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ENERGY EFFICIENCY IN THE LONG RUN IN THE SELECTED EUROPEAN COUNTRIES

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ABSTRACT. In the presented paper assumption is being raised that *ceteris paribus* forecasted energy efficiency until the year 2050 reveals competitive potential, which could be reached if technological progress is ongoing and no radical changes in the energy consumption culture are observed. The research methodology is as follows. In order to clarify what trends of energy efficiency change are preconditioned by the structure of the economy, technological potential and behavioral patterns, activity level and energy intensity in the household sector are forecasted for the selected European countries – Poland, Lithuania and Germany. Lithuania and Poland represent here the countries slightly less economically developed as compared to highly developed Germany. Long-range energy forecasting software LEAP, developed by Stockholm Environment Institute is being employed for the long-term forecasting of energy use and energy intensities in the household sectors. The obtained results, as we have expected, allow verifying if consistent patterns of energy intensity change is existent for currently comparatively less developed and better countries, and if such patterns differ. Peculiarities of energy intensity change in less developed and more developed European countries are to be economically interpreted. The obtained results will allow to judge about change of competitiveness of the considered countries. Provided insights can be instrumental for devising national economic policies oriented on more efficient energy use in the long run.

JEL Classification: N70, O18

Keywords: competitiveness, energy security, energy efficiency, household sector, behavioral patterns

Introduction

Long-run competitiveness could be associated with sustainable economic development. The latter, in its turn, is related to efficient use of the available national resources. Energy resources are always considered to be of strategic importance, for any economy, thus, a lot attention is being paid to their availability and efficient use (Tvaronavičienė, 2016; Kasperowicz *et al.*, 2017; Vojtovic *et al.*, 2018). Efficient use of this particular group of resource affects national competitiveness and the environment, which are important constituents of the sustainable development processes (Balkytė, Tvaronavičienė, 2010; Abr). Efficient use of energetic resources has ultimate aim to reduce volumes used, and in that way to achieve stewardship of available resources (Nawrot, 2013).

1. Literature review

Total energy consumption of any country depends on a wide array of factors. There are two main indicators used for measuring of energy efficiency use, one indicator is used on micro-economic level, and another is used on macro-economic level. The first indicator, used on micro-economic level, allows measuring if asset e.g. appliance, vehicle, building, is energy efficient if to compare it to another analogic household asset or factor of production. If to provide an example, if could be found that one refrigerator, computer, car or cooling/heating system uses less energy is to compare to another analogical item, which less technologically advanced. Hence, energy efficiency on micro-level is about technological potential of energy stewardship. In this case, we talk about energy efficiency of concreate item, for operating of which energy is used. Technology level is precondition of energy efficiency on micro level and macro level. Energy efficiency on macro-economic level is measured by another indicator, which is called energy intensity. Energy intensity shows how much of energy is being used for one European Euro, or another currency. Hence energy intensity determines demand in energy resources. Competitiveness of country, inevitably is affected by total energy intensity (total energy consumed divided by GDP), which is, respectively, sum of energy intensities of separate comprising parts of economy (Anjali, Shahid, 2017; Locmelis *et al.*, 2017).

Let us discuss, what factors affect total energy intensity. One group of such factors is structure of economy, understood as GDP composition. If to adopt generalized approach, it could be claimed that GDP of any country is comprised of three main sectors of economy: industry, services and agriculture. These generalized sectors, in their turn, is fractioned, and comprised and of many sub-sectors (classification and detailed description of attribution of each activity to sub-sector of economy is provided, e.g. by Eurostat). Let us recall, that each sector of economy, and even activities within each sector, are characterized by different energy intensity; i.e. different amount of energy is required per item of production, which, in its turn, is usually measured by one unit of selected currency. Therefore, total energy intensity of any economy inevitably will be dependent on composition of economic activities characteristic for a considered country; structural changes affect total energy intensity for a whole economy (Dudzevičiūtė *et al.*, 2014; Hasanbeigi *et al.*, 2014; Duran *et al.*, 2015). Another important factor affecting energy intensity is level of technological development and ability to implement or commercialize technological achievements, ability to transfer technologies, which are already available (Tvaronavičienė, Černevičiūtė, 2015; Passerini *et al.*, 2017). Technology transfer efficiency, in its turn, again depends on many factors, such as clustering phenomenon

(Ignatavičius *et al.*, 2017) income distribution patterns in particular country (Tvaronavičienė, Gatautis, 2017), behavioral patterns prevailing in society (Tvaronavičienė, 2016) etc.

Besides indicated factors total energy intensity depends used energy mix, transport mode, population growth, GDP level, GDP growth, poverty level etc. Since all those interrelations are too complex to take into account, we adopt methodical approach described below (Bojnec, Papler, 2011; Firlej, 2012; Heaps, 2016).

The aim of the presented research is to reveal what trends of energy intensity change are characteristic for the selected countries with different development level.

2. Methodological approach

As it was indicated above, total energy intensity of economy is conditioned by such main factors, as structure of economy, technological potential and behavioral patterns. In our research we will tackle one specific segment of economy, specifically households. The reason of such selection could be explained in the following way. Households use all technologies, which available for societies and therefore in the best way reflect prevailing behavioral patterns. The same technologies, most likely, are used in other sectors of economy, and the same households serve as employees in their work places, to be it industry, services or agriculture. Therefore, we assume, that level of activity and energy intensity in household sector, taken in long-run can reflect processes, which take place in overall economies of selected countries. Here we need to note, that this hypothesis, is rather conditional, and is formulated just for this research purposes. We admit, that the research limitations are present here. Object of research: activity level and energy intensity in household sector in Poland, Lithuania and Germany, forecasted until the year 2050. Let us explain the choice of countries for this research. Hence, Lithuania and Poland represent countries slightly less economically developed if to compare to the highly developed Germany. We believe, that Poland and Lithuania, being countries of different size but of rather similar level of development, could be instrumental for revealing consistent patterns of development in considered sector, if such consistent patterns exist. Germany in this research would represent countries of the highest development level.

Long range energy forecasting software (LEAP), developed by Stockholm Environment Institute is being employed for long-term forecasting of activity levels of energy use and energy intensities in household sectors of indicated above countries (license is obtained in 2015 year). The results, as it was mentioned above, would allow verifying if consistent patterns of development are existent for currently comparatively less developed countries, if to look for such patterns, which would exist irrespectively of country‘ s size. Germany would represent currently well developed countries, and would signal if current competitive advantage would be maintained in the long run. Obtained results would be instrumental for devising economic policies of national development oriented to efficient energy use in long run.

3. Long-term energy consumption and energy efficiency trends in selected countries, household sector

Let us compare forecasted activity level of households in energy sector in Poland (*Figure 1*) and Lithuania (*Figure 2*). The key assumption used here is *ceteris paribus*, software used: *LEAP*. Depicted in figures forecasting results signal that number of households, using energy would diminish in both countries. Similarity could be found in pattern of change of households' number, while absolute numbers is rather incomparable, what is natural for countries of different

size. Despite size is different, we assume, that due to rather similar level of development, energy intensity should gradually diminish and, in principle, should converge. This assumption could be grounded by providing the following arguments. The first, availability of new technologies, technology transfer phenomenon and transfer of behavioral patterns in energy use in neighboring countries should lead to similar, and converging energy intensities in household sector in long-run (until the year 2050 in our case). The second, comparatively lower level of economic development, if to compare it to such highly developed European countries as Germany, would restrict high energy intensities, since energy stewardship due to high price of this resource has been historically more characteristic to countries of lower level development.

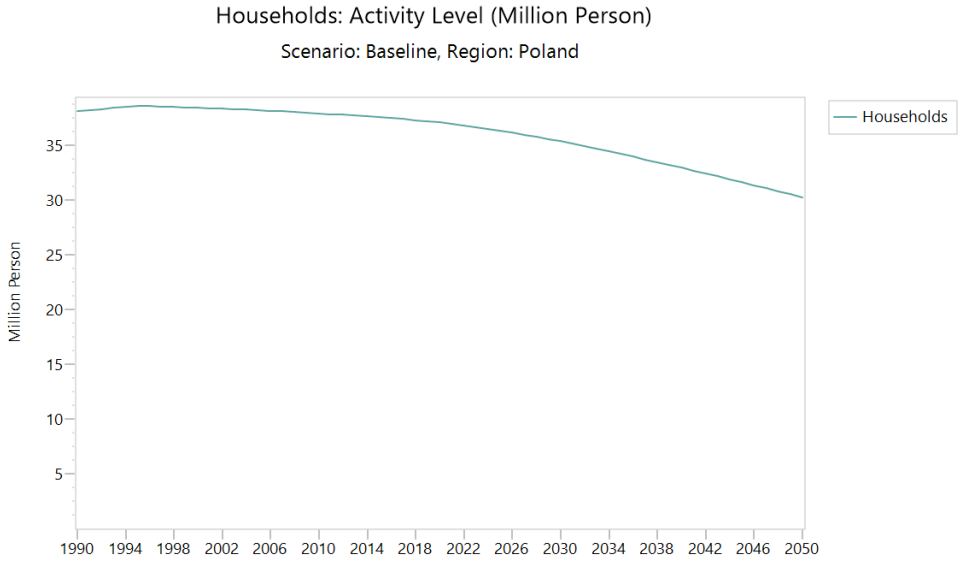


Figure 1. Forecasted *ceteris paribus* activity level of households in the energy sector in Poland
Software: LEAP.

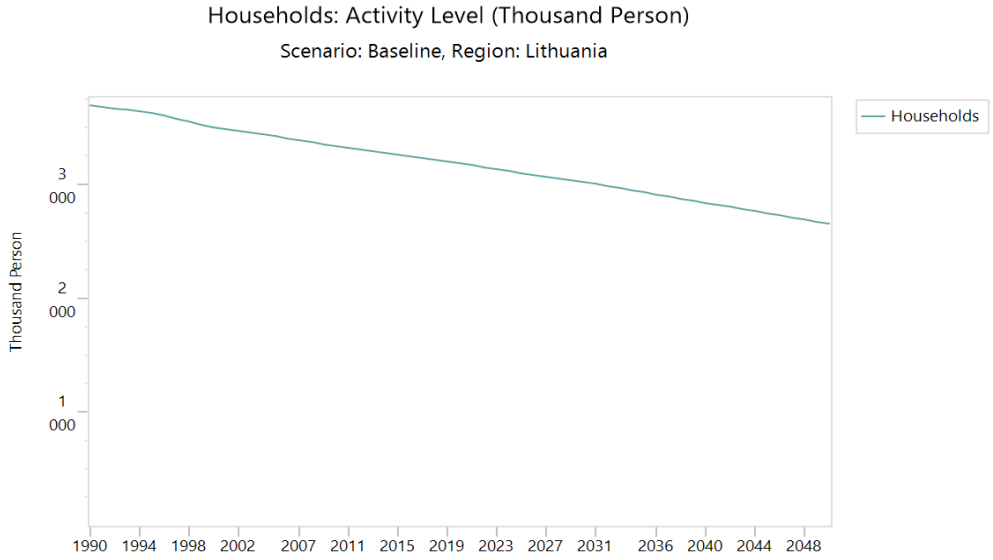


Figure 2. Forecasted *ceteris paribus* activity level of households in the energy sector in Lithuania
Software: LEAP.

Let us examine long-term tendencies of energy intensity change in Poland and Lithuania (*Figure 3* and *Figure 4*, respectively) and let us conclude if assumptions provided above, assuming converging patterns could be verified.

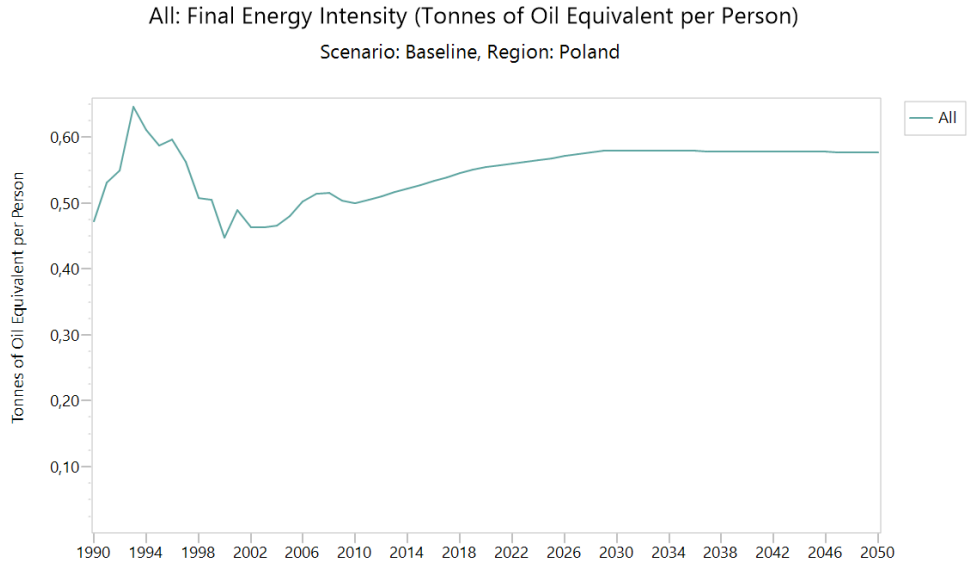


Figure 3. Long-term tendencies of energy intensity change in Poland, estimated in tonnes of oil equivalent per person
Software: LEAP.

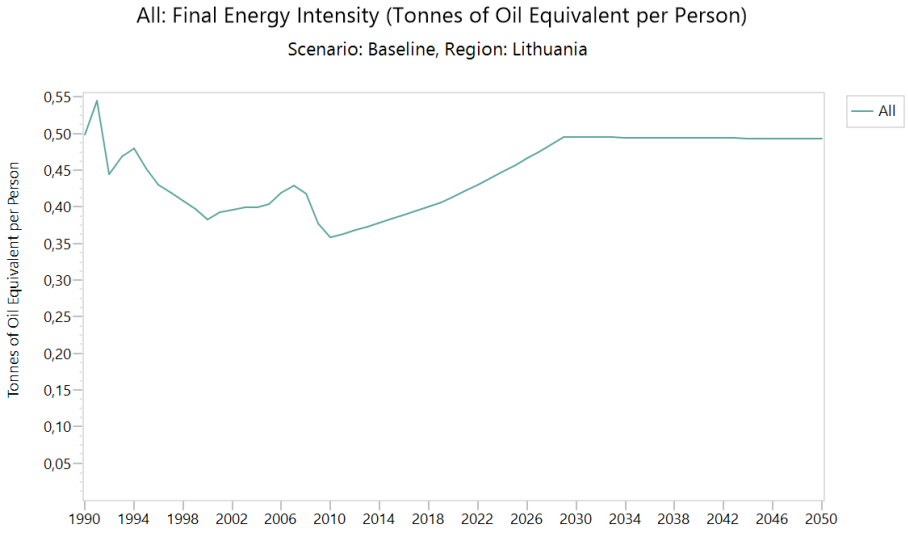
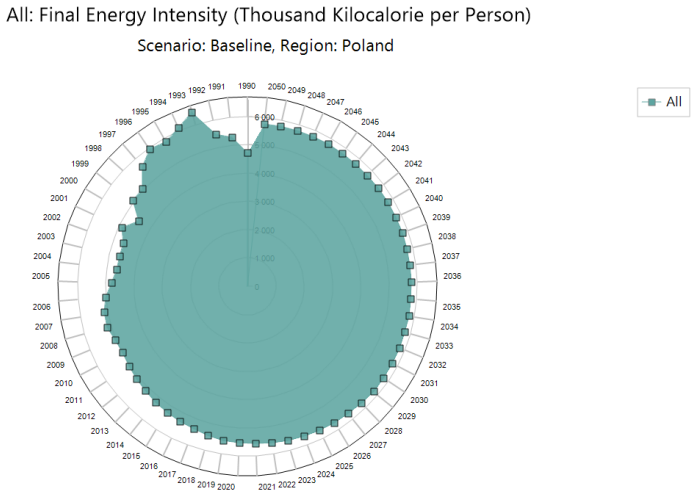


Figure 4. Long-term tendencies of energy intensity change in Lithuania, estimated in tons of oil equivalent per person
Software: LEAP.

Juxtapose of long-term energy intensity tendencies in Poland and Lithuania allows us to come to conclusion, that the following consistent patterns could be revealed: at first, energy intensity gradually diminishes, and after reaching the lowest value, it starts to increase again. At the very end of forecasted period, i.e. in the year 2050 it is lower than at the very beginning of the considered period, i.e. the year 1990.

Naturally, the following question arises: why energy intensity does not demonstrate gradual and sequent tendency of diminishing, and after reaching certain point, starts growing again.

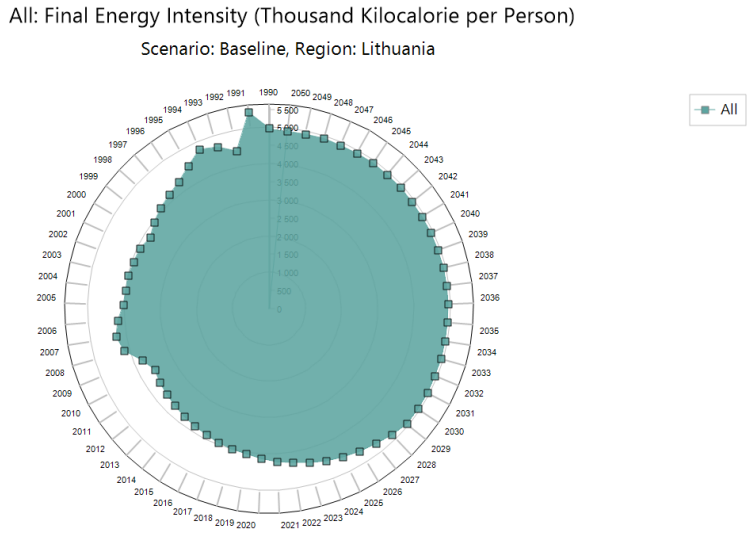
In order to examine better the differences among energy intensity in the year 1990 and forecasted value in the year 2050, let us depict energy intensities in different way (*Figure 5* for Poland, and *Figure 6* for Lithuania, respectively). These figures will allow us juxtapose differences in energy intensities at the beginning and the end of the considered period, and estimate progress potentially achieved, *ceteris paribus*, during these 60 years in both countries.



Note: Energy intensity, in year 1990 was lower than in year 2050

Figure 5. Energy intensity change in Poland, estimated in thousand kilocalorie per person, years 1990-2050

Software: LEAP.



Note: Energy intensity, in year 1990 estimated equal to energy intensity forecasted for year 2050

Figure 6. Energy intensity change in Lithuania, estimated in thousand kilocalorie per person, years 1990-2050

Software: LEAP.

Obtained results, lead us to rather unexpected insights, which requires to be interpreted. We found out that data for Poland shows that energy intensity, in year 1990 was lower than *ceteris paribus* would in year 2050. Data for Lithuania suggests that Energy intensity, in year 1990 is estimated equal to energy intensity, the same conditions, forecasted for year 2050. Despite data for Lithuania is slightly more favorable if to compare to Poland's one, we need to admit, that there are no expected contraction in energy intensity in household sectors of both countries. The provided results contradict the major expectation that energy intensity has to diminish considerably in the long-run due to technological progress. To go further, the following question arises: if technological progress cannot be retarded and technological transfer cannot be interrupted in long run, then why energy intensity does not move in expected direction. We claim that behavioral attitudes towards energy consumption does not allow to diminish energy intensity. To put that into other way, it could be said that with economic grow, improvement conditions of living households consume more and more various devises, which even being energetically efficient lead to increased energy intensity in household sector of selected countries. Lithuania, being very slightly less developed economically, still demonstrates better results in energy intensity, what, in principle, supports provided economic interpretation of obtained results of forecasting.

To make our analysis more robust, let us examine forecasted activity level (*Figure 7*) and energy intensity in household sector for Germany (*Figure 8*), which in our research represents the best developed European countries.

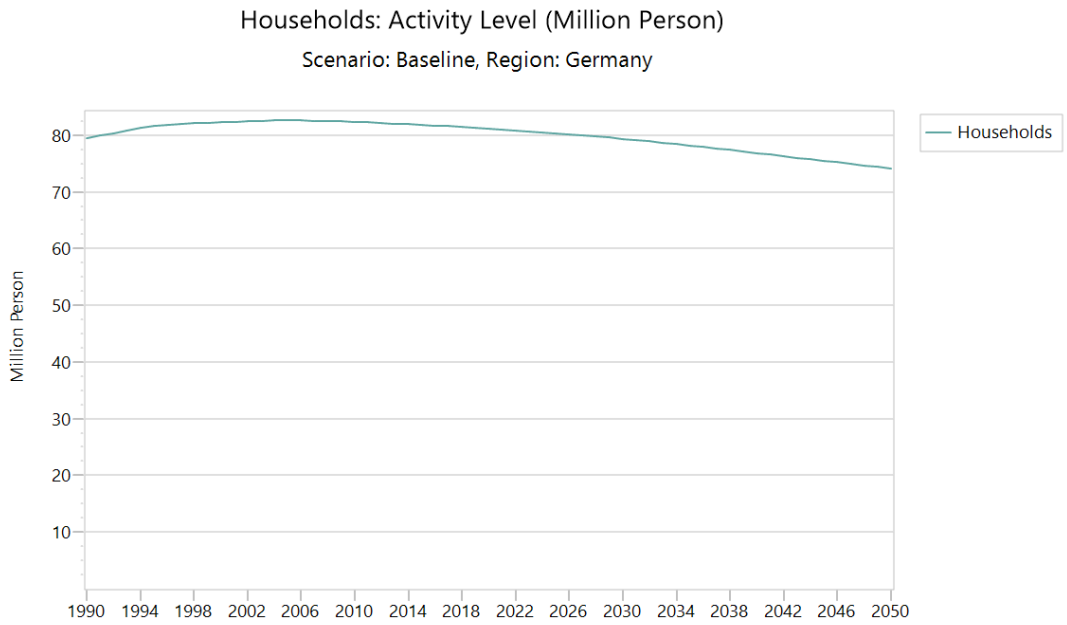
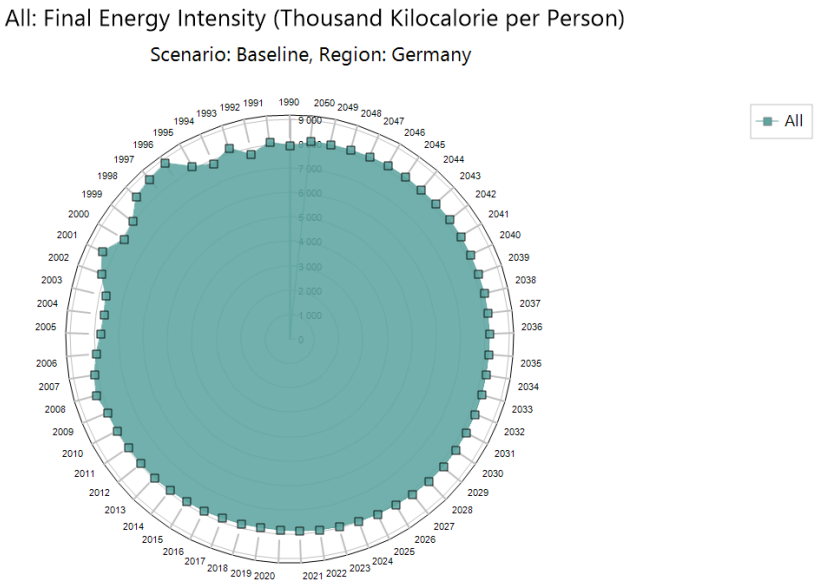


Figure 7. Forecasted *ceteris paribus* activity level of households in the energy sector in Germany
Software: LEAP.



Note: Energy intensity, in year 1990 estimated equal to energy intensity forecasted for year 2050
Figure 8. Energy intensity change in Germany, estimated thousand kilocalories per person, years 1990-2050
Software: LEAP.

The case of Germany supports our insights formulated above: energy intensity of the household sector does not diminish considerably in the long run. Since technological innovations in energy sector inevitably are present, we can conclude that behavioral patterns and scale of devises used by household sector does not allow to achieve diminishing use of energetic resources.

Conclusion

Forecasting of households' activity in energy sector and energy intensities in household sector until the year 2050 in Poland, Lithuania and Germany and interpreting of obtained results allowed us to come to the following conclusions.

Activeness of energy use in all the considered countries would gradually diminish, what would be caused by gradually diminishing number of the households *ceteris paribus.* This tendency is characteristic for all the analyzed countries and this trend does not depend on a country's size.

Energy intensity in selected countries would not diminish considerably in year 2050 despite positive fluctuations, which are observed during the considered period in-between the years 1990 and 2050. If to juxtapose Poland and Lithuania to Germany, it has to be noted that Lithuania and Poland performs better than Germany. This difference in performance of energy intensity in household sector can be explained by behavioral patterns in energy consumption area by households, which increase their consumption, when their economic affordability increases. Actually, affordability does not create stimuli for energy stewardship and absorb effects created by technological innovations in energy sector.

Obtained results may be of high importance for formulation of long-term policies oriented to energy stewardship.

Research limitations. Each forecasting and modeling has its research limitations, since is based on certain assumption. The presented forecasting is based on the *ceteris paribus* assumption, what means that we analyze long-term forecasting results, which are expected in case economic conditions in considered countries would maintain the same tendencies of change. Economic conditions are determined by such parameters as GDP growth, Gini coefficient, reflecting level of inequality, economic structure, transport mode, energy mix, etc. Changing one or several of those parameters would affect results of long-term forecasting. We claim that altering of forecasting assumptions should be based on the analysis of the *ceteris paribus* forecasted results, like in the case we present. Since the obtained results signal that it is necessary to impose a more efficient policy restricting energy use by the households and orient households onto energy stewardship, other than presented assumptions related to forecasting the energy intensity of the household sector could be modelled and then their results analyzed in future research studies.

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