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The environmental impacts of thermal insulation of buildings including the categories of damage: A Polish case study

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ABSTRACT

Households have a big impact on energy efficiency in Poland. About 80% of final energy in the construction sector is used for heating buildings. Due to the significant role which is assigned to the thermal modernization in European documents, the paper attempts to assess the environmental benefits of the investment consisting of thermal insulation of the building external vertical walls, with the use of LCA analysis and divided into three categories of damage. A methodology for assessing the benefits has been proposed and the analyses for different variants have been performed, including the condition of the building before thermal insulation, the used heat source, the type of thermal insulation and the climatic zone in which the building is located. It has been shown that the investment, for all examined variants, is beneficial for environmental reasons. In the worst case, the reduction of the burden on the environment as a result of the investment occurs after 5 years, while in most cases only after one year. The obtained environmental benefits depend primarily on the condition of the building before thermal insulation and the used heat source. The greater are the advantages, the bigger is the demand for thermal energy of the building that also depends on the climate zone. Because of the thermal insulation material the greatest environmental benefits are found in the case of ecofibre. Taking into account three categories of damage, the greatest benefits were achieved in the Resources category.

1. Introduction

Economic development around the world depends on energy supplies, whether in the form of electricity or in the form of thermal energy, which is most often produced in Poland with the use of the fossil fuels. By all means, nowadays the ways of generating the so-called renewable energy are well-known, however the acquisition of the aforementioned energy requires investments, which consume additional mineral resources. There is no method of generating energy which has no impact on the environment, since every method of obtaining energy has certain environmental conditions. Therefore, it is assumed that the best method, among the others, to reduce the impact of energy on the environment will be the improvement of energy efficiency. It is also believed that the saved energy is the cheapest energy. Naturally, the changes in the behaviour patterns of the users of the building may play an important role in the reduction of the energy demand. However, due to the essential role of reducing the greenhouse gases through thermal modernization, which was assigned in the literature of the subject (see McKinsey curve (McKinsey & Company, 2009)), this aspect was marked as leading in the article.

Of course, any method to save energy in households is important and contributes measurably to the environmental protection (Carpio et al., 2014). In Europe, the construction and services sectors are responsible for the biggest final energy consumption in 2010 (41%), followed by transport (32%), industry (25%) and agriculture (2%). Consumption of primary energy in Europe in the construction sector increased within 20 years by 5% (years 1990–2010). In Poland, similarly as in Europe, the highest final energy consumption occurs in the building and services sectors, however, the value of share is higher than the European average and amounts to 44.6%. Households may also be an important link in improving energy efficiency in Poland because of their prevalence. It should be noted that the final energy in the construction sector is largely absorbed for heating buildings (about 80% of the energy is consumed by households) (Adamczyk, 2014). Due to such structure

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of energy consumption in the construction sector, the literature emphasizes that thermal modernization of buildings is an important aspect of improving energy efficiency (Al-Homoud, 2005; Giama and Papadopoulos, 2007; Dylewski and Adamczyk, 2011, 2014a, 2014b). Unfortunately, due to the fact that there is no direct influence of state decision-making on individuals (landlords), there is an existing dilemma about a univocal articulation of the need to undertake thermal modernization investments. However, it cannot be doubted that the largest and most cost-effective potential for improving energy efficiency is found in the housing sector (Żmijewski and Sokołowski, 2010). In the National Action Plan (NAP) on energy efficiency for Poland the following measures were identified (NAP, 2014):

I Horizontal measures:
  1) The energy efficiency obligation system (white certificates);
  2) Priority Programme: Smart Energy Networks;
  3) Operational Programme Infrastructure and Environment 2014–2020 (Investment Priority 4.iv.) – Development and implementation of smart distribution systems for medium and low voltage levels;
  4) Information and education campaigns.

II Measures concerning the energy efficiency of buildings and public institutions:
  1) Thermal modernization and Renovation Fund;
  2) Green Investment Scheme. Part 1 – Energy management in public buildings;
  3) Operational Programme Infrastructure and Environment 2014–2020 (Investment Priority 4.iii.) – Promoting energy efficiency, intelligent power management and the use of renewable energy sources in public infrastructures, including public buildings and the housing sector;
  4) Energy efficiency improvement, Part 3 – Subsidies for loans for the construction of energy-efficient houses;
  5) Operational Programme PL04 – "Saving energy and promoting renewable energy sources" within the EEA Financial Mechanism 2009–2014 (area no. 5-energy efficiency and area no. 6 – renewable energy);
  6) The Green Investment Scheme. Part 5 – Energy management in buildings of selected public finance sector entities;
  7) Energy efficiency improvement. Part 2 – LEMUR – Energy-efficient Buildings for Public Services;
  8) Operational Programme Infrastructure and Environment (OPIE) 2007–2013 (Measure 9.3) – Thermal modernization of public buildings;
  9) Efficient use of energy. Part 6 – OWL – Energy-efficient street lighting;
  10) Regional Operational Programmes for 2014–2020.

Two activities: Energy efficiency improvement and PL04 Operational Programme are addressed to individuals (landlords) to encourage erecting new, energy efficient buildings in Poland which will "distance" the standard requirements. The literature (Dylewski and Adamczyk, 2011, 2012) has shown that at the current prices of energy and thermal insulation materials, it is profitable, economically and ecologically, to perform thermal insulation of building walls with lower values of heat transfer coefficient than it is imposed in the national standards. Some of these activities, as for instance, the Thermal modernization and Renovation Fund, encourage to invest in the so-called thermal modernization of the already existing buildings. The next section will be devoted to the most important legal regulations connected to the so-called Energy Package.

2. Legislation norms

Global climate changes, which are a fact, and the preoccupation with the sustainable development formed the basis of the establishment of the Kyoto Protocol (December 1997) (Molinos-Senante et al., 2015). This protocol is an international treaty supplementing the United Nations Framework Convention on Climate Change (Berre et al., 2013). The Treaty entered into force on February 16, 2005, three months after it was ratified by Russia on November 4, 2004 and then expired on December 31, 2012. It sets standards for reducing greenhouse gas emissions (average emissions reduced by 6% from 1990 during the years 2008–2012; for Poland, 1988 was chosen as the base year) (Szymczyk, 2006).

In Europe, the European Union member states faced even higher requirements for the reduction of greenhouse gases. On January 10, 2007 the European Commission published a package of documents which was called the Energy Package. This package is also known under the slogan 3×20, as it alludes to three main objectives, which are necessary to be achieved by 2020: the first one is to reduce greenhouse gas emissions by 20%, the second one is to increase the production from renewable energy sources to 20% and the third one is the discussed improvement of energy efficiency by 20%.

Notwithstanding the fact that there are still a few years to come before those aims can be achieved, another amendment to the package was proposed in the European Union. During the meeting of the European Council on October 23–24, 2014 the frameworks for climate and energy policy until 2030 were established on the basis of the principles contained in the conclusions of March 2014. The goals binding at EU level and set out in the conclusions from October concern (Gawlikowska-Fyk, 2014):

- limitation of the internal greenhouse gas emissions until 2030 by at least 40% in comparison with 1990 level,
- increasing the share of energy from renewable sources in energy consumption in the EU by at least 27%,
- improving energy efficiency in 2030 in comparison with the forecasts - an indicative target of at least 27%.

Each of these legal acts is reflected in the national legislation of the European Union member states. A number of regulations was developed on the basis of these documents, including the so-called documents of third energy package (see Table 1).

According to the Directive 2012/27/EU on energy efficiency, Member States should establish a long-term strategy for the period after 2020, mobilizing owners and managers to invest in the renovation of residential and commercial buildings in order to improve the energy performance of the building stock. In addition, it is noted that the strategy for improving the efficiency of building substance should apply to cost-effective deep renovations that lead to modernization thanks to which both power consumption delivered and final energy consumption are reduced in buildings particularly when compared to pre-renovation levels, and thus resulting in a very good energy performance (Directive 2012/27/EU, 2012).

Because of the significant role assigned to thermal modernization in European documents, the paper attempts to assess the ecological impact of the investment consisting of thermal insulation of external vertical walls of the building while using LCA analysis and divided into three categories of damage.

3. LCA methodology

The methodology of environmental life cycle assessment (LCA) is a relatively "new" technique that developed rapidly in the 90s