly, and the reason they were included in this paper, they constitute a large portion of the cities' total energy demand. Therefore, large amount of $CO_2$ emissions can be avoided, if the energy efficiency of historic buildings is increased. This constitutes a great challenge, due to the specific characteristics of these historic districts. When it comes to their structure, they were not constructed considering the currently available technologies used for higher energy efficiency. The narrow streets around the buildings, for example, could be an obstacle to implement a district heating system. On the other hand, the heritage laws for protection play an important role when the interventions involve the original appearance of the building in order to correct the energy losses or implement some RES systems, for example, on the roofs. Although some of these interventions can seem aggressive for the historic quarter, the fact is that throughout the years the historic buildings have been adapted to new innovative technologies in each moment, as for instance, the introduction of electricity, telecommunications, running water, centralized heating (and cooling), etc. In this sense, if those changes had not been allowed, currently most of the historic buildings would just be vestiges of the past. The paper presents several projects where innovative ideas and technologies have been used to improve the efficiency of existing and historic buildings in several European countries. Some of the solutions include more energy efficient construction materials, such as textile reinforced concrete; intelligent energy management through microgrids; large scale solar thermal; heat storage; and others. However, one of the main challenges that still remains is that despite the availability of all these solutions, the investments needed are relatively high. Stricter policies and directives need to be created as well as local and national governments need to be involved and engaged in putting more effort towards future investments.

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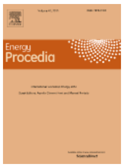


**Biography**

Dr. Iana Vassileva holds a PhD in energy efficiency in buildings, with special focus on consumers' behavior change and awareness regarding energy consumption. She is currently working in several projects involving planning of energy efficient cities and energy efficiency in industrial processes among others.