Kaunas University of Technology
Faculty of Electrics and Electronics

Analysis of the electricity demand forecasting in the Lithuanian household sector

Master's Final Degree Project

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Title of the Final Degree Project

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I confirm that the final project of mine, Evarist Nicolau Fillol Lacomba, on the topic "Electricity demand forecasting in the Lithuanian household sector" is written completely by myself; all the provided data and research results are correct and have been obtained honestly. None of the parts of this thesis have been plagiarised from any printed, Internet-based or otherwise recorded sources. All direct and indirect quotations from external resources are indicated in the list of references. No monetary funds (unless required by Law) have been paid to anyone for any contribution to this project.

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Evarist Nicolau Fillol Lacomba. Electricity demand forecasting in the Lithuanian household sector. Master's Final Degree Project. Dr. Inga Konstantinaviciute of Lithuania Energy Institute, Faculty of Electrics and Electronics, Kaunas University of Technology.

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Summary

The increasing worldwide demand of the energy is implying to elaborate all kind of forecasts and assumptions regarding its supplying. This is due to the fact that these increases will imply a proportional improvement of the capacities of the generation, transmission and distribution systems.

In the case of Lithuania, it has suffered a lot of changes and events in the sector throughout the last decades, such as the closure of its main source of electricity (Ignalina Nuclear Power Plant), the constant liberalization of the national market and its inclusion in the Nordpool net, different stretches of economic growth, migration, etc. Despite all of them, the trend of the electricity consumption in the dwelling has remained increasing constantly.

Even knowing that the share of the electricity household demand represents a 5% of the total energy consumption all around the country, it is important to forecast it since there are not actual studies related with and Lithuania is sunk in a huge dependency in the electricity exports.

Thus, the main aim of the report is to project the possible development of the trends of electricity consumption in the household sector till 2040. This will be reached by applying the econometric and engineering forecast methods.

Contents

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List of abbreviations and terms

BEMIP - Baltic Energy Market Interconnection Plan

CEN - Continental European Network

EPBD – Energy Performance of Buildings

EU – European Union

GDP – Gross Domestic Product

JESSICA - Joint European Support for Sustainable Investment in City Areas

LNG – Liquefied Natural Gas

NPP - Nuclear Power Plant

OECD - Organisation for Economic Co-operation and Development

UN – United Nations Organisation

Introduction

The main goal of the paper is to forecast the long-run electricity demand of the Lithuanian household sector. To do so, it will be necessary to follow a determined sequence of tasks.

The first one required will be to analyse the actuality of Lithuania, the energy, electric and household sectors, the market, etc., by doing a *review of literature.* In this vein, it is interesting to check that there are not scientific publications that deal with this kind of forecast in the country, which makes to project the electricity consumption trends of considerable importance.

In order to choose which methods will be more optimal, it is necessary to break down the *methodology* of this kind of forecasts.

The first method that will be applied will be the *econometric* and it is known as a top-down approach. It is based in the relation of the electricity consumption with macro-economic and socio-demographic factors. Thus, knowing the forecast of these ones from official sources, it will be possible to predict the figures of electricity demand.

The second method that will be used will be the *population distribution of the engineering* method, which is englobed as a bottom-up or end-use approach. The usage of this model is interesting since it considers more factors than the econometric one and its results are already broken down.

The **scientific novelty** is present since it is the first time that Lithuania is object of study of forecasting the long-term household electricity demand. This is due to the fact that it has not been found anything similar all along the review of the literature. Furthermore, it is interesting to check that the approach of the paper will allow to compare the accuracy and other features of a bottom-up and a top-down methods.

Thus, the **main aim** will consist in perform the household electricity demand forecast taking into account the most important factors.

The **tasks** to follow will be to elaborate a review of literature, an analysis of the methodology and the application of the econometric and population distribution methods.

In addition, the paper consists in 72 pages, 67 figures, 22 tables and 82 references.

Review of literature

The first third of the paper is the review of literature. The main goal of this part is to seek the answer of the question of *why is it important to have long-run forecasts of electricity consumption.* To do so, there are two different ways to approach the answer: directly or indirectly.
Firstly, the direct way for replying the inquiry is done in the first pages of the review of literature. It consists basically in showing socioeconomic data and its corelation with the energy consumption, in one hand, and electricity on the other hand.
After this part, it will be exposed and simplified the whole scenario that englobes the Lithuanian Electricity Consumption in the household sector. Thus, it will be shown on an implicit way why the features of Lithuanian market and the policies taken by European Union and Lithuanian Government are gravitating on forecasts of all kind of energy production, supply and consumption, being the electricity consumption of the household sector one of the cornerstones of this big sphere.

1- The need of energy forecasts

On a first sight, there are a lot of factors that have the chance to influence in the energy consumption, such as the weather, the consumer behaviour, the availability of power sources, etc., but the ones that possess the biggest influence are the economic development and the population level.
On the one hand, the economic development will stay growing up because it is unstoppable due to its own definition. There is just a few number of occasions where, due to huge crisis or wars, it has reduced its pace.
On the other hand, it is well known that the world population is going to increase during the incoming decades. Thus, it will be required to build and improve new facilities, increment the supplying of goods and food, etc., and specially the main topic of this thesis: to provide all kind of energy power, including electricity.
The increase of population from 2020 to 2040, the year when the forecast of the paper will take place, will be from 7.8 to 9.5 billion of people according to UN as it can be seen in the figure 1 [1]:

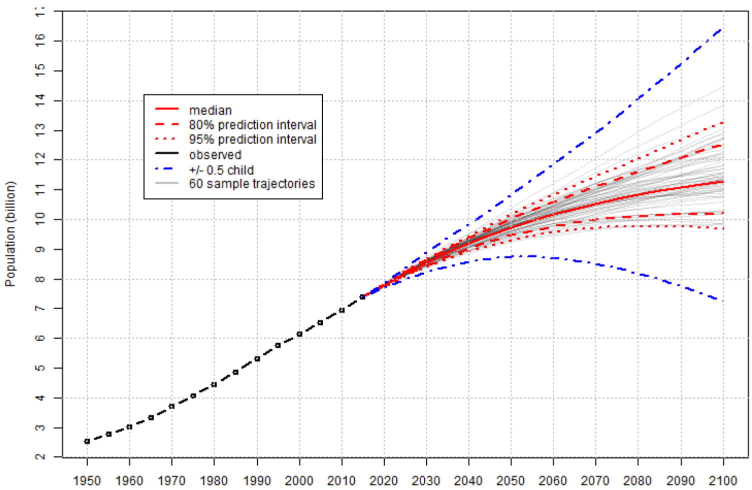


Figure 1: Probabilistic projections of the world population (Source: United Nations, Department of Economic and Social Affairs)

Taking into account all the previous facts, energy demand during 2040 would be near to double its amount compared with 2017 [2], hence, a new policies scenario is needed in order to be able to create a sustainable and secure worldwide energy balance. This scenario is stated by the assessment of current directions and trends in energy and climate matters, even though they might still not be included in formal laws yet.
This huge increment of energy demand will bring to new supplying projections, changing widely among developed and developing countries can be seen clearly in the figure 2:

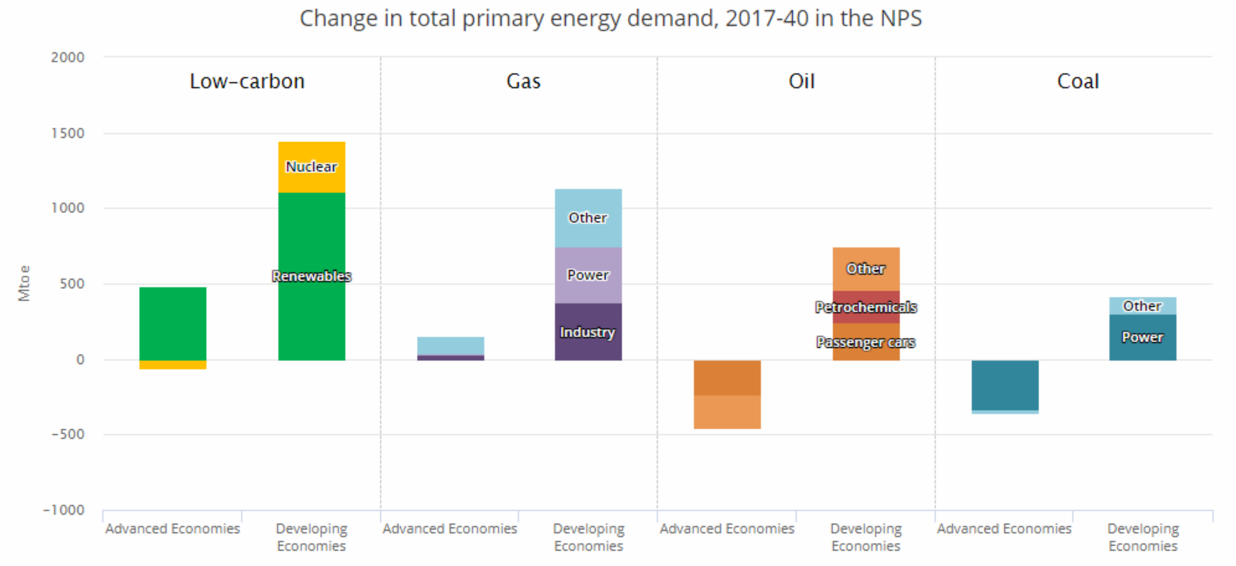


Figure 2 Primary energy demand from 2017 to 2040 (Source: IEA)

Then, energy forecasts play an important role because they will allow to governments and consumers to see how their behaviour is affecting to the climate change, the sustainability of the system and the capacity of its reservoir.
On the one hand, short-run energy forecasts will provide information to entities regarding the possibility of shortages or overrun of any of the fuels requested by the customers acting in consequence by looking for alternative sources, such as interconnections with other markets or purchases of other kind of supplies.
On the other hand, long-run energy forecast will assess the chances of fulfilment of the goals in efficiency and emission matters, the capability of the power plants, interconnections, distribution and transmission nets, etc. This is due to the fact that it is required a period of some years to build such facilities.

1.1- Need of electricity forecast

The difference that comes up when it is time to talk about electricity instead of most of the rest of energy forms is that it is hardly storable. Taking it into account, it can be stated that it is necessary to be precise in the forecast.
The short-term projection it is supposed to be relatively important since all kind of systems need to accomplish the N-1 principle: *the power system keeps working even if one or two major components will stop suddenly to perform*. This means than the rest of operators, such as turbines, power plants, renewable energy sources, etc., should be able to fulfil the extra demand caused by

the disconnection of those sources by producing more energy or electricity. Thus, it could be said that there is currently existing a bit of overcapacity in the sector.

In another vein, if the demands are frequently forecasted with a higher value than its real one, then the system will be designed with a huge excess of installed capacity and it would incur in overruns, even considering the probable future use of the extra installed capacity due to the natural growth of the energy and electricity demand.

Even though, there are some extreme cases where underestimate electric forecasts induce to brownouts or, even, blackouts and overestimate electric forecasts lead to the authorization of a not profitable old power plant [3].

Moreover, the short-run predictions allow the market companies to rationalize the pricing structures and to optimize the demand fulfilments throughout the day, week, season, etc. There should be special attention in the prevention of peak loads, but, nevertheless, the main approach of the forecasts should be the total load shape. The higher the level of detail the more accurate will be the use of tariffs per hours, the imposition of penalties for consumptions higher than the prearrange limits or real time pricing.

In addition to the long-run forecast benefits, the impact of new electrical supplying can be estimated by creating a scenario with the future features of the market while it's checked the addition of it, such a new power plant, a new transmission or distribution system and the usage of possible interconnections.

In addition, the long-run forecast are used mandatorily for planning the construction or closure of power plants in order to be as much efficient as possible. The supplying system has to adapt itself with a gap time of some years for both cases.

On the one hand, if a power plant has to be built, it is required to spend some years till it is able to perform; in the case of Nuclear power plants is 7.5 years for instance [4].

On the other hand, if the shutdown of a power plant is needed, it is advisable to program in advance the adaptation of the production system in order to absorb the electricity supplied by this source.

It is quite important to remark the approach of the capacity of interconnection between countries. The trend of European electric markets is to behave as a single market. The unity of prices is looked for in this case so the interchanges of electricity will be required more and more. In this way, it will be necessary to forecast the capacity for the new interconnections since, as it happens with power plants, it takes some years to project and construct.

Following the previous example, the transmission and distribution throughout the same country has to be evaluated, renewed and upgraded continuously. This is done in order to supply electricity efficiently to the customers.

To conclude this part, long-run forecast will be especially important for developing countries, such as India or China, since they will increase the industry level, the number of appliances and vehicles, etc., as it can be seen in the figures [5]:

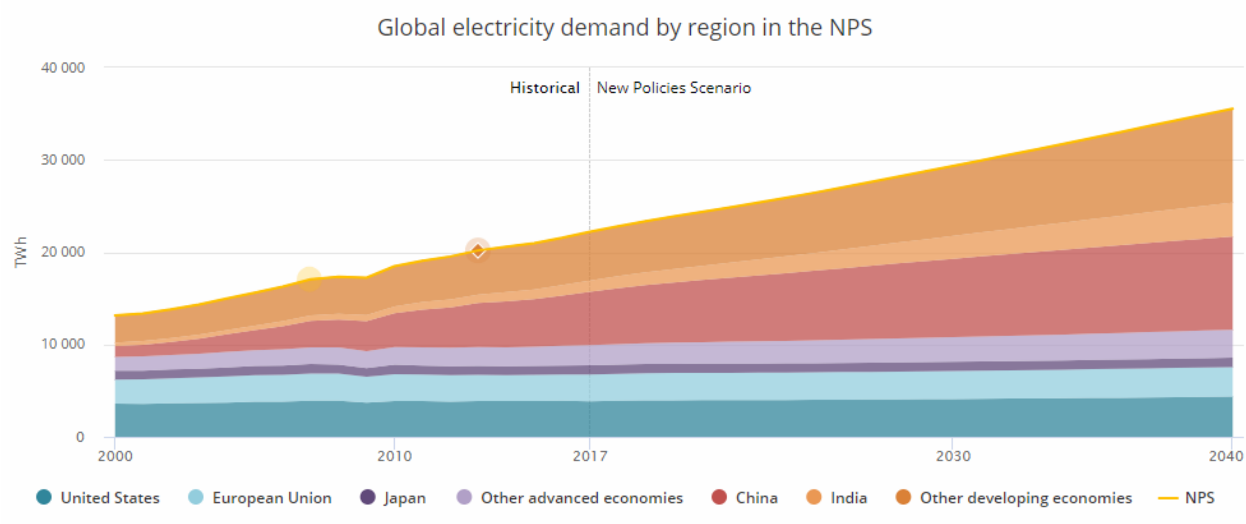


Figure 3 Global electricity demand in the New Policies Scenario (Source: IEA)

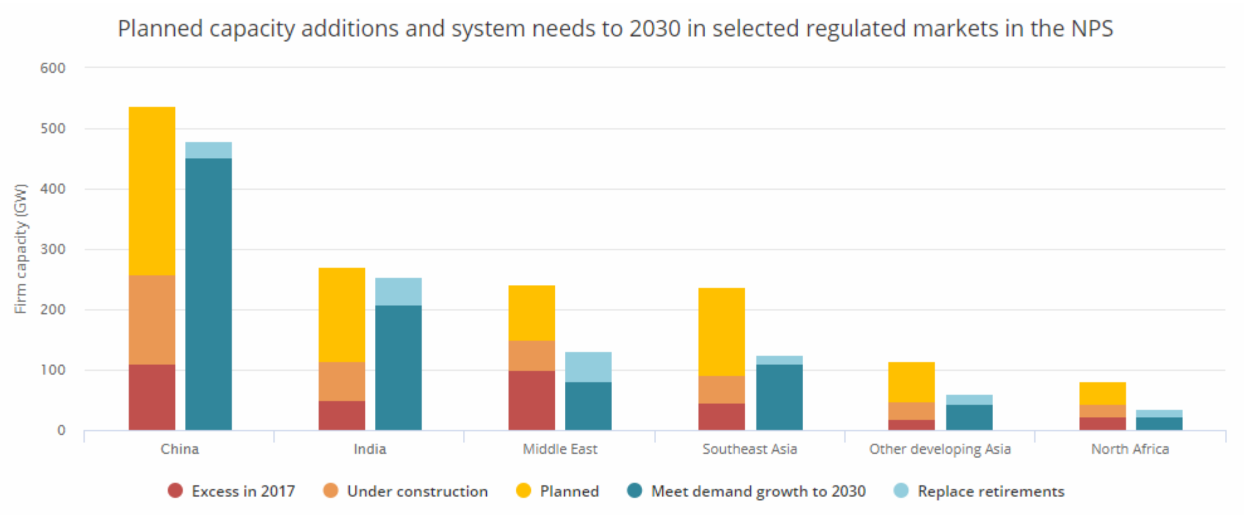


Figure 4 Planned capacity additions in the developing countries till 2030

2- The Lithuanian scenario of the electricity throughout the past two decades

In the previous section the matters of discussion have been treated in a broad way: increase of the population of the world, changes in primary energy demand, needs of short-run and long-run forecasts, etc. but it has to be stated that the frame of the paper will be to forecast the electric household demand of Lithuania. Thus, it is required to go some steps farther. Following the previous example, the transmission and distribution throughout the same country has to be evaluated, renewed and upgraded continuously.

Primarily, the introduction of the Lithuanian market and its features will take place. Once it is done, it will be needed to check the guidelines of the European Union in energy and, then, it will be analysed how Lithuania has adapted to those requirements.

There is a big deal of factor that influence in the electric scenario of a country. The main ones are geopolitics, economics, demographics and energy supplies and those have suffered a lot of changes in the last decades, that will be introduced as a summarise and will be approached deeply later.

The geopolitical matters have been mainly related with the independency from the Soviet Union and the posterior relations with Russia. This is done in order to supply electricity efficiently to the customers.

Economic trends have varied a lot throughout this time. On the one hand, the country was increasing its GDP by 6 to 10 % yearly before the crisis of 2008, due to its quick development. On the other hand, Lithuania has reduced the pace of the economic growth till reaching levels of 2 to 4% per year since this breakdown [6].

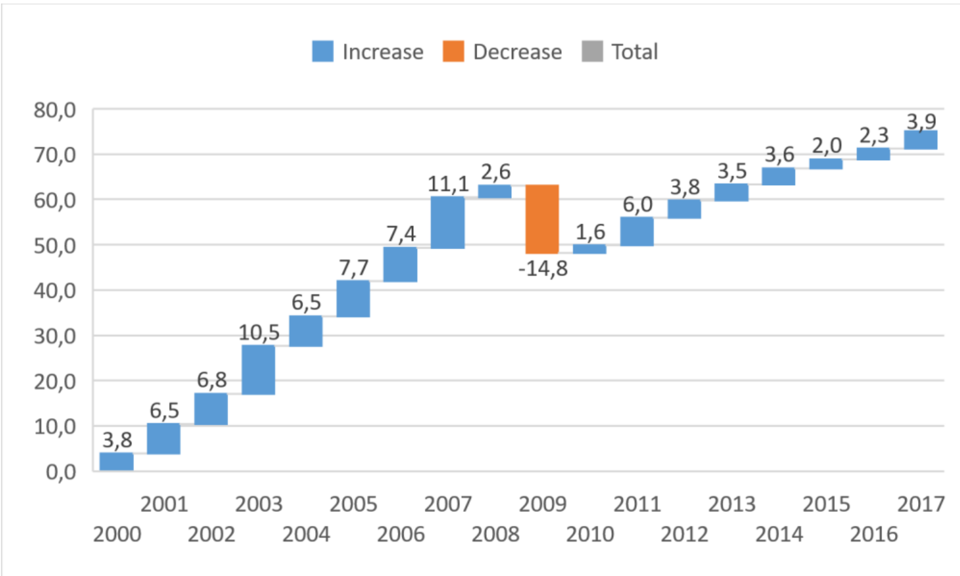


Figure 5 Lithuanian GDP growth (Units: %, Source: Odysee database)

The demographic development has taken a strange trend since the early 90's. Even taking into account that the population of the world is increasing, as it is shown in the figure 1, Lithuania has seen its population decreased by 1 million since those years. Thus, most of the past forecasts that were taken place considering a growing demographic scenario are mainly useless, since the electric demand and the number of inhabitants are closely bonded.

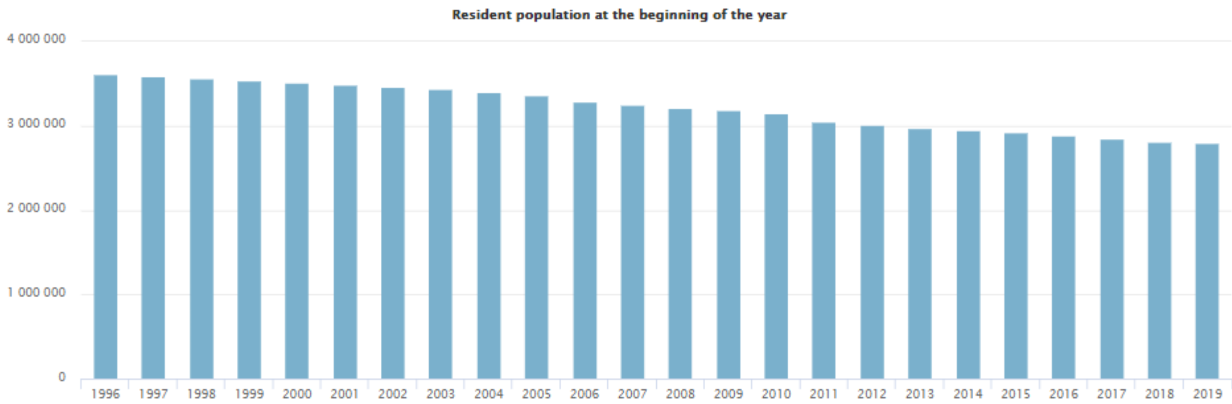


Figure 6 Resident population of Lithuania (Units: Number of inhabitants, Source: Odysee database)

Regarding the energy supplies, the evolution of the industry, the adaptation of the transport to the new technologies, the incorporation of the renewable sources to th grid, the characteristics of the households, etc., it has been created a really dynamic environment in the demands of energy in a broad sense and in the demands of electricity in a narrow sense, although it will be studied later.

2.1- Features of the Lithuanian market

The sector of the Lithuanian electricity has been enduring several changes since 1997, starting from a fully regulated system till reaching a market based system. Since this year, the reforms can be divided in three periods: 1997 to 2002, 2003 to 2009 and since 2010.

2.1.1- First period of the Lithuanian market (1997 to 2002)

Lithuania starts the restructuration of the integrated monopoly by separating the central heat supply from the electric sector by establishing an independent regulator in 1997.
Later, the Law on Reorganization of SPAB "*Lietuvos Energija*" in May 2000 states:

- The unbundling of the activities of distribution, transmission and non-core activities
- The creation of two Distribution System Operators: AB Rytų skirstomieji tinklai and AB "*Vakarų skirstomieji tinklai*"
- Hiring of international consultants by the government in order to arrange DSO's and power plant privatization process

The Law on Electricity in July 2000 reflects:

- The adaptation of the market and the regulatory regime regarding the EU guidelines of transparency and third party participation
- The beginning of the licensing of transmission, distribution and supply activities
- New structure of the market is set [7][8]:

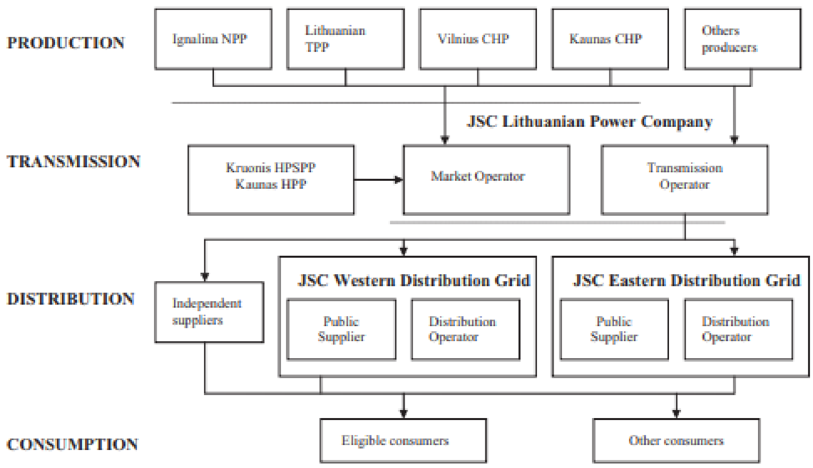


Figure 7 Players in Lithuanian market in 2002 in Lithuania (Source: Electricity market opening impact on investments in electricity sector)

2.1.2- Second period of the Lithuanian market (2003 to 2009)

Regarding its entrance to the European Union, Lithuania has to adapt its energy sector normative to the new standards. Thus, Law on electricity is amended in 2004 according EU Second Energy Package. Two waves of liberalisation are started: the first one was done with the possibility of the return to the regulated end-user prices (Figure 8) and the second one without this feature (Figure 9):

Table 1 First wave of liberalisation of the market (Source: Electricity Sector Regulation slides)

TIMELINE	CUSTOMERS, WHICH CONSUMED AT ONE SITE
January 2002	20 GWh
January 2003	9 GWh
January 2004	3 GWh
July 2004	All non-household customers
July 2007	All customers

Table 2 Second wave of liberalisation of the electric market (Source: Electricity Sector Regulation slides)

TIMELINE	CUSTOMERS, WHICH HAS MAXIMUM ALLOWED CAPACITY
January 2010	400 kW
January 2011	100 kW
January 2012	30 kW
January 2013	All customers, except households
?	All customers

However, Ignalina NPP was dominating the electricity production during those years, provoking the consumers didn't hire another supplier. Even though, this power plant finishes its exploitation at 2009, changing severally the electricity supplying, but this will be analysed more accurately later.

2.1.3- Third period of the Lithuanian market (since 2010)

The Electricity Law was amended again according to the EU Third Energy Package in 2010, which was consisting in these main points:

- Ownership unbundling of generation and supply from commercial activities
- Strengthening of Regulators' independency and power
- Creation of mechanism of international cooperation of Regulators
- Cooperation of the European transmission system operators (TSOs)
- Improvement of energy market operation
- Limits of the third countries participation in the EU energy market

In another vein, Lithuania joins NordPool market with the rest of the Baltic and Scandinavian countries at 1st of January of 2010. This fact was really important for minimizing the effect of the closure of Ignalina NPP, since, on the one hand, it matches in the timeline; and, on the other hand, it allowed Lithuania to import the amount of electricity that was missing, but it will be analysed precisely later. Knowing that the Lithuanian market is based now in the Nordic power market, here the efficiency is increased by calculating the price and flow at the same time, the structure of it remains in the following way:

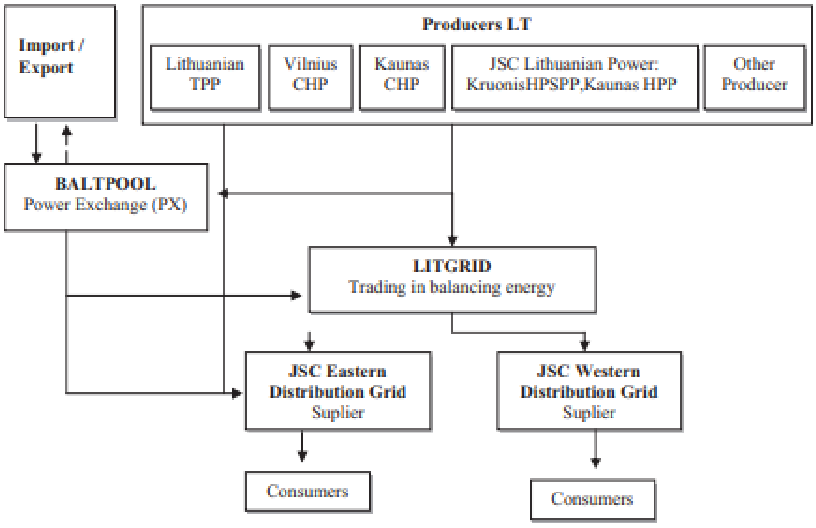


Figure 8 Electricity market model in Lithuania, from 1st of Jan. of 2010 (Source: Electricity market opening impact on investments in electricity sector)

There are two new interconnections operating since 2016, in order to implement the first step on the direction of the integration within the Continental European Network (CEN):

- Nordbalt Link (700 MW) connects Scandinavian Peninsula area with the Baltic Republics
- LitPol Link (500 MW) connects Lithuania and Poland

Figure 9 Links among Lithuania and the rest of the European countries (Source: Elecetricity Sector Regulation slides)

2.2- Closure of Ignalina's Nuclear Power Plant

Ignalina Nuclear Power Plant (INPP) Project was started in 1974 and it was going to be the most NPP in the world by that time in order to supply electricity to the North-west Soviet Union's power system. The first and second units were put into operation in 1982 and 1987 respectively but Unit 3 had to get its construction stopped when the progress was reaching the 60% of completion due to Chernobyl's disaster in 1986. There is a big deal of factor that influence in the electric scenario of a country.

The nuclear power plant earned even more importance due to the independency of the country, since most of the fossil fuels were imported from Russia.

Then again, due to Chernobyl's accident, INPP required intensive international studies in safety matters since the Lithuanian NPP was operating with two RBMK 1500MW water-cooled graphite moderated channel-type power reactors, such as the ones of the Ukrainian plant, although it was performing with four 1000 MW reactors. Even knowing the nature of the problem, the studies concluded that the overall level of security and probability of failure were on the standards of the Western NPP. However, this type of reactor does not have a protective shield that might mitigate radioactive material in the case of an accident.

Thus, Lithuanian government, during the process of preparation for its access in the NATO and EU, had to program the shutdown of NPP. Due to this, Unit 1 stopped its activity in December of 2004 and Unit 2 did the same in December of 2009, when it was accounted a total amount of electricity produced of 307.9 billion kWh since its construction [9].

The present and future milestones in the dismantling and restoration of the place is as it follows [10]:

- ISFSF construction and commissioning (2017)
- SWMSF construction and commissioning (2018)
- VLLWLF commissioning (2018)
- Unit 2 reactor defueling (2019)
- Near-Surface Repository commissioning (2020)
- Units 1 and 2 spent fuel storage pools defueling (2022)
- Units 1 and 2 reactors R1, R2 zones dismantling (2027)
- Units 1 and 2 reactors R3 zones dismantling and decontaminating (2034)
- Unrestricted release of reactor areas (2036)
- Site restoration (2038)

2.2.1- Impact of the closure of Ignalina NPP on the Import and export balance of electricity

Since the restoration of the autonomy of Lithuania, the country has been characterised by producing more electricity than the national amount required, inquiring in the sale of the extra production.
As it can be checked in the Figure 12, the maximum amount of electricity exported was of more than 1600 toe in 2004, before the shutdown of the Unit 1. Even though, the second reactor was able to fulfil the electric demand and to supply the neighbour countries till the definitive closure of the NPP at the end of 2009. From that moment, Lithuania has been forced to import between 600 and 800 toe of electricity, including all the problems that it carries, such as the increase of the price, reliance in foreign countries, reformulation of the interconnection layout, etc., as it can be seen in the following chart [11]:

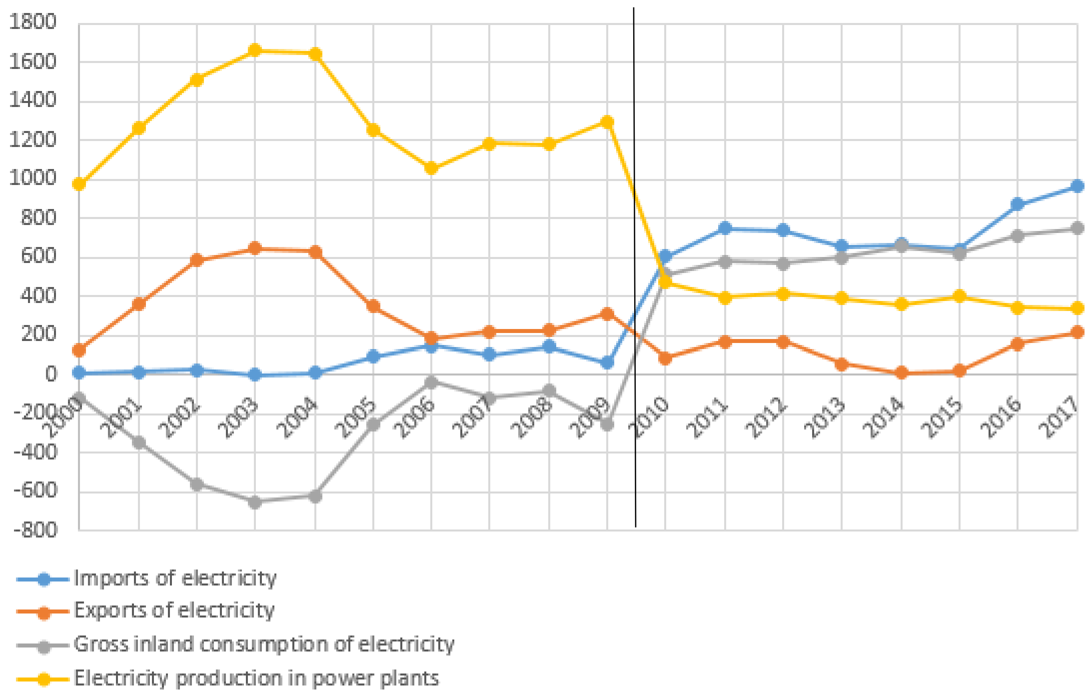


Figure 10 Import-export balance of Electricity in Lithuania (in toe units, Source: Lietuvos Statistikos departamentas)

It is required to point out that, during the worst two years of the last economic crisis, from 2009 to 2010, the closure of Ignalina NPP provoke a decrease of 1% on the national GDP at least [12].
In another vein, BEMIP initiative, which counted with 8 countries of the Baltic Sea, was indirectly affected and promoted by the shutdown of the NPP, preceding the reformulation of the NordPool Market. This measure facilitated the interconnection and the electric transaction among these countries.

2.2.2- Impact of the closure of Ignalina NPP on the electricity supply

The share of the electricity production from Ignalina NPP has been above the 70%, even after the closure of the Unit 1 in 2004. Furthermore, the share in the overall primary energy balance was of 31.7% during its last year of operation [13]. For such a small country without own primary fuel sources as Lithuania, the sudden shutdown of its main energy production source has incurred in drastic changes and the country got adapted with the means they had.
In this case, the share of production sources could not arise that much in order to fulfil the amount of energy that used to be provided by Ignalina NPP. Knowing that, public CHP plants had the bigger shares after the breakdown but it has decreased during the last years. On the other hand, renewable sources, specially wind turbines and both hydroelectric and hydro pumped storage, have been retaking this production quota [14].

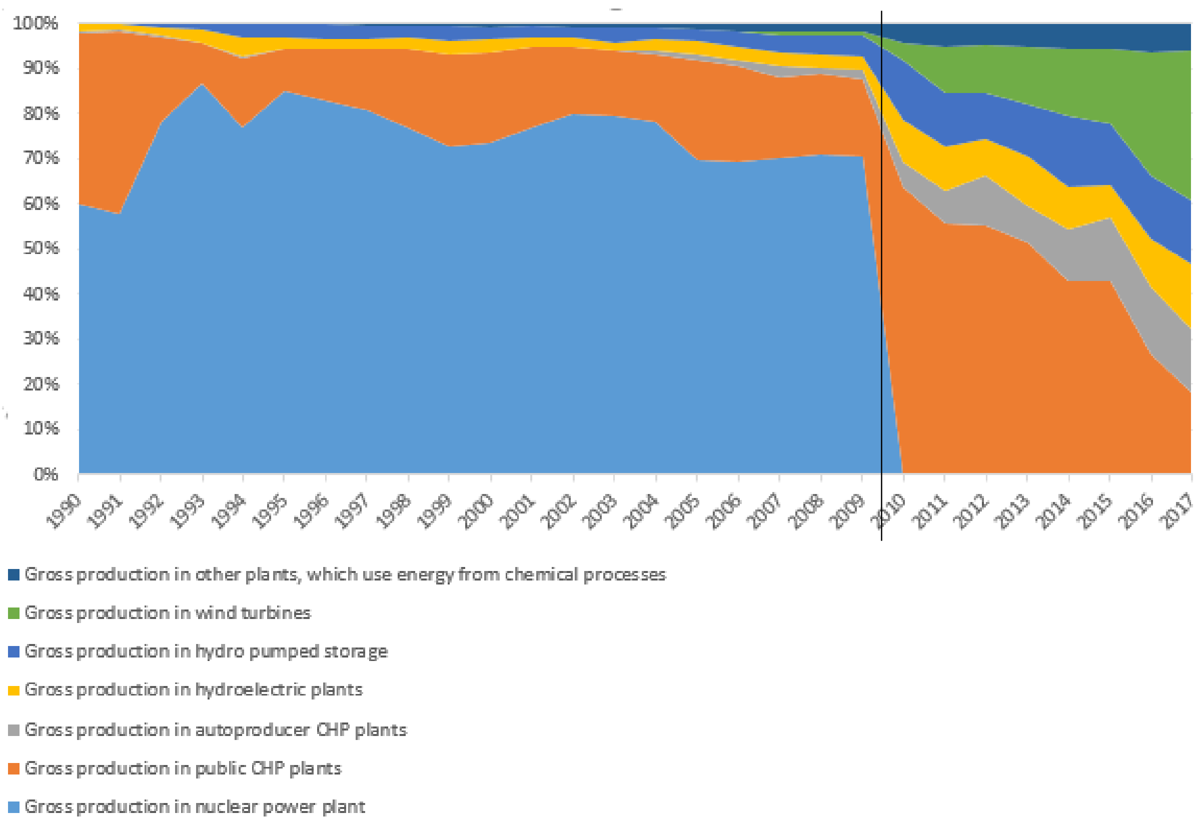


Figure 11 Shares of sources of electricity production in Lithuania (Source: Lietuvos Statistikos Departamentas)

2.2.3- Impact of the closure of Ignalina NPP on the electricity price

Since nuclear plants need to be in constant performance and its operational cost is relatively cheap, the electricity price during the nuclear production period (before 2010) was a big deal lower compared with the post nuclear period.

On the one hand, the nuclear power plant operating expenses are cheaper than the fossil steam and gas turbine and small scale PP. This is due to the fact that the operation and maintenance costs are a bit superior for a NPP but the fuel is way inexpensive, at least compared with the other kind of fuels [15].

On the other hand, the external costs related with health care and greenhouse gas, heavy metals and radionuclides emissions are highly inferior to the most of technologies of production of electricity. For instance, a NPP with European pressurized reactor was incurring in near 0.6 cent/kWh produced, while lignite and hard coal were performing around 5 cent/ kWh and natural gas was around 2.5 cent/kWh. Just some of the renewable sources, such as solar PV and hydropower, were managing to performing with a lower coefficient [16].

No.	Electricity generation technologies	2010	2020	2030
1	Nuclear power plant (European Pressurized Reactor)	0.591	0.587	0.572
2	Heavy fuel condensing power plant	4.865	5.180	4.947
3	Light oil gas turbine	3.206	3.035	2.531
4	Had coal condensing power plant	5.250	4.404	3.425
5	Hard coal IGCC without CO_2 capture and sequestration (CCS)	4.960	3.696	2.891
6	Hard coal IGCC with CO_2 capture and sequestration	4.960	1.463	1.317
7	Lignite condensing power plant	5.381	4.367	3.828
8	Lignite IGCC without CO_2 capture and sequestration	5.312	4.078	3.123
9	Lignite IGCC with CO_2 capture and sequestration	5.312	1.252	1.122
10	Natural gas combine cycle without CO_2 capture and sequestration	2.549	2.126	1.652
11	Natural gas combine cycle with CO_2 capture and sequestration	2.549	0.949	0.827
12	Natural gas turbine	3.786	3.320	2.552
13	Hydropower run of river (10 MW)	0.160	0.159	0.143
14	Hydropower run of river (<100 MW)	0.114	0.113	0.103
15	Hydropower run of river (>100 MW)	0.103	0.102	0.092
16	Hydro power dam	0.199	0.197	0.179
17	Hydro power pump storage (HPPS)	0.193	0.192	0.175
18	Wind on-shore	0.137	0.135	0.124
19	Wind of-shore	0.152	0.150	0.141
20	Solar PV roof	0.548	0.529	0.465
21	Solar PV open space	1.142	1.105	0.981
22	Solar thermal parabolic trough	0.128	0.098	0.071
23	Natural gas CHP with extraction condensing turbine without CO_2 capture and sequestration	2.330	1.975	1.543
24	Natural gas CHP with extraction condensing turbine with CO_2 capture and sequestration	2.330	0.875	0.766
25	Hard coal CHP with extraction condensing turbine without CO_2 capture and sequestration	2.330	1.975	1.543
26	Hard coal CHP with extraction condensing turbine with CO_2 capture and sequestration	4.625	1.131	1.026
27	Natural gas combined cycle CHP with backpressure turbine	2.575	2.288	1.795
28	Hard coal CHP with backpressure turbine	5.005	4.358	3.478
29	Biomass (straw) CHP with an extraction condensing turbine	6.980	6.184	4.818
30	Biomass (woodchips) CHP with an extraction condensing turbine	6.038	5.368	4.004
31	MCFC (natural gas)	2.146	2.049	1.676
32	SOFC (natural gas)	1.273	1.021	0.906
33	MCFC (biogas)	3.400	3.329	2.622

Figure 12 External costs of electricity generation technologies in Lithuania in 2010-2030 (Units: cent(2010)/kWh, Source: External costs of electricity generation options in Lithuania)

Due to all of it, the procurement of electricity had raised its costs. Just taking into account the variation of price in the first semester after the closure, it can be seen that the costs grew by 25% during those months. Furthermore, the higher cost raised till 150% of its value just before the close of Ignalina NPP, and it took place at the end of 2013. Even though, costs start decreasing till reaching values slightly inferiors than in 2010 [17]:

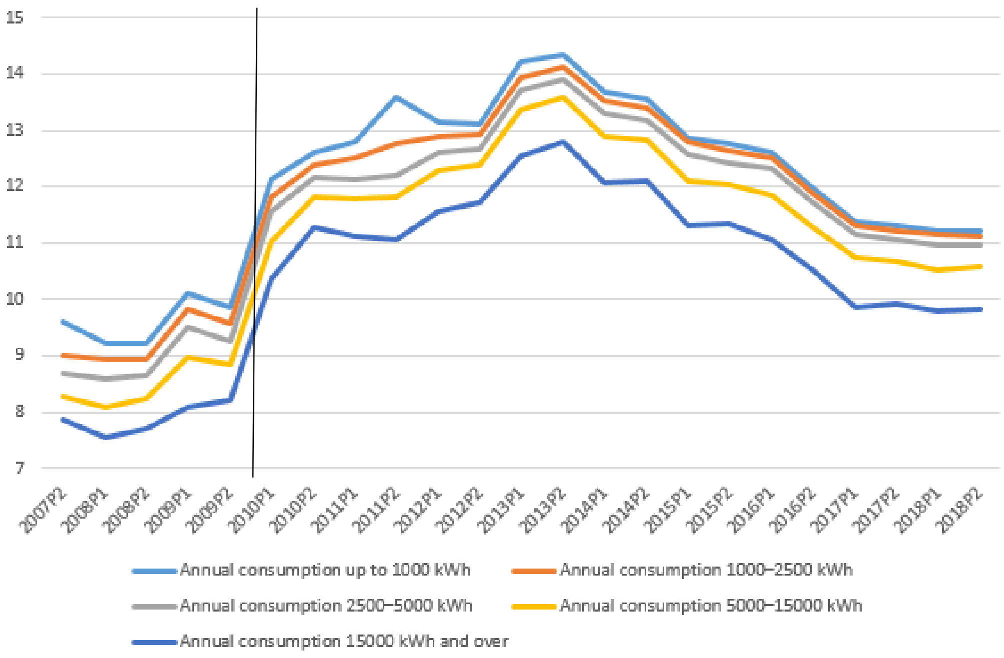


Figure 13 Electricity cost in the dwellings (units: ct/kWh, Source: Lietuvos Statistikos Departamentas)

2.2.4- Dependence on Russian fuel supply

Returning the situation to the scenario of the beginning of 2010, Lithuania loses its most powerful power source and it has to buy other kind of fuels from other countries, especially Russian fuels. As it can be seen in the graph, the price of Russian gas fluctuates a lot, specifically during geopolitical collides or as measure of pressure [18]:

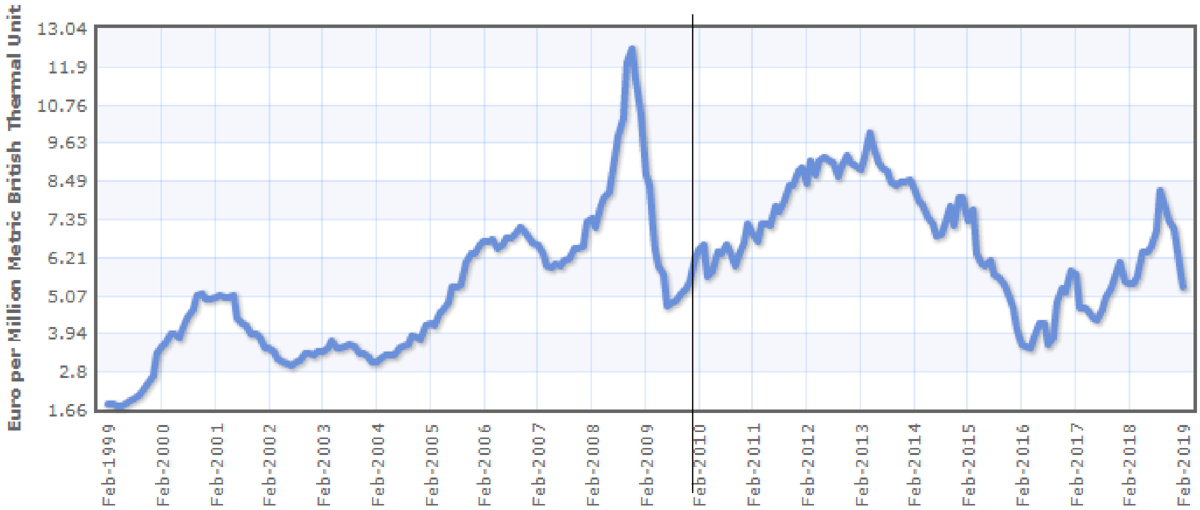


Figure 14 Price of Russian gas supply (Source: indexmundi)

If it is compared the shape of the curve of the electricity cost of Lithuanian dwellings (Figure 15) with the shape of the curve of the price of the Russian gas (Figure 16) it can be seen clearly, on the one hand, that both are closely related, and on the other hand, that this scenario is dangerous

for Lithuania, since the country does not have the autonomy to negotiate or fix the issues that can come up in the procurement of the fuel.
In order to clarify the impact of the dismantling of Ignalina NPP, Lithuania passed from a 50% of energy supply dependence in 2009 till reaching more than 80% on the next year [19]:

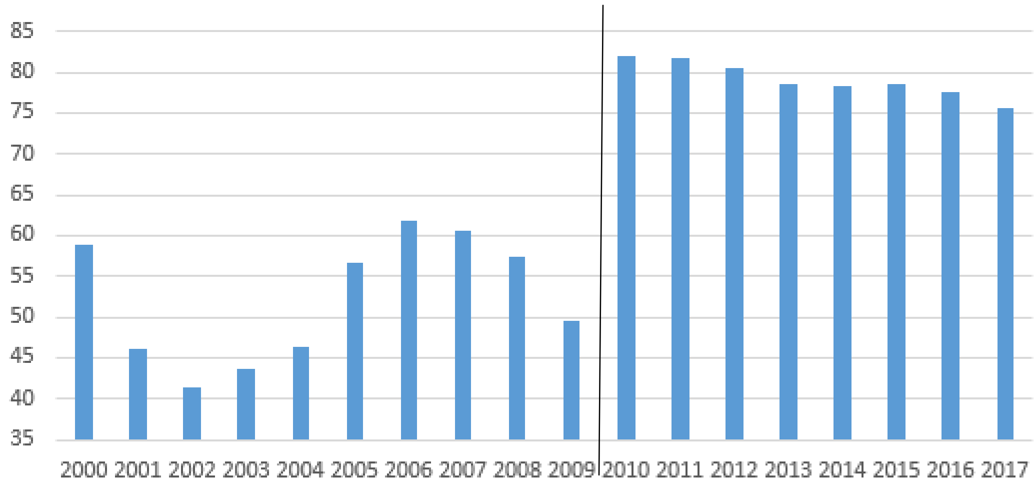
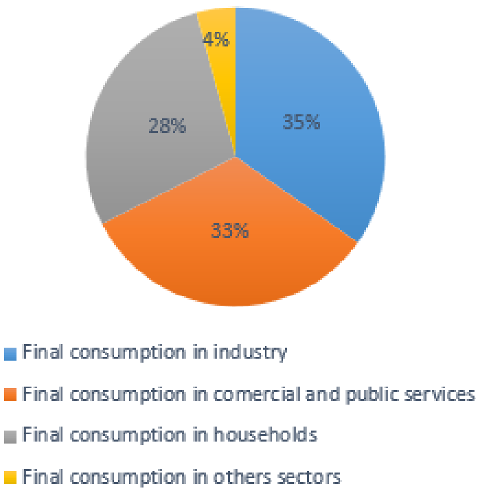


Figure 15Russian Natural Gas Monthly Price - US Dollars per Million Metric British Thermal Unit (Source: Eurostat)

In order to appease the increase of dependency on Russia, the construction of a LNG floating storage and regasification unit terminal in Klaipeda took place, starting the operation on December 2014. This terminal pretends to bring a bit of competition to this market by allowing the entrance of Norwegian and Venezuelan LNG to the Baltic Republics [20].

3- Normative of electric consumption in the dwelling sector

As it can be seen in the third figure, the electricity consumption will have increased 80% comparing it to actual levels. Even though knowing from those curves that European Union demand will remain constant, it's necessary to regulate its commercialization and utilisation in order to improve the efficiency. At the end, on the one hand, energy consumption in commercial and residential buildings represent near 40% of the EU's total energy consumption and, on the other hand, activities related this sector accounts 9% of its total GDP.
In the next figure it is shown that both Lithuanian and EU dwelling sector represent 28% of the total electricity consumption [21]:



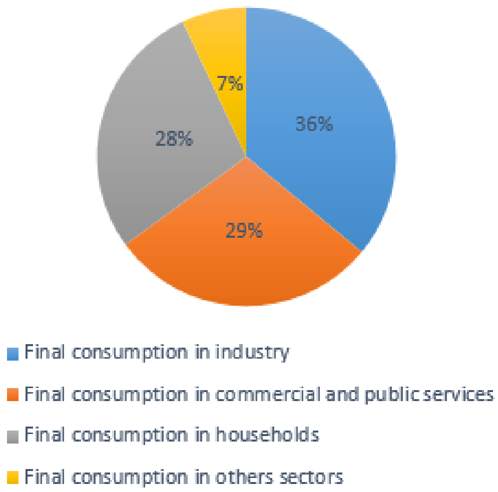


Figure 16 Shares of electricity consumption in 2017 in Lithuania (left) and European Union (right) (Source: Lietuvos Statistikos Departamentas and Eurostat)

Knowing that household is such an important sector, it requires of a special legislation. European Union gives a set of guidelines to its countries that have to be accomplished.

In the case of Lithuania, the country was not concerned in electricity normative till it gets into EU in 2004. Before that date, it was clearly characterised as an economy in transition country, thus, the main concerns were to grow faster economically and to improve the industry. In addition, Ignalina NPP, as it has been said earlier, was able to fulfil most of the electricity demand by its own.

Once Lithuania joins EU, the country has to adapt its normative to the Second Energy Package, firstly, and then to Third Energy Package.

Hence, EU normative will be exposed in the first place and then, its impact on Lithuanian electricity laws will be analysed.

3.1- European Union strategies for the electricity consumption in the household sector

EU sets guidelines in lots of ambits related with the energy production, supplying and consumption [22]:

- Medium- and long-term goals and targets: *Europe 2020* and *2050 Long-term strategy.*
- Clean and renewable exploitation of energy resources: *Clean Energy for EU islands* and *Clean energy for all Europeans* programs.
- Unification of energy markets: *Building the energy union* and *Governance of the energy union and climate action.*
- Dependency and safety of the supplying of fuels and energy: European Energy security strategy.

Nevertheless, this paper will be focused in those branches or parts that will be direct or indirectly related with EU's electricity policies and, especially, with Lithuanian electricity policies during the last years.

3.1.1- Energy Performance of Buildings Directive (EPBD)

EPBD is the main law focused in the improvement of the energy performance of buildings. Being inspired by Kyoto Protocol, the main goal of this directive is to promote cost-effective improvements in the energy performance of buildings.

Its tree main instruments to achieve it take place during different stages of a building's lifetime [23]:

- Member States have to guarantee a determined level of performance for new buildings or large existing ones that are under major renovation. The aim is to reduce the energy costs and loses and to improve the thermal comfort.
- Member States have to implement a certification paper that provides data of its energy needs in order to be used a decisive tool for the assessment of the renovation or purchase of a dwelling or building.
- Member States have to introduce a periodical inspection method for heating and AC-systems, being the improvement of the efficiency of these appliances the goal of this measure.

EPBD was updated in 2016 within the frame the measures of *Clean Energy for all Europeans* program. The new proposals were:

- Incorporation in buildings of long-term renovation strategies in order to proceed to their decarbonisation in 2050
- Use of smart technologies to increase the energy efficiency
- Provisions in case of failure of the expected results

The next figure shows the actual performances (measured performance and the calibration of the thermal model) and EPBD models (intended and verified) [24]:

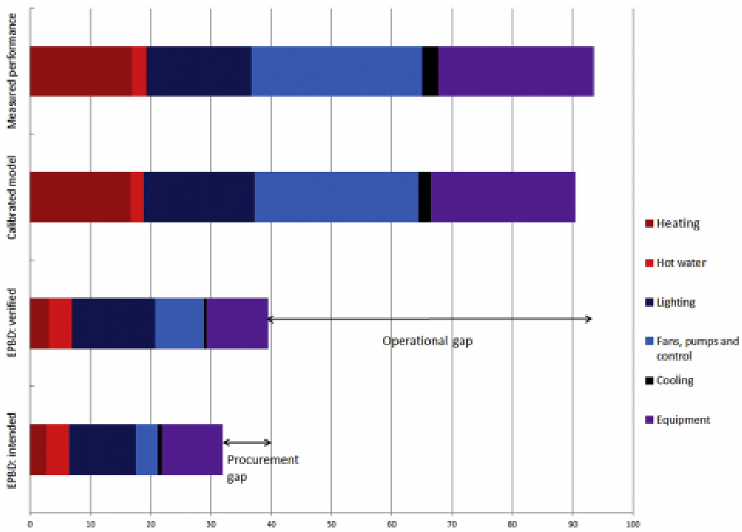


Figure 17 Energy performance of a building according to EPBD (Units: kg CO_2/m^2/annum Source: Towards measurement and verification of energy performance under the framework of the European directive for energy performance of buildings)

Even knowing that the units of the previous graph are related with the savings of CO_2 emissions, it is required to state these figures are proportional to the energy consumption figures.

3.1.2- EU Labelling and Eco-design directives

As it will be checked in this part, not all of the EU measures are aimed on the behaviour of public entities but on the behaviour of the consumers and the companies.

Technology and efficiency advances are implicit in consumer behaviour advances and vice versa: consumers will be able to safe more energy if they have the technology to do so and this technology will be developed if those consumers require it. In this way, technologic progress will be carried out mainly by companies dedicated to manufacture electric appliances and, in order to fulfil EU requirements (Labelling and Eco-design) those enterprises will have to adapt their products.

On the one hand, labelling measure looks for modify consumer behaviour by attaining its awareness about the environment and the energy consumption of the potential appliances to be acquired. This measure seeks to inform the customer on a simple way regarding the product features itself and its production process; at the end, the client does not have to be specialised in energy consumption matters, so the data needs to be clear and concise, as it follows [25]:

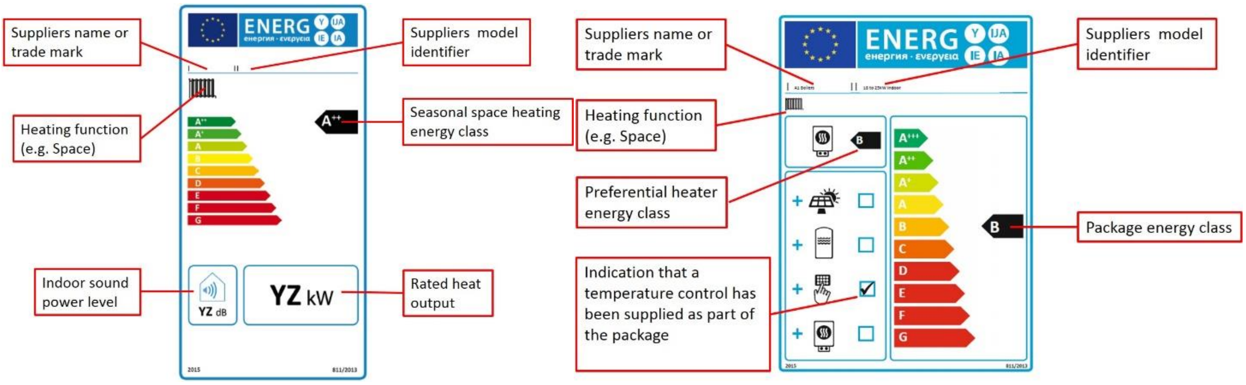


Figure 18 Labels according to EU normative of a space heater (left) as a product and a boiler and temperature control (right) as a result of combining individual products (Source: OFTEC)

In addition, all the measures that have taken place in labelling matters are [26]:

Table 3 Normative related with Labelling in European Union (Source: MURE)

Name	Directive	Impact (TWh)	Status	Year
HH appliances	92/75/EC	24 to 34 in 1996 65 to 75 in 2010	Completed	1992
HH Elec. Refrigerators, freezers and their combinations	94/2/EC	86 in 1999	Completed	1994
HH Elec. Tumble Driers	95/13/EC	3,3 in 2020 8,6 in 2025	Completed	1995

HH Lamps	98/11/EC	86 in 2020	Completed	1999
HH Elec. Ovens	2002/40/EC	8,1 from 2010 to 2030	Completed	2002
A+, A++ labels refrigerators	2003/66/EC	4 in 2020 12 in 2025	Completed	2004
Revised Directive of Energy-related Products	2010/30/EU	460 in 2020	Completed	2011
HH diswashers	1059/2010	1,7 to 2,0 in 2020 3,2 to 3,5 in 2025	Ongoing	2011
HH refrigerating appliances	1060/2010	4 in 2020 12 in 2025	Ongoing	2011
HH washing machines	1061/2010	1,2 to 1,5 in 2020 2,2 to 2,7 in 2025	Ongoing	2011
Televisions	1062/2010	43 in 2020	Ongoing	2011
Air conditioning	626/2011	7 to 16 in 2030	Ongoing	2013
Revised Directive of Energy-related Products	2017/1369/EU		Ongoing	2017

As it can be seen, the impact changes a lot from one directive to another. The specific ones with bigger estimated impact are Lamps, Refrigerators-Freezers and Televisions in this order. On the other hand, eco-design of products provides requirements for environmental friendly designs of appliances in order to reduce the adverse impacts throughout its life-cycle [27]. According to this, companies have issues to implement those requisites in its designs since they take more time to test the performance tests, incur in overrun in the prototyping and suffer additional time or difficulties in the evaluation and implementation of the eco-design benefits [28].

In addition, all the measures that have taken place in Eco-design matters are:

Table 4 Normative related with Eco-design in European Union (Source: MURE)

Name	Directive	Impact (TWh)	Status	Year
Energy-using Products	2005/32/EC	98,6	Completed	2007
HH refrigerating appliances	643/2009/EC	4 in 2020 12 in 2025	Ongoing	2009
For glandless standalone circulators and glandless circulators integrated in product	641/2009/EC	28,5 in 2020	Ongoing	2009
External Power Supplies	278/2009/EC	9 in 2020	Ongoing	2009
Simple set-top-boxes	107/2009/EC	47 in 2020	Ongoing	2009
Standby and off-mode losses	1275/2008/EC		Ongoing	2009
Recast Directive of Energy-related products	2009/125/EC	29,7 in 2020 37,7 in 2025	Ongoing	2010
Requirements for TVs	2009/642/EC	43 in 2020	Ongoing	2011

Washing machines	1015/2010/EU	1,2 to 1,5 in 2020 2,2 to 2,7 in 2025	Ongoing	2011
Dishwashers	1016/2010/EU	1,7 to 2,0 in 2020 3,2 to 3,5 in 2026	Ongoing	2011
Revised Directive of Energy-related products			Ongoing	2012
Requirements for TVs	2018/59/EU		Ongoing	2018

As a conclusion of this part, it can be said that the combination of both Labelling and Eco-design normative is one of the most important improvement in the energy efficiency field. All of the measures exposed previously are related with the saving of electricity consumption of appliances by attaining directly, with the improvement of its efficiency, or indirectly, by allowing the customer to purchase a more efficient product regarding its label.

3.2- Lithuanian strategies for the electricity consumption in the household

Since Lithuania entered in European Union in 2004, government had to adapt its laws, including those ones related with electricity fields. As it has been said, EU's directive can be summarised in *Energy Performance of Buildings Directive*, *Energy Labelling* and *Eco-design*. Even though the country has these guidelines, it is required to set more strategies and a complete normative.

The main reason could be to take care of the environment and the pollution. Nevertheless, one of the main reasons to regulate accurately the electricity supplying chain, the efficiency of its use, etc., remains in the fact that the country is almost fully dependent of the import of energy sources such as petroleum, hard coal and natural gas, as it can be seen in the figure 17. In addition to that, electricity consumption has been increasing in the past years although all the efforts that have been taken for saving energy and despite the fact that the consumption of most of the rest of the energy sources has been decreasing over the last ten years.

Besides, most of the dwelling of Lithuania were built some decades ago in the soviet era, indicating that, due to its old age, these are inefficient in terms of energy and electricity consumption. Thus, Lithuanian normative has to attain important measures for improving the energy exploitation. In this vein, Gaigalis and Sekma (2014) estimated that the measures that were going to be implemented or that were already applicable in Lithuanian household sector had a potential of 70 ktoe in electricity consumption savings regarding the increase of the efficiency of the loads. This level would be achieved by public procurement of the energy efficiency and the greater use of efficient appliances regarding the implementation of the pertinent labelling [29].

Furthermore, heat efficiency saving potential in dwellings was situated in 220 ktoe regarding the improvement and modernization of the public buildings and multi-apartment houses.

All these actions will require to take into account the following question introduced by Vojtovic et al.: *is the rate of electricity consumption in Lithuania low because of the residents' awareness to save energy or as low income of Lithuanian households?* Their study concludes in the fact that the potential to reduce the electricity consumption is relatively low since it manly depends on the financial situation of the households: About 90% of them are already concerned of saving energy since housing expenses are significant.

Nevertheless, the authors state that the improvement and progress in the socioeconomic situation of Lithuania and the living standards of its population will provoke that people will pay more attention to sustainable ways of electricity consumption [30].

3.2.1- Law on Energy Efficiency Improvement

The main legislation that includes and foments all the pertinent measures in electricity saving consumption is the *Law on Energy Efficiency*. It establishes the legal basis for state supervision and regulation of energy efficiency improvement. Its purpose is to guarantee an efficient energy production, supply and consumption throughout all areas of the national economy.

It takes into account the obligations stated by the European Union normative, which establishes an annual average final energy of 1.5% from 2014 to 2020 compared with the consumption levels of 2010-2012. Consumption is relatively low since it manly depends on the financial situation of the households:

Thus, the measures accorded by the Law in order to achieve the minimum requirements determine [31]:

- the assessment of excise or value added tax duties which have an impact on the saving of final energy consumption, such as the taxes on diesel, petrol and liquefied petroleum gas;
- financial instruments that promote the inclusion of energy efficiency improvement, such as grants for the renovation of the insulation of multi-apartment and public buildings;
- technical regulations for product labelling;
- agreements with companies;
- standards and hygiene norms that are not already included in the norms stated by the Republic of Lithuania;
- education and counselling;

3.2.2- Taxes and excise duties on fuel

European Union sets a minimum of taxes in fuels since its consumption has to be regulated and its waste minimized. Thus, the fuels that are taxable in this way are diesel, petrol and liquefied petroleum gas. The three of them are subject to a 21% value added tax (VAT), 6% higher than EU minimum required. In addition, the excise duty on petrol and liquefied petroleum gas exceeds in 21 and 243% respectively.

Taking all of it into account, the cumulative effect of the additional taxes provokes an increment of 5, 15, and 30% on the prices of diesel, petrol and liquefied petroleum gas respectively compared with the minimum standards set by EU.

In order to get a magnitude order of this implementation, it was calculated a total amount of 374 GWh of energy consumption saving in 2014 and it was projected to reach 421.5 GWh in 2015 [32].

Even though most of these savings in fuel are not related with the consumption in households, it can be stated that there is a slight influence regarding the big share of public and auto producer CHP plants in the sector since the closure of Ignalina NPP, as it is shown in the figure 13.

3.2.3 Renovation of multi-apartment buildings

As it has been exposed before, most of the multi-apartment buildings in Lithuania have been built before 1993. The aim of the removal is to improve the insulation of these dwellings according standards of the new buildings under construction, and the following figure can exemplify it [33]:

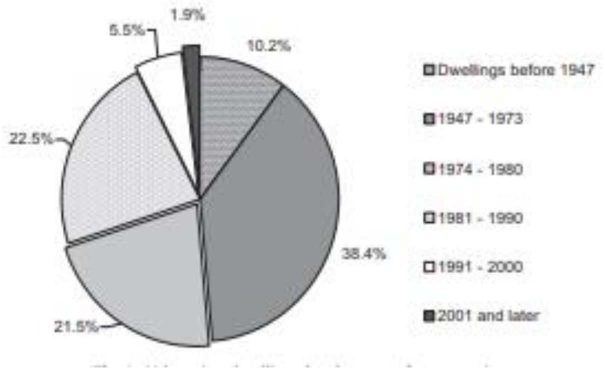


Figure 19 Lithuanian dwellings by the year of construction (Source: Analysis of fuel and energy transition)

Even though the data used for elaborating the graph comes from 2012, the population of the country has decreased by 200.000 since then so it can be stated there has not been a considerable construction of new dwellings during this time so the percentages would have not been varied.
In addition to that, the insulation characteristics of these buildings can be checked in the following tables [34]:

Table 5 Types of multiappartment buildings by its energy consumption (Source: Lietuvos Silumos Tiekeju Asociacija)

Type of multi-apartment building	Share	Comparative energy consumption (kWh/m2/month)	Energy spent in heating 60 m2 (kWh/month)	Heating energy expenses (eur/month)	Amount of dwellings	Amount of population
Full renovated or new construction from 1993	16	9	540	31	113.000	323.000
Partially renovated	7	15	900	51	46.000	130.000
Old and not renovated	60	21	1260	72	420.000	1.200.000
Old and not renovated, very poor silhouette insulation and condition	17	35	2100	121	121.000	340.000

The purpose of the Programme is to motivate the owners of these multi-apartment buildings to reduce heat energy consumption in 2020 by at least 20% compare with 2005 levels by improving their performance. This decrement can be translated in a total amount of energy consumption savings of 1 TWh per year.

The means to attain it are financial support from EU and private funds, which will account on 314 and 60 million respectively. Thus, this funding will be provided following the algorithm JESSICA (Joint European Support for Sustainable Investment in City Areas) and it will consist in soft loans with a fixed annual interest rate of 3% and a repayment period up to 20 years [35].

Nevertheless, the objective stated has been unattainable, as it can be checked in the next table [36]:

Table 6 Energy consumption savings of the Programme for the renovation of multiapartment buildings (Source: MURE

The name of Programme and its measure	Energy Savings, GWh		
	2014	2015	2016
The Programme for the renovation/upgrading of multi-apartment buildings	25,26	138,02	208,07
Renovation of buildings by increasing their energy efficiency at first	12,31	6,44	5,65
Total energy savings	37,6	144,5	213,7

As it can be clearly seen, the target of saving 1 TWh was bigger than the projections of the achievements of the actual measures. In other words, the total amount that was being saved by the end of 2016, when half of the period for attaining the improvements was already over, is 21.37% of the final achievable amount.

The main issues for the implementation of the Programme that have come out during this period are mainly related with bureaucracy, funding and low awareness of the inhabitants of the dwellings. Even though, it is expected to improve its performance regarding the financial support of the Climate Change Program.

Methodology

The methodology part of the paper will be divided in two halves.
On the one hand, the factors that are involving the trends of electricity consumption in the household sector of Lithuania will be exposed firstly. Although there will be some part that can be seen as not that important, all of them will play a decisive role once the results are being calculated and analysed.
On the other hand, the full range of methods able to provide long-term forecasts will be shown in order to choose the pair of them that will match better to the goals, frame and constraints of the paper.

1- Features of Lithuanian household sector

First of all, it is required to retake what has already been introduced in the previous parts of the paper. As it can be checked out in the figure 21, most of the buildings have been built before 1993. Due to this, the renovation of the insulation of these old buildings has taken place in the last years since it was necessary to improve the energy savings in the household sector. Nevertheless, this program has not been successful since 77% of the buildings are still in the queue of the renovations. Although it can be thought easily that the single aim of this point is to describe the technical features of the household sector of Lithuania, nothing is further from this reality.
The behaviour of the population plays an important role in the electricity consumption. On the one hand, awareness of consumers is approached as voluntary consumption saving. On the other hand, the economic level and the impact of the electric consumption bill, shown mainly by elasticity factors, is approached as mandatory consumption saving.
Hence, it will be shown the main macroeconomic and technological factors that influence in the electricity consumption in the dwellings. Macroeconomic ones will be related with GDP, population and price forecasts and technological ones will be attained to the forecast of number of purchase and average power consumption of each electric appliance.

1.1- Impact of the Temperature in Electricity consumption

As it can be stated for every cold country, *the colder winter, the higher energy consumption*. Even though, it cannot be stated this sentence if it is swapped the term *energy* by *electricity*. On a first sight, electricity is pretty far of being the source with biggest share in the final consumption of the household sector [37]:

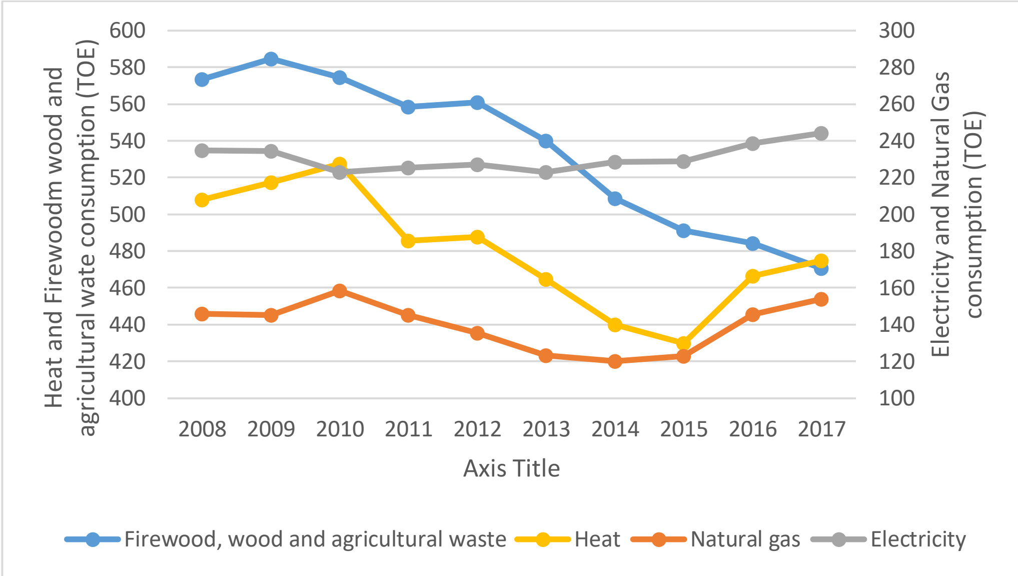


Figure 20 Final consumption sources of electricity in households (Units: thousands of TOE, Source: Lietuvos Statitisko Departamentas)

First of all, it has to be stated that it has been chosen this period since it's the best choice to compare it with the available data of the next figure. As it can be seen, electricity is the third main energy source for dwellings and its trend remains constant, such as Natural Gas' curve. In the other hand, Firewood's and Natural Gas' curves are decreasing, except for in 2016 and 2017 regarding this last one.

Thus, it will be necessary to check why electricity keeps the same shape [38]:

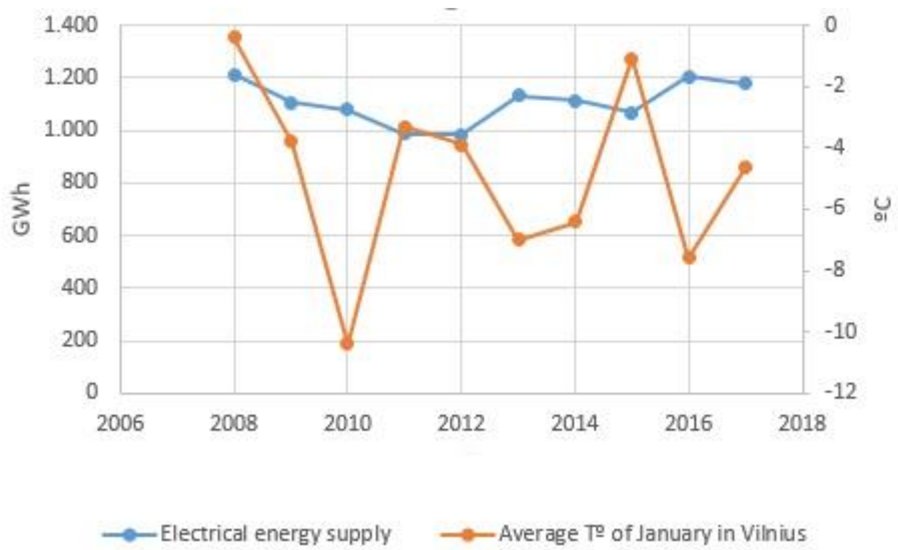


Figure 21 Correlation of Electrical consumption and the Average temperature of January in Vilnius (Source: Lietuvos Statistikos Departamentas)

Hence, it can be affirmed by checking the previous figure that electricity consumption and the Average temperature in January are not related, being this month when Lithuania suffers the lowest temperatures throughout the year. Getting to this point, it could be better to compare the correlation month to month by the most similar data found is the total electricity consumption monthly from 2013 so, on the one hand, it is a small period to compare and, on the other hand, there is no breakdown of sectors.

It is sufficient to check that the drop of six degrees in 2010 compared with its close years did not modify the electricity consumption.
Thus, it can be said that the small variations of the trend are due to other factors that are not related, such as number of sunny hours, application of saving policies, electricity price, renovation of old technologies, etc.
If it is desired to go one step farther, it is possible to ascertain the loads of consumption [39]:

Table 7 Electricity consuption in housholds by type of end use (Source Lietuvos Statistikos Departamentas)

		Electricity, GWh				
		Total by end use	Space heating	Water heating	Cooking	Lighting and electrical appliances
Electricity consumption in households by type of end use | natural units	2017	2837,6	150,4	147,6	170,2	2369,4
	2016	2775	141,5	152,7	185,9	2294,9
	2015	2660	141	151,6	175,6	2192
	2014	2656,2	140,8	154,1	180,6	2180,7
	2013	2591,5	134,8	155,5	178,8	2122,4
	2012	2642	137,4	163,8	182,3	2158,5
	2011	2618,1	136,1	164,9	183,3	2133,8
	2010	2590,2	132,1	168,4	189,1	2100,7

The first figure that requires attention is that most of the electricity is used for lightning and electrical appliances, so it can be stated that this is the main reason about the non-existent correlation about electricity consumption and temperature.
In addition to that, it can be said that gradual drop of electricity consumption for water heating it's due to the increase of the usage of solar energy for hot water.
One last topic to comment about is that electricity space heating has a really low value due to the use of central heat plants and firewood for heating of the dwellings.

1.2- Intensity of electricity and energy consumption

As it is shown in the third and fourth figures, energy consumption is proportional to the economic growth, being the perfect example the developing economies, such as China and India, which have perennial GDP and energy consumption increase. Nevertheless, this relation will be approached in deep later.
In this vein, the intensity of energy consumption is closely related with the economic development of countries. This indicator allows to compare the level of energy resources required for producing and maintaining goods.
On the one hand, if its values are high it means that the country is still developing.
On the other hand, if these are low it can be stated that the country is already developed.

Despite these facts, the trends of both kind of economies will be to decrease these figures. So as to say, developed countries will continue increasing their GDP slowly but they will try not to consume the proportional part of energy resources due to the concern for the environment and/or energy consumption savings.
In addition to that, the economy of developing countries will keep growing up quickly and the energy consumption will increase in a parallel way. This is due because it is more necessary for them to produce and consume goods, increase the number of appliances and vehicles, improve and expand the industry, etc. At the end, these states will reach the intensity level of the developed countries but with a determined number of years of delay, as it can be seen in the next figure [40]:

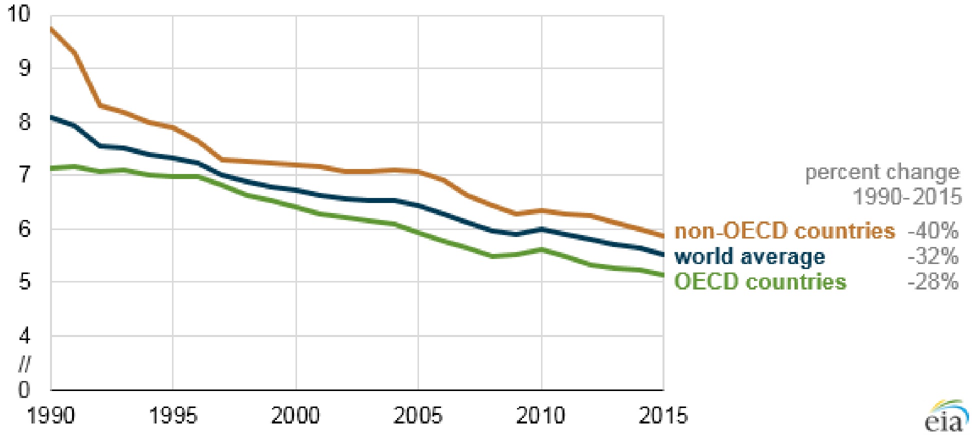


Figure 22 Worldwide total energy intensity (Units: thousands BTu/$ GDP, Source: Geographical Magazine)

In order to take an example that can illustrate the previous statement, it can be seen that OECD countries had the same level of intensity in 2005 than non-OECD countries in 2015.
In order to approach the Lithuanian features of intensity, it is going to be presented its data linked with its surrounding countries (Poland, Latvia, Estonia, Finland and Sweden) in order to be able to compare the figures [41]:

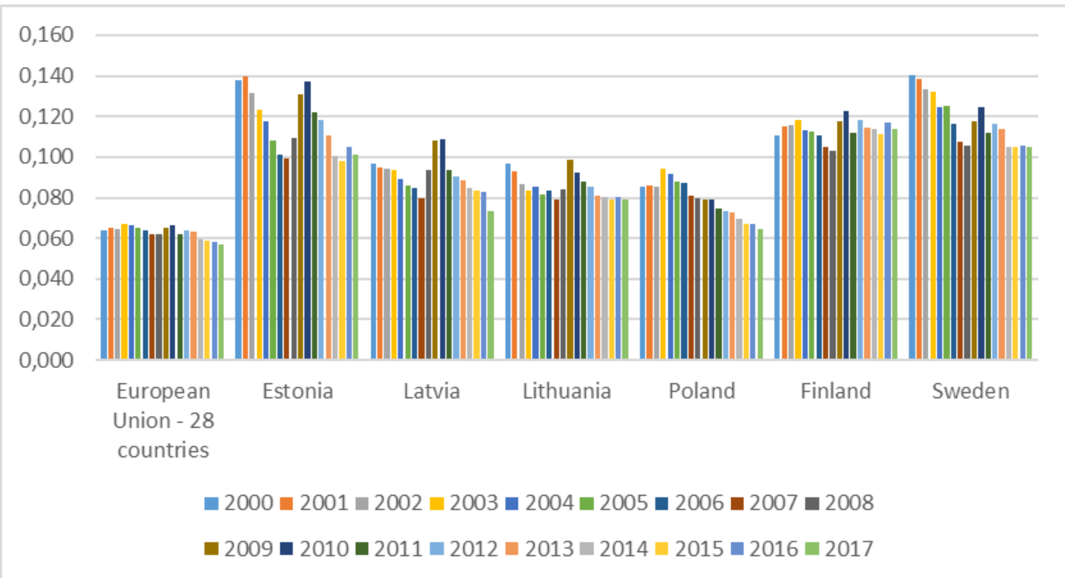


Figure 23 Household Electricity intensity (Units: kWh/thousands 2010 PPP euros, Source: Eurostat)

Despite what has already been said, Lithuania, Poland and Latvia have lower household electricity consumption intensity compared with Sweden and Finland, but this fact only indicates that the

share of electricity in these last countries is relatively strong. In any case, the main conclusion that can be extracted from here is that the trend has remained constant for Lithuania during the past years.
In order to clarify it, it is required to consult the breakdown of energy and electricity consumption [42]:

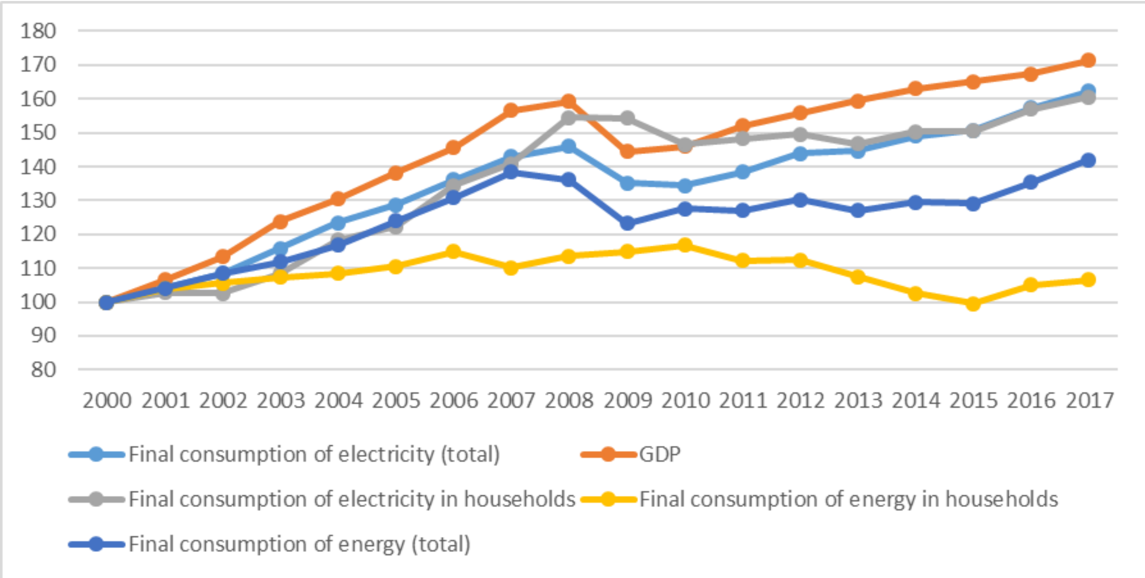


Figure 24 Comparation of Lithuania's GDP with Final electricity and energy consumption in households and in total (Units: 2000 level, Source: Lietuvos Statistikos Departamentas)

The first trend that requires the attention is the final consumption of energy in households, since it is the only one that is kind of similar than in 2000 and because its curve is not parallel to any of them. Even though, the consumption of electricity in the household manages to get nearly the same increase than GDP, basically due to the fact that the demand of other fuels is decreasing because of the growth of the efficiency while the number of electricity appliances is boosting. In order to support it, the figure 22 can be checked again.
Furthermore, the explanation of the trends of the final consumption of energy and electricity is the same than in the previous point, despite the fact that both have parallel curves compared with GDP one.

1.3- Electricity consumption in the household sector

On a first sight, it could be thought that Scandinavian countries are consuming electricity above its expectations according to the comparison of the figure 24 and 25. Nevertheless, there is one huge difference between the energy consumption and the electricity consumption at households according to its relation with the economic development.
This evolution of the economic level allows to purchase electric appliances thanks to the increase of the incomes. It is true that lightning, freezers or washing machines, for instance, are implemented in the dwellings since long time ago and it could be said that its usage is mandatory and common in the day to day.
Nevertheless, the increase of the incomes of the families foment the acquirement of other kind of appliances. This can be stated due to the fact that most of the rest of appliances can be categorized as *dispensable*, so as to say, they were not required for the basic standard of the society some time

ago. In this way, there has been a gradual introduction of a different set of appliances during the last lustrums: smart TVs, computers, dishwashers, electric hobs, air conditioner, oven, microwave, etc.

Thus, this fact mainly provoked the difference of trends among Scandinavian and Baltic countries. Regarding Scandinavian countries, Swede's and Finnish's dwellings had already implemented these devices since long time ago so these families have been basically dedicated to renew these by improving the efficiency with the new appliances, according to the aims of *Labelling* and *Eco-design* normative of the European Union. This fact would explain the constant drops of the electricity consumption in these dwellings, as it can be seen in the next figure [43].

Nevertheless, Baltic Republics and Poland got introduced these devices in the previous decade making the electric consumption grow during those years, although these trends have been balanced in the years since it has happened the same effect than in Sweden and Finland, dwellings are starting to renew its appliances, such as TVs, washing machines, PCs, etc., instead of buying new kinds.

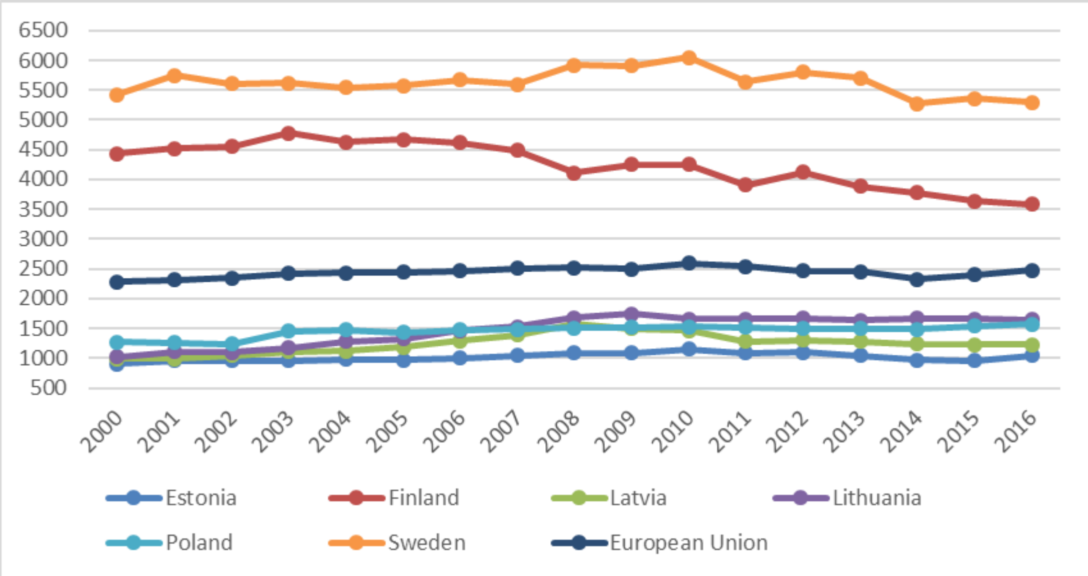


Figure 25 Unit consumption per dwelling for lighting and electrical appliances (Units: TOE/dwelling, Source: Eurostat)

In another vein, this electricity consumption need to be rationalised in order to satisfy the limits of energy savings stated by Europe 2020 Strategy. In order to elaborate conclusions of these figures, it should be compared the previous figure with data of energy savings in all the sectors, firstly, and then going in deep by analysing the household sector [44] [45].

Table 8 Overview of reported energy savings for 2016

	Cumulative savings over 2014-2016 (ktoe)	Estimated annual savings required for 2014-2016 (ktoe)	Comparation between real and expected in 2014-2016 savings (%)	Progress towards achieve the level of savings required by 2020 (%)	Cumulative savings required by 2020 (ktoe)
Estonia	284	113	217	47	610
Finland	4775	903	529	113	4213
Latvia	58	182	32	7	851

Lithuania	188	215	87	19	1004
Poland	3268	3175	103	22	14818
Sweden	3021	1953	155	33	9114

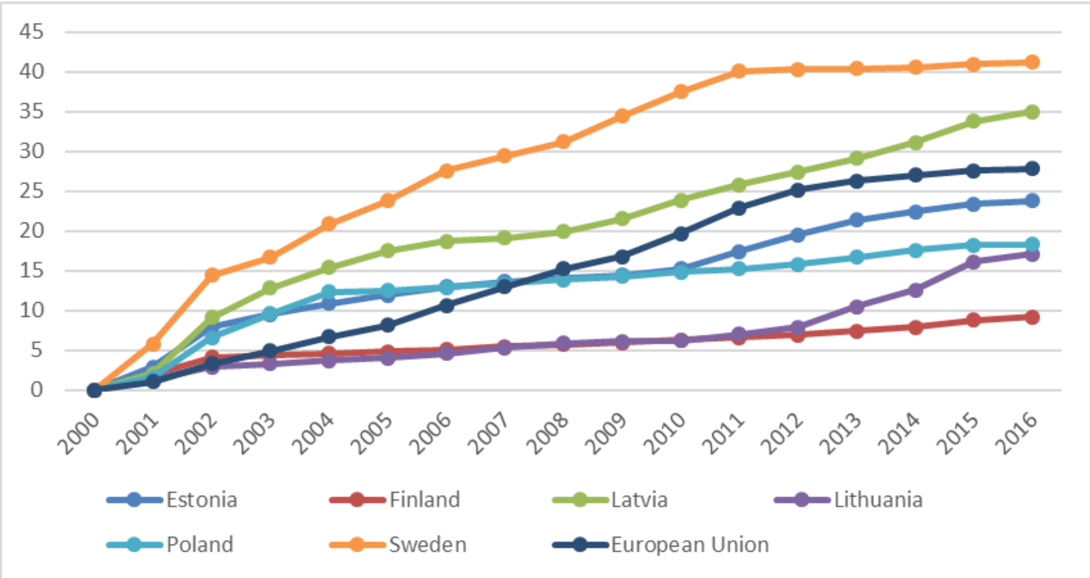


Figure 26 Energy efficiency gains in households (Units: %, Source: Odysee)

As it can be checked, there is no initial correlation among the savings of developed and transition economies. On a first sight, it can be seen that Latvia and Lithuania are improving their efficiency household sector with the best pace during the last years, especially knowing that they are not accomplishing the goal settled for global consumption for 2020. Nevertheless, due to the lack of specific targets for the electricity household sector, it has to be compared the efficiency reached over the total energy consumption with electricity consumption at dwellings, as it is shown in the next figure [46], which makes this data not a decisive factor:

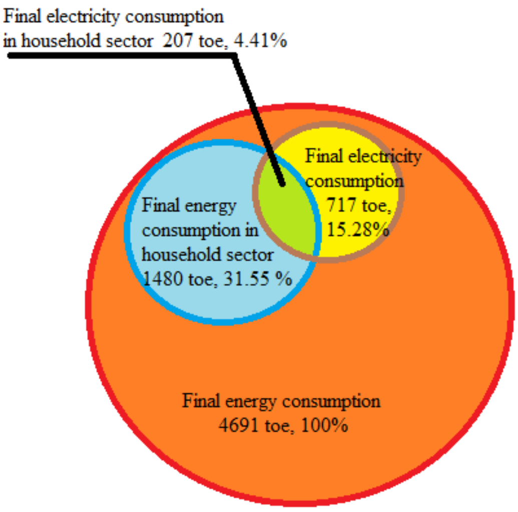


Figure 27 Shares of electricity and energy consumption in Lithuania (source: Lietuvos Statistikos Departamentas)

1.4- Trends of electricity cost

In order to retake what has already been introduced about the factors that regulate the price of the electricity at dwellings and its influence in its amount consumed, it is necessary to talk firstly about European markets.

In the 2.1 chapter it is shown how Lithuania, starting from a public monopoly system of production, transmission and supply of electricity, overcomes in a liberal system of transactions. In a parallel way, European markets have been trying to form a single market in order to cut global prices on the electricity supply. Even though there is a long way to go for earning this equality, the main achievable idea is that cheapest producers will be always supplying, no matter the country where they are settled down. For instance, if Lithuanian companies are producing cheaper electricity than Latvian ones, they will export the difference in order to compensate the otherwise inevitably difference of price. In any case, this will be done if the constraints of interconnections and transmission losses allow to maintain the economic saving.

This compaction of the sale price will provoke that exporter countries will suffer an increment on its prices that would be avoidable if they would just produce the electricity required on their own territories.

In order to gather all these statements in one conclusion, it is necessary to check the figures of Nordpool's market [47]:

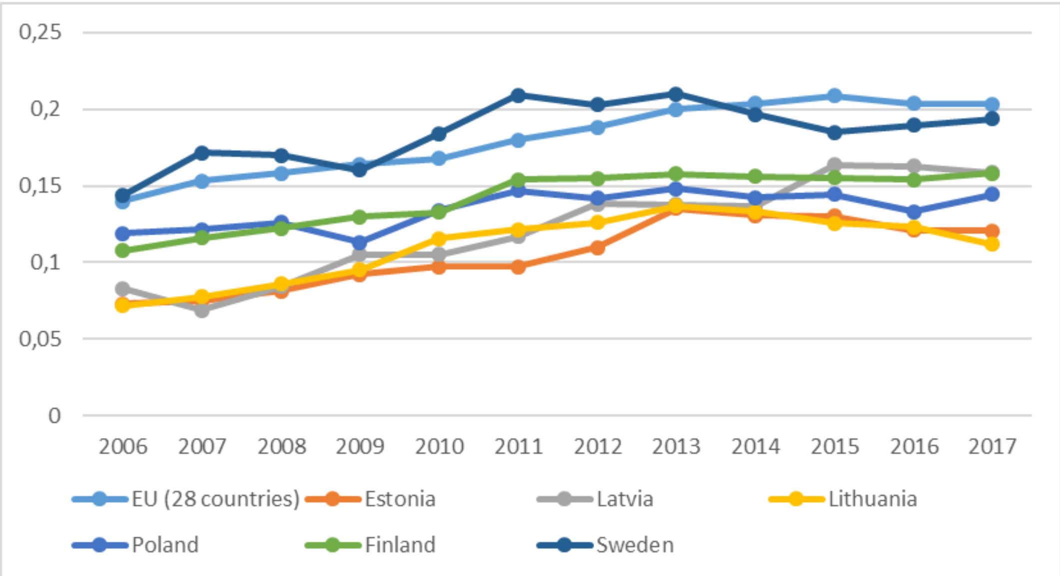


Figure 28 Electricity cost at dwellings in Nordpool's market (Units: cts/kWh, source: Odysee)

The first trend that requires the attention is that Lithuanian costs have been the lower ones in most of the years. As it has been exposed in the point 2.2.3, the closure of Ignalina NPP at the end of 2009 provoked a notorious increase of the price of the electricity and the country itself became the main importer of electricity per capita in the European Union. The main reason that explains this curious fact is that the closer countries (Estonia, Latvia and Poland) produce electricity with relatively low prices and, still, the rest of electricity produced in Lithuania is cheaper than in these countries.

Nevertheless, this adjustment just affects to the production component of the total cost. So as to say, there are other factors that influence in the final bill of electricity in the households [48]:

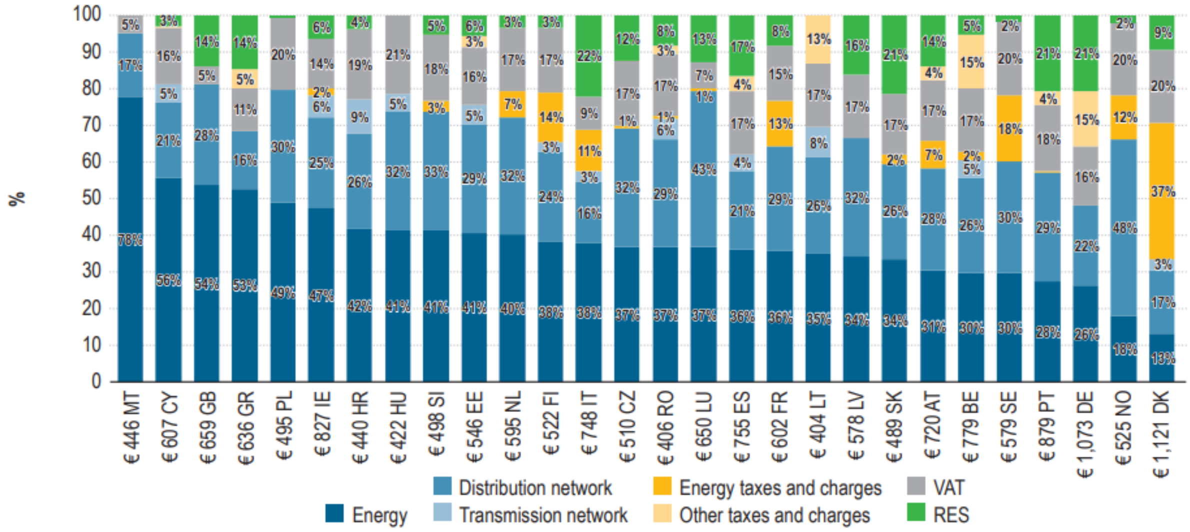


Figure 29 POTP electricity breakdown of incumbents' standard offers for households in EU capital cities (source: ACER)

As it can be seen, Lithuanian household sector electricity cost is divided in three parts that are almost equitable: production, the sum of transmission and distribution and the application of Value Added taxes and energy taxes and charges to these ones. Thus, it can be stated the main factor that explains the huge difference of prices shown in the figure 30.

1.5- Elasticity of the electricity demand

The elasticity is used to evaluate changes in supply and demand according to variation in external factors, such as GDP, population and, like it has been exposed in the previous point, the acquisition cost.

In this paper it will be calculated by comparing the increment or decrement of electricity demand in the household sector by increasing 1% the value of the base magnitude. Nevertheless, not all the factors can be graduated by numerical data, such as the evolution of the share of renewable technologies, the future impact of policies, the awareness of the consumers, etc., as it can be checked in the following table [49]:

Table 9 Macro environment surrounding electricity consumption fluctuations (Source: Forecast of electricity consumption in Lithuania)

Macro factors	Electricity consumption increase	Electricity consumption reduce
GDP	Growing of GDP	Reduction of GDP
Investment	Growing of investment	Reduction of investment
Unemployment rate	Reduction of unemployment rate	Growing of unemployment rate
Growing population	Growing population	Receding population
Growing number of enterprises	Growing number of enterprises	Growing number of enterprises

Technological	New achievements. Using of electricity includes space heating, cooling, water heating, dryer and etc. New manufacturing processes, products and services, or any new technologies that could impact the electricity consumptions, low cost and accessibility	New technology and equipment reduces consumption of electricity
Social and cultural	Positive opinion about electricity consumption in the society and negative about other kind of energy	Society gives preference to other kind of energy
Natural	Alternatives natural resources do not exist. Opening for electricity industry	Other natural resources (oil, wood, coal, gas and etc.). Ecological concerns that affect the production processes of firms and customers' electricity consumption
Legal and government	Political stability, successful trade regulation and tariffs, pricing regulations, environmental protection laws, high minimum wage laws, etc.	Political instability, unsuccessful trade regulations and tariffs, pricing regulations, environmental protection laws, low minimum wage laws, etc.

2- Review of top-down and bottom-up methods of electricity forecasting

The way of approaching the methodology used for the forecast will be to elaborate an analysis of the full range of the available methods based on literature. Getting to this point, it has to be stated that there are lots of ways for classifying all the different groups and subgroups of these methods. Thus, the explanations will be sustained in the following scheme [50]:

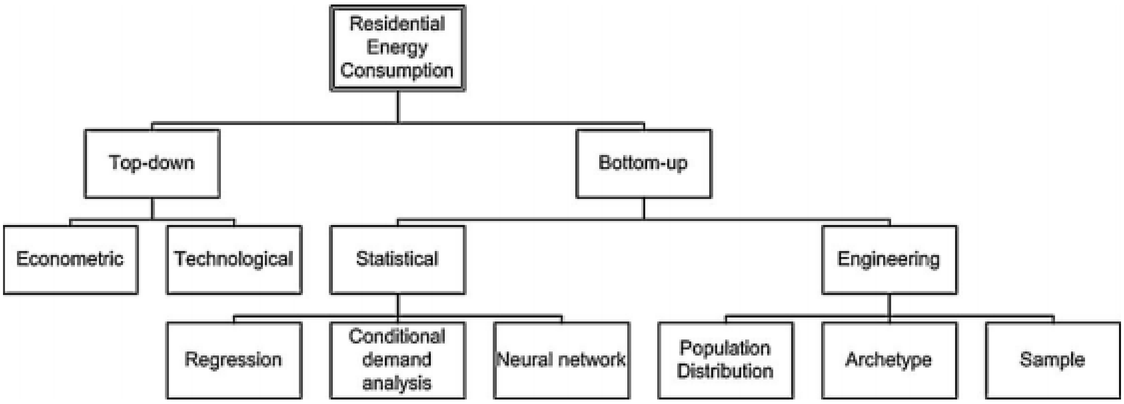


Figure 30 Top-down and bottom-up modelling techniques for estimating the regional or national residential energy consumption (Source: A review)

Regarding this layout of topics, it can be said that there are two main categories, that are subdivided in two halves at the same time: econometric and technological approaches for top-down methods and Statistical and engineering for bottom-up methods.

2.1- Top-down methods

The top-down models are used when it is possible to relate historical time series of national electricity consumption. This method treats the residential sector as a hole of electricity consumption without distinguish the end-use sinks. The way to implement it is by analysing the inter-relations between the level of electricity consumption in the household sector and long-term factors. On the one hand these are mainly englobed in socioeconomic factors such as:

- Macroeconomic indicators (price indices, employment rates, and gross domestic product (GDP))
- Demography evolution
- Dwelling features (construction, renovation and demolition of buildings)
- Amount and type of dwellings
- Climatic conditions
- Policies related with electricity consumption saving at national and EU level

On the other hand, the long-term trends of electricity consumption at dwelling can be stated through the technological development of these dwellings by analysing and estimating of appliances connected to the grid.

Thus, this system is characterised by treating all end-users of an area or country in the same way: it would be considered that all the inhabitants are consuming the same amount of energy by using the same share of electrical appliances. So as to say, it is considered the total consumption and then it is distributed equally throughout the population affected. This is the way of explaining the top-down meaning of the topic itself.

The strengths of these modelling rely in the wide availability of the initial data required and the inertia of its correlation with the electricity household consumption since this rarely undergoes in notorious trend shifts.

Keeping in this way, the drawback of the historical data used is the lack of adhesion of the discontinuous advances in technology and the inexistence of the analysis of each end-use [51].

2.1.1- Econometric approach

First of all, it will be required to state that econometric topic is born itself from the broad junction of economics, mathematics and statistics. This is due to the fact that statistical conclusions are elaborated by analysing the economic theory through mathematic tools. Thus, it can be said that economic models can describe the relationships between electricity consumption and factors that have an important impact on its usage [52].

Hence, the econometric approaches are mainly based in the election of certain historical data in order to not to complicate the elaboration of the model. This statement means that it cannot be used all the variables previously exposed because it would be impossible to quantify the impact of a single factor in the consumption since its effect would be smudged by the effects of the rest of trends to analyse.

This fact is ruled by the level of sophistication. It could be possible to elaborate an electricity consumption forecast just by bond it with the population trends, but it would not be reliable. Thus, it is necessary to use optimal indicators for each end-use sector and each energy source [53].
In this way, it will be required to specify the main trends of the users of energy consumption. In the case of this paper, the electricity consumption trends in households will be mainly related with the GDP per capita and the price of this electricity supplying, beforehand: the bigger economic level and lower the cost, the higher electricity consumption in households.

2.1.2- Technological approach

Technological models relate the electricity consumption regarding the dwelling and inhabitant predominant characteristics. So as to say, this model supposes a determinate level of appliance ownership trends.
This method is similar on a broad way with the econometric one since it uses global characteristics of the population that is object of study without going in deep in its kind of archetype, development levels, etc.
For instance, it is easy to see that, like in the previous example, the higher the economic level the higher the usage of electrical appliance. In this case, the electricity consumption is quantified by chaining it to factors that are no directly related with it.
In the case of the technological approach, its difference with the econometric model is that it related this consumption directly with its sources, the appliances of the dwellings.
To conclude with this part, it can be said that this method has the same advantages and disadvantages than the econometric one but it adds an intermediate step of assuming all the data related with the usage of appliances.

2.2- Bottom-up methods

The bottom-up branch encompasses those models that use data with a lower hierarchical level than the econometric level. The deepness of the level of information can be classified by accounting electricity consumption of groups of houses, individual houses and individual end-uses being extrapolated afterwards to the determined region regarding their weight of the model sample.
The input data is commonly based in dwelling properties such as insulation capability, number and scheduling of occupants, number and usage of equipment and appliances, climate properties and requirements, etc. This high detail level is a strength and a drawback at the same time:
On the one hand, this data is more complicated to acquire than the top-down indicators. This is due to the fact that it is required to treat the values individually instead than as a whole. The main means for taking this information is by surveys done by the population of the sample, sales data of the appliance companies, technical data from building companies etc.
On the other hand, the high level of information allows to classify and improve the outputs by end-users. Within this way, it is possible to identify the areas subjectable to improvements.
These models are using samples of houses or group of houses and the data acquired for these has to extrapolated by using determined coefficients depending on its representation in the sector.

In another vein, bottom-up methods have the chance to capture the effect of the behaviour of its occupants and the evolution of the implementation of renewable sources at dwellings, since both facts have been trending in a really dynamic way in the last years [55].
Thus, it is helpful to present a scheme that clarifies the input and output flows of data for the end-use models [56]:

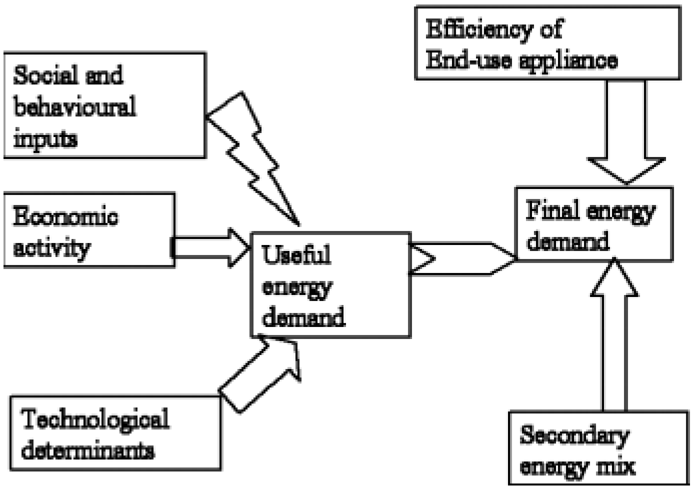


Figure 31 Generic end-use approach (Source: A comparative Study of Energy Models)

2.2.1- Statistical approach

The statistical methods rely on historical data and types of regression analysis used to attribute dwelling electricity consumptions to certain end-uses. Once these relations are settled, the model can be used for estimate the consumption of each of the representative kind of dwellings that are compounding the sample to analyze. Getting to this point, it has to be said that these models can utilize data used in the econometric approaches, such as electricity price, income, GDP, etc.
A capability of this model is that it discerns in the trends of the occupant behavior.
The three statistical techniques that are using sample of houses are:

- Regression: The coefficients that weigh the input and output are calculated by regression analysis. Thus, input variables that are supposed to have a negligible effect are removed and a parameter or combination of parameters used to derive the effects of each indicator into each end-use may or may not have a physical significance.
- Conditional demand analysis (CDA): It utilizes regression based on the usage of end-use appliances in order to regress the total dwelling electricity consumption. The way of obtaining the input data is by elaborating a survey to the occupants regarding their possession of electric appliances and to the electricity suppliers regarding the billing.
- Neural network (NN): This technique allows to break down the effects of the correlations of all the end-uses among them by creating series of parallel neurons, as it is shown in the figure 35 [57]. Thus, each neuron has a bias term and an array of coefficients that are already multiplied by the preceding layer's neurons. Its use has been historically limited due to computational and data requirement cost and the lack of meaning of the coefficients. In any case, this model is mainly used to forecast varying electricity loads seen by utilities due to its ability to capture non-linear characteristics [58].

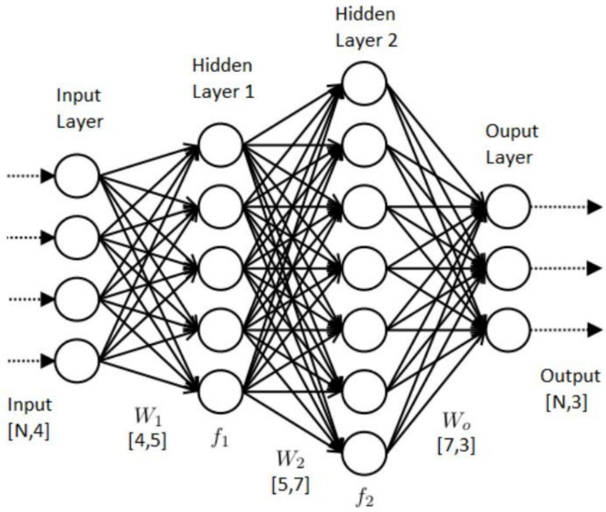


Figure 32 Neural network scheme (Source: The Artificial Neural Networks Handbook)

2.2.2- Engineering approach

The engineering methods rely on direct information of the dwelling and end-use features for calculating the electricity consumption based in the ratings of penetration and usage of each kind of appliance. It is necessary to state that is the only approach that does not require of historical data related with the consumption.

On the one hand, it can be considered as main advantage that it has the highest degree of flexibility and capability regarding the modelling of new technologies. This is due to its lack of historical profitable data for the rest of the models.

On the other hand, the main drawback is that the behaviour of the occupants of the household must be assumed.

The three engineering techniques that will be considered are:

- Distributions: This technique uses distributions of appliance ownership and use without making any distinction of the kind of dwelling. Knowing that the end-uses are calculated separately, the method does not take into consideration the correlation amongst end-uses. Thus, the electricity consumption is calculated by estimating the ownership, use, rating and efficiency of the appliances. Once all of it is achieved, it is just required to extrapolate the results from the sample to the regional or national scale.
- Archetypes: This method is applied when it is estimated a determined classification of dwellings, depending in this case on its size, occupancy, efficiency, etc., known it as archetypes. Each archetype of dwelling has its features of appliances and its values of electricity consumption and, if these figures are scaled up according to the number of households of each kind inside a country, the total consumption for each archetype will be obtained.
- Sample: This approach is based in the utilization of a sample of dwellings as input. If the sample is representative for the country, which requires lots of efforts in the elaboration of the database, the electricity consumption will be find by scaling up these values of a bunch of dwellings to the national stock of buildings [59].

2.3- Decision making of the methods

The most important part of the paper is to decide which of the previous methods will be applied. On a first sight, it could be thought that basing the study in the utilization of just one of the methods can work for getting a magnitude order of the values of the electricity consumption in the households.

Nevertheless, the fact that the forecasts will encompass the timeline till 2040 provokes that final values will vary a lot by just changing slightly the initial coefficients of elasticity, penetration of appliances and so on. Thus, it will be possible to compare the feasibility of the figures year after year by using at least two methods.

In addition to that, it has to be stated that the aim of the paper is merely academic. Knowing that, it will be possible to check in deep the differences of inputs, procedures and outputs of the different methods that will be applied.

First of all, it is interesting to check the usage of each modality of forecast [60]:

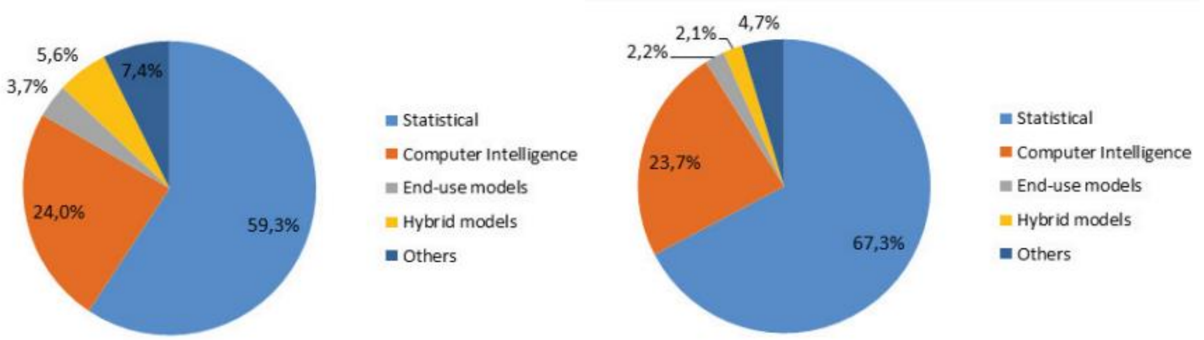


Figure 33 Models by type retrieved from article selection and Share of number of citation of models by type retrieved from article selection (Source: Long Term Electricity Forecast: A Systematic Review)

It is necessary to specify that statistical methods are the same as top-down ones and that end-use model is synonym of bottom-up model.

Once it has been clarified, it can be noticeable than most of the half approaches used are related with top-down models and just a small share is of the forecasts are done by bottom-up models. Thus, it will be great to check the procedure and output especially of this last method since it is rarely found in the literature.

Getting to this point, in order to choose the approach of the forecasts, it will be necessary to check a summarise table of the advantages and disadvantages of each major group of classification [61]:

Table 10 Benefits and limitations of bottom-up and top-down modelling approaches (Source: Building and environment)

Characteristics	Top-down	Bottom-up statistical	Bottom-up building physics
Benefits	- Focus on the interaction between the energy sector and the economy at large - Capable of modelling the relationships between different economic variables an energy demand - Avoid detailed technology descriptions - Able to model the impact of different social cost-benefit energy and emission policies and scenarios - Use aggregated economic data	- Include macroeconomic and socioeconomic effects - Able to determinate a typical end-use energy consumption - Easier to develop and use - Do not require detailed data (only billing data and simple survey information)	- Describe current and prospective technologies in detail - Use physically measurable data - Enable policy to be more effectively targeted at consumption - Assess and quantify the impact of different combination of technologies on delivered energy - Estimate the least-cost combination of technological measures to meet given demand
Limitations	- Depend on past energy economy interactions to project future trends - Lack the level of technological detail - Less suitable for examining technology-specific policies - Typically assume efficient markets, and no efficiency gaps	- Do not provide much data and flexibility - Have limited capacity to assess the impact of energy conservation measures - Rely on historical consumption data - Require large sample - Multicollinearity	- Poorly describe market interactions - Neglect the relationships between energy use and macroeconomic activity - Require a large amount of technical data - Do not determinate human behaviour within the model but by external assumptions

The first decisive factor is to choose one top-down and one bottom-up since it will cover the higher range of possibilities in the results on the one hand, and it will allow to compare the accuracy and performance of both approaches, on the other hand.

Regarding the bottom-up election, it is necessary to do a breakdown of the applicability of its two branches into the frame and features of the long-term forecast of electricity in the household sector. Thus, statistical methods are characterised by:

- High level of statistics detail
- High level of statistics knowledge
- Low level of input data (billing and simple survey information) although it is required to take a large sample of data
- Include macroeconomic and historical data and socioeconomic effects
- Limited capacity of adaptation to the new technologies
- Limited output data
- Limited flexibility

In addition, engineering methods are characterised by:

- Continuous adaptation to the trends of usage of appliances
- Higher flexibility
- Inclusion of the implementation of newest technologies
- Inclusion of electricity saving and consumption policies
- Assessment of combination of usage of technologies on supplied energy
- Lack of historical data
- Lack of macroeconomic data
- Assumptions of occupant behaviour
- Assumptions of market interactions

Once all this decisive factors are known, it is required to focus in the top-down method. As it has already been exposed, this approach is divided in two branches: econometric and technological. Since the technological method does not provide additional advantages compared with the econometric one and taking into account that is more similar to the bottom-up principles, it is advisable to choose the econometric process as main representative of the top-down method.

The econometric approach supports its results in official forecasts of the input values, such as GDP or population, but even knowing these values are not accomplished after some time, the model can be corrected by updating this kind of data according to the newest values.

Once this has been stated, it is necessary to remind the importance of the election of methods of forecast that will be broadly different in order to avoid overlaps of procedures or results and to achieve more credibility. Doing a quick review of the comparison of the econometric model with statistical and engineering models respectively, it can be point out the second method that will be applied in the paper.

Both econometric and statistical approaches are using macroeconomic, socioeconomic and historical data, are considering historical data and performance of the inputs of the process and both have to partially assume the future impact of the newest technologies.

On the other hand, both econometric and engineering methods complement perfectly each other. The econometric model bases its strength in historical data, it gathers the behaviour of the consumers and the interactions of the market by bonding their consumption to their acquisition power and to the price of the electricity itself respectively.

In the other case, the engineering method is hold by the utilization of actual information, it allows to disaggregate the output values regarding the different end-uses, it uses technological data instead of economic data and it permits to adapt and implement the dynamic changes of the supplying technologies.

Once it is clearly defined that the engineering approach is more positive for the requirements of the paper than the statistical one, it is necessary to choose which of the three methods is better to apply.

The main differences among them are the output category of data:

- Population distribution uses standards of usage of appliances according to their economic level
- Archetypes are used to state different kinds of buildings as end-users, taking into account that each archetype will have its own features of appliances
- The sample records the appliance data of a determined number and kind of buildings

Even though knowing that there is not any clearly superior approach, population distribution method will be chosen since the calculus will be hold by an application of the data provided by the *Lithuanian Statistic Department* in its report of *Energy Consumption in Households (2011)*. Although it can be seen that the data is old, it will be corrected by updating the trends of population, GDP, penetration of appliances, etc., that have been taking place till now [62].

Analysis of results

The main goal of the paper is to forecast the electricity consumption in the Lithuanian household sector. As it has been stated before, the econometric and population distribution methods will be applied.
To do so, it will be required to set a sort of boundary conditions firstly. Once it has been stated, the application of both approaches will take place separately. In order to do so, three different scenarios will be simulated in order to exemplify all the range of possibilities and results.
At the end, there will be an analysis of the suitability of each method.

1- Initial considerations

It is necessary to state that the forecasts for Lithuania does not work the same way as the develop countries that have been being object of study of these forecasts. The country has an own socio-economic environment that makes harder to compare it with the cases of other countries.
The main factor is that Lithuania is a country of less than three million of population that has to import most of the fuel and a considerable part of the electricity. For this reason, the country is vulnerable to sudden changes in policies, prices, supplying, etc., by affecting all the inhabitants at the same time.
Another important factor that has to be taken into account is that the nation was involved in two important geopolitical changes: its independency from the Soviet Union in 1991 and its inclusion in the European Union in 2004. Thus, it is a rough task to gather data if it is compared with the rest of EU's countries.
Taking into consideration the economy development of the country, Lithuanian's GDP has growth within abrupt trends during the last two decades, as it can be seen in the figure 5.
In another vein, the demographic trends of the population are concerning the forecasts of all kind of matters, and not even the ones related with electricity and energy. The country has lost nearly one million of inhabitants, as it is shown in the figure 6, which makes that the current population reach just the 75% of its level 25 years ago. Despite this fact, most of the forecast have been considering that the demography will retake its situation and that Lithuania will be slightly repopulated, since it is the trend in most of the European countries at the end. Thus, the paper cannot be based in previous studies, since most of them are sustained by this assumption and, as it can be checked, the country continues losing inhabitants.
Thus, in order to avoid the incurrence in errors since the beginning of the process of forecasting, it has been considered that the best choice will be to consider three kind of scenarios of the socio-economic development of the country: optimistic, basic and pessimistic.
Each scenario links the influence of all the factors that will be used as inputs in order to clarify the possible results. This is due to the fact that most of them are closely bonded. For instance, the more the GDP growths, the more population will stay in the country.
There has been considered three kind of factors in order to its usage: econometric, end-use or common.

2- Econometric method

The econometric method will be used to quantify the different range of figures of consumption depending on the development of the macroeconomic and demographic factors that will be taken into account.
The procedure to follow will be to compare the behaviour of each item with the variations of electricity demand, on the one hand, and between themselves, on the other hand.
Thus, once the correct factors have been chosen and their impact on the electricity consumption has been quantified, it is possible to find the different demand trends out.
To summarise the procedure that will be done, all the assumptions and hypothesis that have been used will be described in the same sequence as it come up, no matter if it will be accepted or refused.

2.1- GDP assumptions

Firstly, it is necessary to remember that the main principle of the three kind of scenarios are the economic development of the country. So as to say, a high increment of the GDP will allow more people to keep living in Lithuania, spend more money in the purchase and usage of appliances, the supplying companies to arise the prices of electricity, to build and maintain more dwellings etc.
On the other hand, a slow development of the economy of the country will provoke the increase of the consumption savings, decrease of the population, etc.
Hence, it can be stated that the forecast of the GDP is the cornerstone where all the assumption will be rounding in a first place.
The values that have been taking into account matches the script of the report, since it has already considered three scenarios [63]:

Table 11 GDP growth projections (Units: %, Source: Litgrid)

	2018-2021	2022-2026	2027-2032	2033-2040
Optimistic	3,7	2,72	2,33	2,1
Basic	2,96	2,18	1,87	1,6
Pessimistic	2,22	1,63	1,4	1,25

It has been required to assume the value of growth from 2033 till 2040, since those years are not attained to the study performed by Litgrid. In order to quantify it, the trend of slowdown of the GDP for each case has been followed.
Once all this figures have been stated, the calculus of the GDPs takes place. The figures of 2018, which are 37199 million of euros, overcome into 64937, 57822 and 52017 million in 2040 for the optimistic, basic and pessimistic cases respectively, as it can be seen in the following graphic:

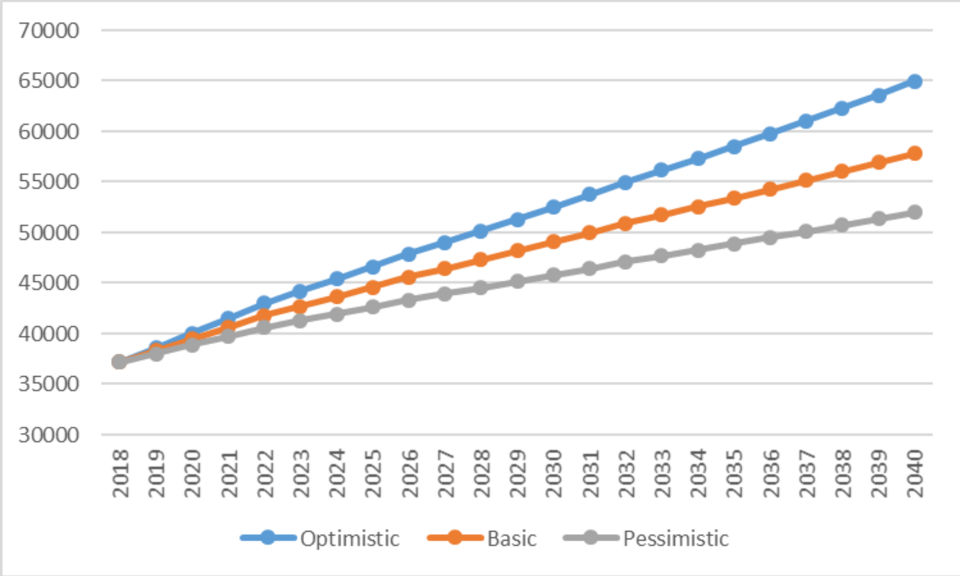


Figure 34 GDP trends projections (Units: millions of euros, Source: Litgrid)

2.2- Population assumptions

The next forecast that has been considered is the population one. This topic is really important since it is the main demographic indicator and it is a good indicative of both econometric and end-use values.

As it has been shown, the trend of the population is over 1.2% of decrease per year in this millennium, achieving near 0 and -3% of extreme values, which indicates that the demographic losses have been remaining relatively constant. Knowing that this topic is object of lots of studies and forecasts, it has been thought that the most accurate idea is to turn to official sources in order to choose three different projections and discern its trends among the scenarios.

Getting to this point, the first inconvenient that come up is that most of the forecasts situate Lithuania with a population level between 2.5 and 2 million around 2040. Thus, it can be seen that the inhabitant level would decrease from 0.4 to 1% per year respectively, which makes sense since it keeps the same trend as the last two decades.

Nevertheless, this last figure would sink Lithuania in an unsustainable environment, since it would mean that the country would have lost almost half of its residents since its maximum peak during the 90s. Hence, the forecast done by Eurostat [64] has been chosen to nourish the pessimistic scenario. In this case, the bottom value of population for 2040 is slightly over 2.1 million.

In another vein, it has been considered to use the mean of two of the main projections for the inhabitant level in the basic scenario: International Futures [65] and Population Pyramid [66]. Getting to this point, it is required to specify that the last five years of projection of the first source has been assumed regarding the constant decrease till reaching 2.37 million and that the projection of the second source states a better value of 2.5 million. Hence, the average of both forecasts would situate a population of 2.44 million.

It has been considered interesting to maintain the same demographic level of the present for the optimistic scenario. This implies that Lithuania's inhabitants would be around 2.8 million, permanently.

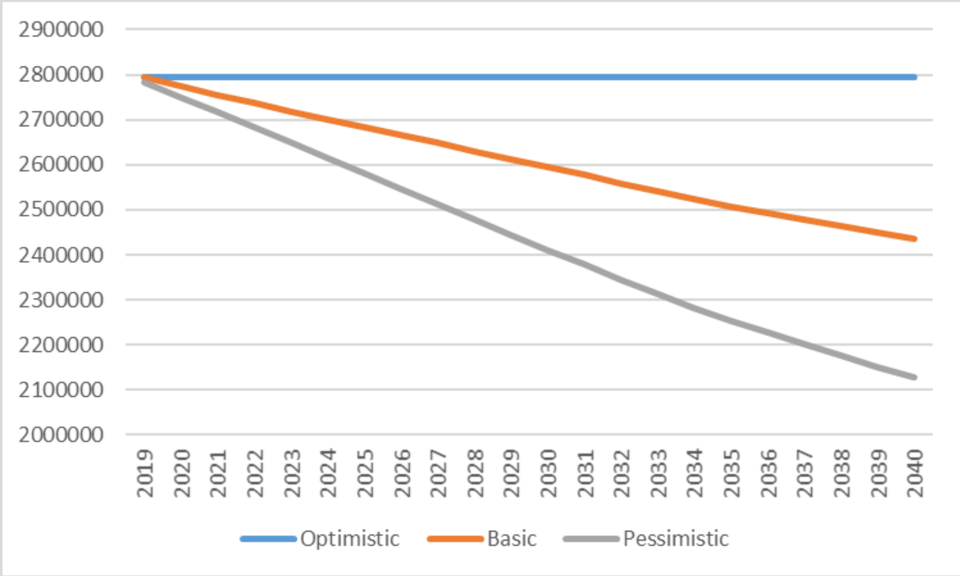


Figure 35 Forecasts of Population (Units: inhabitants, Source: Eurostat, International Futures, Population Pyramid)

2.3- GDP per capita assumptions

In order to approach this calculus, it is just required to divide the forecast of GDP and population. These two values are closely related since the high increase of GDP allows increasing the population by receiving immigration, having higher fertility ratio, arising the number of dwellings, etc., working in the reverse way if Lithuania would have a paralysed growth.

The point of the GDP per capita is that it is the coefficient of two values that are kind of proportional. As it can be seen by resolving the values for 2040, it arises from 13200 to 24000 euros approximately.

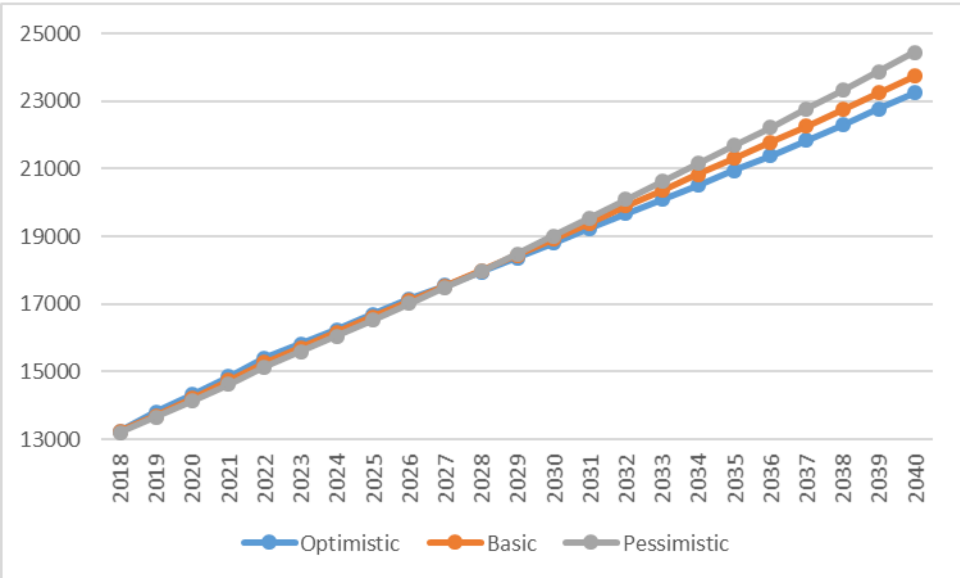


Figure 36 Forecasts of GDP per capita (Units: inhabitants, Source: Eurostat, International Futures, Population Pyramid, Litgrid)

Even though it can be thought that these values are not decisive, the main point of having constant values for each case is that it will mean that there will be a constant growth of the share of the electricity consumption that is related with the purchasing power of the customers in each scenario.

2.4- Elasticity between GDP per capita and the electricity consumption in the households

The econometric models relate most of the outputs with the purchase power of the population. It has to be related logically that the higher the incomes, the higher the consumption and usage of appliances and electricity.

Getting to this point, the figures of the GDP per capita of the past years are related with the consumption by the calculus of the short-term elasticity, as it has been explained in the point 1.5 of the methodology.

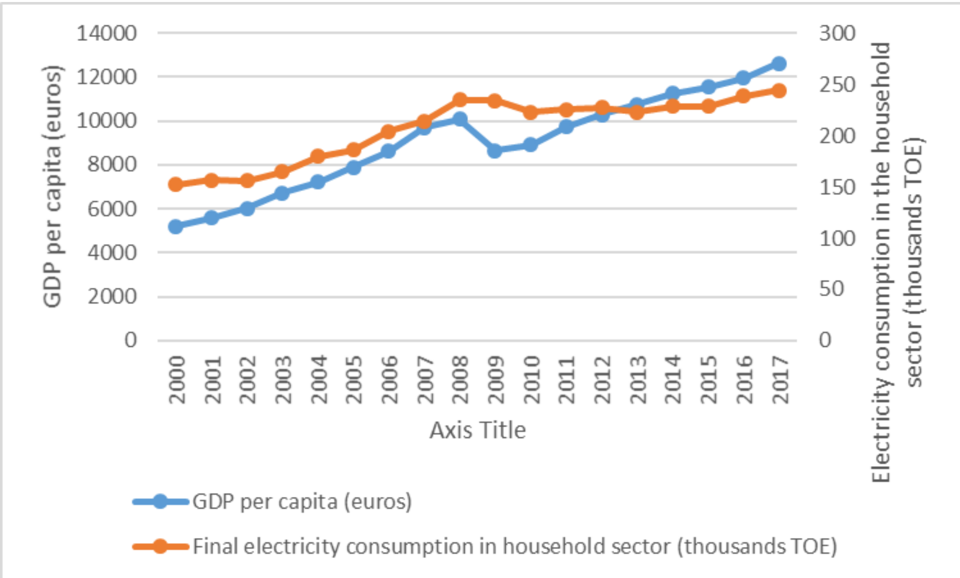


Figure 37 Comparison between GDP per capita and electricity consumption in household sector (Source: Eurostat and Lietuvos Statistikos Departamentas)

As it can be seen in the previous figure, both variables have been kind of related. The elasticity value that has been calculated is 0.40, which makes that for each increase of 1% in the GDP per capita, the electricity consumption in the households will increase 0.40%.

2.5- Price of the household electricity assumptions

As it has been said before, the second main factor that allows to quantify the future electricity consumption in the dwellings is its price.

The procedure for forecasting it is to use the official projections of GDP. Getting to this point, it becomes necessary to explain why should GDP and price be linked and the answer is that the economy handles the cost of production, transmission and distribution of energy. This statement makes sense by thinking that if GDP grows that increment can be used and reinvest in purchasing more appliances, allowing more residents to stay in the country, increasing the price that consumers are able to pay, etc. This whole bunch of factors provokes the arise of the demand, making the prices more expensive according to the *law of supply and demand*.

To summarise it, the higher the economic development of the country, the expensive its supplying, as it can be checked in the 1.4 part of the methodology.
In order to quantify this relation, the values of the comparison between GDP and price of the last two decades can be used [67]:

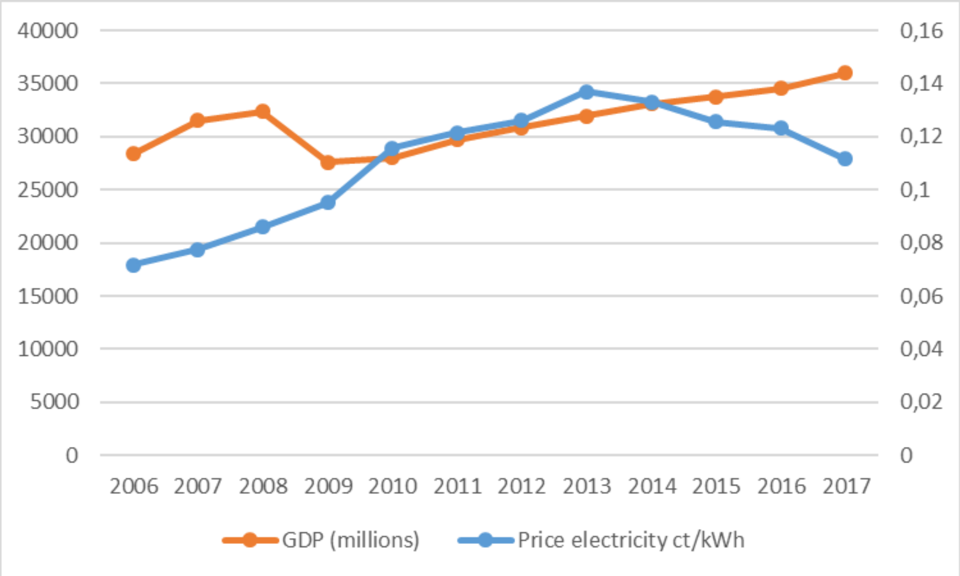


Figure 38 Comparison between Lithuania's GDP and price of the electricity in household sector (Source: Eurostat)

The elasticity calculated from these figures is 1.4, which can be used to bond the three kind of GDP scenarios with the determine price for each index of development:

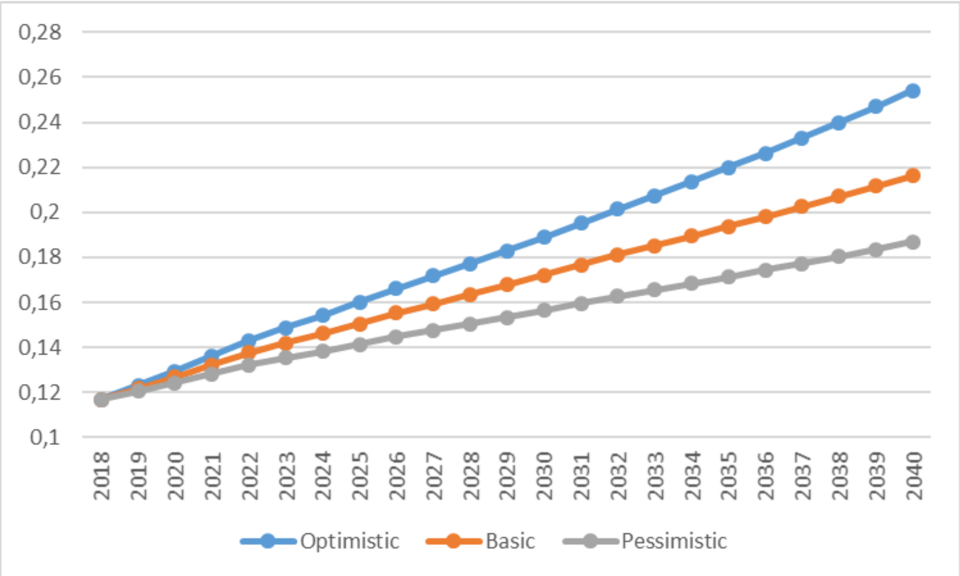


Figure 39 Forecast of electricity prices in household sector (Units: ct/kWh)

2.6- Elasticity between electricity price and consumption in the households

The first thing that requires the attention is that there are just data of the household electricity price from 2006, which makes the sample a bit smaller than for the rest of topics, which figures have been mainly found since the beginning of the millennium.
In another vein, it was supposed to be interesting to analyse the behaviour of the consumers taking into consideration both short-term and long-term elasticities. This is due to the fact that users cannot modify their trends of consumption from day to day.

Thus, in addition to the regular elasticity, it has been calculated a long-term elasticity that takes into account the variations of price and consumption of the four previous years. The recent the year of study is, the bigger its weigh. It has been done according to the next formula:

Equation 1

$$E = \frac{\Delta D\%}{\Delta P\%} = \frac{\frac{D_0 - D_{-1}}{D_{-1}} \times 4 + \frac{D_{-1} - D_{-2}}{D_{-2}} \times 3 + \frac{D_{-2} - D_{-3}}{D_{-3}} \times 2 + \frac{D_{-3} - D_{-4}}{D_{-4}}}{10}$$

Nevertheless, there are two main drawbacks that make impossible to apply this formula for the calculus.

On the one hand, the elasticities will just be able to be calculated from 2010, which reduces the size of the already short sample.

On the other hand, the results of the calculus of the elasticities themselves have incurred in really diverse results from year to year.

Thus, it will just be applied the short-term elasticity, which is -0.16, as it can be seen in the next figure:

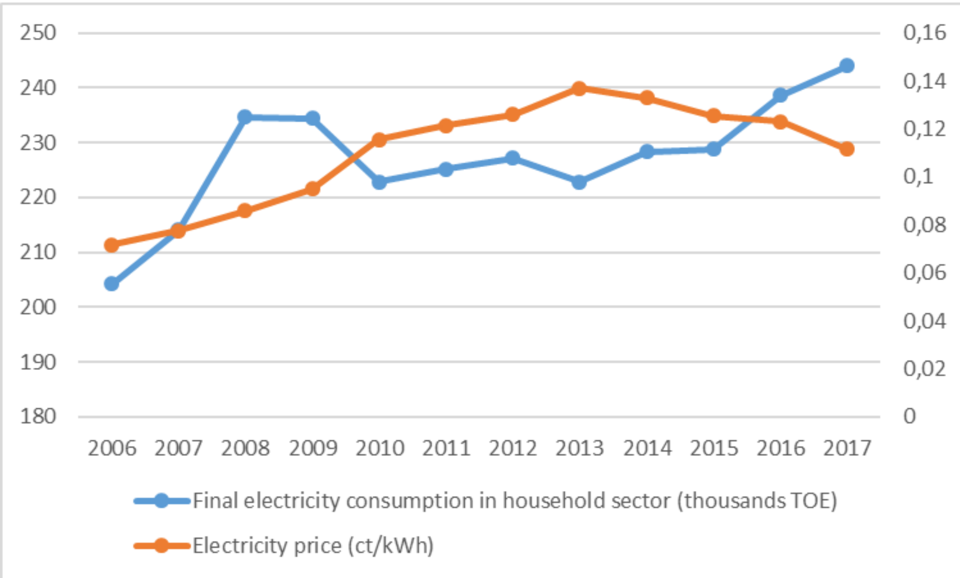


Figure 40 Comparison between electricity consumption and price in household sector (Source: Eurostat and Lietuvos Statistikos Departamentas)

2.7- Socio-demographic assumptions

It has been thought initially that it would be enough to link the electricity consumption with its price and with the purchase power of the inhabitants. Nevertheless, once the results have been analysed, it can be stated than it will be necessary to go one step beyond.

The elasticities have shown that the demand of electricity is nearly inelastic (-0.16) if it is compared with the variations of the price itself, which makes this tool nearly useless.

In another vein, the comparison with the GDP per capita results in an elasticity of 0.40, which is considered as relative inelasticity. Even knowing that this value is higher than price elasticity, it is

not enough for forecasting the demand, since the three cases of GDP per capita development shown nearly the same figure till 2040.
Getting to this point, it is necessary to think about how to approach the econometric method. On the one hand, the consumption is related with three clearly different scenarios of prices, which are varying from 0.254 to 0.187 ct/kWh but this variation does not affect the electricity demand. On the other hand, it is shown that GDP per capita influences in the electric consumption in the household sector relatively, but the difference of its values from scenario to scenario are tiny.
Hence, it will be advisable to use a third factor that will influence in the consumption and that will acquire various figures among the three types of cases.
Knowing that it has been used factors that are merely economics like price and GDP per capita and it has not been enough to implement a feasible forecast, it is required to attain the demand to other kind of factors. In this case, it has been thought that it could be interesting somehow to relate consumption with the socio-demographic development of Lithuania since, as it has been explained before, it is unique due to the constant decrease of the population even considering years with abrupt economic growth.
First of all, it is mandatory to consider the population level itself as a possible factor of determining the consumption. Once it is compared the trends of both topics throughout the pass of the last two decades, it can be stated that there is no connexion between them, since the logical relation will be the more populated the country, the higher its consumption [68]:

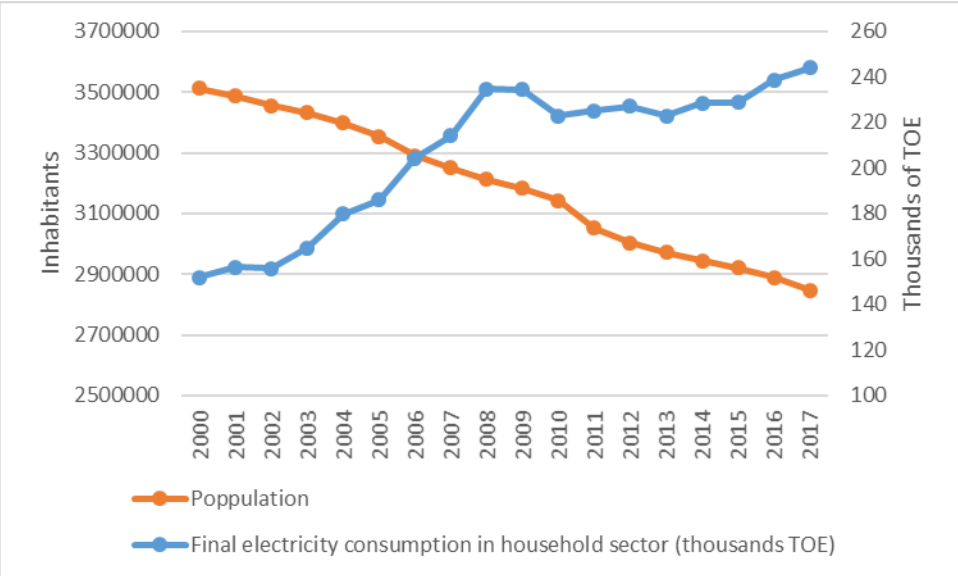


Figure 41 Comparison between Lithuania's population and electricity consumption in household sector (Source: Lietuvos Statistikos Departamentas)

These curious trends may be explained due to the occupancy of dwellings by these inhabitants, since there will be nearly the same consumption of appliances, such as lightning, space heating, etc. Hence, it is shown, in first place the relation of the electricity consumption with the number of dwellings that are occupied [69]:

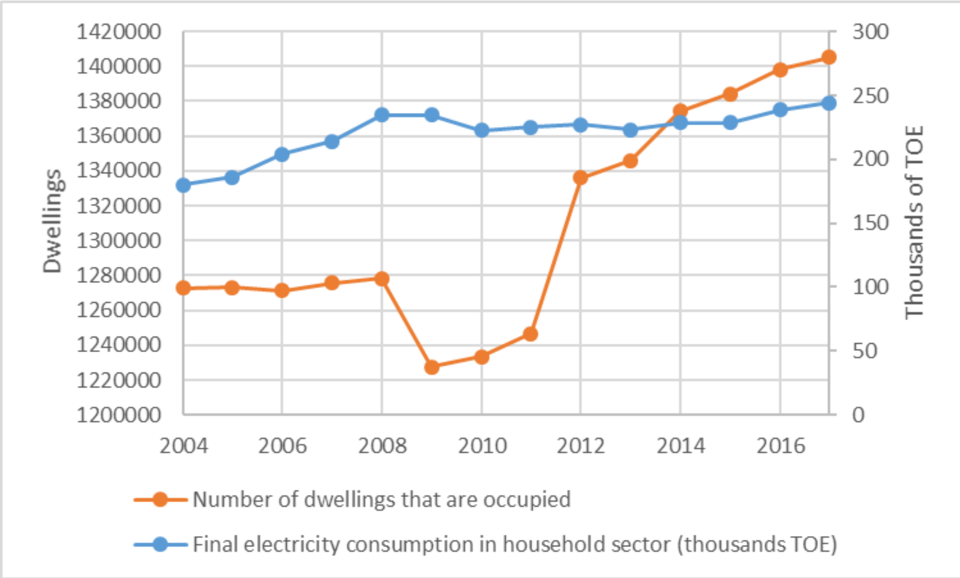


Figure 42 Comparison between number of occupied dwellings and electricity consumption in household sector (Source: Lietuvos Statistikos Departamentas)

Once it is stated that these values can be used for the forecast, it is necessary to find the elasticity that would allow to bond the forecasts of the number of dwellings with the future household electricity demand. Even though its global value has been extremely high (8.1613), it has been corrected by erasing the four most extreme values (2005 and 2008 with elasticities of 121.90 and 48.10 respectively and 2006 and 2010 with -13.89 and -9.96). Thus, the new value of elasticity that will be used in the future calculus is 2.52. Once the progress has arrived to this point, it is required to state the figures of the future Lithuania occupation of the household sector.

2.8- Socio-demographic influence on the electricity demand

In order to project the future number of occupied housing, it is necessary to analyse the trends of occupation of those years which data is provided:

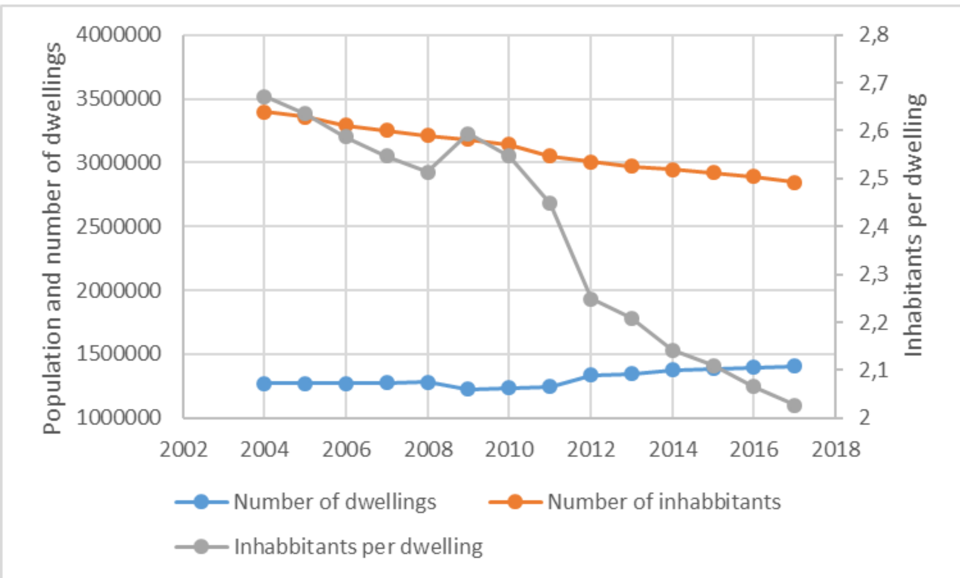


Figure 43 Comparison amongst number of dwellings, inhabitants per dwelling and population (Source: Lietuvos Statistikos Departamentas)

As it can be seen, there has been a constant decrease in the number of inhabitants per dwelling without taking into account the 2009 year, when the crisis hit the economy in the country. So as to say, the situation has overcome from having 2.67 in 2004 occupants per household till reaching nearly 2 in 2017. Nevertheless, this values are useless if it is not set into the European context [70]:

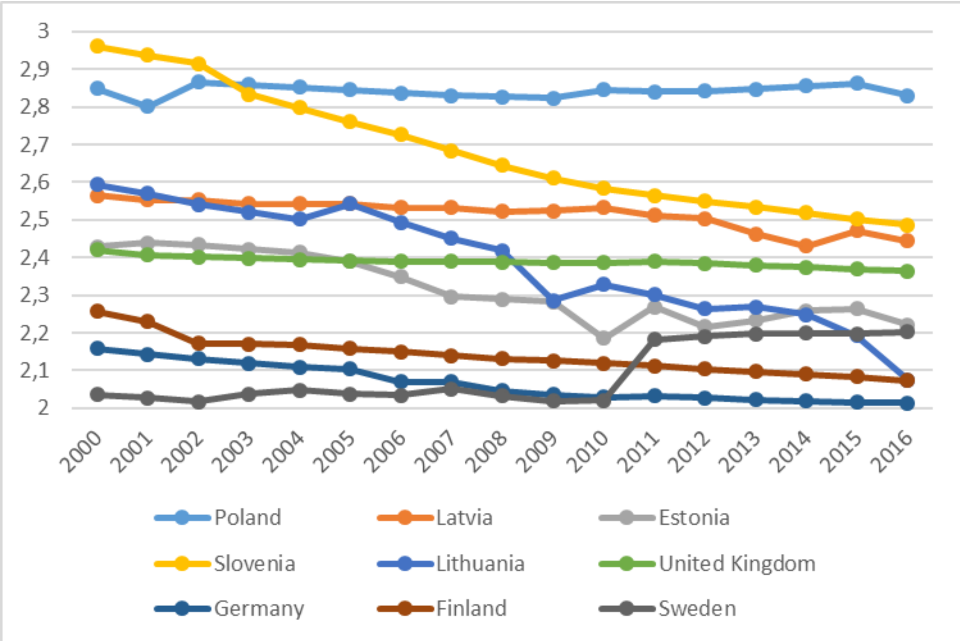


Figure 44 Comparison amongst the level of inhabitants per dwelling in various countries of Europe (Source: Eurostat)

In order to discern the trend of Lithuanian occupancy of the household sector it has been chosen two groups of countries to study:

- Developed countries: (Germany, United Kingdom, Sweden and Finland)
- Transition economy countries: (Latvia, Estonia, Slovenia and Poland)

The first assumption for choosing these countries is not to have a remarkable touristic environment such as Spain, France or Italy, since there are lots of dwellings in these countries that are empty during the yearly low season.

The second assumption has been to separate the countries in two groups according to their purchasing power, considering that Lithuania is an economy in transition.

Hence, it can be stated that, even knowing that all the nations trend to decrease the occupation of the dwelling, Lithuania is the one with a bigger drop. In other words, the country has passed from having the same level than Latvia till reaching the figures of Germany and Finland, which are the countries with lower ratios.

To conclude this part, it can be stated that Lithuania has an occupancy that is becoming unsustainable to its economic level. So as to say, if the trends of the country kept in the same way, the economy balance would be wrecked and the situation would not be feasible.

Getting to this point, it has been tried to study the influence of the economic development in the occupancy and the yearly values of elasticity have been constant, making a final average of -0.66.

Thus, if this value is applied to resolve the decrements in percentage of occupancy in comparison with the different forecast of GDP, the figures to use should be:

Table 12 Initial projections of the ratio of development of the occupation of the dwellings (Units: %, Source: Litgrid)

	2018-2021	2022-2026	2027-2032	2033-2040
Optimistic	-2,45	-1,80	-1,54	-1,39
Basic	-1,96	-1,44	-1,24	-1,06
Pessimistic	-1,47	-1,08	-0,93	-0,83

Once this figures have been applied to the three different cases, it has been checked that the occupancy level for the optimistic case, for instance, would decrease till 1.36 in 2040. This value, as it has been suggested before, is really unsustainable since it would mean that most of the population live alone. Thus, in order to create more probable scenarios, the trends of occupation have been modified in the following way:

Table 13 Final projections of the ratio of development of the occupation of the dwellings (Units: %)

	2018-2021	2022-2026	2027-2032	2033-2040
Optimistic	-2	-1,3	-0,8	-0,5
Basic	-1,2	-0,3	0	0,5
Pessimistic	-1	0	1	2

Getting to this point, it is necessary to remark the factors that provoke an increasing or decreasing on the trend. Even knowing that this topic could be the cornerstone of another paper, its main aspects will be tried to be summarised.

In first place, it is noticeable that the higher the occupation, the cheaper the cost of living. This is due to the fact of sharing the expenses and bills of electricity, appliances, rental fees, etc.

The main aspects that characterise the population pyramids play crucial roles, such as the fertility, the mortality, the age of the population, etc. Thus, a country where a small amount of people is living per household can be related with low ratio of fertility, high ratio of mortality or a pyramid of population dominated by grown people. For instance, if a country has a huge amount of young people, this will have to share a dwelling with their parents, which makes the occupation ratio increase.

The immigration has to be approached as well for explaining the ratio of occupation. If a country is receiving immigrants, this will fill a dwelling and they will try reduce its expenses by living as much people as possible on it. In another hand, if lots of people emigrate from a country, they will leave the total or partially empty homes back.

Hence, the consideration of all these factors have been used in order to assign proper values of occupation trends of the previous table for Lithuania according to the economic development of the country, remaining the shapes of trends in the following way:

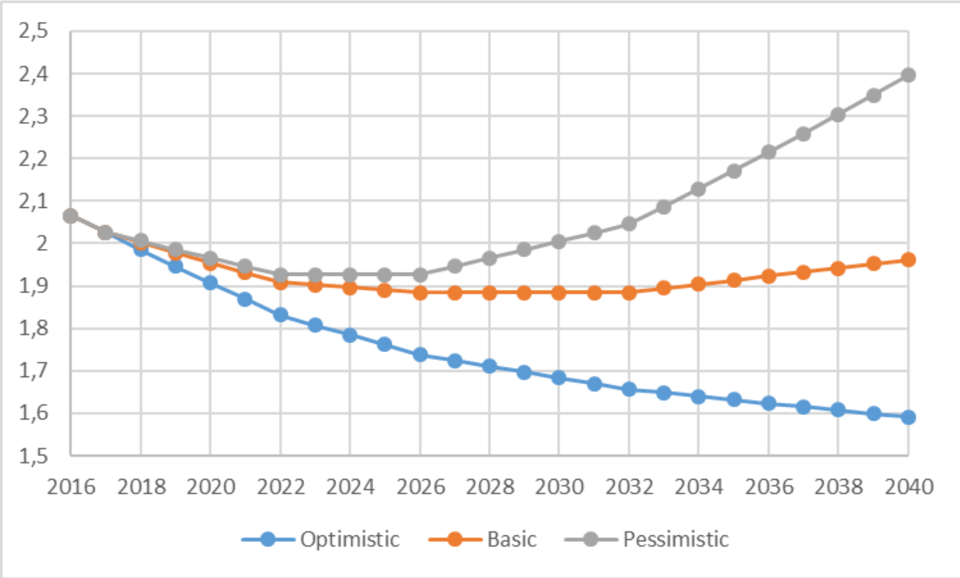


Figure 45 Forecasts of ratios of occupation in household sector (Units: inhabitants/dwelling)

As it can be seen, the optimistic scenario of the development of the economy would imply that the trend would be to keep decreasing but with a lower progressive pace, similar to the developed economies that have been analysed. This would be done by fomenting Lithuanians to own touristic houses, allowing young people to live by their own earlier, etc.

The basic scenario would provoke that Lithuania would stabilise its occupancy and it would reach the values of the rest of its similar economies, such as Latvia or Estonia, since those ratios would keep decreasing slowly.

The pessimistic case would simulate that the occupancy levels would go back to the time of the beginning of the millennium.

Once the trends of occupation per dwelling have been approached, it is possible to state the situation of the housing sector for each scenario by dividing, in each scenario, the population between the occupation per dwelling:

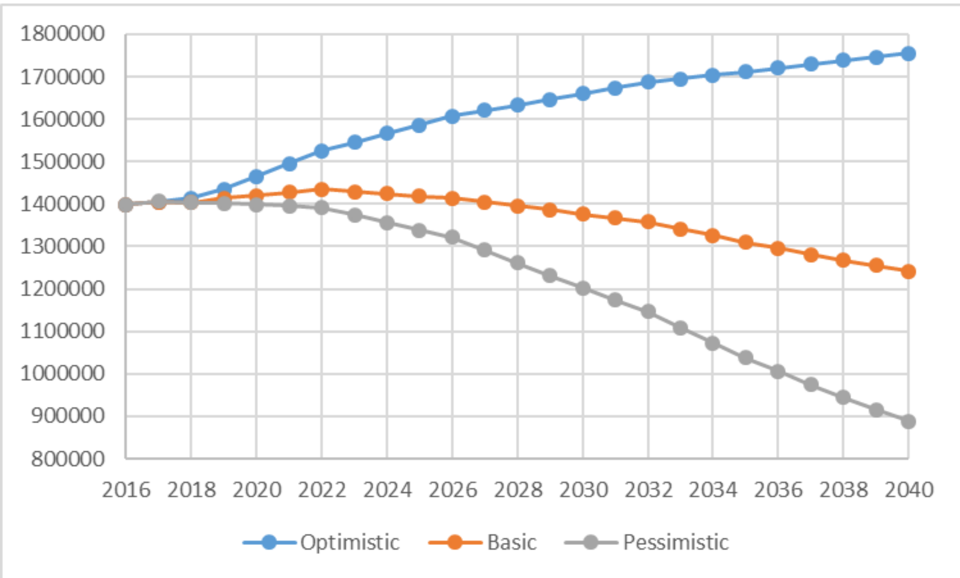


Figure 46 Forecasts of the number of occupied dwellings

2.9- Analysis of the electricity demand in the household sector according to the Econometric Approach

Once all the factors that will influence in the becoming of each consumption scenario are stated, which are the forecast of the electricity price, the GDP per capita and the number of occupied dwellings, the curves of each consumption case can be found out by multiplying the variations of the factors by their elasticities, which would result in the following situations:

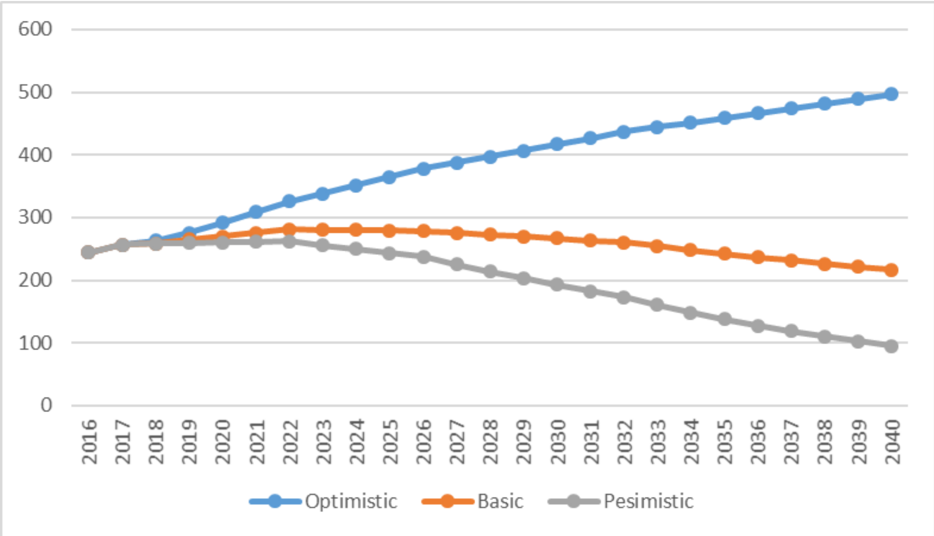


Figure 47 Forecasts of electricity consumption in Lithuania's household sector of the econometric model (Units: ktoe)

Furthermore, if the following equation is applied, it will be possible to resolve the values of the average annual growth rate:

Equation 2

$$\alpha = \left(\frac{E_m}{E_k}^{\frac{1}{m-k}} - 1 \right) * 100$$

Thus, the figures will be 2.88, -0.47 and -3.69% for the optimistic, basic and pessimistic scenario respectively.

In order to discern the features of each curve, it will be necessary to summarise their features separately by using the next table:

Table 14 Trends of the factors used for the electricity demand forecasting

	Optimistic	Basic	Pessimistic
Population level	Remain constant	Decrease slowly	Decrease highly
GDP	Increases highly	Increases fairly	Increases slowly
GDP per capita	Increases fairly	Increases fairly	Increases fairly
Electricity price	Increases highly	Increases fairly	Increases slowly
Occupation per dwelling	Decreases fairly	Decreases slowly and it gets balanced then	Gets balanced and it increases then
Number of dwellings	Increases fairly	Increases slowly and it decreases slowly then	Increases slowly and it decreases fairly then

As it can be seen firstly, GDP per capita and electricity demand are not decisive factors.
On the one hand, GDP per capita remains nearly the same in three forecasts and considering that the demand is relatively inelastic, it cancels this factor as a differentiate one.
On the other hand, electricity price varies from scenario to scenario but the consumption is almost inelastic, so it turns to be that this factor is not decisive as well.
Getting to this point, it is necessary to compare the shape of the curves of the last graphs, which are related with the number of dwellings and the electricity demand in the household sector. As it can be seen, the values from case to case are proportional. The only difference is that the trends of the number of dwellings are more abrupt since there are more factors (price, GDP per capita) in the electricity consumption that are balancing the figures from year to year.
In another vein, the values of the electricity demand of the optimistic scenario warn that the consumption in 2040 will be the double of the actual for the same level of population. Even knowing that these figures are not so feasible, the way of procedure and the usage of the factors have been done in order to take the best figures for the socio-economic development of Lithuania.
The basic scenario utilizes neutral considerations by taking the figures that are more probably to happen. Thus, it is shown that the trend of electricity consumption will increase in the first years of the forecast and it will decrease later, reaching the actual level of demand in 2035.
The pessimistic scenario uses the hypothesis with biggest drawbacks for the socio-economy of the country. As it is explained for the optimistic scenario, the values that are shown are improbably to be accomplished but the goal of these two cases is to shown the most extreme figures of consumption. Thus, the electricity demand level would be stabilized and it would start decreasing then till reaching less than the half of the actual level.
To conclude, it is interesting to remark that the coefficient of the figures of the scenario optimistic and basic and the coefficient of the scenario basic and pessimistic is nearly the same, near 2.3, which means that the three cases are proportional.

3- Bottom-up method

The second method used for forecasting the demand of the household electricity will be the population distribution. This approach is englobed in the engineering branch of the end-use models, also known as bottom-up models.
In order to refresh what has already been said of this method, it is necessary to state that the main source of input information is provided by a survey done to a fraction of the population of a country. The procedure is as it follows: an entity (ministry, institute, private company, etc.) requests the data of the appliances to the owners of the households. Once all the information is collected, the values are extrapolated to cover the whole population of the country and it is just necessary to forecast and sum afterwards the values of all the end-uses, which are the appliances in this case, in order to resolve the final figures of electricity consumption for the whole period.
As it can be already seen, the main difficulty of this method is to gather reliable input information since, the more accurate data the more expensive. In the case of study, the data that has been collected consists in a survey of 2009 [72] that requested for notify the main features of the

household (such as occupants, area, etc.) which appliances were owned by that time and when they were purchased. In addition, the total sample of dwellings that was utilized was of 5793.
Getting to this point, it is necessary to state that there were two main drawbacks.
On the one hand, the year of elaboration of the survey is quite old, since the trends of consumption have changed a lot in the last ten years. For instance, if it is compared the bottom-up method with the econometric one, it will be checked that there are eight years of difference in the gathering of the information, since the forecast of the econometric method takes place starting from 2017. Hence, the availability of each appliance per dwelling is:

	Iš viso, procentais *Total, per cent*	Miestas, procentais *Urban area, per cent*	Kaimas, procentais *Rural area, per cent*	Vidutinis prie-taiso amžius *Average age of the appliance*	
Kaitrinės lemputės	89,4	88,1	92,5	-	*Incandescent light bulbs*
Halogeninės lemputės	33,1	37,1	23,9	-	*Halogen lamps*
Liuminescencinės lemputės	34,2	34,3	34,1	-	*Fluorescent lamps*
Elektrinis virdulys	66,9	66,1	69,9	3,2	*Electric kettle*
Patalpų šildytuvas	6,1	6,3	5,7	5,9	*Space heater*
Skalbimo mašina	86,4	86,0	87,4	7,7	*Washing machine*
Šaldytuvas	98,5	98,8	98,0	8,7	*Fridge*
Šaldiklis	17,8	8,6	38,7	7,4	*Freezer*
Indų plovimo mašina	4,8	5,4	3,6	3,5	*Dishwasher*
Televizorius	98,8	99,0	98,3	7,1	*TV set*
Kompiuteris	47,1	50,0	40,5	3,7	*Computer*
Elektrinė viryklė	29,5	31,9	23,9	6,5	*Electric cooker*
Mikrobangų krosnelė	53,7	55,1	50,5	5,0	*Microwave oven*
Karšto vandens boileris	14,6	10,5	23,9	5,8	*Boiler*
Oro kondicionierius	0,8	0,6	1,1	3,7	*Air conditioner*
Šilumos siurblys[1]	0,8	...	...	...	*Heat pump*[1]

[1] Vieno ir dviejų butų namuose.
[1] *One-dwelling building and a dwelling in two-dwelling building.*

Figure 48 Availability of electrical appliances in dwellings

On the other hand, the survey misses two important features. The main one is that the power of appliances owned is not requested. The second one is the lack of the amount of each appliance itself, since it is just asked if the appliance is owned or not and since when.
Knowing that, it has been proposed to complete the information with more sources and, for this case, official data from the Lithuanian Statistic Department [73] will be used for taking the figures of cooking, space heating and water heating, as it follows:

Table 15 Breakdown of household electricity consumption (Source: Lietuvos Statistikos Departamentas)

	Total by end use	Lighting and electrical appliances	Water heating	Cooking	Space heating
2009	2726,1	2200,0	182,6	196,3	139,0
2010	2590,2	2100,7	168,4	189,1	132,1
2011	2618,1	2133,8	164,9	183,3	136,1

2012	2642	2158,5	163,8	182,3	137,4
2013	2591,5	2122,4	155,5	178,8	134,8
2014	2656,2	2180,7	154,1	180,6	140,8
2015	2660	2192	151,6	175,6	141
2016	2775	2294,9	152,7	185,9	141,5
2017	2837,6	2369,4	147,6	170,2	150,4

3.1- Initial considerations

The bottom-up method has been approached in a parallel way as the econometric method by linking each end-use with macro-economic or socio-demographic factors. The main difference lies in the fact that bottom-up methodology obliges to calculate the consumption of each appliance separately.

In addition, three different future cases (optimistic, basic and pessimistic) will be considered, which will use similar basis forecasts than in the previous method, such as GDP, population, number of dwellings, etc., pertinent to each scenario and each end-use.

Hence, the calculus will just consider those appliances that are used in the Lithuanian household sector and that will have an important power consumption. In this case, it has been considered as unnecessary to forecast the usage of small appliances like mobile phones, tablets, electric kettles, etc., englobing all of them in the same end-use know as *rest.*

Despite the previous consideration, it has been thought that there will be some appliances that were rarely used in Lithuania when the survey took place in 2009 but that had a remarkable potential of penetration in the household sector. In this matter, dishwashers and air conditioner play an important role since the purchase and consumption for each scenario will be totally different.

In another vein, the rest of conventional appliances that will compound all the range of end-uses will be: lightning, PCs, televisions, refrigerators, washing machines, microwaves, cooking, space heating, water heating and the rest.

3.2- Lightning

In the case of the forecast of the lightning consumption, it has been required to compared the trends of the past years in order to foresee the usage in the incoming years. Sadly, it has not been possible to find data of the actual electricity demand of this end-use for Lithuania. Nevertheless, it is possible to check in the following figure how much the consumption has changed [74]:

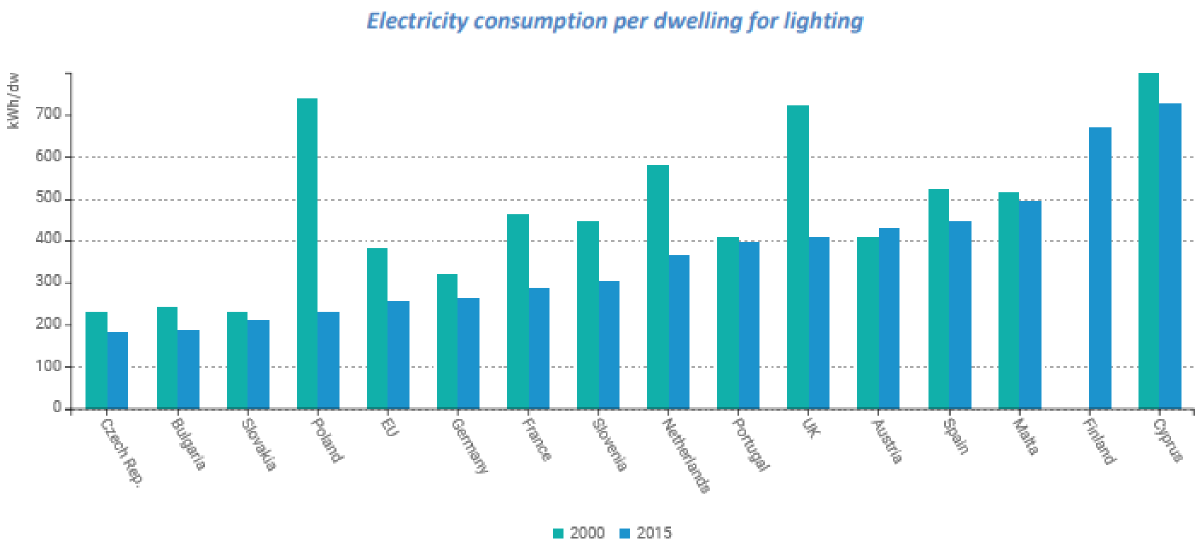


Figure 49 Electricity consumption per dwelling for lightning in the European Union (Source: Odysee)

If the trend of Poland is checked, it is noticeable that it has decreased two thirds its lightning electricity consumption from 2000 to 2015. Regarding the European Union, the trend has changed from demanding nearly 400 kWh per dwelling till reaching 250. In the case of Lithuania, the country was consuming 412 kWh per dwelling by 2000 [75], so it has been assumed that the consumption in 2015 has decreased till 250 kWh per dwelling, like the European average.
In the first place, it has been considered that the efficiency gains for the lightning will be decreasing since it would be harder to implement upgrades throughout the pass of the time, as it follows:

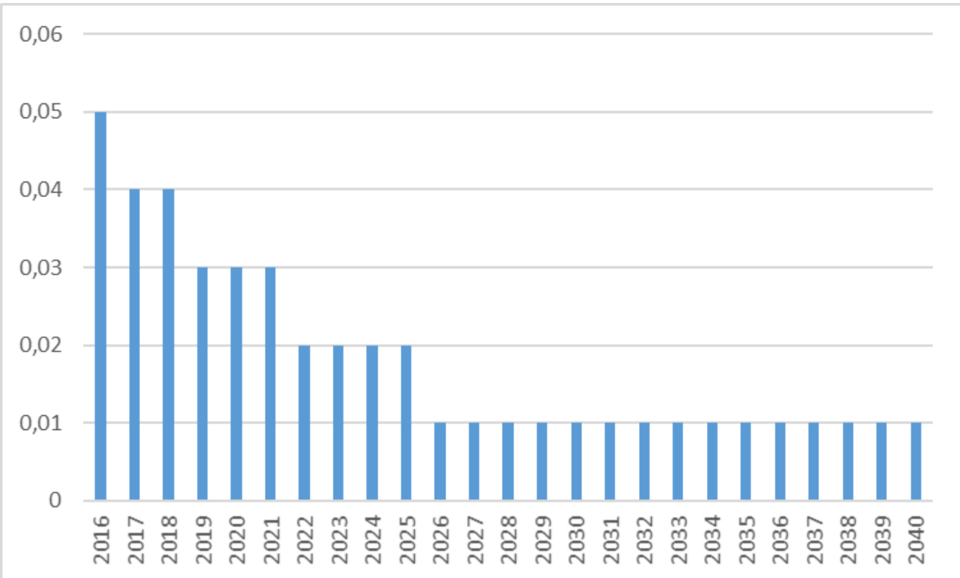


Figure 50 Efficiency gains of the lightning consumption compared with the previous year (Units: %)

Getting to this point, it has been considered to bond the consumption to the number of Lithuanian dwellings, which makes the next trends if the efficiency gains are taken into account as well:

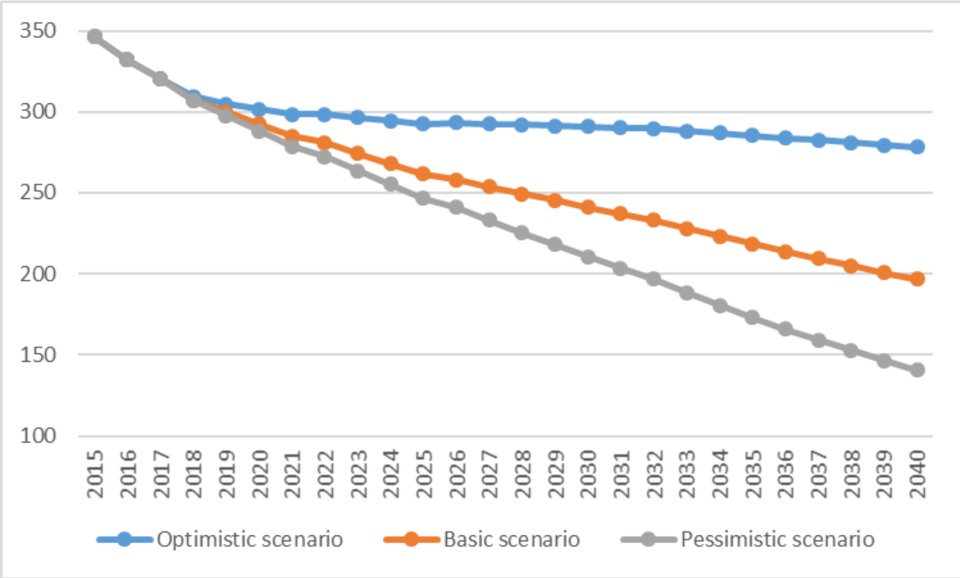


Figure 51 Forecast of lightning consumption (Units: TWh)

It is positive to point out that all the trends will decrease but, as it can be seen, the increase of number of dwelling nearly compensates the increase in the efficiency in the optimistic scenario, while it reaches less than half of its value in the pessimistic scenario in 2040 compared to 2015 levels.

3.3- Personal computers

For the personal computer and laptop part, it is necessary to state firstly that it has been estimated an average power of 150 W per computer and that it is used around four hours per day by 90% of the population whose ages lay between 15 and 65 years old.
In addition, it has been considered a yearly increase of 1% in the usage of these appliances.
Getting to this point, linking the usage of laptops exclusively to the population allows to forecast the following trends:

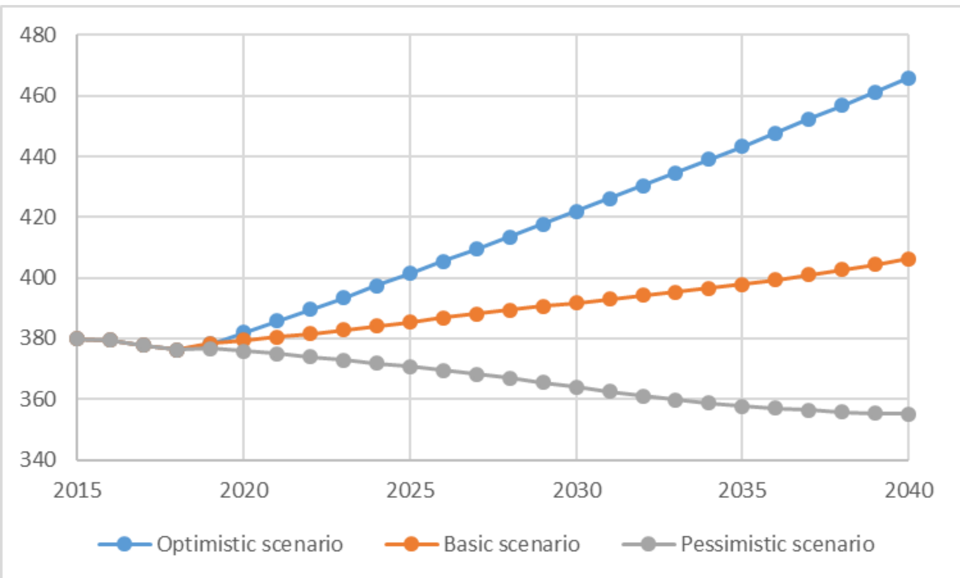


Figure 52 Forecast of PC consumption (Units: TWh)

The results turned to be similar in all the scenarios, making necessary just to point out that the increase of consumption due to the growth of the usage is bigger than the decrease of population in the basic case. Thus, it can be stated that the demand of the PC end-use will not be affected by macroeconomic factors, so as to say, it behaves as a necessity good.

3.4- Televisions

In order to start with the explanation of this part, it is necessary to state that the data from the survey of the *Energy consumption in households* [76] is partially useless since it states that 98.8% of the households were owning a TV but it is not said nor its power nor its amount per dwelling. Nevertheless, the survey gathers data of the occupation per dwelling, which will be useful for making assumptions in the behaviour of the users.
Thus, the forecast of the consumption of the television has been based in the determination of the social factor that characterise its usage. It is inevitable to think that there will not be the same consumption of television in a dwelling of one person rather than in one of five, since it can be used by more than one person at the same time, in opposition to the usage of laptops for instance. Thus, knowing that the number of dwellings of 2015 was slightly inferior to 1.4 million, the assumptions of consumption have been taken as it follows:

Table 16 Breakdown of TV consumption in the Lithuanian household sector

Type of dwellings	Ratio	TVs per dwelling	Unit consumption (W)	Usage of each TV hr/d	Consumption per dwelling (hrs/d)	Power (TWh)
For 1 person:	0,335	1	65	4	4	52,81111
For 2 people:	0,307	1,4	70	3,4	4,76	59,06922
For 3 people:	0,182	1,8	80	3	5,4	44,14063
For 4 people:	0,122	2,2	85	2,6	5,72	32,6956
For 5 or + people:	0,054	2,6	90	2,4	6,24	16,5018

It has been considered that the lower the occupation, the lower the unit consumption per TV, since it will be easier to have both old TVs in the bigger dwelling since it is probably that once the TV gets below the standards of the current TVs, it is replaced and moved to a secondary room. In this vein, in a small dwelling with just one TV, it will be easier to have new televisions since they will be replaced continuously.
In addition to that, it will be easier to share the consumption of TV among the inhabitants of the dwelling as bigger the occupancy is, as it has been said before.
Getting to this point, it is necessary to state it will be considered a 2% of reduction of the consumption due to the lower usage [77] and the higher efficiency. In addition, it has been decided to link the consumption to three factors: population, occupation per dwelling and GDP.
In addition, it has to be said that their elasticities have been considered:

- 1% for the population, since it will be proportional to the TV consumption
- -0.5% for the occupation per dwelling, due to it’s not that decisive that people will leave the homes, since the TV will still be consumed by the still-occupants of this household
- 1.5% for the GDP because the higher the purchase power the bigger the TV

Thus, it is necessary to show the figures of the forecasts:

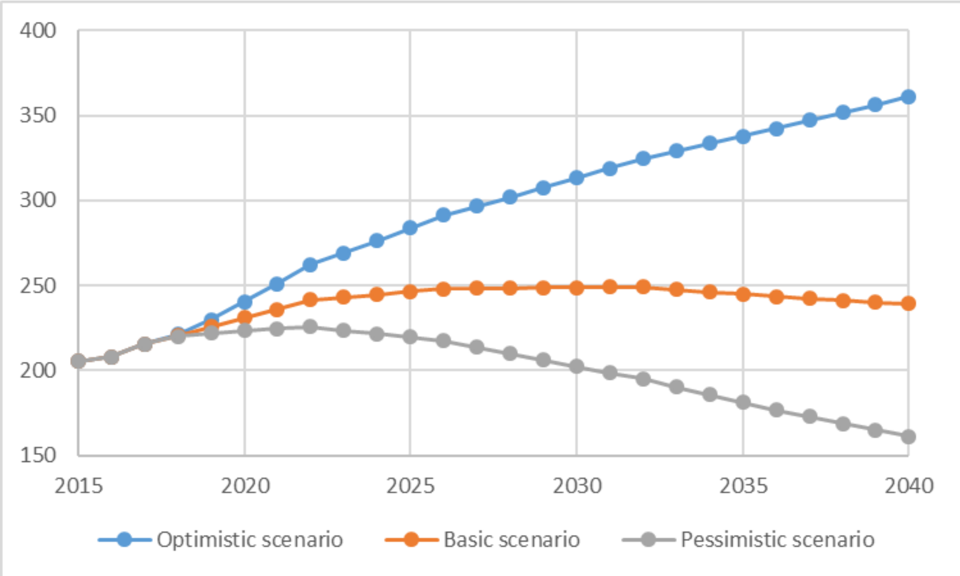


Figure 53 TV consumption forecast (Units: TWh)

The breakdown of the figures would be explained by realising that, despite the continuous increase of GDP, the decrease of population and usage and the growth of the occupation per dwelling provoke the decrease of the TV consumption from 2030 and 2022 for the basic and pessimistic scenario respectively.

3.5- Refrigerators

Regarding the forecast of the consumption and usage of refrigerators, it has been possible to sum the data from the Lietuvos Statistikos Departamentas [78] and the *Monitoring the market with sales data* [79] in order to formulate an accurate actual consumption.

Thus, it can be stated than 86.4% of the dwelling had a refrigerator from the first source by 2009. In order to implement the input values, it will be considered that there were 0.9 refrigerators per dwelling and that the amount will increase slowly by the pass of the time.

In another vein, the figures of yearly consumption per appliance can be estimated by extrapolating the average year of purchase to the average yearly average consumption of the appliance itself.

This methodology will be used similarly in the assumption of actual consumption of washing machines, microwaves, air conditioners and dishwashers, so it will not be necessary to repeat the explanation.

Hence, the input data for the forecast of the consumption of the refrigerators will be:

Table 17 Sales consumption and availability of Refrigerators (Source: Lietuvos Statistikos Departamentas, monitoring the market with sales data)

Year	2009	2010	2011	2012	2013	2014	2015
Average consumption of sales (kWh/yr)	271	263	256	244	235	231	229
Refrigerators per dwelling	0,9	0,91	0,92	0,93	0,94	0,95	0,96

Hence, taking into account that the savings in the unit consumption are being slowed down, it has been considered just a 1% of yearly efficiency gains. Knowing that, and reminding that the consumption of a refrigerator is singly related with the number of dwellings, it is possible to resolve the forecasts:

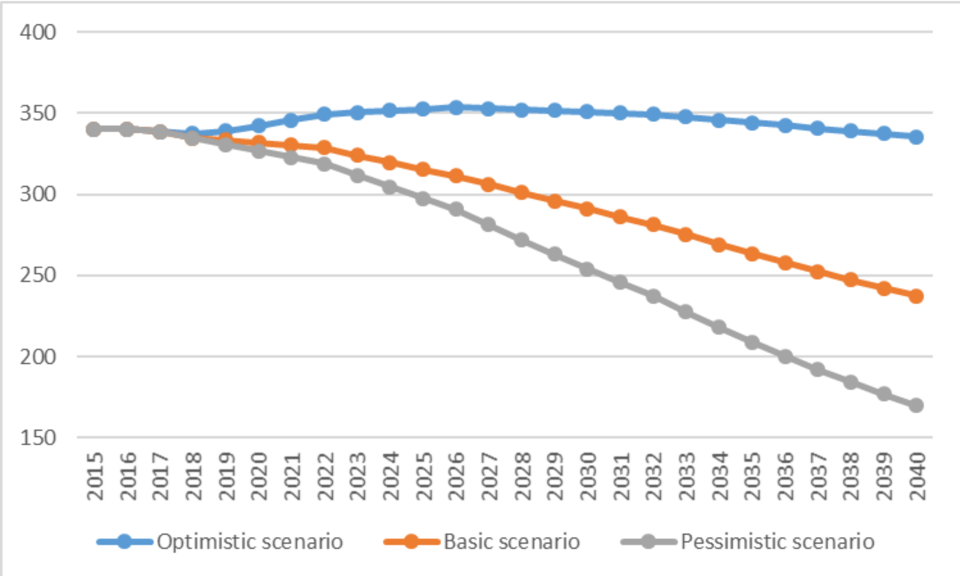


Figure 54 Forecast of consumption of Refrigerators (Units: TWh)

The most remarkable trend is the one of the optimistic scenario since the increase of number of dwellings makes grow the consumption till 2027, when the yearly increase of efficiency compensates the consumption.

3.6- Washing machines

The washing machine consumption forecast has been elaborated in a parallel way of the refrigerator one. Thus, here there are the input assumptions:

Table 18 Sales consumption and availability of Washing machines (Source: Lietuvos Statistikos Departamentas, monitoring the market with sales data)

Year	2009	2010	2011	2012	2013	2014	2015
Average consumption of sales (kWh/yr)	226	225	217	205	194	185	179
Washing machines per dwelling	0,87	0,9	0,92	0,93	0,94	0,95	0,95

Furthermore, it has been considered a 2% of decrease of consumption due to the improvement of the concern of the users and the increase of the efficiency.
In another vein, the trends of the forecasts have been linked with the trends of number of dwellings, which produces these results:

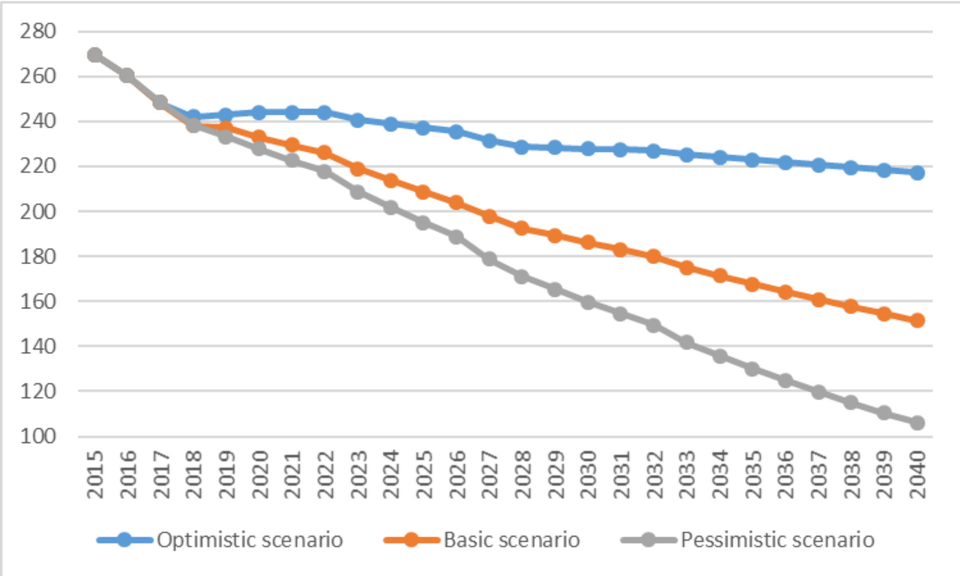


Figure 55 Forecast of consumption of Washing machines (Units: TWh)

In this case, it is interesting to check the trend changes between the forecast of consumption of refrigerators and washing machines just by setting an average of 2% of unit savings instead of 1%, which makes that even the optimistic scenario considers constant drops in the consumption.

3.6- Microwaves

In this part, it has been necessary to consider an average power per appliance of 70 kWh/yr in 2009. Apart from that, it has been advisable to take an increase of 1% in the efficiency.
In another vein, the rest of inputs that have been used are as it follows [78]:

Table 19 Sales consumption and availability of Microwaves

Year	2009	2010	2011	2012	2013	2014	2015
Average consumption of sales (kWh/yr)	70	68	66	65	64	63	62
Microwaves per dwelling	0,57	0,6	0,63	0,66	0,68	0,7	0,72

There is one big difference between the usage of the microwave and the previous appliances: it still has potential of purchasing. As it can be seen, the number of microwaves per dwelling was approximately of 0.57 in 2009, which can be extrapolated to 0.72 for 2015. In this case, depending on the economic development, microwaves will have potential of keeping being purchased or not, as it is shown in the next figure:

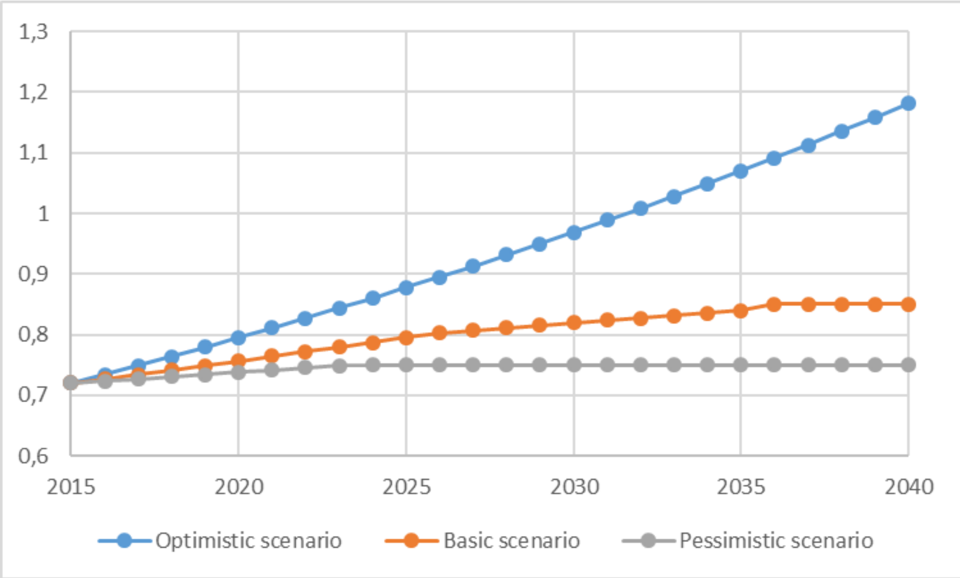


Figure 56 Trends of owning of microwaves

Taking all of it into account, it is necessary to say that, knowing that the microwave is one of the cheapest appliances, it‘s consumption is related necessarily with the purchase power but it‘s not a decisive factor, since it the number of dwellings plays a bigger role.
Getting to this point, the forecast can be elaborated:

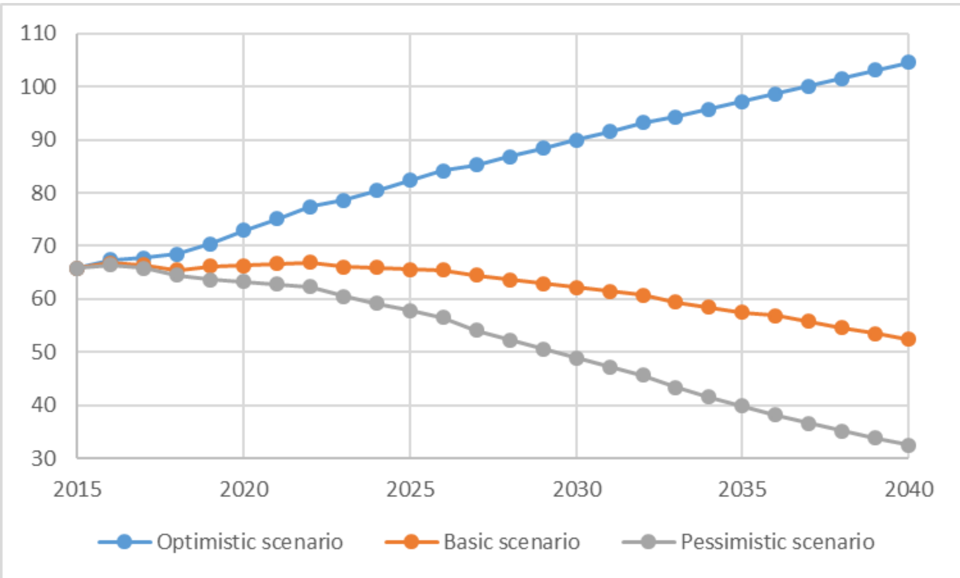


Figure 57 Forecast of consumption of Microwaves (Units: TWh)

As it can be compared with the two previous forecasts, the range of consumptions varies widely due to different potential of penetration of the microwaves according to the purchase power of the population.

3.7- Air conditioner

The procedure of the calculus of the future consumption of air conditioner has taken the parallel way of the microwave: appliances that are not totally implemented in the dwellings.
The main difference lies in the fact that just 1% of the households had air conditioner by 2009. Thus, the main considerations of the unit power and the penetration of the appliance in the sector are as it follows [79]:

Table 20 Sales consumption and availability of Air conditioners

Year	2009	2010	2011	2012	2013	2014	2015
Average consumption of sales (kWh/yr)	400	395	390	385	380	375	370
Air conditioners per dwelling	0,012	0,03	0,06	0,09	0,12	0,16	0,2

On the other hand, the possible trends of penetration of the Air conditioner in the Lithuanian households are:

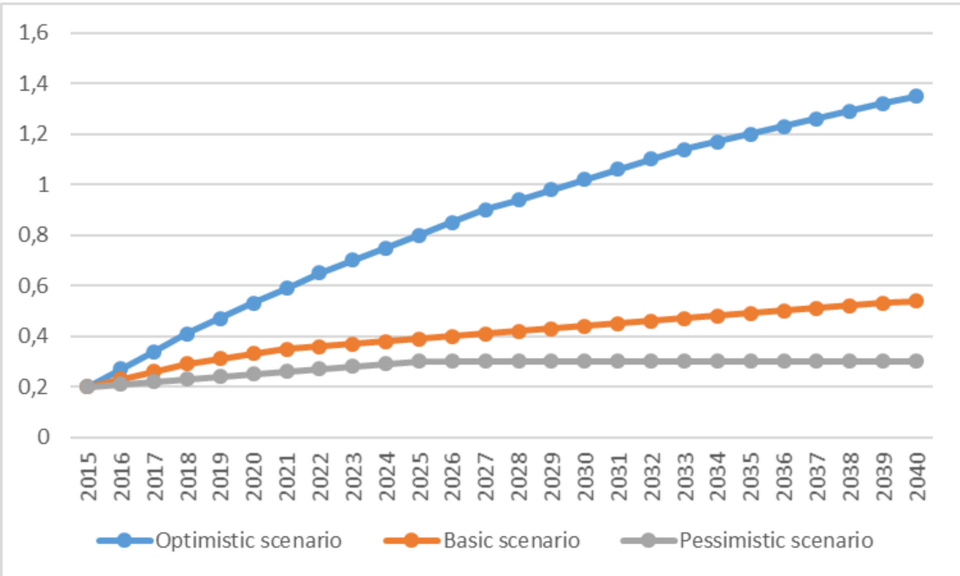


Figure 58 Trends of owning of Air conditioners

The wide range of possibilities can be taken into account the development of the climate change of the economy. For instance, it could happen that the temperature of Lithuania and the purchasing power would increase highly in the incoming years at the same time, fact that would provoke that most of the dwelling would acquire at least one unit of this appliance.
On the other hand, if the economy develops slowly and the temperature remains constant, the purchase of air conditioner will keep in the same level.
In addition, it has been considered a yearly increase of efficiency from 1 to 2%.
Knowing that, it is necessary to link the consumption with the number of dwellings and with the GDP, since the higher the incomes the higher the affordable expenses in the electric bill:

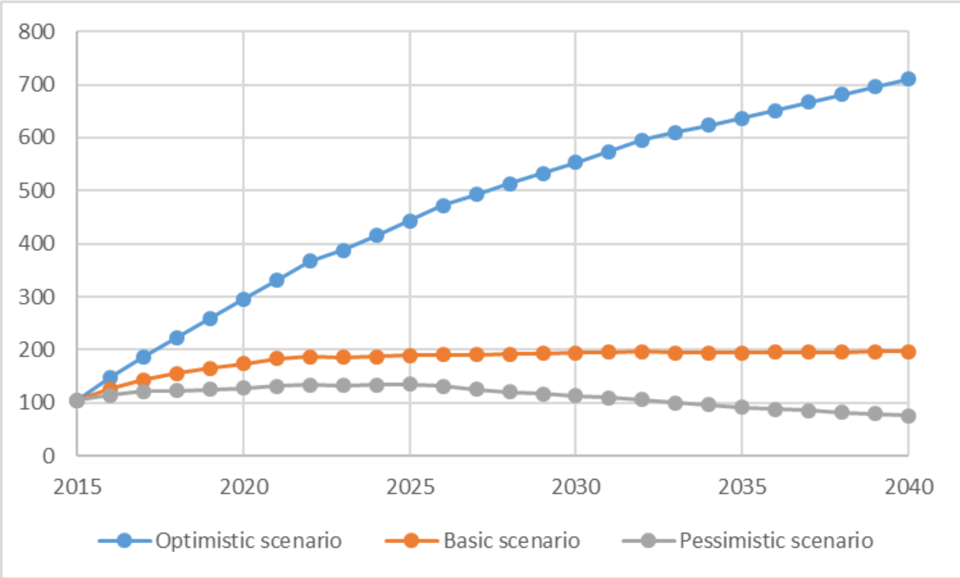


Figure 59 Forecast of consumption of Air conditioner (Units: TWh)

These big differences among scenarios are explained due to accumulation of lots of factor (climate change, GDP, number of dwellings, consumer behaviours, etc.) which widen more and more the range of possibilities.

3.8- Dishwashers

The explanation of the assumptions, calculus and procedure of the dishwasher is completely the same than for Air conditioners: both are not implemented in the Lithuanian society, the acquisition mainly depends in the purchase power, etc. Thus, the availability of the past years can be represented as it follows [80]:

Table 21 Sales consumption and availability of dishwashers

Year	2009	2010	2011	2012	2013	2014	2015
Average consumption of sales (kWh/yr)	400	395	390	385	380	375	370
Dishwhashers per dwelling	0,05	0,08	0,10	0,13	0,15	0,18	0,2

The trends are slightly similar as well except because the roof of number of dishwasher will be reached when there will be one old and one new performing at the same time in a small fraction of the dwellings:

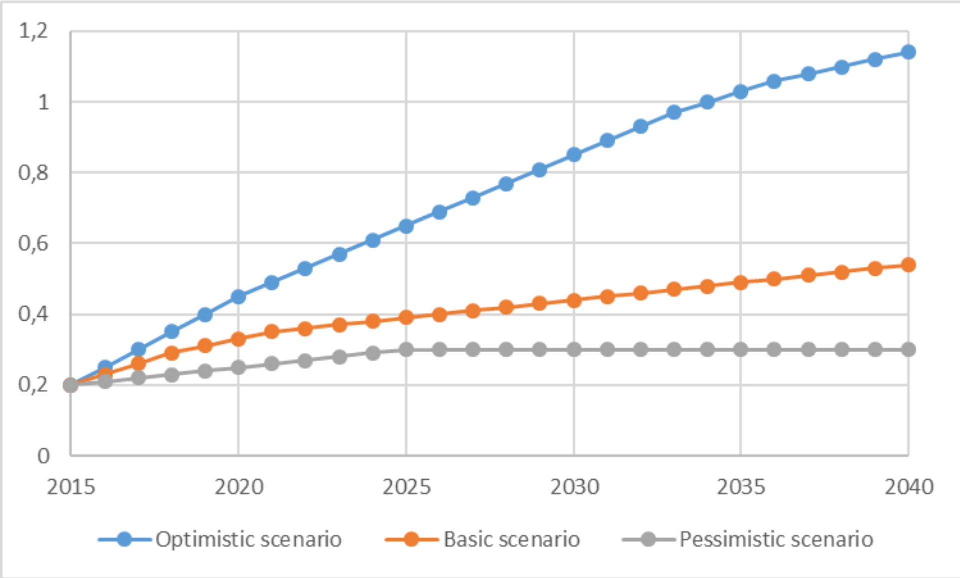


Figure 60 Trends of possession of dishwashers

Thus, the forecast of consumption will be:

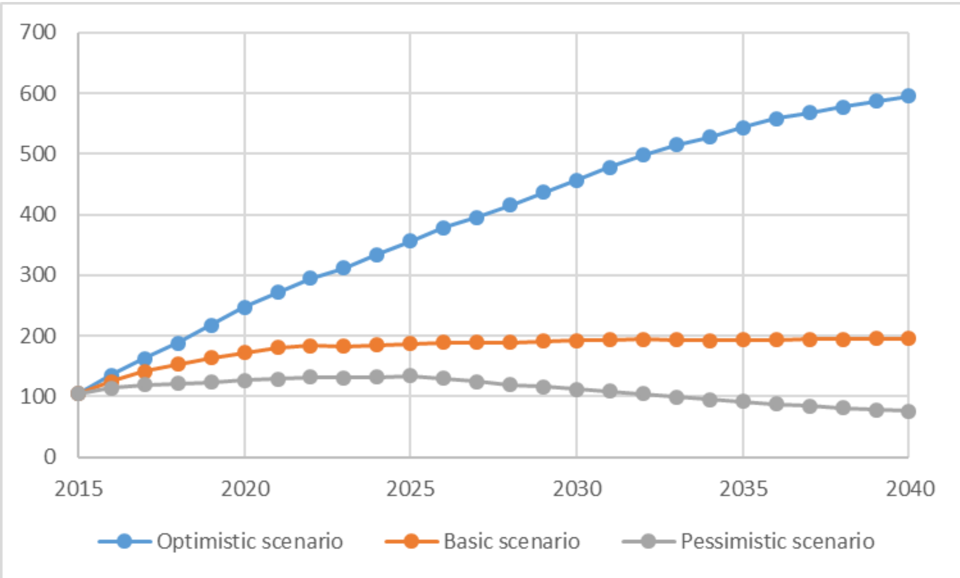


Figure 61 Forecast of consumption of Dishwashers (Units: TWh)

3.9- Cooking, space heating and water heating

Cooking, space heating and water heating end-uses have been calculated in a simpler way compared with the other appliances since it has been taken the data from the report of *Energy consumption in households* [81] and the Lietuvos Statistikos Departamentas [82]. As it can be seen in the next figure:

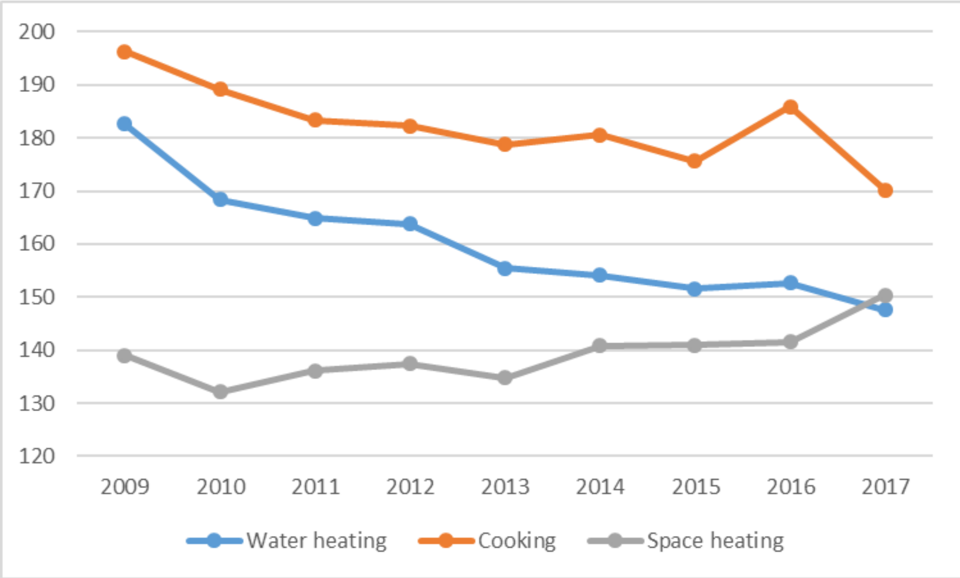


Figure 62 Trends of consumption of Water heating, Cooking and Space heating (Units: TWh, Source: Lietuvos Statistikos Departamentas)

It can be subtracted from the previous graph that both water heating and cooking trends have the same shape as the population level and that space heating curve is similar to the amount of dwellings one. Hence, it is easier to think that these relations will be kept to forecast each end-use demand.

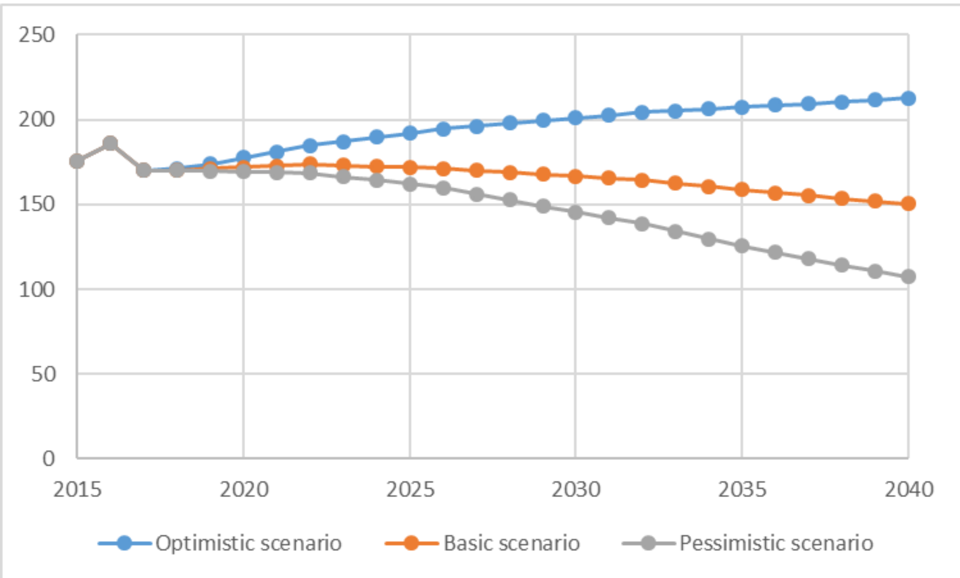


Figure 63 Forecast of consumption of Cooking (Units: TWh)

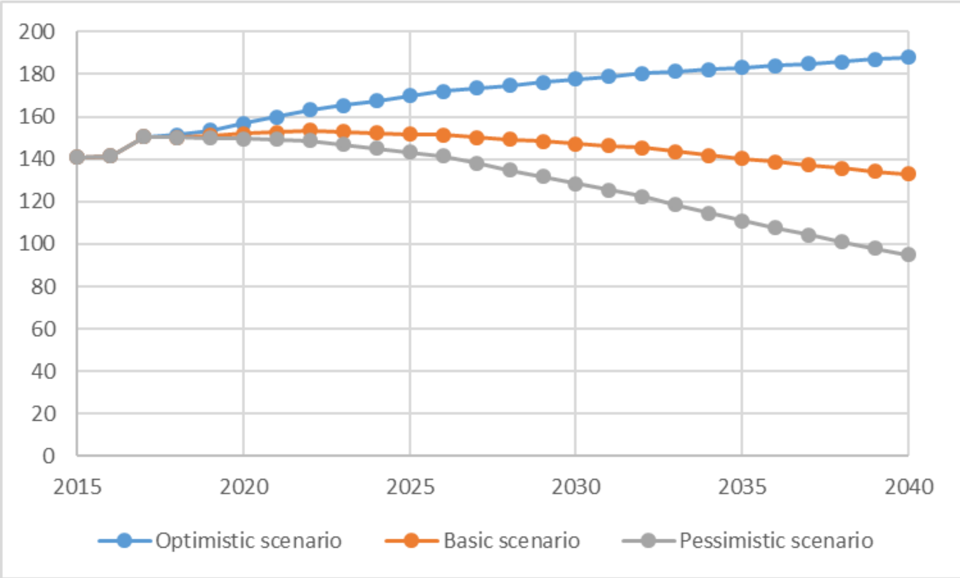


Figure 64 Forecast of consumption of Space Heating (Units: TWh)

As it can be checked, the shape of both trends and of the forecast of the amount of dwellings is completely parallel and it just changes the initial values of consumption of Cooking (170 TWh) and Space heating (TWh).

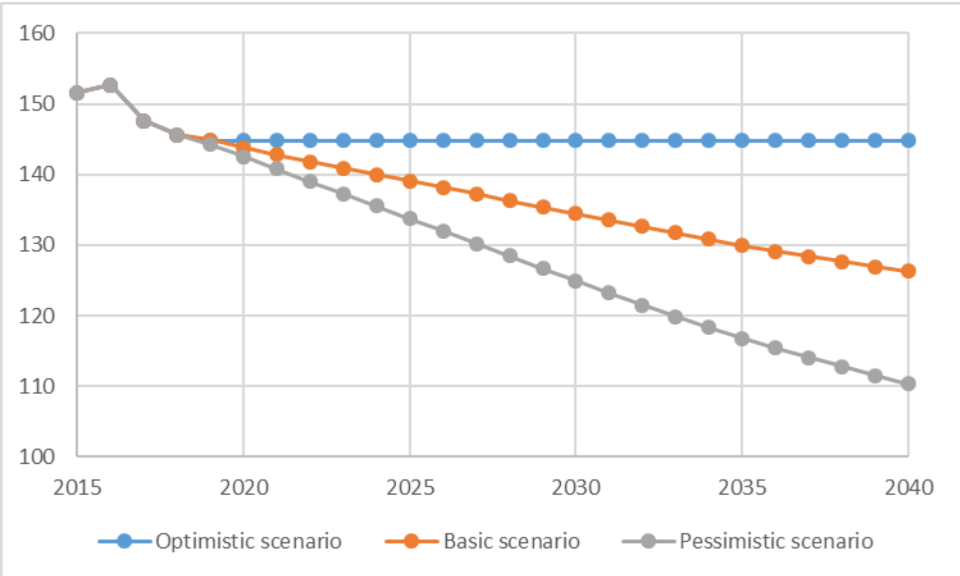


Figure 65 Forecast of consumption of Water heating (Units: TWh)

On the other hand, it is necessary to remark that the water heating consumption is parallel to the population.

3.11- Other appliances

The last of the end-uses is not an end-use itself. Knowing that there are a gross bunch of appliances, it has been decided that it would be optimal to calculate the demand of the eleven that are mostly used. Thus, in order to gather the data of the rest of devices like tablets, mobile phones, electric kettles, etc., it will be considered as a whole in one end-use apart, which will be called as *other appliances.*

The calculus of the actual demand has been done by subtracting the consumption of the previous end-used to the whole of the 2660 TWh of the household electricity consumption, which makes an amount of 563 TWh of consumption of the rest of the appliances.

Knowing that this term is hard to analyse and quantify, it has been decided to bond its trend to the forecasts of amount of dwellings, GDP and population of Lithuania. Thus, the curves that have been calculated are as it follows:

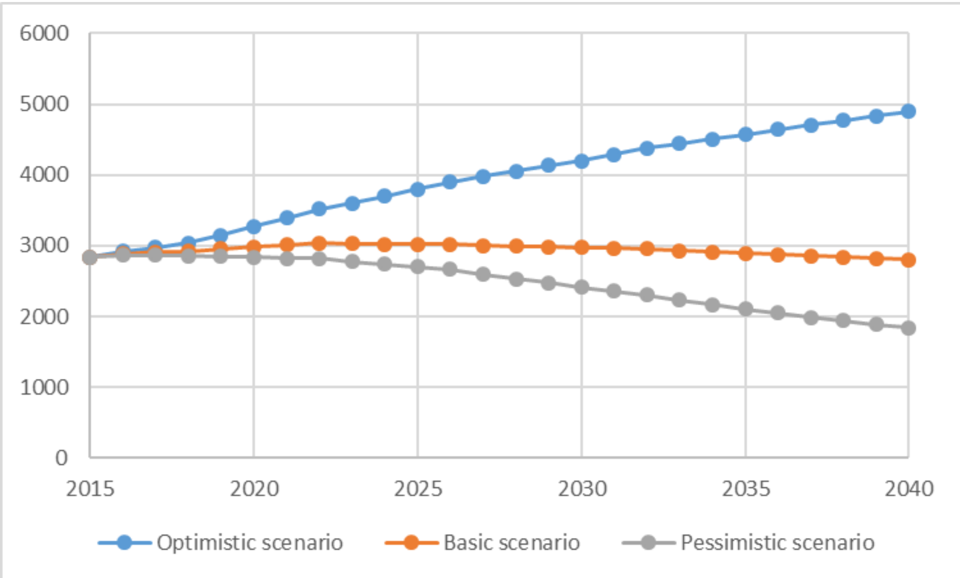


Figure 66 Forecast of consumption of household electricity of the end-use model (Units: TWh)

As it can be seen, the trends differ a lot from one to another and that is due to the fact that the most extreme considerations, related with the possible development of the Lithuanian socio-economy.

Nevertheless, there is not a general explanation about the shape of each curve because it is the sum of twelve different end-use demands so, in order to show the figures and trends, it would be necessary to break down the graphic by checking the forecast of the consumption of each appliance.

In addition, it can be said that the average annual growths ruled by the second equation for each case are 2.20, -0.05 and -1.72 % for the optimistic, basic and pessimistic case respectively.

4- Comparison of econometric and bottom-up methods

Getting to this point, it is interesting to compare the results of both methods for the average annual growth rate and the trends of each scenario for both methods:

Table 22 Comparison between annual average growth rates

	Optimistic scenario	Basic scenario	Pessimistic scenario
Econometric model	2,88135939	-0,473	-3,69153
End-use model	2,20037621	-0,05103	-1,72437

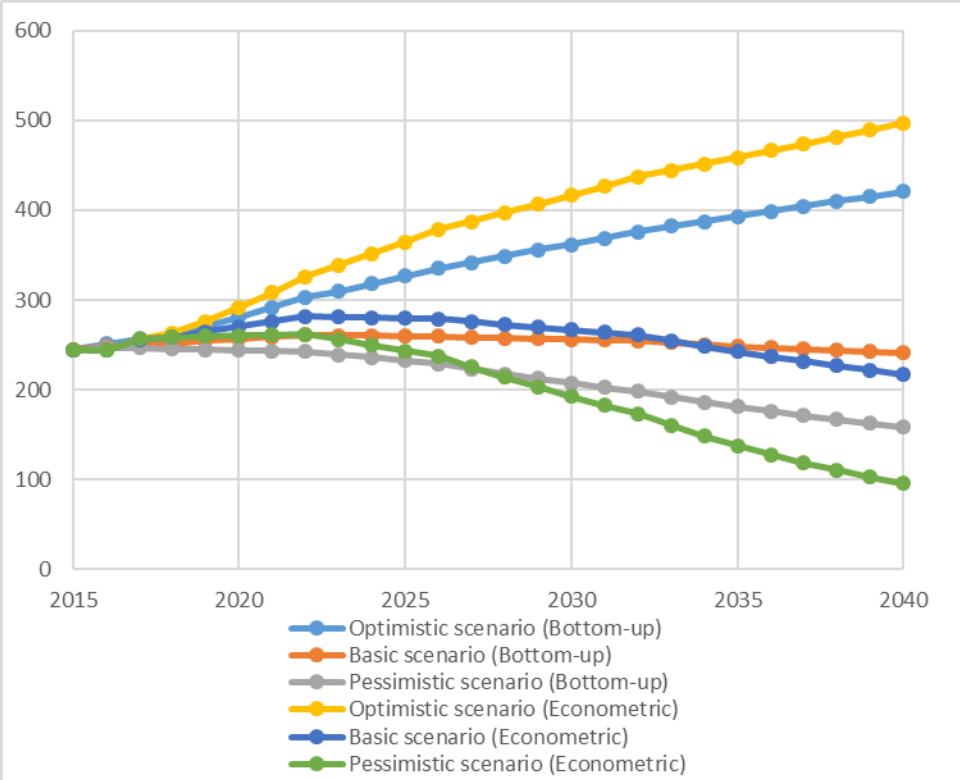


Figure 67 Forecast of consumption of household electricity by econometric and bottom-up (Units: ktoe)

As it can be corroborated, the figures of each scenario are different depending on the method used:

- In the optimistic scenario, the interval that separates both econometric and bottom-up methods increases constantly till reaching a break of 76 ktoe in 2040, as the values ascend till reaching 497 and 421 ktoe respectively.
- The basic scenario shows the most similar trends among all the scenarios. The econometric method has a peak in 2022 of 282 ktoe and a bottom of 217 ktoe in 2040 while the end-use model remains more stable, since its peak and bottom are situated in 261 and 241 ktoe respectively.
- The trend of the pessimistic scenario of the econometric model keeps increasing till reaching 261 ktoe in 2022 but it starts decreasing till descend till 95 ktoe. On the other hand, the curve of the end-use method is characterised by a constant decrease till getting 158 ktoe in 2040. It is remarkable that the values of both trends get crossed in 2029.

Even though knowing that the differences in the optimistic and in the pessimistic scenarios are that wide, there is an explanation for the results.

In first place, the econometric model does not take into consideration the efficiency gains of the technologic advance, while in the bottom-up model it is taken into account and, moreover, its effect is accumulative, so as to say, the longer the time passed, the higher the yearly savings.
In second place, the econometric model discards the behaviour of the consumers. On the one hand, it assumes in the optimistic scenario that it is possible that there will be two units or more of the same appliance, such as dishwashers or microwaves, being used at the same time in a dwelling. On the other hand, it accepts as well that if the economy gets that paralysed like in the pessimistic, it can happen that consumers will not replace an appliance once this does not work anymore.
Besides these considerations, it has to be taken into account that a considerable part of the inputs of the bottom-up had to been assumed, decreasing the precision and reliance in the model.
Thus, in order to formulate an opinion regarding the suitability of each method, it can be stated that the most probably trend of household electricity consumption will be the econometric one for the basic scenario.
Nevertheless, the range of the electricity demand forecast figures will be bounded by the optimistic and pessimistic scenarios of the end-use approach since it gathers the additional constraints that have already been mentioned previously.

Conclusions

1- The *literature review* shows that there is a lot of concerning in energy forecast matters. The constant increase in the demand of all the kinds of energy, such energy, oil, natural gas, etc., is directly related with the constant growth of population and economy development all around the world. Thus, it is necessary to project the trends of these demands in order to adapt the capacities of the production, transmission and distribution systems. In the Lithuanian household sector, the case of study, there has been lots of changes in the last decades, such as liberalisation of the market, fluctuation of the prices, sudden changes in the demand, etc., which is interesting to analyse in order to project the figures of long-term consumption.

2- There is a huge amount of *methodologies* for forecasting energy consumption. Nevertheless, if the forecast is bounded to the electricity demand in the household sector, the range of possibilities gets limited to econometric, technological, statistical and engineering approaches. On the one hand, the econometric method are chosen because it allows to compare the relation between causes (inputs) and consequences (outputs) and due to the low difficulty of getting its data and because it is the most used. On the other hand, these results are compared with the figures of the engineering (population distribution) approach since both methods complement each other. In addition, in order to represent all the range of possibilities, three scenarios are represented, which are the two extremes (optimistic and pessimistic) and the most probable one (basic).

3- The *econometric* method shows that the basic scenario will imply a decrease of the household electricity consumption from 244 ktoe in 2016 till reaching 217 ktoe in 2040. In addition, the demand figures of the optimistic and pessimistic scenario are 497 and 95 ktoe respectively. In addition, the average growth rates will be stated in 2.88, -0.47 and -3.69 %.

4- The *end-use* method states that demand will decrease to 241 ktoe for the basic case. Furthermore, the range of possibilities varies from 421 ktoe of the optimistic scenario to 158 ktoe of the pessimistic one. Furthermore, the average growth rates will be 2.2, -0.05 and -1.72%.

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