Renewable and Sustainable Energy Reviews 80 (2017) 421–429

Contents lists available at ScienceDirect

Renewable and Sustainable Energy Reviews

journal homepage: www.elsevier.com/locate/rser

The impact of thermal insulation investments on sustainability in the construction sector

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ARTICLE INFO

Keywords:
Sustainable construction
Thermal insulation investment
Economic benefits
Environmental benefits
Social benefits

ABSTRACT

Sustainable construction is the only way to ensure the implementation of the principles of sustainable development. The paper presents the importance of the thermal insulating investment of the building in three areas: economic, environmental and social. It shows the influence of the existence of the building on the environment, with a particular focus on the investment process involving thermal insulating of external vertical walls of the building. The paper proposes a methodology for assessing the environmental and economic benefits. The analyses for various combinations were performed, including the condition of the building before thermal insulation, type of construction material of the building, the heat source used, type of thermal insulation and climate zone, in which the building is located. The obtained results indicate that the thermal insulation investment is, for all examined variants, beneficial for ecological reasons and for almost all economic reasons. The highest values of economic benefits were obtained for the variant of the coldest climate, and the variant in which the building before thermal insulation has the worst thermal performance, the most expensive type of heat source (i.e. the biggest costs of obtaining 1 kWh of thermal energy) and the least expensive material used for thermal insulation. The highest values of environmental benefits were obtained for the variant of the coldest climate, which is obvious, but also for the variant, in which the building before thermal insulation has the worst thermal insulation, the least environmentally friendly type of heat source and the most eco-friendly insulation material applied. The paper also articulates social benefits resulting from such an investment.

1. Introduction

The concept of "sustainable development" has recently become one of the world's most widely used terms, however, it seems that the it is least understood among the public. Its importance is often perceived by the society too superficially, since it is usually identified with environmental protection. Of course, "environmental protection" is one of the principles and the objective of sustainable development, moreover, it is also assumed that the rules are: more effective use of non-renewable resources and the desire to replace their with substitutes, striving for stable economic growth, reducing the nuisance of the environmental elements, striving to provide ecological security to the public and the fight against poverty.

The problem with understanding this concept could also be on the side of the lack of unanimity of the attempt to define this paradigm among scientists. Heinen [1] in 1994 showed that there is no unanimity in the approach to the definition of "sustainable development" because of the different scales of environmental programs and various social groups and institutional structures concerned. Radermacher [2] stated that it was probably the cause of publishing a large number of books, chapters, and articles containing the words: "sustainable" and "sustainable development" in their titles without giving in them the definition of the term. In the literature it is possible to find a large variety of definitions of this paradigm [3–6]. Jacobs [7] lists up to 386 definitions, mainly targeted at particular sectors – e.g. environmental, economic, social, etc. The concept of "sustainability" or "sustainable development" was first described by the Brundtland Commission in 1987: as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [8].

Generally it can be stated that "sustainable development" is striving to improve the quality of life of the society inhabiting the Earth while maintaining social equality, biodiversity and the wealth of natural resources [9]. The concept of "quality of life" is nowadays strongly subjective. In literature it was considered to be correct the conception of the multidimensionality of the concept emerging under the influence of both individual and environmental factors, which included [10,11]:

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http://dx.doi.org/10.1016/j.rser.2017.05.173
Received 30 September 2016; Received in revised form 8 December 2016; Accepted 20 May 2017

Nomenclature

d	thickness of the thermal insulation layer [m]
K_c	cost of the heat generated [PLN/kWh]
K_e	LCA result of obtaining 1 kWh of thermal energy [Pt/kWh]
K_m	cost of thermal insulation material [PLN/m^3]
K_w	cost of assembly of thermal insulation for 1 m^2 of the surface of building wall [PLN/m^2]
K_l	LCA analysis result of thermal insulation material [Pt/m^3]
n	number of years of thermal insulation use [y]
S_n	cumulative discount factor
r	real annual interest rate
s	real annual growth (in percent) of the cost of heating
p_u	usable area of the building [m^2]
p	surface area of the external vertical walls [m^2]
Uo	heat transfer coefficient of the wall without thermal insulation layer [W/m^2 K]
U_n	heat transfer coefficient of the wall with thermal insulation layer [W/m^2 K]
D_{Uo}	heat demand for the building without thermal insulation [kWh/m^2 y]
D_{Un}	heat demand for the building with thermal insulation [kWh/m^2 y]
λ	thermal conductivity coefficient of thermal insulation material [W/m K]
LCA	life cycle assessment
toe	the tonne of oil equivalent
C&D	construction and demolition
W_1	construction material – cellular concrete of class 500 kg/m^3
W_2	construction material – lime-sand blocks (silicate) SILKA E
S_1	heat source – coal boiler
S_2	heat source – condensing natural gas boiler
S_3	heat source – electricity boiler
I_1	type of thermal insulation – polyurethane foam PUR
I_2	type of thermal insulation – ecofiber

- intimate relations,
- family life,
- friendship,
- work,
- neighbourhood,
- place and housing conditions,
- education,
- health,
- standard of living,
- nationality.

Among these dimensions there were, among other things, mentioned *place and housing conditions*, which are implemented as a result of the investment and its effect is building. Buildings by reason of scale of the phenomenon as well as the time interval of their use and high pollutant load generated at this time are essential for the implementation of the sustainable development paradigm [12,13]. The number of buildings in cities (per unit area) is significantly increasing when compared to other areas, it causes the concentration of the total amount of impurities of all components of the environment [14]. Currently, people strive to sustainable urban development in the context of improving the quality of life in the city. Improving the quality of life in the city aims to improve the ecological, cultural, political, institutional, social and economic conditions, without leaving a burden for future generations [14–17].

The trends to improve ecological conditions (and not only) in terms of reducing pollutant emissions to the atmosphere were set out in the United Nations Framework Convention on Climate Change (UNFCCC), which was signed in 1992 and began to be in force since 1994. Another global document on climate change was an international treaty supplementing the United Nations Framework Convention on Climate Change called The Kyoto Protocol of 1997 [18–21]. The result of these documents in the European Union was the climate and energy package of 2007, which, among other things, assumed the improvement of energy efficiency by 20% by 2020 compared to the forecast demand for fuels and energy [22,23]. According to the projections developed in 2007, hypothetical primary energy consumption in 2020 would amount to 1 842 Mtoe, and the final energy – 1347.5 Mtoe [21,24]. Therefore, lowering the level by 20% means that in 2020 in the European Union:

- primary energy consumption cannot be more than 1483 Mtoe,
- final energy consumption cannot be more than 1086 Mtoe.

All legislative actions in the European Union aimed at achieving the objectives. In most European Union countries, there was introduced and still is continued to set out the legal reduction of energy consumption in new buildings, and those undergoing refurbishment and modernization. The European Union developed and published a number of legal acts concerning the improvement of energy efficiency of buildings. The most important are:

- Directive 2009/28/EC of the European Parliament and of the Council of 23 April 2009 on the promotion of the use of energy from renewable sources and amending and subsequently repealing Directives 2001/77/EC and 2003/30/EC;
- Directive 2009/125/EC of the European Parliament and of the Council of 21 October 2009 establishing a framework for the setting of ecodesign requirements for energy-related products**;**
- Directive 2010/30/EU of the European Parliament and of the Council of 19 May 2010 on the indication by labelling and standardising product information of the consumption of energy and other resources by energy-related products.
- Directive 2010/31/EU of the European Parliament and of the Council of 19 May 2010 on the energy performance of buildings.
- Directive 2012/27/EU of the European Parliament and of the Council of 25 October 2012 on energy efficiency, amending Directives 2009/125/EC and 2010/30/EU and repealing Directives 2004/8/EC and 2006/32/EC

Some European countries have a pro-effective policy, in relation to housing resources, in a very radical manner. Michelsen and Madlener [24] provide the principles to improve the energy efficiency of the housing sector in Germany. The German Government (already in 2010) announced targets for reducing energy demand of residential buildings by at least 80% by 2050 as compared to 1990 [25]. In contrast, renewable energy sources will cover the remaining energy requirements. The presented approach to improving energy efficiency in Germany can affect in a significant way the improvement of the environment, but the important issue is also the issue of cost-effectiveness analysis of these assumptions.

The aim of this paper is to demonstrate the ecological, economic and social benefits resulting from the investment which is thermal insulation of the building in the context of sustainable urban development. The project of the building thermal insulation has a significant impact on improving the quality in environmental, social and economic terms, it can also be attributed the political and institutional aspects to this investment. Due to such a broad context of meanings of this