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Cost curves of energy efficiency investments in buildings – Methodologies and a case study of Lithuania

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ABSTRACT

This paper aims to calculate potential energy savings for space heating and hot water by 2030 for the Lithuanian building sector by implementing energy efficiency solutions. Policy recommendations are derived by showing which buildings and energy efficiency measures should be addressed in order to determine the full energy saving potential in the most effective way. Different cost curves for energy savings potential are applied, and these curves show the investor perspective and overall economic perspective. Final energy demand can be reduced by 56% by year 2030 if the least-cost energy efficiency solutions for each building type are selected. Energy performance class A implementation for the apartment buildings built before 1990 and supplied by district heating is the most cost-effective measure. If we consider the overall economic perspective, energy performance class A+ + (deep renovation) for the same buildings is the most cost-effective measure. The results call for (I) policies to support building renovation that address buildings with low energy performance instead of subsidising energy prices and (II) policies promoting deep renovation (A+, A+ +) in order to avoid lock-in effects and ensure the transition of the Lithuanian building stock towards nearly zero-energy buildings (nZEBs).

1. Introduction

The EU has proposed a 40% goal for the reduction of GHG emissions by 2030, together with targets of 27% for both renewable energy and improved energy efficiency. In the Clean Energy for All Europeans package, the European Parliament and Council proposed a binding 30% energy efficiency target for 2030, up from the current target of at least 27%. This aim is particularly addressing the building sector (Arias Cañete et al., 2017). The building sector within the European Union accounts for about 40% of final energy consumption (European Commission, 2017). European households in EU-28 were responsible for 26% of the final energy consumption in 2012 (Eurostat, 2014). Increasing the renovation rate, renovation quality and effectiveness of building renovation are the key activities to achieve the targets (Arias Cañete et al., 2017).

However, the building sector is very complex, and cost-effective investments, especially effective public investments, require detailed analyses of the building sector. Such analyses must consider a building's thermal characteristics, climate conditions and supplied energy fuel prices.

The Lithuanian National Energy Efficiency Action Plan claims that the highest potential to achieve total national energy savings is in residential buildings. Energy efficiency improvements in residential buildings are expected to contribute to total energy savings by 1000 GWh by the year 2020 (European Commission, 2013c). Under the implementation of the Energy Efficiency Directive of the European Parliament (Art 4, EED), Lithuania defined its priority to finance the renovation of multi-family houses that were built before 1993, which are buildings of Energy Performance Classes (EPCs) E, F and G (European Commission, 2013c). Although the renovation of the multi-family houses is the main instrument for achieving national energy savings, the rate of renovation is very low. In the last decade, just 2.6% of the total multi-family houses stock has been renovated (Bointner et al., 2014). One of the reasons for this meagre progress is that the renovations have been hampered by a lack of clear and long-term strategies thus resulting in low incentives from the public for thermal building renovations as well as other instruments that support a smooth renovation process (Bointner et al., 2014). Another barrier is the subsidisation of energy prices, which makes the thermal renovation less cost-effective.

Conservation supply curves and marginal abatement cost curves are well-established instruments that show the economic assessment of investments and energy-related benefits. These curves are widely used in academic journals and scientific reports, and they can be applied in many different sectors, including the building sector (Jakob, 2006), (Wächter, 2013), (Kesicki, 2012), (Jaccard, 2010). These curves are

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often used as a tool for making political decisions and setting preferences for climate protection and energy-saving measures by determining their costs and benefits. These instruments enable investments in energy efficiency solutions to be prioritized by their cost-effectiveness in order to achieve energy savings targets or to reduce greenhouse gas emissions. Although these tools deliver beneficial effects and are widely used by policymakers, the curves are often criticized for their lack of information about assumptions, their application of simplified methodology and misleading applications when costs are negative (Kesicki and Strachan, 2011), (Chappin, 2016), (Levihn, 2016), (Taylor, 2012).

In this paper, we provide the methodology and application of different cost curve approaches to show the energy saving potential and cost-effectiveness of investments in energy efficiency solutions in the Lithuanian residential building sector. The calculation is based on a bottom-up approach of disaggregating the building sector and assessing the techno-economics of the investments in energy efficiency solutions.

This paper aims to show the energy saving potential that can be reached by 2030 through implementing energy efficiency solutions in the residential building sector and applying least-cost options of the investments from the building investor's point of view and the overall economic point of view. Moreover, policy recommendations are derived to show which buildings and energy efficiency measures should be addressed and which policy instruments can be used in order to achieve energy savings targets in the most effective way.

This paper contains the following steps: (I) the methodology is defined, starting with the breaking down of the building stock and showing the application of two concepts of cost curves; (II) the Lithuanian residential building stock and its energy demand for space heating and hot water are described; (III) results are provided which show the most feasible investments for different building types from the investor point of view and the most cost-feasible investments to achieve national energy savings targets and, finally, (IV) discussion and policy recommendations are derived.

2. Methodology

Energy savings potential for space heating and hot water in Lithuania's residential building stock by 2030 is shown using energy savings cost curves. To create the cost curves, the following main methodology steps were carried out.

- Taking into account building type, construction period and heating supply system, 30 building types were defined. Additionally, data on the total building floor area were collected. The main data sources were project ENTRANZE, ZEBRA2020 and national statistics (Bointner et al., 2014), (Valstybės įmonė registrų centras, 2014), (ENTRANZE, 2016).
- Based on the data, the following 15 energy efficiency solutions were defined: energy efficiency improvements of the building envelope and domestic hot water supply system (energy efficiency improvements of the building envelope are related to five building class standards from D to A++); installation of a non-grid connected heating system (heat pump, ground source) in combination with these five building class standards; and finally installation of a solar thermal system in combination with the five building class standards and the heat pump system. Energy efficiency solutions and their techno-economic data came from the Lithuanian cost-optimality report.
- Energy savings and the cost of energy savings were calculated by implementing the abovementioned energy efficiency solutions.
- Total energy demand and energy savings by 2030 in each building type and in the total building stock was estimated using the calculated renovation rates.

From all of these data, the two types of cost curves were generated. The first cost curve shows the building investors' perspective, and the second shows the least-cost options to achieve energy saving targets.

2.1. Breaking down the Lithuanian building stock

The building stock was categorized into 30 building typologies while taking into account building type, construction period and heating supply system. The building types were defined based on the available data sources regarding the total stock gross floor area by construction period and building type. These data were provided by the Lithuanian State Enterprise Centre of Registers, Lithuania (Valstybės įmonė registrų centras, 2014). Data on the energy supply systems and their shares were collected from the IEE project ENTRANZE (ENTRANZE, 2016). Two building types were defined, which are single-family houses and multi-family houses, and the five following construction periods were specified: 1800–1940, 1941–1960, 1961–1990, 1991–2009 and 2010–2012. Buildings were further distinguished by the supply systems, with heat being supplied by district heat, gas or a boiler with biomass.

2.2. Energy demand calculation

For each building type, the final energy demand for space heating and hot water was calculated. Firstly, the determination of the specific energy needed for space heating was carried out using the monthly energy balance approach based on the EN13790 "Energy performance of buildings – Calculation of energy use for space heating and cooling" methodology (ISO 0, 1379, 2008). The calculation was conducted with the building simulation tool Invert-EE/Lab which can calculate monthly and yearly specific energy demand for space heating based on the abovementioned norm by providing the tool with the country-specific input data (Müller, 2015). The following data for typical Lithuanian buildings were assessed, and these data were necessary to calculate yearly energy need for space heating using the monthly energy balance approach:

- Description of buildings and building components (building geometry, thermal transmittance of building envelope elements). The U-values of the building elements of the buildings built in different periods were defined in the Lithuanian cost optimality report (European Commission, 2013a) and in the Technical Regulation of Construction STR 2.01.09:2005 (Ministry of Environment of the Republic of Lithuania, 2005).
- Transmission and ventilation properties, including temperature adjustment factor of building elements, ventilation type, heat recovery type (ISO 13790, 2008), (Ministry of Environment of the Republic of Lithuania, 2005).
- Heat gains from internal heat sources and solar radiation, such as shading reduction factor, glazing type, area of glass, solar irradiance (ISO 13790, 2008), (Ministry of Environment of the Republic of Lithuania, 2005)
- Climate data, for example, monthly outdoor temperature, solar radiation.
- Occupation behaviour and comfort requirements, including user profiles, indoor temperature (set-point temperature), hot water demand (ISO 13790, 2008), (Ministry of Environment of the Republic of Lithuania, 2005).

The yearly energy demand for space heating was calculated for each building type before implementing a renovation option. In the next step, five energy efficiency solutions related to the improvement of the building envelope and another 10 energy efficiency solutions related to the installation of a non-grid connected heating system were defined (see section "Energy efficiency solutions"). Energy savings were calculated for all building types while implementing different energy efficiency solutions.