International Journal of
Sustainable Energy Planning and Management

# The Effects of Utility Cost Reduction on Residential Energy Consumption in Hungary – a Decomposition Analysis

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**ABSTRACT**

The residential energy consumption is influenced by a lot of factors. Understanding and calculating these factors is essential to making conscious energy policy decisions and feedbacks. Since 2013 the energy prices for households have been controlled by the government in Hungary and as a result of the utility cost reduction program a sharp decline can be observed in residential electricity, district heating and natural gas prices. This paper applies the LMDI (~Logarithmic Mean Division Index) method to decompose the absolute change of the residential energy consumption during the period of 2010–2015. I calculate the price, the intensive structure (it means the change of energy expenditure share on energy sources), the extensive structure (it is in connection with the change of energy expenditure share in total expenditure), expenditure (it is the change of per capita total expenditure) and population effect. All of that shows the impact of the specific factor on the residential energy consumption by income deciles. My results have verified the preliminary expectations: the decreasing energy prices for households have a positive impact on energy use and it has been strengthened by the expenditure effect as well. However, the intensive structure, the extensive structure and the population effect have largely offset it.

***Keywords:***

Utility cost reduction;
Decomposition;
Energy consumption;
Residential sector;

URL:
dx.doi.org/10.5278/ijsepm.2017.13.5

## 1. Introduction

Hungary is a highly developed country in East-Central Europe and member of the European Union. The real GDP growth rate averaged 1.7% during the period of 2010–2015 and the GDP per capita was 26.457 USD (PPP, current international $) in 2015 [1]. It is a small country with a population under 10 million. The economic structure is dominated by the service sector (its contribution to the GDP was 64%), while the industry sector accounted for about 31.9% of the GDP in 2015 [1].

After the regime change the Hungarian residential energy consumption has showed a declining tendency in the final energy consumption. However, the proportion of that exceeds the EU-28 average (it was 25.3% in 2015) according to the Eurostat (2017) (see more details in Appendix 2). Both the Hungarian *NES 2030* and *NEEAP 2020* documents set the highest energy saving target values in the household sector (until 2020 and 2030), but the available analysis and forecasts anticipate a slightly increasing tendency in residential energy consumption [2, 3]. The sharp decline in residential electricity, district heating and natural gas prices in 2013 and 2014 resulted in a new situation: the ratio of residential expenditure on energy services to total expenditure significantly decreased, the inflation rate has declined and the economic and income situation of the poorest families significantly improved. But the price drops negatively affected consumer energy awareness and energy efficiency investments [11].

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## Abbreviations

| | |
|---|---|
| NES 2030 | National Energy Strategy 2030 |
| NEEAP 2020 | National Energy Efficiency Action Plan until 2020 |
| ECARAP | Energy and Climate Awareness Raising Action Plan |
| KSH | Central Bureau of Statistics |

Investigating and quantifying the factors affecting the residential energy consumption is indispensable to making an efficient energy policy, to fulfil the targets and to select the right instruments. This analysis contributes to quantify the effects of price reduction. It has to be seen that these impacts make achieving the energy efficiency goals harder. Furthermore it is a very unique situation that a highly developed country applies the instrument of price control, while in the last few years many developing countries (such as China, Iran and Kyrgyz Republic) made a serious effort to reform the pricing mechanism for the energy prices in the household sector. Examination of the situation serves interesting context and it contributes to the existing literature as well.

The rest of this paper is organized as follows: Section 1.1 shows the prior situation to the utility cost reductions program, makes a comparison between the state of the Hungarian households and the other countries in the European Union, and it covers the prices and structure of household expenditure. Section 2 and 3 introduces the logarithmic mean Divisia index (LMDI) method and the international experiences related to the topic. Section 4 and 5 apply the method to the Hungarian residential energy consumption and quantify the price, the intensive structure, the extensive structure, the expenditure and the population effect. Finally, the last section concludes this study with policy implications.

### 1.1. Before and after the utility cost reduction

The energy intensity of an economy is essentially affected by two factors: changes in the energy intensity of economic sectors (intensity effect) and the shift in the mix of products or activities (structural effect).

Before the regime change (1989–1990) the different characteristic of the economic structure in Western Europe and in Hungary appears in the energy use as well. In spite of the forced industrialization in the socialist countries the energy use per capita was higher in the European Union. After the regime change the energy efficiency increased dynamically in the transition economies. Former results of the decomposition analysis show that between 1990 and 2015 in East-Central Europe the intensity changes had a more significant affect on the energy use and the impact of structural change is smaller in comparison. These tendencies are the opposite of Western Europe where the structural and inteisty effect are both determinative. It can be stated that the developed, western countries were not forced to restructure their economies and there the changes were results of natural processes. (Figure 1)

Nowadays the Hungarian GDP per capita is far behind the EU-average, it was 14,519 USD in 2015. But the value of the energy intensity is nearly equal with the EU-average (the difference is only 10 percentage) and the energy use per capita is lower as well (circa three quarters of the EU-average) (Table 1). Hereinafter the more specific data (from the study's point of view) will be presented.

After the regime change the prices of food and other commodities, including fuel have moved together generally, but the growth of the service and especially the residential energy prices was higher than the inflation rate. This gap has started to narrow after the utility cost reduction program in 2013–2014. (Figure 2)

According to the National Consumer Centre Hungary (2017) since the act on the enforcement of utility cost reduction (Act No. LIV of 2013) became effective, the prices of the main energy carriers (such as natural gas, electrical energy and district heating) in the household sector have been reduced in three consecutive steps in Hungary [5]. This price reduction was unified so it was not differentiated according to the income levels of households.

In the first phase (between 1st January 2013 and 31st October 2013) the price decline was 10% (compared to the prices on 1st December 2012), in the second phase it was 11.1% (compared to the prices on 31st October 2013) in case of all housing-related energy services. In the third phase the natural gas price decreased by 6.5% (from 1st April 2014), the electricity price by 5.7% (from 1st September 2014) and the price of district heating by 3.3% (from 1st October 2014). So the prices have fallen by totally 25.19% in case of natural gas, 24.55% in case of electrical energy and 22.63% in case of district heating for the household sector without differentation. According to Energiaklub (2015) the households spent more on energy services by only 5–6% in 2015 than in 1996 in real terms [6].

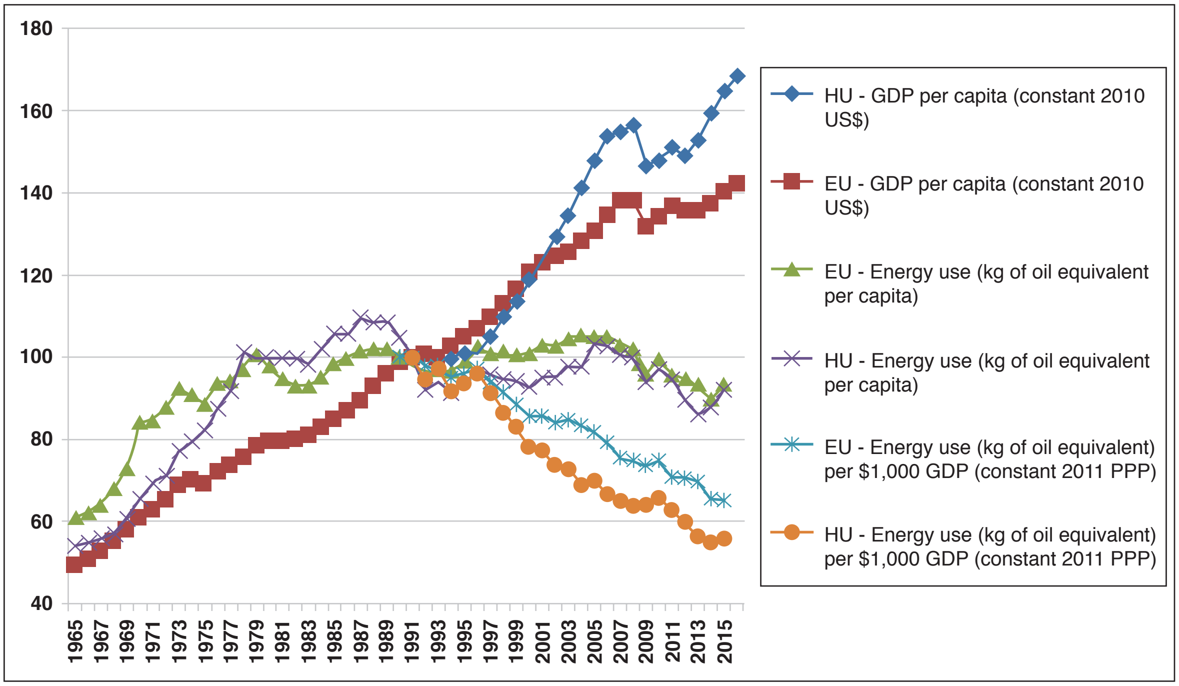



Figure 1: Changes of the GDP per capita, energy intensity and energy use per capita in the EU and in Hungary (1990-2016; 1990=100%). Based on data from [1]

**Table 1: Changes of the GDP per capita, energy intensity and energy use per capita in the EU and in Hungary (1990-2015). Based on data from [1]**

| | Indicator | 1990 | 2000 | 2010 | 2015 |
|---|---|---|---|---|---|
| **EU-28** | GDP per capita (constant 2010 US$) | 24 745 | 30 254 | 33 658 | 35 100 |
| | Energy intensity (Energy use (koe) per $1,000 GDP (constant 2011 PPP)) | 134 | 115 | 100 | 87 |
| | Energy use (kg of oil equivalent per capita) | 3 441 | 3 472 | 3 420 | 3 207 |
| **HU** | GDP per capita (constant 2010 US$) | 8ˇ814* | 10 440 | 13 026 | 14 519 |
| | Energy intensity (Energy use (koe) per $1,000 GDP (constant 2011 PPP)) | 175* | 137 | 115 | 98 |
| | Energy use (kg of oil equivalent per capita) | 2 774 | 2 448 | 2 569 | 2 433 |

Figure 3 shows the overall structure of consumption expenditure in the European Union. Here I notice that the share of expenditure on housing, water, electricity, gas and the other fuels subcategory is much higher (in case of Hungary it was 39.3% in 2010) than in the previous studies (such as [8]). In the latter these data are 22.2% in 2010 and 19.1% in 2015 (see Appendix 3). The significant deviation is attributable to the following reasons. The mentioned publications are based on *final consumption expenditure of households by consumption purpose (COICOP 3 digit, EUR, current prices)*[2] published by Eurostat and the *annual per capita expenditure by COICOP, income deciles, regions and type of settlements* data (published by KSH). The expenditure data are expressed in current prices, EUR and HUF. The difference is due to the methodology. Accordingly, the KSH (2017) data table is based on micro data, the data table of Eurostat on macro data [4, 7]. The most important methodological difference in quantitative terms, but not the only one, is the owner-occupier imputed rent [7]. Typically, these are national accounts data so the micro data don't contain that. The other difference is due to that the micro data refer to the individual private households, but the macro data

[2] Eurostat code is [nama_10_co3_p3]

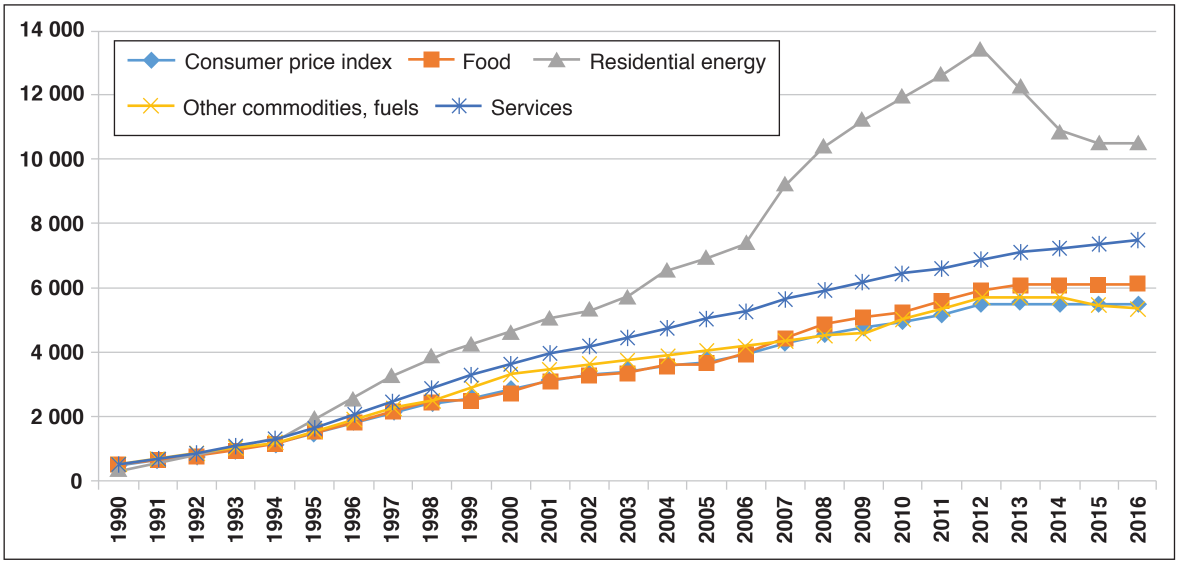



Figure 2: Changes of the consumer price index (1990–2016; 1960 = 100%). Based on data from [4]

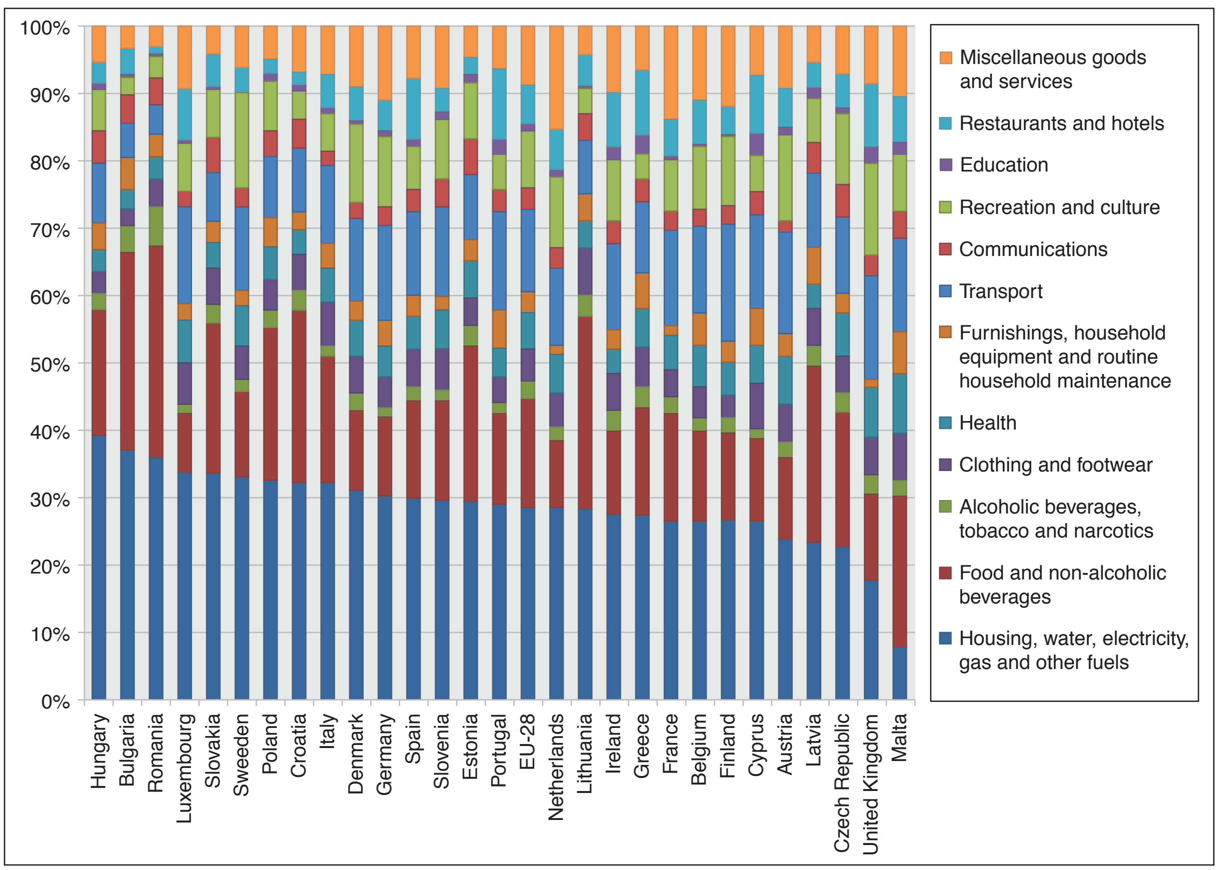



Figure 3: Overall structure of consumption expenditure in the European Union by detailed COICOP level (2010, %)[3]. Based on data from [7]

[3] Eurostat code is [hbs_str_t211]

contain the institutional households and persons living in collective households or in institutions.

Furthermore, in case of the data in Figure 3 the structure of consumption expenditure is determined per 1000 unit (and it shows the data in EUR and pps) so actually it hides the differences among the household expenditure figures of the European Union member countries (obviously a household in Western Europe has higher per capita income so the disposable income is higher as well).

It can be stated (Figure 3) that the share of expenditure on housing, water, electricity, gas and other fuels represents a significant part in all member states (maybe Malta is the only exception) but their share is scattered on a wide scale. Before the utility cost reduction in 2010 the highest proportion of this kind of expenditure was in Hungary (39.3%) surpassing the neighboring countries as well. The expenditure on housing and housing-related energy services exceeds significantly the expenditure on food and non-alcoholic beverages or transport as well.

As the REKK (2013) concludes the high rate of housing and energy expenditure can be explained with two factors: on the one hand it is related to the high energy prices, on the other to the relatively low levels of disposable income. In the following segment I deal with the question of prices [8].

Examining the data in current prices (similar to [8]) Hungary really belongs to the middle range (both in the European Union and in the OECD). But looking at the data from the aspect of purchasing power standard the situation is totally different (Figure 4). Comparing the prices including all taxes and levies, it is clear that in 2010 the energy price including gas and electricity was the highest in case of Hungary and the negative consequences were experienced (by 2015 Hungary improved a lot on its position and in both cases Hungary got into the middle third – Hungary was the 18$^{th}$ in case of gas prices and electricity prices as well).

As a result of the high energy prices in 2010 the households spent over 25% of their total expenditure on housing and energy as reported in the KSH (2017) database (it was more than their total expenditure on food and non-alcoholic beverages). Böcskei (2015) emphasizes that as a result of the high energy prices and

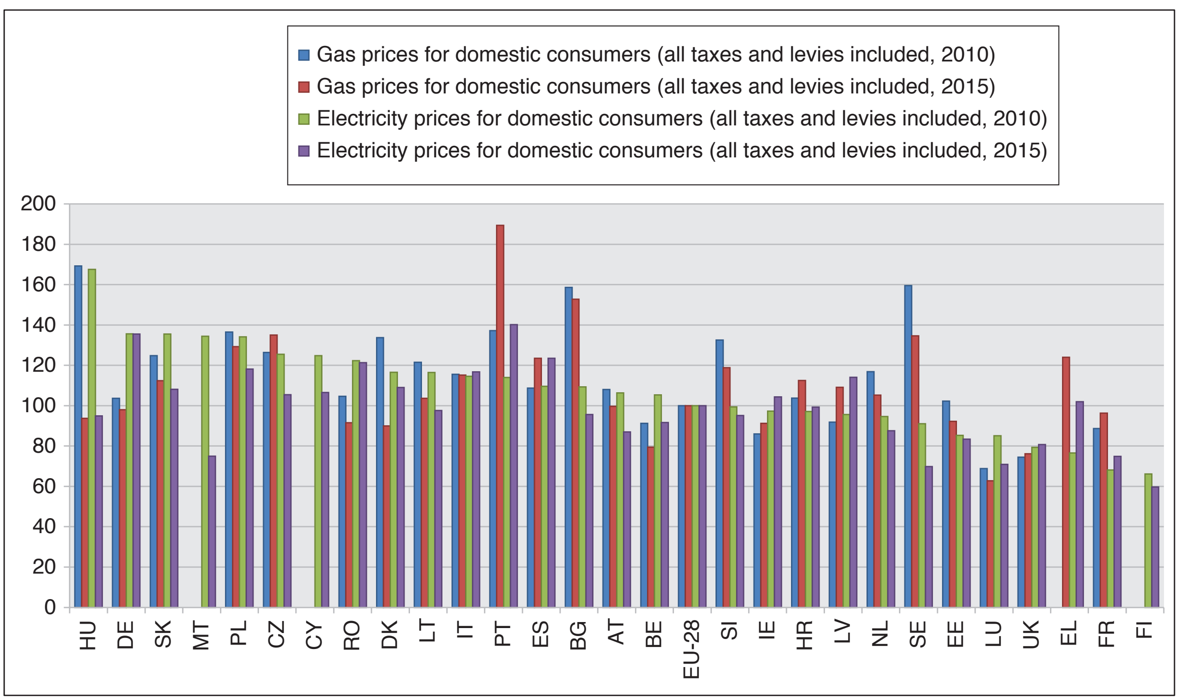



Figure 4: The electricity prices for domestic consumers (Band DC: 2 500 kWh < Consumption < 5 000 kWh ~ medium sized households) and the gas prices for domestic consumers (Band D2: 20 GJ < Consumption < 200 GJ ~ medium sized households) in the European Union (basic data in pps, EUR, 2010, 2015; EU-28 = 100%). Based on data from [7]

the low levels of disposable income, the number of households with accumulated debt towards energy utility companies has significantly increased in 2011–2012 [9].

While under these circumstances the state intervention and the measures to reduce the energy prices and the expenditure on housing-related energy services for domestic consumers are considered justified, the efficiency of the applied measures (the price control) is doubtful. On the one hand it results in high fiscal pressure and imposes a significant burden on the energy sector while hampering the new energy investments. Moreover, it makes it more difficult to perform the strategic goals determined by the national energy strategies (such as [2]) because the energy subsidies erode the competitiveness of the renewables, and don't encourage energy saving and the energy efficiency. On the other hand, the changes of the international market prices are hardly reflected in the national energy prices.

Beöthy (2017) emphasizes that the effects of oil price reductions (which started in the second half of 2014) is traceable in the short-term contracts, which are directly indexed to the price of oil from April 2015 [10]. But the decline of the market prices doesn't appear in the regulated end prices of natural gas universal service (similar tendencies can be observed in the electricity markets). Probably the profit of the cheap import remains with the Hungarian Gas Trade Ltd, but I notice here that in 2013-2014 when the oil prices soared, the significant part of the losses was born by it as well (in case of electricity the costs of the state intervention were paid in greater part by the large consumers and in smaller part by the universal providers and by the distribution companies). These findings are confirmed by the OECD (2014) [11].

Hereinafter my main objective is to examine the effects of suddenly falling residential energy prices on residential energy consumption. I am looking for the answer to the question how much the price effect itself increased the residential energy consumption between 2010 and 2015 in Hungary and what other factors offset it.

## 2. Theoretical background of residential energy consumption

Residential energy consumption is affected by many factors, such as energy price, household income, willingness to save, energy structure, urbanization, energy efficiency, consumer habits. Since the pioneering work of Haas (1997) [12] there have been a number of studies (such as [13, 14, 15]) on the decomposition of residential energy consumption.

In the last few years many countries (such as China, Iran and Kyrgyz Republic) made a significant effort to reform the pricing mechanism for the residential energy prices and to liberalize the energy markets. Consequently, a separate group of studies emerged focusing on the assessment of the impact of the respective state measures (such as [16, 17, 18, 19, 20]). A wide range of methodologies can be found in the topic of residential energy consumption, such as analysis based on input-output models, econometric and index decomposition methods. This latter approach was elaborated after the 1973 oil crisis to quantify the factors affecting the energy and environmental indicators [15]. Generally the following factors are calculated: population, income, prices, energy intensity and energy mix (it is actually the structural change). In most cases the energy consumption is corrected with climate but sometimes the weather is an independent factor in the index decomposition analysis (such as [21]).

Two broad categories of the decomposition techniques can be distinguished, the structural (SDA) and the index decomposition methods (IDA). Both of these techniques have many types. Typically, the SDA approach is used when data are at a lower disaggregated level (such as the data based on input-output tables) while the IDA mainly uses data at higher level of aggregation [22, 23].

Index decomposition analysis is a widely used tool in the topic of residential energy consumption (such as [14, 15, 16, 17] and emission (such as [24]). With that, both the absolute (additive approach) and the relative (multiplicative approach) change can be decomposed and the effects can be quantified. Hereinafter these approaches are shown.

Let $V$ be an energy-related aggregate. I assume, that it is affected by $n$ variable, so $x_1$, $x_2$, … $x_n$. The aggregate can be divided into $I$ subsector (in my case these subsectors are the income deciles), where the changes take place. The connection among the subsectors can be described by the next ones:

$$V = \sum_i V_i = x_{1,\mathrm{i}} x_{2,\mathrm{i}} \ldots x_{n,\mathrm{i}} \tag{1}$$

By the multiplicative method I decompose the relative changes [25, p. 867]:

$$D_{tot} = \frac{V^T}{V^0} = D_{x1} D_{x2} \dots D_{XM} \quad (2)$$

where:

$$V^0 = \sum_i x_1^0, x_{2,i}^0 \dots x_{n,i}^0 \quad (3)$$

$$V^T = \sum_i x_{1,i}^T x_{2,i}^T \dots x_{n,i}^T \quad (4)$$

By the additive method I decompose the absolute changes:

$$\Delta V_{tot} = V^T - V^0 = \Delta V_{x1} + \Delta V_{x2} + \cdots + \Delta V_{xn} \quad (5)$$

where:

$$V^0 = \sum_i x_{1,i}^0 x_{2,i}^0 \dots x_{n,i}^0 \quad (6)$$

$$V^T = \sum_i x_{1,i}^T x_{2,i}^T \dots x_{n,i}^T \quad (7)$$

The methodology of the index decomposition analysis has been significantly improved in the last few years and many kinds of methods are available simultaneously (such as the Laspeyres-, Paasche-, Marshall Edgeworth-, Walsh-, Fisher Ideal, Drobish, LMDI and the AMDI-methodology). The detailed mathematic deduction can be found in [26] and [27]. Hereinafter the LMDI method (~*Logarithmic Mean Divisia Index*) is employed in this paper [26]:

$$\Delta V x_1 = \sum_i L\left(V_i^0, V_i^T\right) * \ln\left(\frac{X_{1i}^T}{x_{1i}^0}\right) \quad (8)$$

$$L(a,b) = \frac{a-b}{\ln(a) - \ln(b)},\ f \text{ or } a \neq b$$
$$= a,\ f \text{ or } a = b \quad (9)$$

It has several great advantages such as the ability to handle zero values, path independency, consistency in aggregation and the perfectness in decomposition (the calculation doesn't result in residual term) [15, 23, 25]. More details about the LMDI method can be found in [25].

## 3. Methodology

The sample period is from 2010 to 2015. Annual data as listed below are applied in the calculations collected from the Eurostat and the Hungarian Central Bureau of Statistics (KSH):

- final energy consumption of the households by energy sources, such as solid fuels, total petroleum products, gas, nuclear heat, derived heat, renewable energies, electrical energy and waste (non-renewable), (unit: toe; source: [7]);
- heating degree-days by NUTS 2 regions which includes actual heating degree-days and mean heating degree-days over period 1980-2004 (unit: day; source: [7, 28]);
- annual per capita expenditure by COICOP and income deciles (unit: HUF; source: [4]);
- population (unit: capita; source: [4]).

Here I note that the subcategories of the annual per capita expenditure by COICOP levels data was consistent with the final energy consumption of the households by energy sources (the nuclear heat and waste consumption of the houesholds was zero every year in Hungary).

The short time period can be explained by the fact that the KSH has been publishing the annual per capita expenditure by COICOP and income deciles data only from 2010, so the lack of data hampers long-term analysis. Furthermore, the main objective of this study is to examine the effects of utility cost reduction on residential energy consumption and in my view the applied LMDI method allows it in spite of the short time period.

The final energy consumption of the household sector is climate corrected so the heating degree days are used to normalize the energy consumption. Making these calculations the following formula was applied (case of Enerdata Odyssee and Eurostat).

$$E = E_{wc} * \frac{1}{1 - k * \left(1 - \frac{DD}{DD_n}\right)} \quad (10)$$

where: $E$ is the energy consumption (climate corrected), $E_{wc}$ is the energy consumption, $k$ is the heating share for normal year, $DD$ is the heating degree days, $DD_n$ is the heating degree days (25 years average – 1980–2004). The $k$ reference value is 0.6 which was determined by using the KSH's data collection results in 2008 [29].

Similar to Zhao et al.'s (2012) study the identity of the LMDI index decomposition analysis in this paper is below [17]:

$$E = \sum_i \sum_j \frac{E_{ij} Y_{ij} Y_i L_i}{Y_{ij} Y_i L_i P_i} P_i \quad (11)$$

where: $E$ is the final energy consumption of the household sector (climate corrected; unit: TOE); $Y$ is the residential energy expenditure (annual per capita expenditure on electricity, gas and other fuels; unit: HUF); $L$ is the annual total expenditure (unit: HUF); $P$ is the population (unit: capita); $I$ is the income deciles; $j$ is the type of energy consumed by residents, such as solid fuels, total petroleum products, gas (piped and bottled), electrical energy and district heating.

Zhao et al. (2012) examine the urban residential energy consumption and apply data with regard to energy-using activities and energy-using products as subcategories [17]. I follow this study by building my model because its applied factors are appropriate for my research issue as well. However, in my case the income deciles and the type of energy sources are the levels of aggregation. On the one hand it can be justified by the available data and on the other hand – according to my preliminary assumptions – during the period of 2010–2015 the changes of the residential energy consumption were influenced mainly by the prices and the disposable income not the changes of the consumer habits (to track this latter would only be possible by using long time series).

For a clearer presentation I introduce five new intermediate terms to present the five previous terms in formula 9, respectively, so:

$$E = \sum_i \sum_j PR * S1 * S2 * EP * PO \quad (12)$$

Applying the additive form of LMDI the changes of residential energy consumption between any two years ($t$ and $t$–1):

$$\Delta E_{tot} = E_t - E_{t-1} = \Delta E_{PR} + \Delta E_{S1} + \Delta E_{S2} + \Delta E_{EP} + \Delta E_{PO} \quad (13)$$

where: $\Delta E_{PR}$ is the price effect, $\Delta E_{S1}$ is the intensive structure effect, $\Delta E_{S2}$ is the extensive structure effect, $\Delta E_{EP}$ is the expenditure effect, $\Delta E_{PO}$ is population effect. All of that shows the impact of the specific factor on the residential energy consumption by income deciles. The price effect represents the impact of energy price change, the intensive structure effect is the change of energy expenditure share on energy sources by income deciles, the extensive structure effect is the change of energy expenditure share in total expenditure by income deciles, the expenditure effect is the change of per capita total expenditure by income deciles and finally the population effect is the change of population size by income deciles.

These specific factors can be expressed as follows:

$$\Delta E_{PR} = \sum_i \sum_j W_{ij,t} \ln\left(\frac{PR_{ij,t}}{PR_{ij,t-1}}\right) \quad (14)$$

$$\Delta E_{S1} = \sum_i \sum_j W_{ij,t} \ln\left(\frac{S1_{ij,t}}{S1_{ij,t-1}}\right) \quad (15)$$

$$\Delta E_{S2} = \sum_i \sum_j W_{ij,t} \ln\left(\frac{S2_{i,t}}{S2_{i,t-1}}\right) \quad (16)$$

$$\Delta E_{EP} = \sum_i \sum_j W_{ij,t} \ln\left(\frac{EP_{i,t}}{EP_{i,t-1}}\right) \quad (17)$$

$$\Delta E_{PO} = \sum_i \sum_j W_{ij,t} \ln\left(\frac{PO_{i,t}}{PO_{i,t-1}}\right) \quad (18)$$

where $w_{ij,t}$ is the logarithmic weighting scheme in year $t$, specified as:

$$W_{ij,t} = L\left(E_{ij,t}, E_{ij,t-1}\right) = \frac{\left(E_{ij,t} - E_{ij,t-1}\right)}{ln\left(E_{ij,t} / E_{ij,t-1}\right)} \quad (19)$$

Assuming that:

$$E_{ij,t} \neq E_{ij,t-1} \quad (20)$$

if:

$$E_{ij,t} = E_{ij,t-1} \quad (21)$$

so:

$$W_{ij,t} = E_{ij,t} \quad (22)$$

## 4. Applying the LMDI method - results

The changes and results are provided in Figure 5. It shows the changes of the residential energy consumption and the impact of price effect ($\Delta E_{PR}$), the intensive structure effect ($\Delta E_{S1}$), the extensive structure effect ($\Delta E_{S2}$), the expenditure effect ($\Delta E_{EP}$) and the population effect ($\Delta E_{PO}$) on the shift. Any of these effects eventually shows how much the specific component would have contributed to the changes of the dependant variable (assuming that the other factors are fixed). In my case the outcome variable is the residential energy consumption. Next the explanations of the effects are discussed in a broader context.

The final energy consumption of the Hungarian household sector declined every year during the period of 2010–2013, but in 2014 and in 2015 growth is experienced. In spite of that these tendencies don't change the general trends: in the examined entire time period residential energy consumption decreased in Hungary.

Figure 6 confirms that this general trend applies in the European integration as well. The final energy consumption of the household sector – excluding Malta and Bulgaria – decreased everywhere in the European Union during the period of 2010–2015 which is consistent with the goals and strategies for energy efficiency in the integration. But the changes in the total final energy consumption are not so clear: in some member states the energy consumption increased because in 2010 the impact of the 2008–2009 financial crises still had been felt, the performance of the industry was under the expectations and the households restricted their consumption. Naturally it is the case with total final energy consumption. By 2015 most of the members were on a growth path and it positively affected the energy use.

The *price effect* had a negative impact on the residential energy consumption (it was negative) between 2010 and 2012 but as a result of price drops and the decreasing energy expenditure after 2013 the situation is significantly changed. If there was no structural and population effect, the price effect itself would have increased the dependant variable by 407 toe (~17.02 PJ) between 2012–2013, by 347 toe (~14.54 PJ) to 2014 and by 124 toe (~5.21 PJ) to 2015 (more details in Appendix 1). The *NEEAP 2020* declares the energy saving target of the Hungarian government is 40 PJ in the residential energy consumption for the period of 2010–2020 [3]. But the energy use growth caused by the

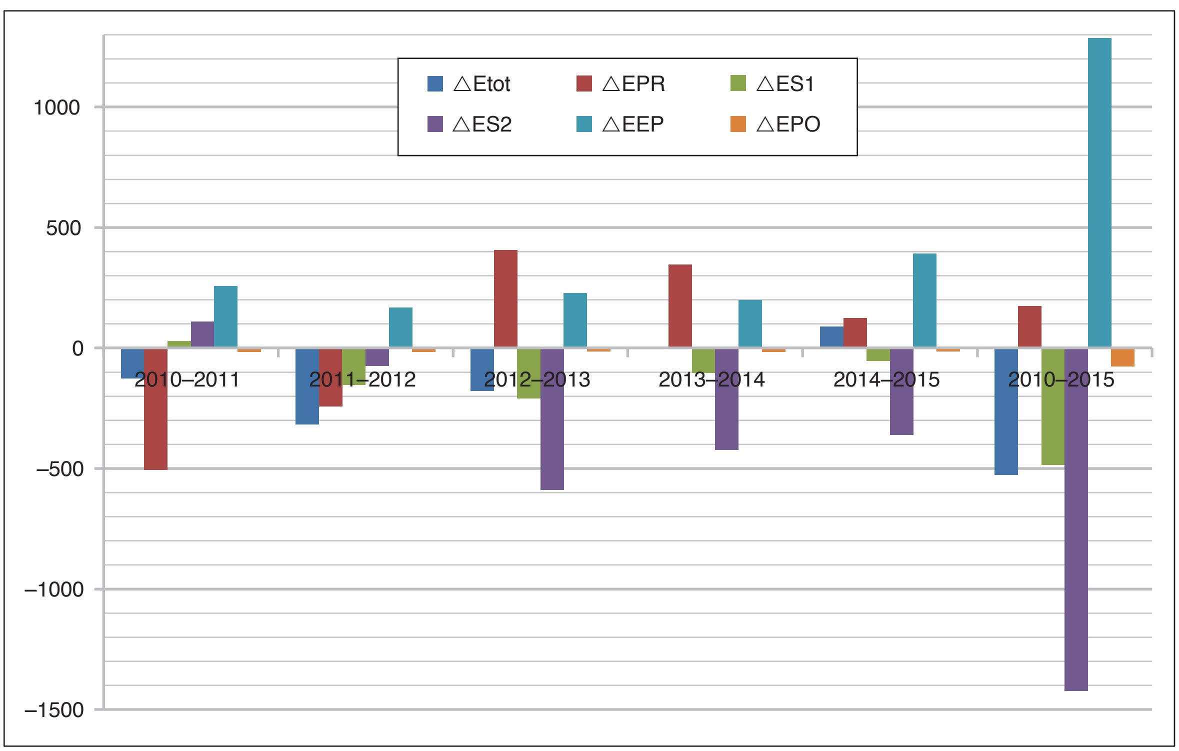



Figure 5: Decomposition results of residential energy consumption in Hungary (2010–2015, 1000 TOE)

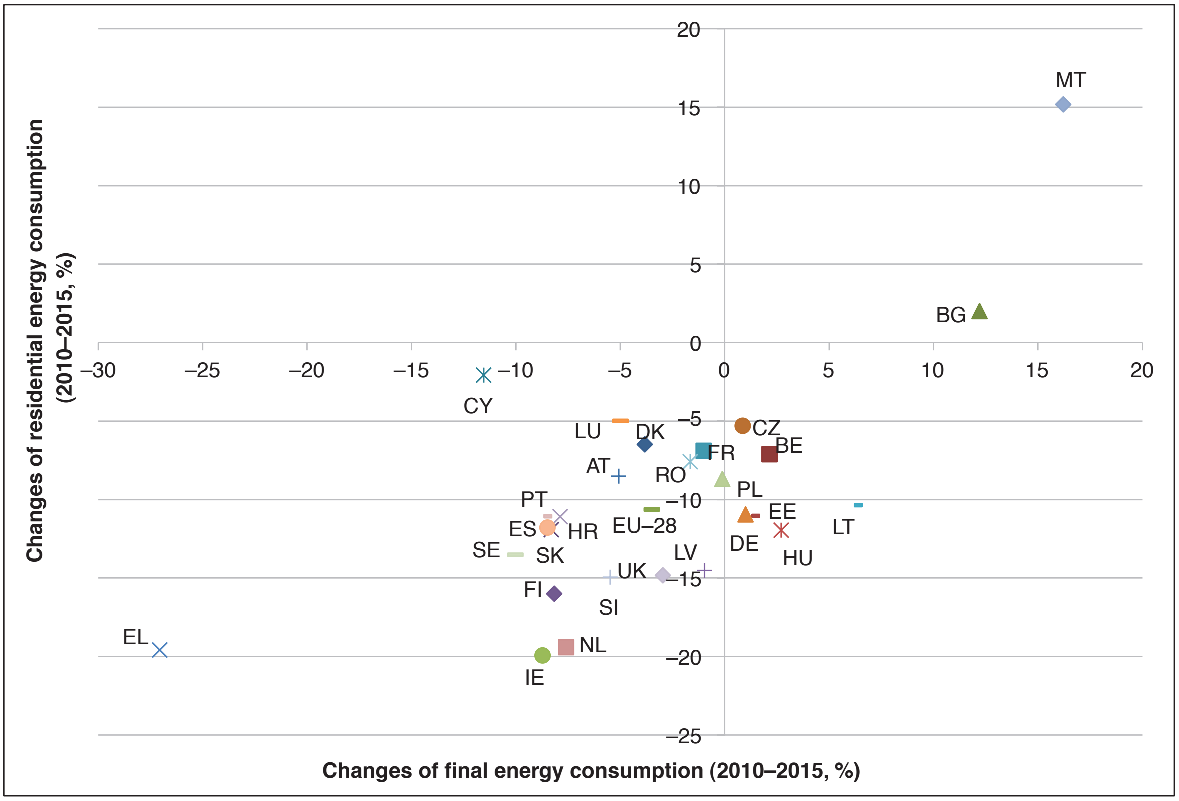



Figure 6: Changes of final energy consumption and residential energy consumption during the period of 2010–2015 in the European Union (with climatic corrections, %). Based on data from [5]

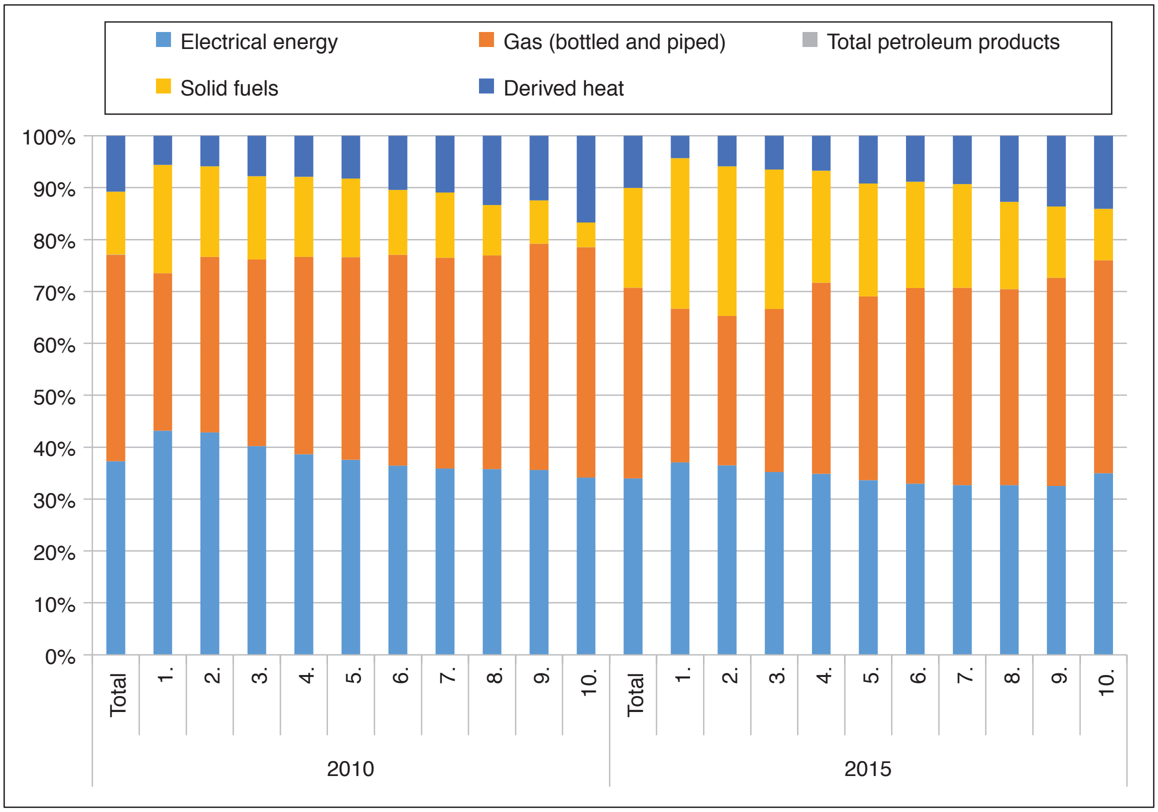
price drop is significant, which makes it harder to achieve the strategic goals.

The rebound effect can be logically concluded from the price effect. According to Sorrell (2009) "the rebound effect is an umbrella term for a variety of mechanisms that reduce the potential energy savings from improved energy efficiency" [30]. The main objectives of the households with the energy efficiency improvements (such as insulation, renovation, boiler replacement etc.) are to spend less on housing related energy services and to decrease their utility costs. The utility cost reduction in 2013 and 2014 has created a similar situation, actually the size of the price effect is equal with the rebound effect. It shows the rate of energy consumption increase as a result of 20% reduction in cost allowed by an energy efficiency improvement as compared to the percentage of the loss in the potential energy savings. In 2013 it was 7.3% (this is the size of the price effect relative to the energy use in 2013), in 2014 it was 6.6%, in 2015 it was 2.4% which is under my former results (see [31]) but it is broadly consistent with experiences reported in professional literature.

Hereinafter the main energetic features are shown to clarify the interpretation of the structural effect. In the empirical studies using IDA the energy structure is assigned priority, which significantly affects the final energy consumption. Obviously the structure of residential energy consumption and the structure of energy expenditure can be greatly different [15]. In spite of that the absolute size and relative share of solid fuels (it means mainly the firewood) decreased, while the related expenses significantly increased in all of income deciles (both in absolute and relative terms). This is primarily explained by the fact that the price of firewood was not affected by the utility cost reduction (moreover it became more expensive, but the price of electricity, gas and district heating declined) so the shift of proportions is even more prominent.

It can be stated that by 2015 not only by households in the bottom deciles (so by the poorest families) but by the middle class as well the share of solid fuels has exceeded 20% in the energy expenditure. (Figure 7)

Natural gas remains dominant part of the energy consumption but its significance slightly declined in the




Note: 1st decile represents the poorest households, 10th decile represents the richest households

Figure 7: Structure of residential energy expenditure by deciles (2010, 2015, %). Based on data from [4]

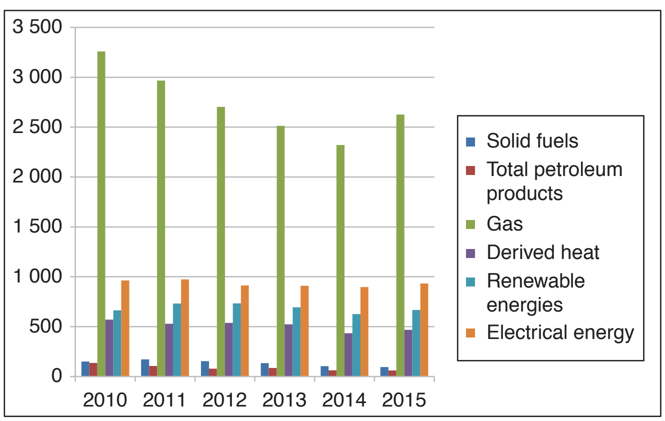



Figure 8: Residential energy consumption by energy sources (2010–2015, TOE). Based on data from [7]

examined time period because of the spreading of renewable energy sources and increasing share of electricity. This latter can be explained mainly with the expansion of the air-conditioners and electrical appliances (Figure 8).

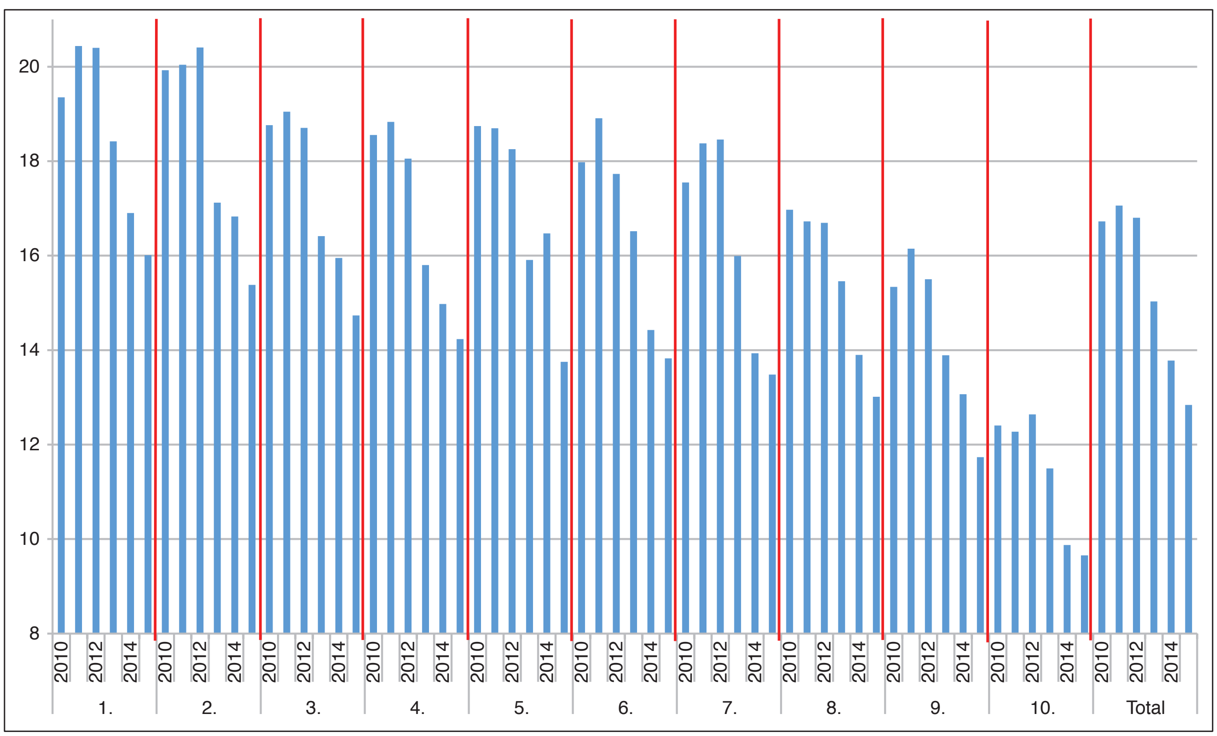
In 2000 the households spent 17.68% of their total expenditure on housing and energy, but in 2010 this proportion is over 25% as reported in the KSH (2017) database (it is a little bit higher than the Eurostat data – see Appendix 3). By comparison the households spent 27.84% of their total expenditure on food and non-alcoholic beverages in 2000 and 22.8% in 2010. The shift between the two items can be explained by decreasing food-related expenses of households. Accordingly stagnating or declining incomes force consumers to change their buying habits in favour of cheaper products. The expenditure on housing and energy is inelastic in the short term (in the long term it is only relatively elastic as well) so the households face a major burden in adapting to such circumstances [29].

However, there are many options for energy savings, such as replacing obsolete heating, cooling, ventilation and lighting appliances, renovating residential houses (although I note here that it is the most expensive possibility) and improving the energy efficiency. Another option is to prescribe mandatory energy standard for all new buildings and to promote energy efficiency. The national energy strategies (such as [2, 3]) emphasize as well that there is huge energy saving potential in renovating residential houses. After 2013 the ratios seemed to have turned, in 2015 the expenditure on food and non-alcoholic beverages is the biggest item (24.49%) and the share of housing and energy expenditure goes below 21.5% (Figure 9).

According to the KSH's micro-census in 2010 the heating represents two-thirds of the residential energy costs (it contains the electrical energy, the piped and bottled gas, the solid and liquid fuels, the district heating) and the remaining one-third is the water heating, cooking, lighting and the operation of electrical appliances for every income group. The energy expenditure per capita increases proportionally with the income level and there are huge differences in the share of energy expenditure to the net income: in 2015 it was 20.57% in the lowest income decile (which raises the issue of energy poverty), in the highest income decile only 6.6% (the average is 10.92%). These values significantly improved compared with the data in 2010, where these were respectively 23.15% and 8.4% (the average was 13.6%) [29].

Explanation of this context contributes to understanding the structural effect, which can be divided into two main parts, to the intensive ($\Delta E_{S1}$) and the extensive part ($\Delta E_{S2}$). The intensive part is affected by two factors, on the one hand the price change between various energy sources and the structural shift in the energy mix [17]. The extensive part shows the energy intensity development, that is, the energy expenditure per unit of annual total expenditure. It can be explained by three factors: the first is the change of consumer habits (through modification of the energy-using activities and there is a structural shift between these activities), the second is the energy efficiency changes (such as the households replace the outdated boilers and use energy saving bulbs, etc.), the third is the price change resulting in energy expenditure changes in order of magnitude. For example, a positive extensive structural effect shows the following.

Despite the households' buying energy efficient appliances and devices, their energy consumption grows because of the shift toward the more energy intensive activities (such as the family moves into a larger house




Note: 1st decile represents the poorest households, 10th decile represents the richest households

Figure 9: Share of expenditure on electricity, gas and other fuels to the annual per capita expenditure, by deciles (2010–2015, %). Based on data from [4]

where they need to heat more or every room is equipped with an air-conditioner system). In Hungary typically the negative structural effect can be discerned. This can be explained by the improving energy efficiency to a lesser extent and by the energy expenditure decline resulting in price reduction to a greater extent. Next I discuss it in more detail.

In 2010–2011 both the intensive and the extensive effect had been positive, after that it changed to negative. In case of the intensive structural effect it suggests that between 2010 and 2011 there was an increasing demand for cheaper energy sources and many families switched to a less modern, but more favorably priced wood as fuel. During the period of 2012–2015 the effect is negative because at that time there was a shift toward the more expensive energy sources (such as electricity) which is related to the spreading of electrical appliances and air-conditioners.

The *extensive structural* effect is positive between 2010 and 2011, which can be explained with the increasing share of energy expenditure to the total annual expenditure. By 2012 the effect became negative (but at that time there was no price reduction) and opposite progress can be observed among the income deciles: while in the 1$^{st}$ and in the 7$^{th}$–8$^{th}$–9$^{th}$–10$^{th}$ the energy expenditure increased, in the 2$^{nd}$–3$^{rd}$–4$^{th}$–5$^{th}$–6$^{th}$ deciles it decreased, which signals that these latter households restrain their consumption and use cheaper energy sources (typically the expenditure on solid fuels, especially wood grew). Probably the high energy prices hit these households the most. Between 2013 and 2015 the energy expenditure declined because of the price drop (it is the case for all the income deciles), so the effect is negative.

The *expenditure effect* had positive impact on residential energy consumption in every year which can be explained by the rising income and standard of living.

The population of Hungary constantly declines in number and it can be detected in the *population effect* as well. In all of the examined years it had a negative impact on the residential energy consumption, and the values are similar (the values are scattered around 0.5 PJ).

Beyond the LMDI index decomposition analysis I examined whether the price decline or the rearrangement between expenditure items reduced the social inequalities.

The Lorenz curve is especially suitable for the graphical representation of the social inequalities, which has become a popular tool to illustrate not only the income, but the expenditure-related inequalities as well (such as [33, 34]). The Gini coefficient is derived from the Lorenz curve. The latter "shows the share of spending (or income) by households ranked by spending (or income). The further the curve is below the 45 degree line, the less equal the distribution. Correspondingly, the Gini coefficient is calculated as the area between the Lorenz curve and the 45 degree line divided by the total area under the 45 degree line." [33] The higher the coefficient, the more unequal the distribution is.

Figure 10 represents growing inequalities in case of all three indicators (energy expenditure, total expenditure, net household income) during the period of 2010–2015 and the values of the Gini coefficient confirm it as well. However, in the case of energy expenditure and total expenditure the disparities are lower compared with the net household income and this suggests that households have the ability to borrow and save to offset the provisory changes.

## 5. Conclusion

The comprehensive study of the situation preceding the passage of the act on the enforcement of utility cost reduction (Act No. LIV of 2013) confirms that in Hungary the share of expenditure on housing, water, electricity, gas and other fuels (measured in pps) was one of the highest in the European Union which imposes a greater burden on vulnerable households, especially the poorest lower-income families. The Act No. LIV of 2013 has positively affected both the absolute value of the housheold expenditures and the structure of these spendings in all income levels. At the same time the effects of oil price reductions (which started in the second half of 2014) doesn't appear in the regulated end energy prices so the households can not benefit from the lower world energy prices. Consequently, the measures to reduce the energy prices and the share of energy expenditure are justifiable, but many negative tendencies have to be considered.

It is a problem, that the the passage of the act was really fast. The real and strong participation of the interested stakeholders was limited. Futhermore, the price control of energy sources in the residential sector and the completed price reduction are contrary to the national energy strategy goals, whose pillars are competitiveness, sustainability, and security of supply. According to the NEEAP 2020 "the most efficient and effective way, also

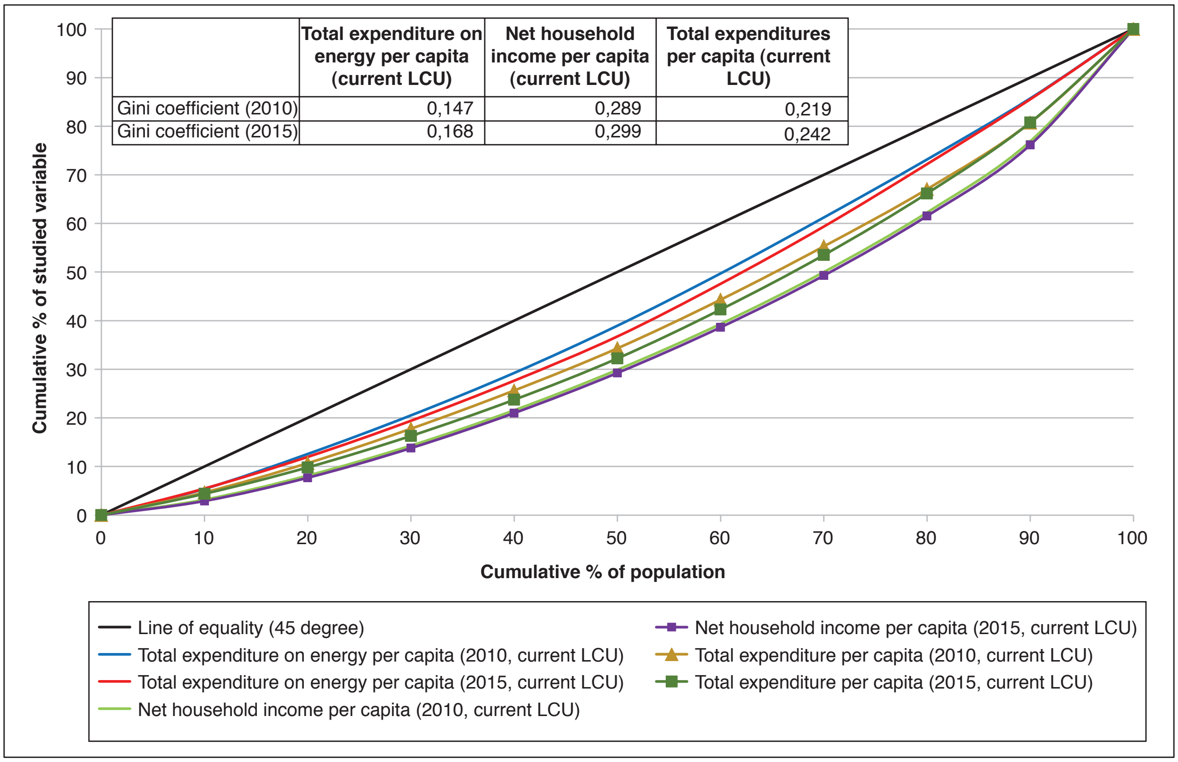



Figure 10: Lorenz curves and Gini coefficients. Based on data from [4]

viable in the short term, of increasing the security of supply is to lower consumption and to treat energy conservation and energy efficiency as priorities." [3, p. 9].

Because the price of gas, electrical energy and district heating has fallen by almost a quarter in 2013–2014 in the household sector, in my calculations it induced 17.02 PJ between 2012 and 2013, 14.54 PJ in 2013–2014 and 5.21 PJ in 2014–2015 in additional energy use. While this price effect was counterbalanced by the structural and population effect, in any case it makes the fulfillment of the objectives (related to energy efficiency) more difficult.

In my view emphasis should be placed on raising the residential awareness and it must be clear that the households should spend their cost savings on energy efficiency investments (such as retrofit, thermal insulation and replacing outdated boilers) because in the long term this is the only way to reduce their energy expenditure. As the ECARAP states "for the Hungarian population the cost-oriented motivation is the most approppriate" [35, p. 45], so the awareness raising campaigns should focus on that.

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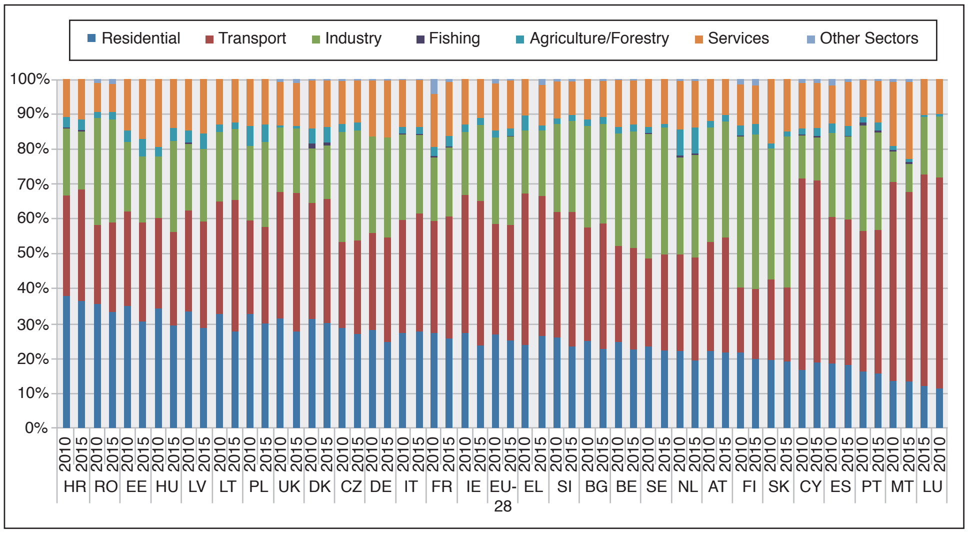
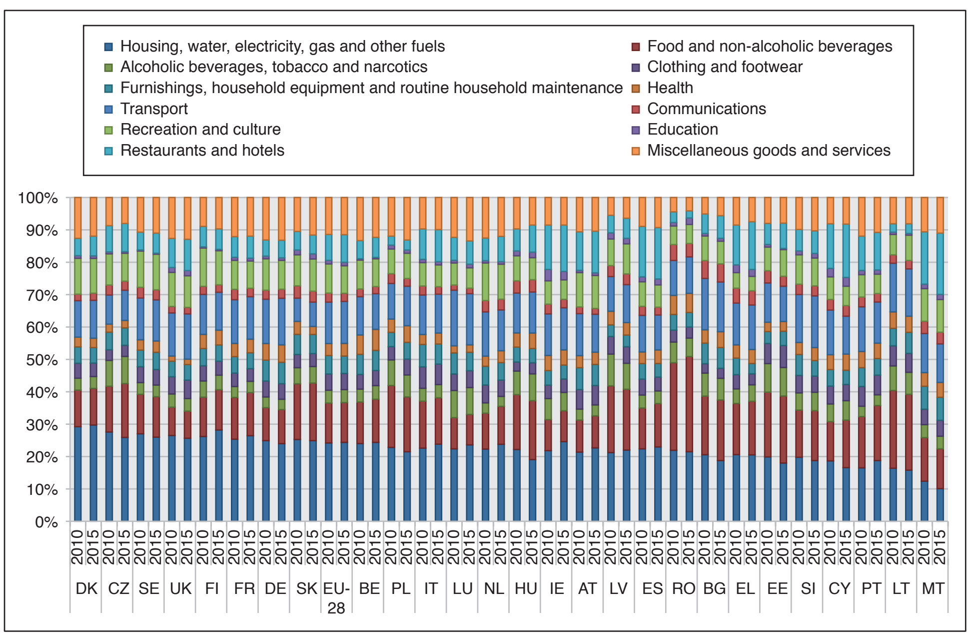
## Appendices

**Appendix 1: Decomposition results of residential energy consumption in Hungary (2010–2015, PJ)**

| | $\Delta E_{tot}$ | $\Delta E_{PR}$ | $\Delta E_{S1}$ | $\Delta E_{S2}$ | $\Delta E_{EP}$ | $\Delta E_{PO}$ |
|---|---|---|---|---|---|---|
| 2010–2011 | –5,23 | –21,23 | 1,24 | 4,61 | 10,79 | –0,65 |
| 2011–2012 | –13,22 | –10,13 | –6,44 | –3,06 | 7,05 | –0,63 |
| 2012–2013 | –7,46 | 17,02 | –8,78 | –24,61 | 9,50 | –0,59 |
| 2013–2014 | 0,12 | 14,54 | –4,33 | –17,69 | 8,28 | –0,67 |
| 2014–2015 | 3,73 | 5,21 | –2,19 | –15,11 | 16,39 | –0,57 |
| 2010–2015 | –22,07 | 7,22 | –20,31 | –59,60 | 53,81 | –3,19 |




Appendix 2: Changes of final energy consumption by sector in the European Union (2010, 2015, %). Based on data from [7]




Appendix 3: Final consumption expenditure of households by consumption purpose in the European Union (2010, 2015, %; EUR, current prices). Based on data from [7]