Planning and Evaluation Tools for Energy Efficiency Policy in the Housing Sector in Latvia

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ABSTRACT

One of the challenges faced by energy modelers and policy makers is the quantification of both achieved and forecasted energy savings associated with different energy efficiency policy measures. The case of Latvia's first and second Energy Efficiency Action Plans is used to illustrate the application of two evaluation and modeling approaches: the top-down method and system dynamics modeling. The paper presents how improper use of the top-down method fails to capture energy user responses to changing conditions in the event of economic crises, and how the result may lead to absurd conclusions. The simulation results from the systems dynamics model are used to investigate inhabitants' responses to different energy efficiency policy tools.

Introduction

World energy demand is continually increasing; overall consumption of primary energy has increased nearly three times in the past and it is predicted that pattern will continue. Carbon dioxide emissions have increased substantially along with the growth in energy consumption, thus contributing to climate change. According to the UN Framework Convention on Climate Change and the Convention's Kyoto Protocol on the reduction of greenhouse gas emissions, European Union countries must reduce these emissions by 8% compared to 1990. A reduction in energy consumption and the introduction of energy efficiency measures is the most significant investment towards CO_2 emission reductions, with the European Union making this one of its main priorities. EU Directive 2006/32/EC on energy end-use efficiency and energy services (ESD 2006) states that each member state shall reduce its end energy consumption by 9% by 2016 against the baseline year. This must be done in accordance with an action plan to be developed by each member state and must be coordinated with the European Commission. A variety of energy efficiency policy measures to help achieve this goal may be included in this plan.

The main aim of this paper is to evaluate the national energy efficiency plans by comparing two different evaluation and modeling approaches: the top-down method and system dynamics modeling. The case of Latvia illustrates the advantages and disadvantages of both methods.

The paper starts with an overview of modeling approaches used for planning and evaluation of residential energy efficiency policies. It is followed by a description of the application of the top-down method and system dynamics for National Energy Efficiency Action Plans. In the next section we present preliminary results from utilisation of both methods. The final section draws preliminary conclusions and outlines next steps for further research.

Overview of Evaluation and Modeling Approaches

A large number of models, mostly optimization and systems engineering models, have been created over the years to support national energy planning. The use of these models, such as the Market Allocation model MARKAL (*Fishbone et al. 1983; Loulou, Goldstein & Noble 2004*) has provided policy makers and planners with insights on policy impacts and energy technologies, in addition to offering projections on demand and supply.

There are two types of models based on validity: "black box" or correlation models that are purely based on data, and "white box" or causal-descriptive models that are based on theory. "Black box" models are used for forecasting purposes and are valid if the model's output matches the "real" output, for example, regression models. For "white box" models, the validity of the internal structure of the model is essential, because the behaviour of the system can be modified by adjusting its structure. Although in the most of the cases demand-side energy models are "black box" models driven by data such as MEDEE (Lapillonne & Chateau 1981; Strub 1979), "white box" models for the energy demand side have been developed as well, such as FREE (Fiddaman 1997).

"Black box" models may be divided into "bottom-up" and "top-down" models. Both methodologies have been described in many sources (e.g., Böhringer & Rutherford 2009; Boonekamp 2006; Tuladhar *et al*. 2009; Swan & Ugursal 2009; Weyant & Hill 1999). Top down models are used at the aggregated level by fitting historical time series of national energy consumption based on macro-economic and social relationships. They are divided into econometric models and technological models. Econometric top-down models are based on energy use in relation to variables like income, fuel prices, and GDP to express the connection between the energy sector and economic output. Technological top-down models include other factors that influence energy use, i.e., technological progress, saturation effect, and structural change. The main disadvantage of top-down models is the lack of details on current and future technological options since they are focused on the macroeconomic trends observed in the past that might not be appropriate in economic recession or climate change situations. The most well known top-down methods are the energy efficiency index (ODEX) indices used in Europe, which comprise 26 separate indicators for the end-use sectors of industry, households and transportation (ADEME 2009; Odyssee 2003), and the decomposition analysis, in which analysis is based on total energy consumption and GDP.

Bottom-up models are used at the disaggregated level; therefore a detailed database of empirical data is needed. Depending on the type of input data and structure, the bottom-up method can be used as two different approaches: statistical, and engineering or building physics. A well known bottom-up method is the MURE simulation tool used at the EU level (MURE 2003). It determines impacts of different past energy efficiency policy measures in EU member states. In some cases both bottom-up methods are combined into hybrid models, for example, the CHREM model consists of both statistical and building physics modules (Swan, Ugursal & Beausoleil-Morrison 2011).

The bottom-up method illustrates the immediate and direct impacts of energy efficiency policies, while the top-down method assesses general equilibrium effects over the longer period. Some authors suggest bridging both methods through the use of hybrid models (Bataille *et al*. 2006; Laitner & Hanson 2006). The main challenges in "black box" modeling are the choice of a reference system, the choice of variables for a reference trend, shifts in the reference system, the choice of aggregation level, interaction between savings effects, interaction between savings effect and other effects, and the choice of quantity of energy to be applied.

"White box" modeling tools such as system dynamics are graphical modeling tools that are specifically designed to ensure structural transparency as well as an explicit exposition of the relationship between the underlying systems structure and the resulting systems behavior over time.

Data quality and availability are always key concerns for all modeling exercises. The lack of data, or data gaps, does not impact the validity of "white box" system dynamics models as much as it would affect the quality of projections generated with "black box" econometric and optimization models. Barlas (*Barlas 1996*) provides an excellent explanation of why the availability of data is not crucial for creating good system dynamics models, but he also states that the validation of system dynamics models has to be carried out rigorously, both for structural validation (when an additional set of tests is needed relative to econometrics and optimization) and for behavioral validation.

Every methodology, as well as its applications, has strengths and weaknesses. These depend on the specific characteristics of the methodology and on the issues being analyzed.

The research project EMEEES (EMEEES 2009) has involved extensive investigation and analysis in developing a proposal for energy savings evaluation to implement European Union's Directive 2006/32/EC concerning energy end-use efficiency and energy services (ESD 2006). Different top-down and bottom-up methods have been analyzed and compared and calculation guidelines have been prepared. The project suggests using top-down ODEX indices for specific energy consumption, unit energy consumption and the diffusion of energy saving technologies. The project team suggests the use of six different bottom-up methods. Furthermore, the team suggests combining those methods to get the desired and cost-effective results. The authors argue that estimating the multiplier effect and the free rider effect with the bottom-up method can be costly, but that structural effects of top-down indicators often cannot be corrected. For the residential building sector, EMEEES concluded that top-down methods are the best for energy taxation while bottom-up methods have to be used for other energy efficiency measures.

Hull *et al*. (Hull, Gallachoir & Walker 2009) provides an overview of modeling methods underlying EU member states' National Energy Efficiency Action plans. The authors conclude that some countries have developed sophisticated energy end-use models, while many still use simple bottom-up accounting analyses, with specific energy efficiency policy measures simply listed together with the estimated impact. Some action plans include quantitative estimates, and only a few plans include the rebound effect. Furthermore, they find that many countries use ODEX indices for their Energy Efficiency Action Plans (EEAPs).

This paper focuses on the top-down method and system dynamics modeling.

Approaches to Assess Residential Energy Efficiency Policy

The residential sector is currently the greatest end-use energy consumer in Latvia, accounting for 38.8% of overall energy end-use in the country (LEF 2011). In 2010, the total housing floor area in Latvia reached 61.1 million m^2 (CSBL). The household sector in Latvia includes multi-family buildings (61.5% of the total residential building stock) and single-family buildings (38.5%) (CSBL). Located in Northern Europe with a cold climate (more than 4000 annual heating degree days), the greatest energy consumed in the residential sector is for heating energy, with an average annual consumption 180 kWh per m^2. The most challenging task for energy efficiency policy is to overcome the lack of collective action, which arises from the ownership structure of multi-family buildings. Apartments are owned by individual occupants, and the implementation of common energy efficiency measures in the building can be performed with an agreement of at least 51% of apartment owners.

System Dynamics and the First Energy Efficiency Action Plan

To ensure the implementation of the European Union's Directive 2006/32/EC on energy end-use efficiency and energy services (ESD 2006), Latvia's government has prepared the first and the second EEAPs, covering periods from 2008–2010 and 2011-2013 (LEEAP 2008, 2011). The overall goal of the action plans is to reduce end-use energy consumption by 3483 GWh (adjusted for climate) by 2016. The national energy efficiency goal of cumulative energy savings is shown in Figure 1.

The total energy savings planned in the residential sector from 2008 to 2016 are 2701 GWh—more than in any other sector. The policy measures include energy audits in buildings and building energy certification, subsidies for energy efficiency measures in multi-apartment buildings (110 million EUR), subsidies for energy efficiency measures in public buildings (social housing), information of energy consumers and the development of secondary legislation according to Directive 2002/91/EC (EPBD 2002). Expected energy savings by 2016 from multi-apartment building subsidies are 1900 GWh, and for public building subsidies are 570 GWh; there is no estimate for audits and building energy certification.

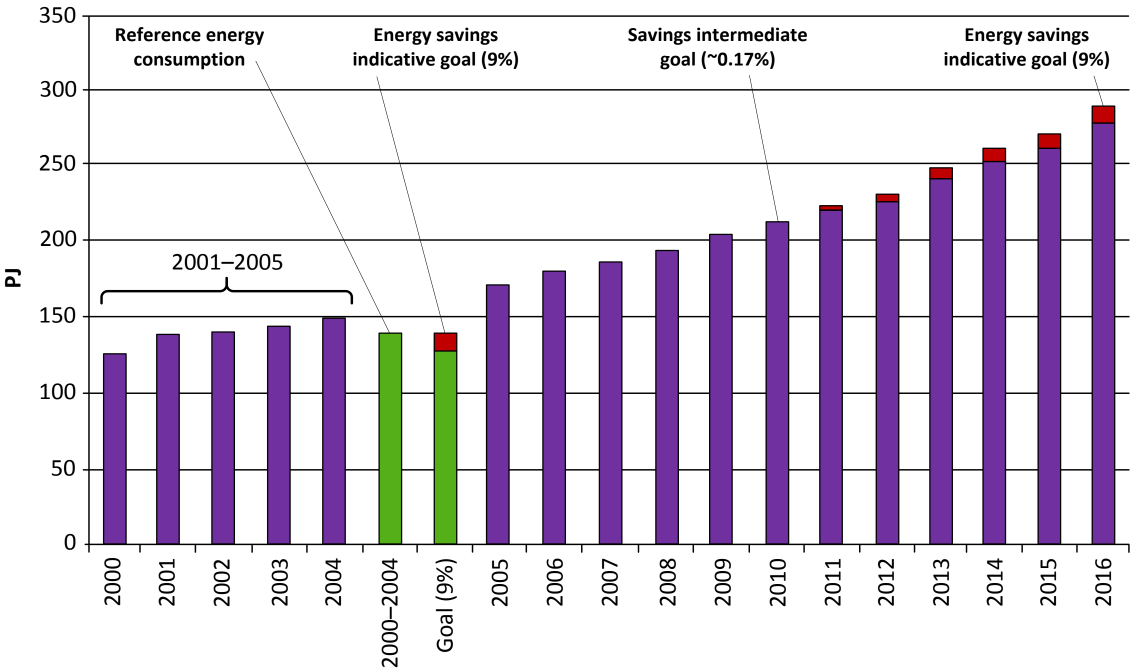

Figure 1. National energy end-use and planned cumulative energy savings (adapted from LEEAP 2008)

A combined action policy and media discourse analysis carried out by Riga Technical university (VASSI 2009) shows that the policy measures included in the first EEAP have, to a great degree, been based on the oversimplified assumption that energy efficiency goals are equally important both to society and the government, and that the low participation and interest shown by inhabitants were related to the lack of legislation and information of a technical nature. The research concludes that energy efficiency measures have to be reviewed in the wider socioeconomic context considering that inhabitants' motivation is affected not only by rational reasons but also by a combination of complex socio-economic factors.

Another evaluation of Latvia's first EEAP was carried out by "Energy Efficiency Watch" (CEC 2009)—the initiative designed to influence the development and the implementation of the national energy efficiency action plans. The study concludes that "the residential sector dominates the EEAP, and most savings are expected to come from buildings measures, mainly from improvement to the heating system. In some cases, savings estimates may be slightly overestimated, but proper assessment is not possible due to the lack of details on underlying assumptions and implementation of the measures. The EEAP provides two lists of measures; however their role, interaction and contributions to the target are not clarified. A lack of details on implementation and impacts of various measures impedes firm conclusions on whether the target can be met." (CEC 2009, 96)

The third evaluation of Latvia's EEAP was carried out by a "white box" modeling tool. In our previous research we created a system dynamics-based integrated modeling framework for comprehensive planning and continuous impact assessment of energy efficiency policies in residential sector in Latvia (the majority of energy efficiency measures in residential buildings are related to improvement of thermal properties of the building's envelope). A detailed model description is presented in Blumberga *et al*. (Blumberga *et al*. 2011). This is a mathematical simulation model for national residential energy efficiency policy formulation and evaluation and serves primarily to quantify the impacts of policy implementation, identify opportunities and avoid dead ends across sectors. The model, based on supply and demand of energy efficiency services in the residential sector, is capturing feedback (across and within both supply and demand sectors), non-linear dynamics, and delays. While system dynamics modeling captures the interactions, feedback, delays and non-linearity of complex systems, microeconomic theory (Oikonomou *et al.* 2009) provided an analytical framework to address research problems related to social, economic and institutional dimensions of residential energy efficiency. The first simulation results for Latvia's first EEAP and policy measures planned during 2008 and 2016 revealed that the residential energy efficiency goals set by the government cannot be reached (see curve 8 in Figure 2). Only 55 GWh can be saved, which accounts for 2% of planned savings. It also showed that the subsidy scheme, which is the main policy tool used in the Latvia's first EEAP, is a short-term solution and has no long-term effect if used alone. Furthermore, the model was supplemented with various other policy tools, and the outcome generated by simulation as illustrated in Figure 2 shows that only 21.6% of planned savings can be reached by 2016.

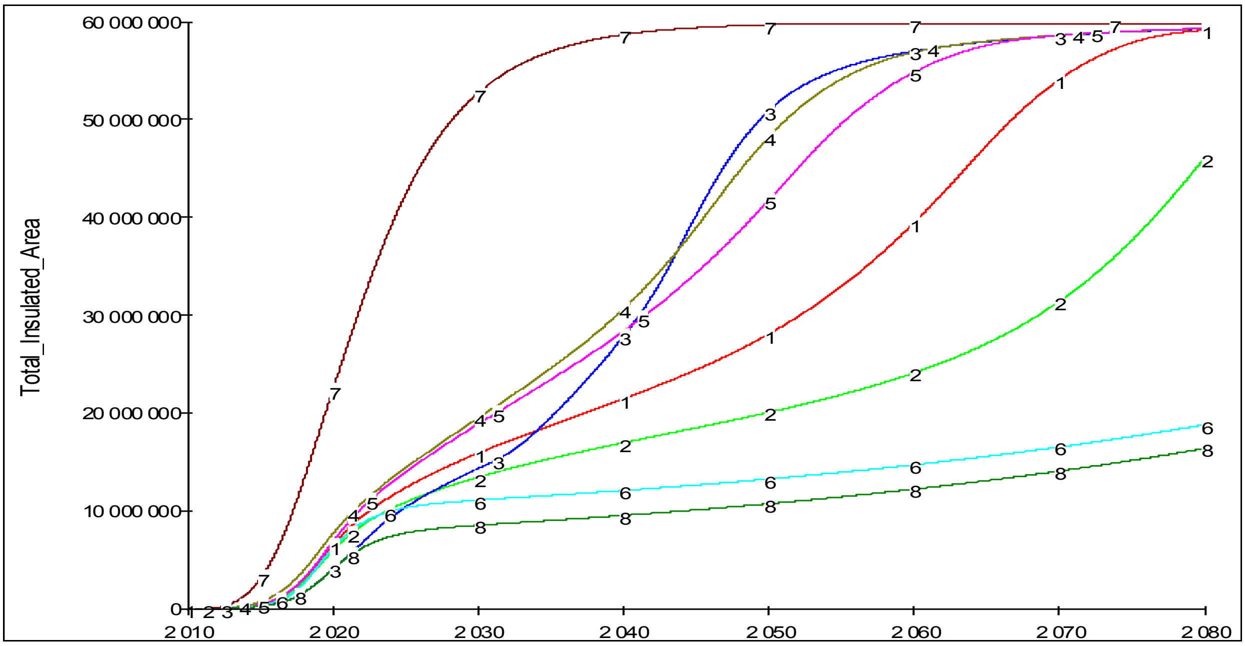

Figure 2. Energy efficiency dynamics as a result of EEAP policy tools and additionally suggested energy efficiency policies (1- 'one stop shop', 2 – CO_2 tax, 3 – increased minimum energy efficiency requirements, 4 - research and development support, 5 - standard procurement documentation and contracts, 6 – information campaign, 7 – combination of all policy tools, 8 – subsidy scheme)

The Top-down Method and the Second Energy Efficiency Action Plan

Latvia's second EEAP (LEEAP 2011) reviews energy savings achieved from 2007 through 2009 for the main end-use sectors, including the residential sector. The "Guide and template for the preparation of the second national energy efficiency action plans" (JRC 2010), drawn up by the European Commission's Joint Research Centre, was used during the preparation of the second EEAP. To calculate energy savings, the top-down method based on ODEX energy efficiency indicators was selected. The indicators are residential energy consumption for heating adjusted by the climate correction coefficient (kg_{oe}/m^2), preparation of hot water (t_{oe}/person) and electricity consumption for equipment and lighting (kWh/household) (electricity consumption for equipment and lighting does not include consumption for heating and preparation of hot water). 2007 was selected as the reference year for calculating energy savings, and energy savings were calculated for the period of 2007 through 2009. The main data source for calculating energy savings was the database of the Central Statistical Bureau (CSBL).

The savings reported in the second EEAP as achieved from 2007 through 2009 are illustrated in Figure 3. Heating energy consumption was reduced by 1030 GWh (approximately 38% of the total cumulative savings expected in the residential sector by 2016), while the water heating and electricity consumption increased. The total savings in the residential sector are reported as 693 GWh. The authors of the second EEAP concluded that “residential energy savings can be attributed to energy efficiency improvement and economy measures for heating, whereas energy savings are not evident in the preparation of hot water and use of electrical equipment during this period. It can be expected that the transition of electricity consumption analysis to recommended and more detailed efficiency indicators will show energy savings in this type of energy consumption.” (LEEAP 2011, 38-39)

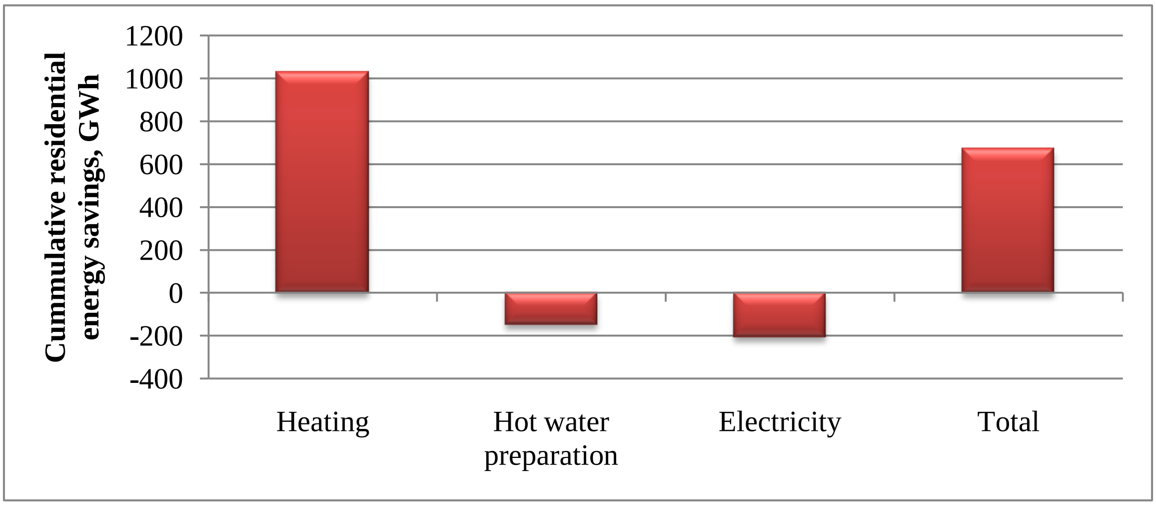

Figure 3. Residential energy savings achieved during 2007 and 2009 (adapted from LEEAP, 2011)

Results

The improper use of the top-down method can lead to absurd conclusions, as well illustrated by Latvia’s case when energy savings are not validated by econometric methods and adjusted for economic downturn. The European Union’s Directive 2006/32/EC on energy end-use efficiency and energy services specifies: “adjustments (need) to be made for extraneous factors, such as degree-days, structural changes, product mix, etc. To derive measures that gives a fair indication of energy efficiency improvement.” (ESD 2006) Authors of the top-down methods of energy savings suggest correcting savings for autonomous trends and market energy prices by econometric regression analysis, and skipping other factors due to lack of available data (Lappilone, Bosseboeuf & Thomas 2009), whereas the “Guide and template for the preparation of the second national energy efficiency action plans” suggests interpreting the results of top-down models (JRC 2010).

The 2008-2010 world financial crisis marked the beginning of a series of severe economic crises in Latvia. The crises started with the bursting of the real estate and credit market bubbles, resulting in the GDP falling by 18% in 2009, causing unemployment to rise and the bankruptcy of many companies (CSBL). National statistics show that the energy balance mirrored the GDP fall, including in the residential sector. Figure 4 illustrates events in Latvia’s economy during 2007-2010. Decreasing income and higher energy bills due to fuel price increases, along with a lack of available resources for investment in energy efficiency measures, made people decrease energy services (reduced indoor temperatures and number of heating days) provided by heating during the economic recession. Sixteen percent of the average household budget was spent on energy in 2010 in Latvia, compared to 10.2% in 2007 (CSBL).

As the theory of planned behaviour states, people make planned, rational decisions based on cost-benefit rationality (Oikonomou *et al*. 2009). Economic theory suggests that the demand for energy is based on a number of factors such as per capita income, economic production output, and the supply and cost of available energy alternatives. In the economic downturn, when income decreases and energy prices increase, savings are not realized through improvements in energy efficiency, behavioural change, or technical energy efficiency—that is, the technical ratio between the quantity of primary or final energy consumed and the maximum quantity of energy services obtainable (heating) —but rather by reducing the quantity of energy services provided by heating, such as decreased room temperatures (reduction of room temperature by 1°C gives 5% to 8% of energy savings) and shortened heating seasons.

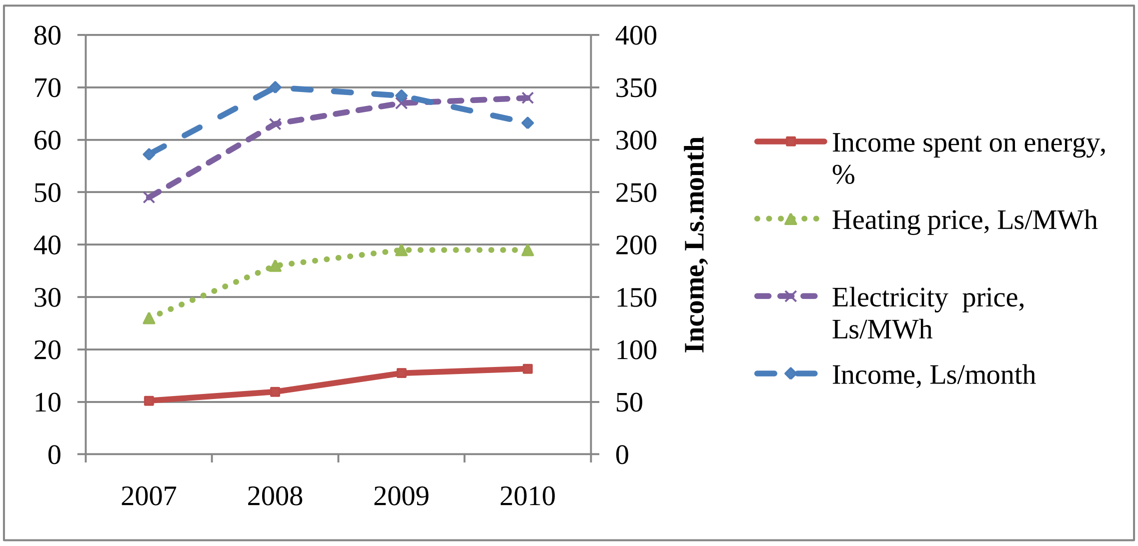

Figure 4. Income and energy prices in Latvia 2007-2010 (data from CSBL) (1Ls =0.7EUR)

There were only two energy efficiency policy measures applied during this period. Both of them were in force from the beginning of 2009 and were the first energy efficiency policy tools employed in residential sector since 1990. The first was a subsidy scheme—"Improvement of energy performance of multi-family buildings"—financed by the European Regional Development Fund, for which the state budgeted 63 million EUR. This scheme aimed at activities to increase building energy efficiency for multi-apartment buildings and financed 50% of eligible investment costs that could not be higher than 50 EUR/m^2. The implementation of the subsidy scheme started in April 2009 and is to continue during 2012 until all funds are spent. It is being implemented by Latvian Investment and Development Agency (LIDA). Additional policy tools such as information dissemination activities, standard procurement documents, and requirements for energy audit quality accompany this scheme. The second policy tool is secondary legislation to implement and administer the requirements of Law on Energy Efficiency and the European Union's Directive 2002/91/EC on Energy Performance of Buildings. These legal acts, such as regulation of energy auditors, building energy certification and building energy performance calculation, have been in force since January 2009 (EPBD 2002).

We have used data collected from intervention of actual policies implemented during April 2009 and February 2012 to perform analyses of energy efficiency improvements in residential sector during 2007 and 2009. Based on various information sources we assumed that there were approximately 15,000 m^2 of heated area involving energy efficiency measures annually in 2007 and 2008. Energy savings are calculated based on data from energy audits submitted to the subsidy scheme (LIDA, 2012). The average heating energy consumption before implementation of energy efficiency measures was 180 kWh/m^{2}year and average savings was 45%.

Figure 5 illustrates the dynamics of project application and implementation activities (as cumulative area) and cumulative energy savings during the beginning of 2007 and of February 2012. It shows that around 46% of all applications get funded, and that there is a time delay between the signing of agreements and the implementation of energy efficiency measures. 32,500 m^2 of heated area, or 13 buildings, implemented energy efficiency measures during 2007 and 2009. This resulted in 2.6 GWh cumulative savings created by improvement of technological energy efficiency during

2007 and 2009. These data show large inconsistencies with the reported energy savings of 1030 GWh for heating of buildings from 2007 through 2009. The very simple bottom-up building physics calculations confirm that savings of 1030 GWh were not reached by technological energy efficiency improvements, because that would be equivalent to an average of 13 million m^2 or 4,200 multi-family buildings being fully insulated, assuming that in average 80 kWh/m^{2}year were saved and average heated area in building was 3000 m^2 (equivalent to 60 apartments).

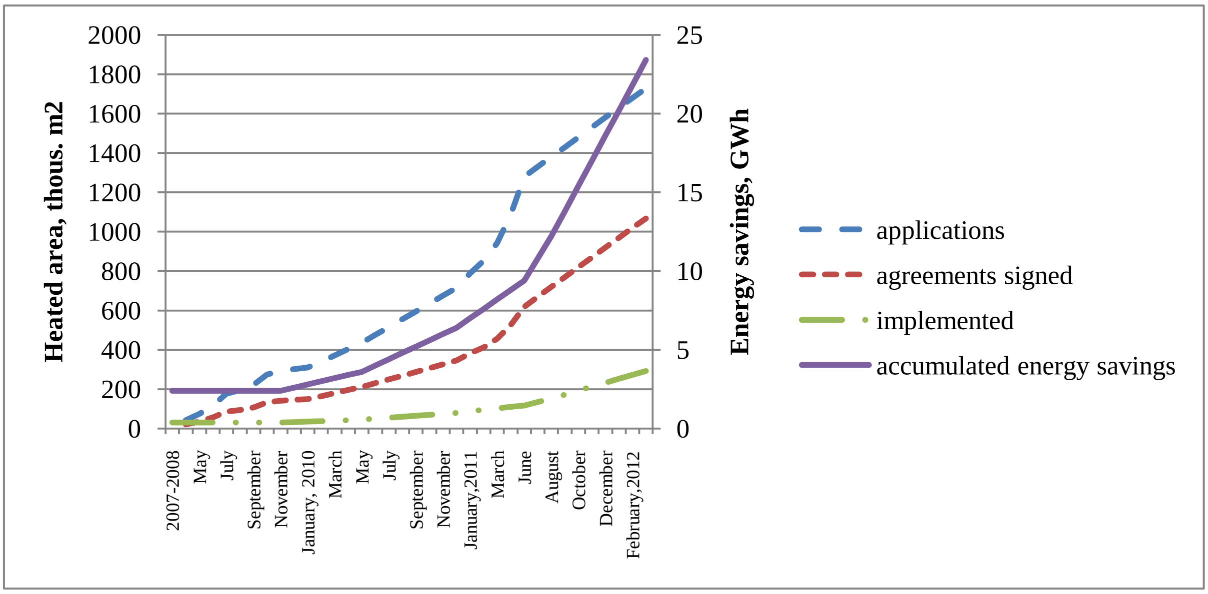

Figure 5. Project application, implementation and energy savings dynamics from the beginning of 2007 till February, 2012 (E-map 2012; Galinska 2010; Valantis 2011; LIDA 2012)

Another example to illustrate misuse of top-down indicators is the situation when the transport sector is undergoing an economic downturn. Latvia's second EEAP reports 2680 GWh energy savings in road transport during 2007-2009 (see Figure 6). It accounts for about 28% of savings from the first EEAP's baseline consumption and differs from the goal of EEAP for 2016 (407 GWh) by a factor of 13! Latvia's second EEAP does not report any significant policy measures taken during 2007-2009.

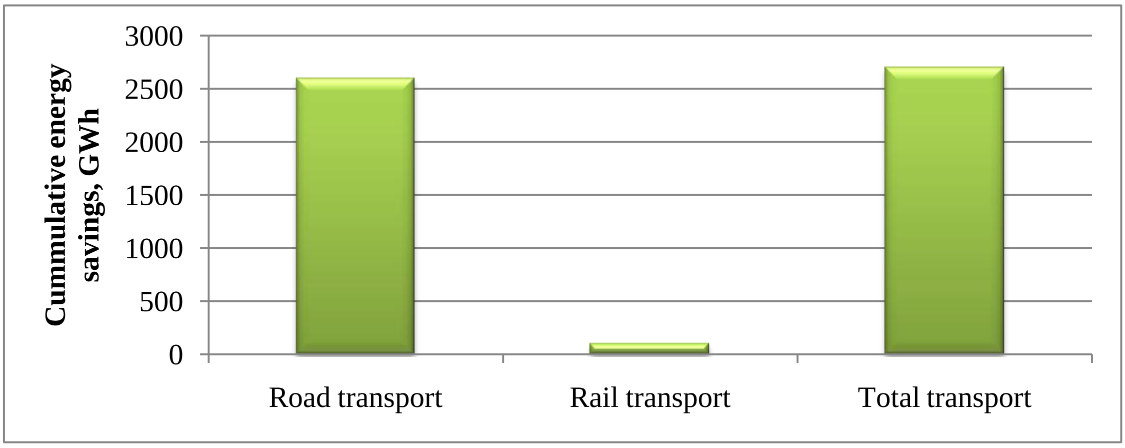

Figure 6. Transport sector energy savings achieved during 2007 and 2009 (adapted from LEEAP 2011)

As illustrated in Figure 4, economic crises have caused decreased income, related to the increased unemployment rate. In turn, this has led to reduced use of private sector transportation, reinforced by increased fuel prices. As the economy falls, commercial road transport decreases as well. National statistics include information about the number of cars owned by inhabitants and companies, but it does not provide information about car use. In economic crises people use cars less and the related top-down ODEX indicator (energy consumption in road transport per one specific road transport equivalent unit) represents energy consumption divided by number of registered cars, not cars in use. In addition, the effect of the "black market"—specifically, illegal fuel purchases—has to be taken into account. The Ministry of Finance assumes that the "black market" constituted 20-30% of GDP (BNS 2012).

Discussion

The use of the "black box" top-down approach for evaluating energy-efficiency policies is limited due to very lack of detailed data. The factors and effects underlying top-down indicators need careful explanation. Analysis of Latvia's second EEAP provides an example of how application of top-down indicators in countries in economic recession can misrepresent reality and lead to absurd conclusions about energy user responses to changing conditions. In the two cases described, macroeconomic indicators—energy consumption for heating and energy consumption for road transport—show significant decreases. If results are not interpreted by means of econometric methods in the context of the market and other events, one can draw a misleading conclusion that this is due to technological and behavioral improvements in energy efficiency. This can hardly be true if no incentives or other policy measures by the government have been taken, as was the case with Latvia. One of the reasons behind decreased energy consumption for heating could be lowering thermostat settings and shortening the heating season, leading to decreased comfort. Energy consumption for road transport was also reduced not by tremendous energy efficiency improvements but rather by lowering comfort: fewer cars were in use and the share of "black market" fuel increased during the economic downturn. There is a danger in relying too much on top-down indicators without employing proper interpretation techniques or other modeling methods. As a result, the government will face increasing energy consumption during economic recovery as people have more resources and stop sacrificing comfort for fuel savings.

Unlike "Black box" top-down models, the "white box" system dynamics model is built based on the structure of the complex real world system. The model for Latvia's housing sector was built before data about the energy efficiency subsidy scheme and complementary policy tools were available. The results shows that Latvia's EEAP goal cannot be met, and that after the subsidy scheme expires, the diffusion process will slow down, if no additional measures are taken. The structure of the system is transparent and easy to adjust for any new events or actions.

Conclusions

In this paper we presented the difference between two modeling approaches used for assessment of residential energy efficiency policies: the "black box" and the "white box" models. We examined Latvia's residential energy efficiency policies to illustrate the advantages and disadvantages of both methods. "Black box" top-down models have to be used with great caution, and it is important to understand the role of interpretation of results and the context of events. In contrast, the "white box" model has a transparent structure that provides information on different variables, including their relations, feedbacks and delays. The other difference is the time scale—in "black box" models the assumed future is based on past data, while in "white box" models the structure generates the behavior. This distinction is of great importance today when everything is changing very rapidly.

In the research presented in this paper, the data that are available after two years of operation of the subsidy scheme are used. Further research will focus on tests of the system dynamics model described in Section 3 based on real data on project implementation and energy consumption monitoring as soon as they become available from the LIDA.

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