

Energetic revitalization of existing buildings

Abstract

This article applies to the problem of energetic efficiency of the buildings and is especially focused on the oldest ones. Growing costs of energy, technological barriers, as well as great costs of renovation are the factors that cause the problems in implementation of efficient energetic solutions. It happens, that for above-mentioned reasons the oldest buildings lose their utility values and often become ruins.

The aim of this paper is to pay the attention to the problem of traditional buildings' revitalization, through increasing their energy efficiency. This problem was noticed in many countries and solving it became in some countries (i.ex. Germany) a rapidly growing branch of the building sector. Unfortunately in Poland this subject is still unpopular, however there are some interesting examples of monumental buildings' revitalization, that were based on increased energetic efficiency.

The article presents the types of renewable energy sources, legal acts and statistical data that relates to the subject of this work. The possibilities of traditional buildings' revitalization using modern technologies were also presented.

To extend the terminology relating to existing buildings' modernization through increasing their energy efficiency there was a new term of energetic revitalization introduced to this work. Authors hopes that it will allow to pay more attention to often ignored problem of energy efficiency of the oldest buildings, and in long term to improving the technical condition of existing buildings and rising their utility values.

Keywords: energetic revitalization, renewable energy, traditional architecture, vernacular architecture

1. Introduction

It seems that in our times it's impossible to function without energy, especially the electric one. This simple truth concerns everybody: people, companies and even whole countries. The increasing Earth population (in 2025 our planet will be inhabited by more than 8 billion people)¹, as well as rapid changes of developing countries (which began at the turn of 20th century) are the main reasons for growing requirement for fossil fuels and unfortunately the increasing pollution of natural environment. Extensive emissions of greenhouse gases and the reduction of woodlands at the expense of areas occupied by human settlements and farmlands led to the climate changes of the entire planet. So the humanity dependency on energy is the destructive factor, that in the long run can

¹ source: <http://www.census.gov/population/international/data/idb/region.php?N=%20Results%20&T=13&A=aggregate&RT=0&Y=2012&R=1&C=> [access: 11.02.2016]

lead to disaster. On the other hand, demand for energy has become a driving force of civilization changes and economic development. The economic and social transformation, as well as the growth of environmental awareness have resulted in the search for alternative sources of energy and with the passing time in increasing their share of global energy consumption.

For several years, efforts have been undertaken to counteract the effects of global warming and to encourage more investments in renewable energy sources. However, according to the Directive 2002/91/EC of the European Parliament and of the Council on the energy performance of buildings *“the residential and tertiary sector, the major part of which is buildings, accounts for more than 40 % of final energy consumption in the Community and is expanding”* [3]. The attention that is given lately to energetic problems of the construction sector led to popularization of passive buildings², energy-saving buildings, low energy houses and even so-called zero-energy building which are self-sufficient in terms of energy production and consumption.

Unfortunately, the problem of energy-efficient buildings in Poland still seems to be secondary. Statistical studies performed in Poland show, that the main criterion for buying a dwelling is price of 1 m²³. Nevertheless, the increasing environmental awareness, as well as the introduction of programs for co-financing the construction and reconstruction of buildings using renewable energy sources resulted in erection more passive and low-energy buildings. In recent years several zero-energy buildings were constructed. Unfortunately still in most cases new buildings are constructed in the cheapest way, just to meet the basic requirements of Polish regulation on the technical conditions that should be met by buildings and their location [10].

The problem of energy efficiency is even more important in case of existing buildings, especially historic ones, that due to rising energy costs, technological barriers, conservation restrictions and the high costs of modernization lose the chance to gain efficient energy solutions. Many times the eldest buildings lose their functionality and often turn to ruin. But does it have to be this way? Do the problems with energy efficiency of the oldest buildings must mean their end?

The aim of this elaboration is to draw attention to the problem of revitalization of traditional buildings by improving their energy efficiency. This problem was already noticed all over the world and solving it became in some countries (i.e. Germany) a rapidly growing branch of the building sector. Unfortunately in Poland this topic is still a niche, though there are some interesting examples of revitalization of historic buildings based on increasing their energy efficiency. In this work authors will present a legal status and statistical data of described problems. The possibilities for revitalization of traditional buildings using modern technologies will be also presented.

² According to Wolfgang Feist PhD. definition passive house is defined as *“a building of extremely small heating energy demand (15 kWh/m²/year), where the thermal comfort is ensured by passive heat source (residents, electrical equipment, solar heat, heat recovered from the ventilation), and reheating the air ventilating the building that therefor need no active heating”*. [Wnuk 2006]

³ A study on preferences and satisfaction with purchasing the dwelling, that was performed in 2014 by TNS Polska for otodom.pl on a group of 510 residents of the five biggest Polish cities shows, that the most important criterion for most people searching the apartment was the price (68% of respondents).

For the purpose of this elaboration and in order to expand the nomenclature for the modernization of existing buildings by improving their energy efficiency a new definition of energetic revitalization was introduced. In the authors' opinion it can make people pay more attention to the often overlooked issue of the oldest buildings' energy efficiency.

2. Passive and renewable energy sources in traditional buildings – legal acts

2.1. European Union regulations

A problem of energy efficiency and renewable energy sources has been a subject of work of the EU institutions for more than ten years. In this field particularly important are directives of European Parliament and of the Council, that set a framework for action on energy efficiency in the building sector, as well as for unification of laws, regulations and administrative provisions in the Member States.

The main objective of Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings was to reduce carbon dioxide emissions and to improve the energy efficiency of buildings. It also sets guidelines for the preparation of the energy performance of buildings and application of minimum requirements on the energy performance of new and existing buildings. The Directive also introduced definitions of building, energy performance of the building, air-conditioning system, energy performance certificate of the building, etc. Some of the provisions refer to the renovation of existing buildings and suggest improving their energy performance in order to meet minimum requirements in so far as this is technically, functionally and economically feasible. The Directive leaves Member States a choice of minimum energy performance requirements, but may be set either for the renovated building as a whole or for their components or individual systems.

In 2010, the Directive 2010/31/EU of 19 May 2010 on the energy performance of the buildings [4] amended the above mentioned act. What's most important, this document approves the mandatory target of at least 20% share of energy from renewable sources by 2020. In comparison with the earlier directive revised requirements also apply to the introduction of National Plans for increasing the number of nearly zero-energy buildings, introduction of energy certification of buildings or building units, regular inspection of heating and air-conditioning systems in buildings, and independent control systems for energy performance certificates and inspection reports. The directive contains new definitions of nearly zero-energy building, energy from renewable sources, district heating or cooling, and the major renovation. What's most interesting according to provisions of the Article 9 of the directive Member States shall ensure that by 31 December 2020 all new buildings are nearly zero-energy buildings and after 31 December 2018, new buildings occupied and owned by public authorities are nearly zero-energy buildings.

Referring to existing buildings Directive states that *'major renovations of such buildings, regardless of their size, provide an opportunity to take cost-effective measures to enhance energy performance. For reasons of cost-effectiveness, it should be possible to limit the minimum energy performance*

requirements to the renovated parts that are most relevant for the energy performance of the building’.

2.2. Polish regulations

Polish Construction Law of 7 July 1994 [2] is the basic legal act concerning the construction. It states that every building and its equipment should be (considering the expected period of use) designed and built in a way that ensures adequate energy performance and the rationalization of energy use. In case of new and existing buildings under reconstruction which are used by public authorities, it is recommended to install devices that are using energy generated from renewable sources and technologies that allow to construct buildings of high energy efficiency. Moreover, in case of works involving the thermal insulation of the building that cover over 25% of its envelope it is required to fulfil the minimum requirements for the energy efficiency and thermal protection.

More detailed provisions concerning renewable energy sources and improving energy efficiency of buildings are included in Regulation of the Minister of Infrastructure of 12 April 2002 on the technical conditions that should be met by buildings and their location [10], and particularly in the section 10 called “Energy saving and thermal insulation”. The provisions of the Act clarify, that the building and its heating system, ventilation, air-conditioning, hot water system, and in case of public, collective residential, production and storage building also built-in lighting system should be designed and constructed in the way that enables fulfilling the minimum requirements for EP-factor value⁴, thermal insulation of building envelope and window area. Regulation contains also a formula for calculating the maximum value of the EP-factor, and states that the building should be designed and constructed in a way that reduces the risk of its overheating in the summer. Appendix 2 of above mentioned Act which is entitled “Requirements of thermal insulation and other requirements related to energy savings” contains the maximum values of U-factor (overall heat transfer coefficient) which tightening took place on 1 January 2014 and further changes will be followed by 1 January 2017 and 1 January 2021. Appendix also contains the formula for the maximum area of windows and glass partitions, requirements for surface condensation, airtightness and air penetration.

On August 29, 2014 an Act on energy performance of buildings [1] was introduced in Poland. It defines a specific demands for preparation of energy performance certificates, inspection of the heating and air-conditioning systems in buildings and the principles of drawing a central register of energy performance of buildings. Unfortunately, according to art. 3, p. 4, demands of above mentioned Act does not apply to historic buildings, places of worship and partially to farms, factories and residential buildings. So the range of exclusions is significant which means, that in practice the above mentioned buildings do not have to meet the increasing requirements for energy efficiency. In consequence it results in the

⁴ EP-factor sets the annual calculation demand for non-renewable primary energy for heating, ventilation, cooling and warming the domestic water and for built-in lighting, in case of public, collective residential, production and storage buildings.

higher global energy consumption in Poland and especially in Polish building sector.

The big advantage of the above mentioned act is the demand for evolving the National Plan for increasing the number of buildings of low energy consumption [7]. The main objective of this document which is currently still under preparation is the gradual change of building regulations relating to energy saving and promotion of educational, scientific and research projects, as well as trial projects related to renewable energy sources. The draft of the Plan contains the definition of the building of low energy consumption⁵, data on the number and age of the buildings in 2011⁶, data on production and consumption of renewable energy in Poland (2008-2011), forecasts of the potential of renewable energy sources by 2020 and recommendations of the International Energy Agency on the structure of energy consumption in residential buildings. The draft also contains a summary of changes implemented to the building regulations, that relates to the energy saving and environmental protection, as well as detailed information on programs promoting energy efficiency in individual Polish regions as part of Regional Operational Programmes.

The Regulation of the Minister of Infrastructure and Economic Development of 3 June 2014 on the methodology of calculating the energy performance of the building and dwelling or part of the building constituting an independent technical-utility part and the preparation and design of energy performance certificates [9] complements the demands of the Act on energy performance of buildings. Along with the method of calculation of the energy performance this document also contains definitions of renewable and non-renewable primary energy, final energy, auxiliary final energy and heat gains.

3. Energy consumption in building sector – statistics

Directive 2002/91/EC of the European Parliament and of the Council of 16 December 2002 on the energy performance of buildings consists the information, that *“the residential and tertiary sector, the major part of which is buildings, accounts for more than 40% of final energy consumption in the Community and is expanding”*. The Directive 2010/31/EU of 19 May 2010 which is the amendment of above mentioned act indicates that *„buildings account for 40% of total energy consumption in the Union. The sector is expanding, which is bound to increase its energy consumption”*.

Very interesting statistics are contained in the draft of National Plan for increasing the number of buildings of low energy consumption. It shows that in 2013 energy from renewable sources accounted for 7.22% of the global production and its share was increasing. Data on energy demand show, that households are among the biggest consumers of energy in Poland (about 20% of global energy consumption). Moreover the structure of energy consumption in Polish residential

⁵ It is a building, that applies to the technical requirements of energy saving and thermal insulation mentioned in art. 7, item. 1, p.1 of Construction Law of 7 July 1994 (and in particular section 10), as well as in Appendix 2 to the Regulation of the Minister of Infrastructure of 12 April 2002 on the technical conditions that should be met by buildings and their location, which will be compulsory from the 1 January 2021, and for buildings occupied, or owned by public authorities – from 1 January 2019.

⁶ Data from National Census of Population and Housing in 2011.

buildings is unfavourable (72% of the energy is consumed by heating and ventilation systems, 15% by domestic hot water systems, and 13% by house devices, lighting and cooking) and it differs from the structure in most Member States of European Union. It is also far from the structure of energy consumption recommended by the International Energy Agency (35% of energy should be consumed by heating and ventilation systems, 27% by hot water systems, and 38% by cooking and electrical appliances). At the time of the examination 49.1% of domestic households were still using solid fuel heating appliances (19.2% of them were using the most redundant heating appliances – stoves, mostly tiled ones). 41.5% of households were heated by the heating network, 9.8% by gas boilers and 5.4% by electric energy (usually as auxiliary heat).

Data on existing buildings⁷ confirmed, that in 2011 there were 5.54 million buildings and 12.96 million dwellings in Poland. There were approx. 404.7 thousand of the oldest buildings (built before 1918). It gives 7.3% of the total. 803.9 thousand buildings were erected between 1918 and 1944 (14.3% of total). This shows that old buildings are a significant part of the total, so they are worth paying attention to the problem of their energy efficiency. When it comes to existing buildings the most interesting data concerns the relationship between the age of the building in Poland and its energy consumption⁸. The examination shows that the energy consumption strictly depends on the age of the building and is most unfavourable in the oldest buildings and most favourable in the newest ones. The oldest buildings erected before 1918 showed approx. 3 times as big annual energy demand as buildings constructed between 2003 and 2011. It shows a very big problem with implementation of the modern energy requirements to the oldest buildings.

4. National programs of supporting implementation of renewable energy sources in Poland

There is a wide range of programs and initiatives in Poland currently, that support financial activities in the field of environment and water management, as well as promote the principles of sustainable development. Only a part of these initiatives are funded from the state budget, other are financed by environmental protection funds, EU funds, funds of local authorities, commercial banks, countries not belonging to the European Union, etc. Many programs are financed by the National Fund for Environmental Protection and Water Management. In 2015-2020 it will be running the priority programs in four key categories: protection and sustainable management of water resources, rational waste management and protection of soil surface, protection of biodiversity and ecosystem services, as well as protection of the air. The following initiatives are implemented within the last category:

- a program of improvement the air quality,

⁷ data from the publication: *Zamieszkané Budynki. Narodowy Spis Powszechny Ludności i Mieszkań 2011*, GUS, Warsaw 2013,

⁸ data from the joint publication edited by S. Mańkowski and E. Szczechowiak: *Strategiczny projekt badawczy pt. Zintegrowany system zmniejszenia eksploatacyjnej energochłonności budynków*. Volume I, Part A: „Uwarunkowania przekształceń w budownictwie”, Warsaw-Poznań 2013.

- 'Lemur' program, which aims to reduce energy consumption and reduce or eliminate CO2 emissions in relation to design and construction of new energy-efficient public buildings and collective residential buildings,
- a program of subsidies for energy-efficient houses which aims to prepare investors, designers, manufacturers of building materials and contractors to the requirements of the Directive of the European Parliament and of the Council 2010/31/EU of 19 May 2010,
- a program for energy efficiency investments in small and medium-sized companies, whose task is to reduce energy consumption,
- 'Stork' program which aims to reduce or eliminate CO2 emissions by increasing the energy production from plants using renewable energy sources,
- 'Prosumer' program which aims to support scattered renewable energy sources, that is done by subsidizing the purchase and installation of small plants or micro installations of renewable energy sources to produce electricity or heat and electricity for individuals and housing communities.

The Fund's activity resulted until 2014 in completing construction of 39 single-family houses in the standard NF40, dozens of houses in the standard NF15 and 10 positively verified housing estates and multi-family buildings. It also resulted in completion of 64.7 thousand plants for the production of energy from renewable sources. The wide range of these initiatives enables co-financing the projects for both new and existing buildings.

An interesting initiative to improve the energy efficiency of existing buildings is the Green Investment Scheme – GIS, which is implemented as a derivative mechanism of emissions trading. It enables co-financing the investments for reducing energy consumption of existing buildings and among others for thermal modernization of public buildings (implementation of the thermal insulation, replacement of old windows, external doors and indoor lighting, reconstruction of heating systems, replacement of HVAC systems, preparation of project documentation, implementation of renewable energy technologies and energy management systems).

Similar goals are pursued by the programs of EU Cohesion Fund and especially the Operational Programme Infrastructure and Environment which in 2014-2023 has a budget of 271 million EUR.

Other funds to finance the thermal modernization of public buildings, replacing the heat sources are the Norwegian Financial Mechanism and the EEA Financial Mechanism, as well as Swiss-Polish Cooperation Programme.

Above mentioned programs of financing the projects of environmental protection and promotion of the principles of sustainable developments enabled the constant raising of share of renewable energy sources in global energy production in Poland.

5. Energetic revitalization – definition

In order to expand the nomenclature for the modernization of existing buildings by improving their energy efficiency a new concept of **energetic revitalization** was introduced to this elaboration. It means a revitalization of existing building which has lost all or part of its usability in the way that increases its energy efficiency and simultaneously preserves its aesthetic and cultural values.

In authors opinion introduction of above mentioned definition can contribute in paying more attention to the often overlooked problem of energy efficiency of the oldest buildings and in the long run can lead to the improvement of their technical condition and their usability.

At the same time practical use of energetic revitalization can help to raise a share of using the renewable energy in traditional buildings and finally to achieve the demand of 20% share of renewable energy sources in Poland by 2020. This could be of course one of the aspects of the implementation of criterion 20%.

The following mathematic definition of energetic revitalization is proposed by authors of this elaboration:

$$\delta_{budynku} = \frac{\sum_{i=1}^n P_i}{P_{zainst.}}$$

where:

$\delta_{budynku}$ – traditional building's energetic revitalization index,

P_i – renewable energy source plant of a nominal power P_i [W],

$P_{zainst.}$ – nominal power of energy consumption in traditional buildings (specified in building permission or in statement of connection⁹).

Energetic revitalization index could be also specified as percentages:

$$\delta_{budynku\%} = \frac{\sum_{i=1}^n P_i}{100 \cdot P_{zainst.}} [\%].$$

Simultaneously it is possible to extend the examination area of energetic revitalization index i.ex. to the metropolitan area, or the whole region. Its mathematic definition would be as follows:

$$\delta_{teryt.} = \sum_{k=1}^z \delta_{budynku,k}$$

where:

$\delta_{teryt.}$ – traditional building's energetic revitalization index specified for a particular area (i.ex. metropolitan area), and defined as a sum of individual buildings' energetic revitalization index.¹⁰

Simultaneously it is possible to introduce the energetic revitalization index of analyzed area specified as percentages:

$$\delta_{teryt.\%} = \sum_{k=1}^z (\delta_{budynku,k} / 100) [\%].$$

⁹ If it's unable to determine the nominal power it could be defined in accordance to valid building's volume guidelines.

¹⁰ According to the definition, the energetic revitalization index specified for a particular area will affect buildings with introduced energetic revitalization plans only (the value of energetic revitalization index must be different than zero).

The analysis made by authors show, that right now the energetic revitalization index specified in the region of Wielkopolska for individual communities varies from 0 to about 1%. These data indicate the enormous potential of energetic revitalization.

6. Possibilities of traditional buildings' energetic revitalization

According to data presented in previous chapters, the implementation of renewable energy sources in the building sector is progressing and seems to be constant and irreversible.

Education and investment incentives result in raising environmental awareness of Polish society, but also in more popular low-energy solutions in buildings' construction. Unfortunately, the amount of Polish programs co-financing is relatively low (especially when comparing it to other Western European countries). It makes the implementation of environmental project in the building sector is slow. Besides, more restrictive energy efficiency requirements introduced in last years affect new and reconstructed buildings only. That's why many existing buildings do not have to meet the requirements of thermal insulation and air tightness, not to mention the use of renewable energy sources. A question arises, if it is possible to increase the energy efficiency of the oldest buildings and then, is it possible to preserve their aesthetic and cultural values?

Despite the frequent problems with thermal insulation and dampproofing, traditional buildings have several advantages that could be useful in the process of energetic revitalization. Such buildings usually have thick walls, so the implementation of even thin insulation can significantly reduce heat loss. Unfortunately this problem is complex, since external walls' thickness and their properties can vary even within the same building. It makes each design process of thermal modernization should be preceded by accurate calculations. This may allow to learn the properties of partition but also to eliminate a problem of improperly designed insulation (which may occur in condensation of water vapour, or in humidification of walls). This issue is even more important in case of historic buildings, where the assembly of insulation is usually possible inside the building only and this solution is not recommended in temperate climate zone. It is necessary to use the appropriate insulating elements, and place it in the wall in the proper way. The traditional method of insulation on the inside is to use a special vapour barriers inside the room. In this way it is possible to limit the water vapour infiltrating the partition, however the efficient ventilation system to drain out excess moisture is then necessary. It is also recommended to introduce the air gap inside of such partitions. Currently the whole systems of walls insulation are available on the market. Such mineral insulation boards are also known in Poland as a climatic boards. This method eliminates the need of a vapour barrier, since it involves the water vapour condensation inside such board in the winter, and its evaporation in the summer. In some historic buildings the air-conditioning systems are used to adjust the parameters of air humidity.

Building's insulation on the inside, besides the unfavourable water vapour condensation, doesn't eliminate thermal bridges i.ex. on the joint of slabs and

walls¹¹ and can change the appearance of building's interior, which could be problematic in case of historic buildings.

The advantage of old buildings in terms of thermal comfort can be certainly a small glazing area especially, if windows' replacement that may prevent the extensive heat loss is possible.

An important advantage of improving the energy efficiency of old buildings comprises usually a slope roofs. It is usually possible to create a various types of insulation systems in case of such roofs and it should be considered that the roof is the main barrier for warm air leakage. Unfortunately the inappropriate thermal insulation can change the internal and external parameters of the building i.ex. by covering the valuable roof truss.

Slope roofs are also a good places for solar and photovoltaic panels location and many times this solution is accepted by conservatory officers especially if the southern roof slope is not located at the front, or if building is not a monument but only lies in the area of conservatory protection. Even if it's impossible to locate panels on the roof, it is usually possible to assemble them on special racks on the unshaded area of the site. It should be noted, that racks allow also to locate panels on flat roofs or low-slope roofs.

In attics there is a possibility of locating recuperators, that warm the air ventilating the building using the waste heat i.ex. from the household appliances or residents. The incoming air can be also pre-heated by ground heat-exchangers.

Larger plots (very popular in case of old buildings) can be a place, where the horizontal ground source heat pumps are located. These appliances could be cheaper and more effective than the vertical ones.

The southern wall of existing buildings can be used as a heat accumulators. In this case it is suggested to introduce as big glazing as possible, or to add a new glass elements. Unfortunately, these solutions are many times impossible taking into account the requirements of conservatory office.

A common solution in contemporary architecture is to screen the historic buildings or their parts using partitions made of insulated glass. It allows to leave the old parts of buildings exposed, providing the proper air tightness and thermal insulation.

The reconstruction of partitions (usually the southern ones) is more and more popular way to accumulate the solar heat. Such a wall usually consists of at least one layer of glazing and the absorber and accumulation layer. However it seems, that the biggest potential have the transparent accumulating materials. Systems of transparent plaster, or so-called aerogels, or thermosiphon air panels are already being developed. Some buildings are heated or cooled using a Phase Change Materials, that have an adjustable melting/solidifying temperature (depending on the composition of the substance)¹². Such materials can act as warming or cooling agent (whether they are melting or solidifying), that transmits energy to the building structure, or to the domestic hot water system.

¹¹ There are ways to minimize the effect of thermal bridges, i.ex. by using the insulation wedges on the joint of walls and roof, or by installing the insulation tapes in the gaps between skirting and floors. It is also possible to install heat-insulating load-bearing elements for the thermal partitioning of free cantilever balconies.

¹² depending on the composition the melting point of phase change material may vary from -5°C to 190°C.

7. Conclusions

Data presented in this elaboration confirm that the increasing use of national and foreign funds, as well as the involvement of state institutions lead to the raise of environmental awareness and the development of new buildings constructed using passive and low-energy technologies. More and more often the energy-efficient solutions are used for reconstructing of existing buildings. Unfortunately, in case of historic buildings this process can cause a change of their form and affect their aesthetic qualities. It happens, that investors give up the reconstruction process, because of the excessive demands of the conservation office. In response to these problems the definition of energetic revitalization was introduced to this elaboration. It means such increasing of energy efficiency of existing buildings, that preserves their aesthetic and cultural values. Introduction of this concept can help to achieve the demand of 20% share of renewable energy sources in Poland by 2020. The method proposed in elaboration, as well as the estimated percentage rate in analysed region indicate a huge potential for energetic revitalization.

The methods of reconstruction of traditional buildings using modern technologies presented in this work show that energetic revitalization is usually possible, but its costs are very high. A greater involvement of state and foreign funds and further search for less invasive methods of increasing the energy efficiency of buildings is required.

In authors' opinion the problem of energetic revitalization is much larger than presented in this work. The elaboration is a prelude to a broader discussion on this subject, as well as to searching for more exact methods of implementation modern technologies in existing buildings which could help solving problems of renewable energy in the architecture and historic buildings' conservation.

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