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Estimating Potential and Costs of Reducing CO_2 Emissions in Lithuanian Buildings

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The EU is considering increasing the GHG emissions reduction target by 2020 from 20% to 30% by committing each member state to tighten up its emission reduction goals. According to the recent study such decision could cost some 2 365 million LTL to Lithuanian economy. Evaluation and comparison of CO_2 abatement costs incurred by the state implementing a variety of measures in different sectors allow choosing a most cost effective policy scenario. The paper focuses on CO_2 emissions related to energy use in buildings. First, this paper reviews the role of the Lithuanian building stock in overall GHG emissions. Then the paper examines the existing studies on the CO_2 mitigation potential and cost in buildings. Given the limitations of existing evaluation and lack of comprehensive modelling in the existing studies, this paper proposes a framework for examining the technology options aimed to inform policy making on the options to reduce CO_2 emissions in Lithuanian housing and service sectors.

Keywords: *energy efficiency, CO_2 emission reduction costs, renewable energy, climate change mitigation, energy use in buildings.*

1. Introduction

The EU declares its global leadership aspiration in combating climate change. Recently the European Commission has made an attempt to extend the greenhouse gas (GHG) emission reduction target by 2020 from 20%to 30% by committing each member state to tighten up its emission reduction goals. Under the 20% EU target, Lithuania has committed not to increase GHG emissions more than 15% outside the emission trading system compared to base of 2005. In the case of 30% the EU target, assuming the same principle of commitments distribution among the countries, Lithuania could be forced to keep the increase in their GHG emissions under the 5% limit compared to base of 2005 (Valuntiene et al. 2010). According to the recent study (Valuntiene et al. 2010) such decision could cost some 2 365 million LTL to the Lithuanian economy.

Among the anthropogenic GHG emissions the energy ones represent the largest share. Approximately 65% of global GHG emissions and 83% in developed countries come from energy production, mostly from direct fuel combustion (IEA 2011). In energy related GHG emissions, one third could be attributed to energy use in buildings. The Intergovernmental Panel on Climate Change (IPCC) in the Mitigation Report has pinpointed the building sector as the one having the most cost efficient measures to mitigate carbon emissions (Levine et al. 2007). Acknowledging significance of the building sector role in climate change mitigation, leading countries have elaborated models to simulate scenarios and to develop strategies of GHG mitigation in this sector. For example, policy measures of climate change mitigation in the UK are developed using several models to account for carbon dioxide (CO_2) reductions in residential buildings (Johnston et al. 2005; Kannan et al. 2009; Natarajan et al. 2011). However, there was indicated a critical lack of bottom-up assessments of GHG reduction opportunities and associated costs in buildings worldwide, especially in developing countries and economies in transition (Ürge-Vorsatz and Novikova 2008). The importance of bottom-up approach to consider technology options of climate change mitigation is highlighted in Vanvuuren et al. 2009.

This paper reviews the existing studies on GHG mitigation in Lithuanian building stock and analyses the most recent and comprehensive one (Valuntiene et al. 2010) referred further as the COWI study. This study has aimed to establish the potential and costs of CO_2 mitigation measures in different Lithuanian economy sectors when considering the increased CO_2 reduction target. After the analysis of findings and limitations in the existing evaluation of the carbon saving potential and costs of technical options to reduce carbon emissions, particularly in Lithuanian building stock, we argue that a complex modelling is needed to choose CO_2 reduction measures that are economically feasible and have a potential to cover a considerably large part of the building sector. Therefore, this paper presents a new framework of the model to evaluate GHG reduction strategies, their costs and impacts on the whole economy.

The paper is organised as follows. Section 2 highlights the role of the energy use in buildings in overall GHG emissions. Section 3 provides the rough estimations of a carbon saving potential based on the top-down approach which is currently applied to inform policy making in Lithuania. We explain why this approach has its own serious drawbacks for the purpose of designing climate change mitigation measures. In section 4, we look at the existing attempts to evaluate the potential and costs of CO_2 reduction at the scale of the national building stock. The most comprehensive study in this regard is analysed in more detail in order to assess the reliability of its findings and underlying limitations. Section 5 presents the framework of the new model aimed to inform policy making on the options to CO_2 emissions in Lithuanian housing and service sectors.

2. Contribution of Lithuanian building stock to the CO_2 emissions

21.6 Mt CO_2 eq. was emitted in Lithuania in 2009 (National GHG inventory 2011) and it is expected to grow together with the economic development. 12.8 Mt CO_2 eq. emissions are attributed to the sectors that do not participate in the emission trading system (non-ETS sectors). Figure 1 illustrates how GHG emissions are expected to change in the non-ETS sectors in different scenarios of economic development and how this looks in the light of 20% and 30 % goals (Valuntiene et al. 2010). The three groups of columns represent three scenarios of economic development. The scenario of the optimistic economical growth, therefore, corresponds to the highest increase in GHG emissions. While the higher dashed line in the Figure represents the existing GHG emission target for Lithuania, the lower one shows the limit in a case of the tightened emission target.

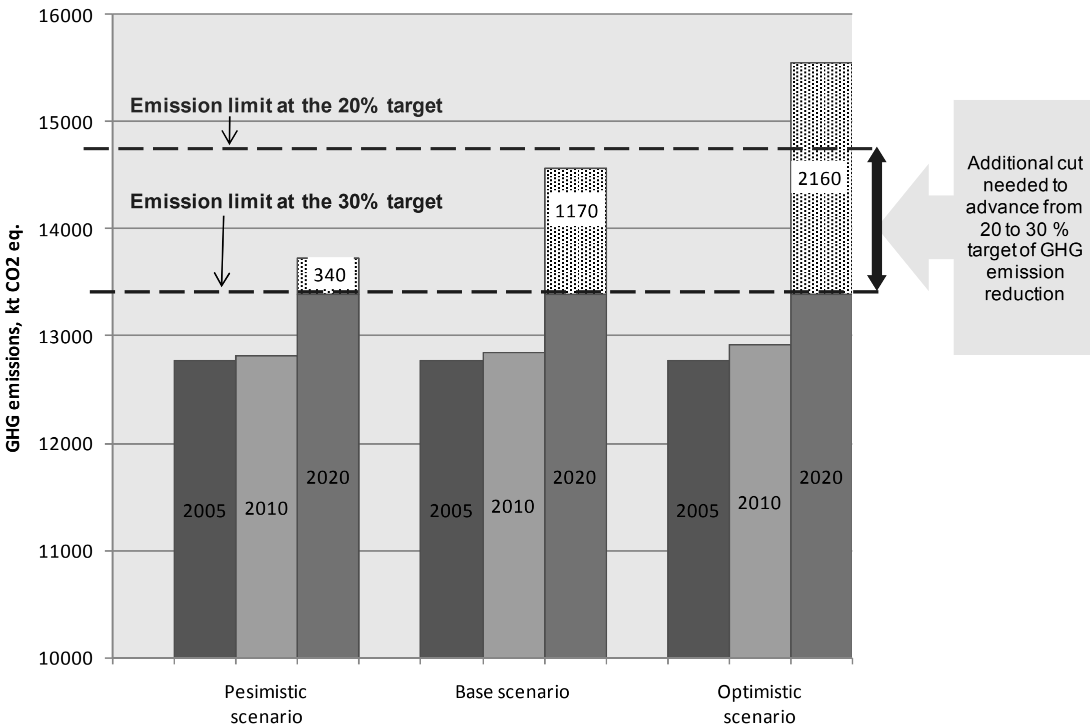

Fig. 1. GHG emissions and reduction commitments in Lithuania up to 2020 goals (Valuntiene et al. 2010)

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As it is seen in the Figure 1 only the optimistic scenario of economical development would require additional measures for not to exceed the existing GHG limits. However, in a case of the more stringent GHG target, the base economy development scenario would require the additional measures to cut GHG emissions by 1170 kt CO_2 eq. in Lithuania by 2020.

Figure 2 presents the breakdown of GHG emissions among different sectors of Lithuanian economy in 2009.

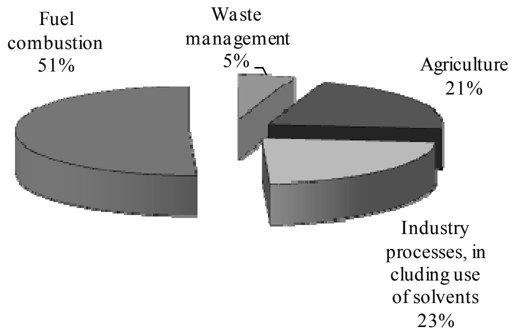

Fig. 2. GHG emissions in different sectors of Lithuania 2009

In Figure 2 the diagram shows that CO_2 emissions from fuel combustion have comprised the half of the GHG emissions in 2009. Figure 3 indicates the breakdown of GHG emissions from fuel combustion in various economy sectors.

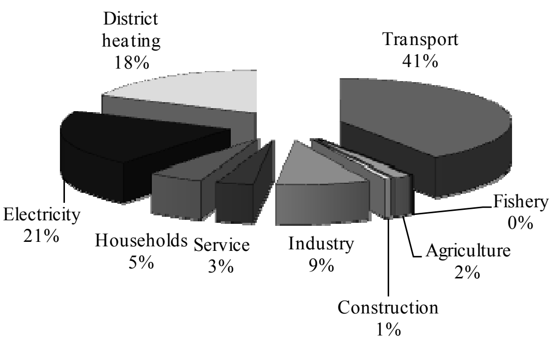

Fig. 3. GHG emissions from fuel combustion technologies in different sectors, Lithuania, 2009

Statistics on energy use in the building sector is incomplete in Lithuania, thus we need to operate with available indicators and make assumptions. Final energy consumption in Lithuanian statistics is represented split into seven main sectors: industry, construction, transport, agriculture, fishing, commercial and public services and households (Statistic Lithuania 2010). This makes it considerably difficult to evaluate the building energy consumption and associated carbon emissions. Building sector comprises all of households, service sector, most of district heating (DH) and significant part of electricity. From the energy consumption statistics (Statistic Lithuania 2010) it can be estimated that the households use 58% of district heating and 33% of electricity. Service sector uses 22% of district heating and 35% of electricity. Therefore approximately 4,15 Mt CO_2 eq. or 38% of emissions from fuel combustion can be attributed to the building sector. Given that a part of energy consumption in other sectors also goes to space heating, this number could be larger. Therefore, it can be approximately estimated that the building stock is responsible for more than 19% of the total GHG emissions in Lithuania. Given that CO_2 represents 92% of all six energy related GHG (IEA 2011), in this paper we consider only CO_2 emissions.

3. Top-down evaluation of CO2 emission reduction potential in Lithuanian buildings

In Lithuania, while preparing strategic documents that establish energy efficiency and renewable energy targets, the role of the building sector is evaluated by employing the top-down approach. By using this approach, the evaluation of the existing GHG mitigation potential could be based on energy efficiency and renewable energy targets in the sector as assessed in the recent EU wide study by Fraunhofer ISI (Fraunhofer ISI 2009). According to the study the economic potential of final energy savings in Lithuania accounts for 759 ktoe in 2020, 38% of this energy could be saved in residential and public buildings. The major part of savings, 221ktoe could be achieved as fuel savings in buildings, mostly for space heating. The rest 68 ktoe of final energy goes to electricity savings, mainly in public buildings. Given the carbon intensity factor of electricity from the grid is 0,707 tCO_2/MWh_{el}, then 68 ktoe of electricity savings correspond to 559 kt CO_2 reduction. Assuming that the carbon intensity factor of district heating is 0,223 tCO_2/MWh_h, the savings in heating will yield 573 kt CO_2.

However, these estimations are tentative as the relationship between buildings and the structure of energy system in the country are not taken into account. Not all energy savings or renewable energy use can be converted to the CO_2 emission reduction potential simply by introducing conversion factors for electricity, DH and fuel. Buildings are the integer part of the energy systems and should be analysed in this context. The top-down approach is suitable to analyse the overall CO_2 reduction potential in the building sector and to size this potential in relation to all sectors of the country economy. But this approach has serious drawbacks when considering the particular technical options, their potentials to reduce CO_2 emissions and the implementation costs. When accounting the savings of GHG emissions it is essential to look at what place of the energy supply chain the energy is saved. For example, if solar collectors are installed to prepare domestic hot water in building using heat from DH network, such a measure affects the base load of heat plant. If DH utility uses biomass, such a measure would not affect CO_2 emissions. If the DH utility uses fossil fuel to produce heat, the decrease in the base load may result in the inefficient use of existing DH boilers and, consequently, increase CO_2. Therefore, while designing CO_2 emission mitigation strategies it is essential to consider the overall heat supply chain in order not to support the measures that would have a negative impact on the operation of district heating and increase CO_2 emissions.

4. Analysis of existing evaluations of CO_2 emission reduction potential and costs in Lithuanian buildings

The research on interventions in large-scale carbon emission reductions in Lithuanian buildings is scarce. Several attempts have been made to assess the impact of the particular energy efficiency and renewable technology options on cutting GHG emissions in buildings. Recent study has compared the costs and the CO_2 emission reduction potential of different energy supply options in modernised multi-flat residential buildings (Janulis et al. 2010). Another research is aimed at estimating the GHG reduction potential by changing behaviour of energy consumers (Streimikiene and Volochovic 2011). Other studies focused only on the particular options to reduce fossil energy use in buildings, for example, Milutiene et al. (2010) have reviewed a potential to use passive solar solutions to save heat in the built environment. There are also studies on energy efficiency and renewable energy use in Lithuanian buildings without estimation of carbon savings.

Until now the COWI study (Valuntiene et al. 2010) is the only attempt to evaluate CO_2 emission reduction costs in the whole Lithuanian building stock. Consequently, further we analyse the findings and limitations of this study in detail.

The COWI study addresses the emission reduction options and costs across all sectors of the Lithuanian economy. The purpose of this study is to give the approximation of costs in Lithuanian economy in the case of the carbon emission target tightening. Given the unavailability of suitable models of energy use in Lithuanian building stock as well as a broad scope and resource limitations, this study has employed a quite simplistic approach evaluating costs to reduce CO_2 emission in buildings. This approach could be summarised by the following steps:

1. Select intervention measures that fulfil certain requirements as described below;
2. Calculate the required subsidies to make the selected options economically feasible;
3. Evaluate the overall costs, carbon saving potential taking into account possibilities to replicate these measures across all building stock.

Further, we analyse each of these three steps as undertaken in the COWI study.

As a first step, in order to find out the preliminary cost of additional CO_2 reduction costs in buildings, technical measures were selected. The selection of the measures was restricted by several constrains. Given the aim of the study (additional cutting of emissions by 2020), only technical measures for the reduction of CO_2 emissions feasible in short time, fully commercialised and having wide replication possibilities were considered. As the target is for the 2020, i.e. the measures should be implemented during the next 8 years, the technologies already in the market were analysed. The possibilities to implement these measures in the scale of the whole building stock were also taken into account.

To avoid double calculations due to the unambiguous effect on carbon emissions in terms of interactions among different parts of the system “energy user – production unit”, the costs of cutting CO_2 emissions were assessed by analysing only the technology options that have no impact on the energy use in district heating systems.

Also the measures tackled by the support schemes that are already implemented or in a pipeline were not considered, for example, energy efficient building renovation targeted by the Lithuanian residential building refurbishment programme (Government 2009a) and the renovation programmes of public buildings. The assumption is made that the existing measures are capable to reach the 20% target, but the new measures will be required to achieve the increased target. While it is theoretically possible to tighten energy efficiency requirements in the existing programmes and gain additional carbon savings, it is not feasible given that the implementation of these programmes encounters significant difficulties.

The three technologies were chosen as fulfilling the above listed conditions:

- to replace existing gas boilers by pellet boilers;
- to install heat pumps instead of existing gas boilers;
- to install solar collectors in order to diminish electricity consumption in domestic hot water heaters.

CO_2 reduction costs were evaluated from the side of the state budget as the support in the form of investment subsidising. Therefore, as a second step of the evaluation in the COWI study the financial analysis is performed aiming to evaluate what subsidies are required to make the considered measures financially feasible to households and service business.

For the purposes of this study a range of assumptions has been made. It is assumed that the project is feasible when an internal rate of returns is 12%. The evaluation period taken was 15 years. The carbon factor of electricity from the grid as used in calculations was 0,707 tCO_2/MWh_{el}. The other assumptions used in the COWI study are listed in Table 1.

Table 1. Assumptions used in COWI study

	Heat pumps	**Solar collectors**	**Pellet boilers**
Specific investments	3509 LTL/kW	2860 LTL/m^2 for flat plate collectors 3660 LTL/m^2 for evacuated tube collectors	427 LTL/kW
Performance	seasonal COP = 4,5	415 kWh/m^2/year for flat plate collectors 560 kWh/m^2/year for evacuated tube collectors	seasonal efficiency 85%
O&M costs	16 LTL/kW per year	0,5 % of investment per year	2 % of investment per year
Price of natural gas	1026,5 LTL/1000nm3 + 3,4 % annual increase		
Price of electricity	439 LTL/MWh + 3,7 % annual increase		
Price of pellets	467 LTL/t + 3,4 % annual increase		

To establish the total potential for the technologies under evaluation, the heat supply situation was analysed in the COWI study. According to the Lithuanian district heating association, approximately 63% of households in Lithuanian cities are connected to district heating. A large part of these households receives all heat for space heating and hot water from the district heating all around the year, but some households are not receiving heat during non-heating season and most often use electric boilers to heat domestic water from May to October. According to statistics, households have consumed 234,4 ktoe of electricity in 2009, electrical space heating and domestic hot water preparation comprised 60,9 ktoe. Therefore it was assumed that 20% of this consumption or 142 GWh is used to heat domestic water.

About one fifth of the households in Lithuania use individual boilers, fuelled by biomass or natural gas. In 2008 households used 145 ktoe of natural gas (Statistics Lithuania 2009). 17,2 ktoe was used for food preparation, that leaves 128,6 ktoe of natural gas used for space heating and domestic hot water preparation. It causes 301,5 kt of CO_2 emissions annually. Assuming 90% of seasonal efficiency of natural gas boilers and a typical heat load profile, 128,6 ktoe of natural gas constitute 115,7 ktoe (1346 GWh) of total annual heat demand and 673 MW of installed capacity. It is assumed that the 25% can be replaced by pellet boilers and the half of remaining buildings heat pumps will be installed by 2020. This assumption is based on the considerations about the lifetime of existing gas boilers and the suitability of pellet boilers. Pellet boilers are not a viable alternative in every case. Serious drawbacks of pellet boilers are the need for space to store fuel and SO_2, NO_x, particle emissions. That makes pellet boilers unsuitable in densely urbanised and otherwise sensitive areas. In areas, that are not suitable for pellet boilers, gas boilers can be replaced with more expensive but not locally emitting flue gas alternative – heat pumps. In the case of pellet boilers the rebate that is equal to the difference between installation of the new gas boiler and pellet boiler is considered a sufficient incentive to convert to biomass. The total installed capacity of pellet boiler installed would reach 168 MW. The specific subsidies required would be 274 LTL/kW.

In the case of heat pump installation the difference between the specific costs of installation of gas boiler and the combination of heat pump and gas boiler are evaluated and are equal to 1268 LTL/kW. The total installed capacity of heat pumps accounts for 25 MW.

Solar collectors are assumed to be installed in buildings that are provided with heat from district heating during the heating season, they use electrical boilers to prepare hot water during summers. The total estimated installed area of flat solar collectors is 68000 m^2. The required specific rebate to install a collector is 1535 LTL/ m^2.

The evaluation results for each technology option are summarised in Table 2.

Table 2. Costs of GHG savings for technology options analysed in the COWI study

Technology	Total costs, million LTL	Total GHG savings, kt CO_2 eq.	Specific costs, LTL/t CO_2 eq.
Pellet boilers	46,1	57,0	153
Heat pumps	31,9	10,5	561
Solar collectors	105	20,0	815

Evaluation of the costs in the COWI study indicates that the full potential due the technologies under investigation could reach 87,5 kt CO_2 emission reduction annually. That would require 371 million LTL in total or 353 LTL of investments per one tonne of CO_2 emission mitigation annually. Nevertheless, taking into account the simplifications and assumption used, these numbers are very approximate and suitable only for the purpose of the study undertaken. The COWI study has limited the analysis with the measures that can be clearly attributed to the demand side of the energy chain and double counting can be avoided. But such an approach leaves out the most of possible options that are potentially more cost effective and environment friendly than the explored ones.

More accurate and flexible models are required in order to inform policy decisions in the field of carbon emissions caused by energy use in buildings. The main requirements for such a model are analysed in the following section.

5. Framework for a new building stock model to evaluate carbon emission reduction

There are many routes to cutting GHG emissions in buildings from a technological standpoint. Demand side measures could be grouped into five types: envelope insulation and tightening, energy efficiency of engineering systems and appliances, monitoring and control systems, behavioural changes of occupants, use of renewable energy. Whilst numerous measures are technically feasible, the experience of many countries shows that significant challenges exist to design and implement the support schemes giving the desired results.

One of these challenges is the need to look how the measures interact with each other and with the whole energy system. None of the studies described in the Section 4 consider the whole energy supply chain when evaluating potential savings of different energy efficiency and renewable use options in buildings. This issue is recognized in the COWI study which employs a bottom up approach, but this study simply dismisses the options that would have an impact on the energy system. Based on the described characteristics of the heating sector as well as on the review of models being used to design the policy measures for climate change mitigation, we draw the following features of the Lithuanian building model.

To develop the conceptual framework of a model enabling us to analyse the potential and costs of CO_2 reduction in buildings we further overview the features of Lithuanian energy system.

GHG is emitted when combusting fossil fuels in electricity or heat generators and depends on kind and quantity of fossil fuel. As natural gas already comprises the major part of fossil fuel combustion for energy, tackling CO_2 emissions by improving the fossil fuel mix is not an option in Lithuania. CO_2 emissions could be reduced in the building sector only by reducing the quantity of the fossil fuel burned. The quantity of fossil fuel burned depends on the share that is covered by renewable energy sources, efficiency of energy conversion, transportation and distribution, end-user appliances and a demand of energy services. Figure 4 shows the energy supply chain in the building sector to consider when converting energy saving and renewable energy measures into GHG emission savings.

Most of electricity generation units are now connected to the national grid in Lithuania. Only small part of electricity is generated at the demand site. All buildings use electricity from the same national grid, thus when reducing electricity demand or integrating RE technologies at the buildings site, the electricity production in the most polluting electricity source could be decreased. The double counting of CO_2 savings can be avoided by harmonising the targets of increasing a renewable energy share at the production side with the electricity saving targets at the demand side.

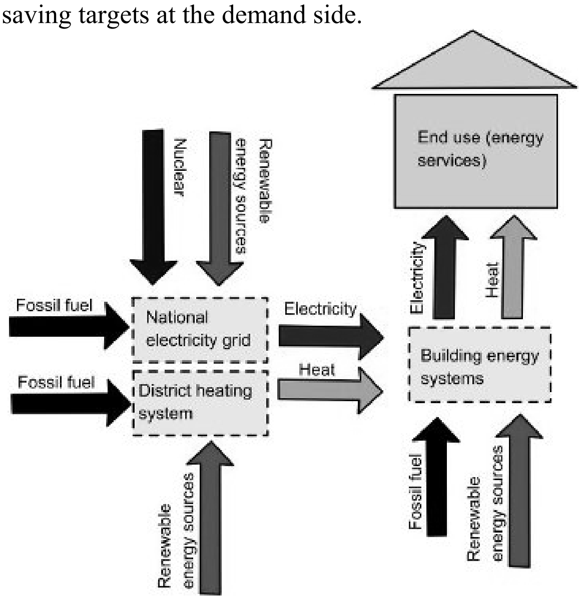

Fig. 4. Energy supply chain in the building sector

The situation is more complicated in the case of a heat supply chain as district heating networks are separate for each city or even parts of the city. Also, the individual heat generators that are installed at the site of heat demand are much more common than in the electricity sector. For example, if the buildings under consideration are connected to a DH utility that produces heat from biomass or are heated by individual biomass boilers, heat demand decrease in these buildings will not impact CO_2 emissions.

There are also measures which are linked with both heating and electricity systems. The increase in lighting energy efficiency decreases electricity use, but reduces internal heat gains and, therefore, a heat demand for space heating rises. Another technology, which in some countries is promoted as carbon saving option but has to be considered with great care, is a heat pump. Commercially feasible heat pumps use electricity for compression. The amount of electricity used depends on the coefficient of performance, which on its side depends on such country specific factors as temperatures of heat source and sink. The fuel mix and efficiency of electricity production in the country is also important, as the use of the renewable energy heat source could be cancelled by use of electricity in this technology.

Based on the above considerations, this paper focuses on the framework and attributes of a new building energy use model targeted to enable an increase in energy efficiency and renewable energy use, leading to CO_2 reduction in Lithuanian building stock. The existing research advocates that only highly disaggregated bottom-up approaches produce results credible enough to inform the design of sound policy measures (for example, Vanvuuren et al. 2009, Hoogwijk, M. et al. 2010). Therefore, as the first step, energy demand at the building level needs to be modelled.

On the basis of the models that are used in other countries, we propose to create a model founded on physics of buildings as well as on statistical data about building types, insulation levels, heating systems and heat sources. Such an approach would help allocate the existing energy saving potential among different energy and fuel types used in households and public buildings. The effects of every type and combination of energy saving and renewable energy use measures need to be evaluated referring to Lithuanian buildings. Therefore, a reasonable number of reference buildings should be modelled. The need to elaborate two different models for housing stock and public buildings may arise during the modelling attempt.

Given the demonstrated requirement to analyse the whole chain of energy, the second part of the model should employ a system framework of Lithuanian electricity and district heating sector. For a consistent approach to addressing multiple uncertainties in long term pathways of Lithuanian energy system, a scenario structure needs to be used. An important point is that the scenarios are built by looking to the long-term future of Lithuanian electricity and DH sectors, and in particular the policy decisions influencing this future. In particular, the scenarios of energy production should address a share of renewable and nuclear energy in the future fuel mix as well as deployment of cogeneration and development of DH systems.

The quality of the modelling results depends not only on the model, but also on the data fed into the model. Therefore, the analysis of different energy efficiency and renewable energy options under Lithuanian conditions, for example, seasonal energy performance of different heat pump technologies, is also an important step in finding the most cost effective paths to low carbon economy in Lithuania.

6. Conclusions and discussion

The building sector is responsible for more than 19% of the total or 38% of energy related GHG emissions in Lithuania, which corresponds to the situation in other developed countries. As the building sector in other countries is considered to have one of the most cost efficient carbon emission reduction potential outside emission trading system, we have reviewed existing attempts to evaluate this potential and corresponding cost in Lithuania. The COWI study was found to be the only study analysing all Lithuanian building stock. The investigation of three technology options in this study – pellet boilers, heat pumps, solar collectors – has resulted in the potential of 87,5 kt CO_2 emission reduction annually at average specific cost of 353 LTL/CO_2 eq. This emission reduction in buildings would contribute by 7 % to additional savings in Lithuania required in the 30% EU target scenario. The results of the COWI study indicate that a significant CO_2 emission reduction potential exists in the building sector even when only several options could be included into evaluation.

As the analysis of the COWI study and the energy sector in Lithuania has shown, the lack of both appropriate statistical data and a model of building stock prevents the analysis of most energy efficiency and CO_2 reduction measures in buildings. Therefore, effectiveness of the existing and planned energy and climate change policies cannot be assessed. For sound recommendations to be given to policy makers, it is vital to develop bottom-up energy models of Lithuanian building stock.

Energy efficiency and renewable energy potential cannot be directly converted into the potential of CO_2 emissions decrease without taking into account the structure of energy systems and modelling the impacts of the particular measures and technologies. To design policy measures for GHG emission reduction in the building sector, an elaborated analysis is needed. To reduce emissions such modelling needs to include the whole energy supply chain and bottom-up analysis of the available technical options.

The paper presents the framework for a building stock model that would allow exploring carbon reduction options in the sector. Whilst only the short term targets are addressed in the paper, the model is likely to be especially useful to design policy measures for meeting long term energy efficiency, renewable energy and carbon saving targets.

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