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# Analysis of Consumer Behaviour Related to Electricity Consumption

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**Abstract**: Almost three-quarters of carbon dioxide emissions originate from households' activities and among the major contributors to climate change is the energy sector. Therefore, increased attention is being paid to energy-efficient behaviour in the household segment. Over the past decades, a limited number of studies focused on the in-depth understanding of consumer behavior within energy consumption and on comparison of consumers' own perceptions towards their effectiveness in energy consumption to the reality substantiated by the precisely measurable amounts of energy they have been consuming. This study extends the authors' previous research on changes in consumer behavior, triggered by access to the personalized simplified and user-friendly data related to the energy consumption of a particular household. The focus is on describing the behavior patterns in electricity consumption related to consumers' age and size of agglomeration they inhabit. The study includes data on 3 years' consumption of over 30 000 households from Slovakia. It provides conclusions relevant to the area of the Central European region at least, as among the main factors influencing the energy consumption are weather and dwelling conditions.

***Keywords***: energy efficiency, disaggregation, behavioral principles, consumer behavior

***JEL Code***: C12, M31, M37

## 1. INTRODUCTION

Energy production is one of the major factors contributing to climate change as most of the current energy supplies originate from fossil fuels. According to the data from March 2022 [11], 62 % of the world's electricity have been produced by using fossil fuels. The largest source of electricity is currently coal (36%), which is responsible for a quarter of all energy-related CO2 emissions and therefore significantly threatens humans' ability to stabilize the climate. Combined, clean electricity sources generate 38% of the world's demand – including hydro (15%), nuclear (10%), wind (7%) and solar (4%) power. It means that fossil power has a downward trend as together wind and solar have generated more than 10% of the world's electricity, which is twice the share compared to the year 2015 when the Paris Climate Agreement was signed.

The urgency of actions towards preventing or at least slowing down climate change also reflects in prioritizing the topic of global energy efficiency improvement by the United Nations (UN) as one of the three major objectives of their Sustainable Energy for All (SE4ALL) initiative (UN 2020). The aim is to keep the rise in temperature within 2°C by 2050 and 1,5°C by 2100, considering the rapid economic and population growth [29].

And here comes the tricky part, as humans have become heavily dependent on energy consumption to maintain sustainable economic development, which leads to further increase in the world's demand for energy [3, 22]. Electricity demand continues to climb, growing by

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5.4% in 2021 and achieving a new record [11]. Due to the complexity of the issue, there is no single universally and effectively applicable policy instrument for environmental protection and sustainable development, which would result in effective mitigation of CO2 emissions [15]. There have been numerous initiatives investigating options for changing the course of climate change. Along with the initiatives to increase the level of energy produced by renewable resources, also energy conservation and energy efficiency are priorities for governments worldwide. Over the past decade, they have motivated intensive research to understand how energy is consumed, and how to translate that knowledge into meaningful information to enable energy consumers to take responsibility over their energy consumption [31] and decrease it or in other words improve their energy efficiency.

To achieve the goals, the activities and initiatives need to be targeted properly. As surprising can be perceived the fact that not the biggest production companies, but household sector is a major contributor to greenhouse gas emissions, because of the consumption of a wide range of goods and services. Households account for more than 60 % of global greenhouse emissions. To achieve the targets from the Paris Agreement and to maintain the global average temperature rise below 2 °C plus to further limit it to 1.5 °C above pre-industrial levels, is unrealistic without changing the consumption behaviour of household sector [21].

The share of home appliances such as refrigerators, televisions, and air conditioners accounts for around 50 % of the emissions. This effect would be explained as consequence of the regulations on the amounts of CO2 emissions produced by the corporate sector. The limits have forced producers to control their emissions and invest in technologies minimizing the impact of their activity on the environment to avoid the fees for exceeding these limits. Policymakers in the United States and European Union are paying increased attention to residential and commercial buildings as a potential source of major reductions in energy consumption that will help meet that target. The building sectors together account for around 40 % of total energy consumption in these nations and are well understood to have huge potential for cost-effective energy savings that can both reduce greenhouse gas emissions and improve the reliability of the electric grid [20].

Over the past 50 years, a limited number of studies have attempted to better understand consumer perceptions of their utility use and their possible effects on consumer decision-making. An even smaller number of studies compared consumers' perceptions to actual energy use or savings [19]. This study links up to research on behaviour changes of consumers based on a simple access to disaggregated data related to their energy consumption presented in a transparent and easily understandable version [17]. We focus on describing the behavioural patterns in electricity consumption related to age and size of agglomeration. The study includes consumers from Slovakia. As among the main factors influencing the energy consumption is weather and dwelling conditions, the results of the study have the potential to effectively cover the Central European region with similar climate conditions and household management style.

## 2. THE CURRENT STATE OVERVIEW

Burning the fossil fuels to generate electricity belongs to the major factors causing environmental deterioration. A pleasant ecological environment is not only essential for the good quality of life but supports the economic development of nations as well [34]. Among the approaches considered to be relevant in improving the undesirable development is the implementation of policies resulting in changes in consumers' behaviour related to energy consumption. As household energy consumers produce the most of carbon dioxide emissions, they represent the high relevancy target group within activities aimed at increasing energy efficiency.

 

### *When knowing less is for worse*

Many strategies for realizing potential savings (e.g.: product labelling programs, subsidies for the purchase of efficient devices, behavioural programs that encourage efficient energy use, etc.) rely on the assumption that the buildings' owners and end users make informed investment and operational decisions [20]. If the precondition of an informed consumer isn't fulfilled, these strategies would probably be ineffective. Unfortunately, studies have revealed the presence of several economic, technological, and organizational barriers, which influence the level of consumer awareness and result in poor implementation rates of energy efficiency measures. [18].

As the example could serve the study by Attari [1], which confirms differences between consumers' perception and reality. It presents, that consumers tend to overestimate the energy consumed by their low energy-consuming devices and slightly underestimate the amounts used by their most energy-consuming devices. They mostly associate energy savings with reducing the operating time of the devices. Understanding consumers' misperceptions can help to design the policies and information campaigns, that will support consumers to make their homes consume less energy. [20].

### *How to navigate human's autopilot to changes in energy consumption?*

Households' energy consumption has a large saving potential estimated up to 27% of their current energy use, which can be saved through more efficient energy use [37]. This is closely related to sustainable changes in consumers' behaviour within energy consumption that can be effectively nudged by respecting behavioural principles in designing the energy efficiency policies and campaigns [7]:

a) **Habits**. It is more difficult to change daily routines requiring little or no cognitive effort, which is of significant relevancy in the case of electricity use.

b) **Rewards**. The change is conditioned by reward, ideally shortly after the action. In the case of energy efficiency an example is easy access to the data on consumption, which is now available thanks to disaggregation technologies analysing the aggregate household main power measurement in the house and disaggregating this into individual appliances [9].

c) **Consequences**. The consequences of the change are important to us. In this field, No. 1 is an electricity bill. The first-hand output from smart meters is disaggregated data presented in the kilowatt-hours (kWh) consumed. The useful insight for designing the disaggregation report comes from the study by Hargreaves [16] examining the communications of energy consumption. It provides the finding that consumers prefer their energy use to be presented in monetary units (e.g. euros) instead of kWh or carbon dioxide emissions. Confirming such insight is useful in decision making, whether to put extra effort into transforming the data from disaggregation into monetary units to improve the user experience and the outcome of the steps supporting the behaviour towards energy efficiency.

d) **Involvement**. People need to feel involved and effective to make a change. In case of electricity consumption, accessibility of information and complexity can lead to the feeling of helplessness and inaction. The solution is again energy disaggregation, nicknamed the Holy Grail of energy efficiency as you can hardly improve something, that you cannot measure [14]. Currently, there have been applications linked with disaggregation technology, which can produce a user-friendly regular report with the status of consumption in kWh and tips on how to lower it.

e) **Approval**. Humans' behaviour is strongly influenced by other people's behaviour. An example of the tool enabling common natural influence among consumers is benchmarking similar consumers to present the effective level of consumption and support the feasibility of recommendations.

Studies on barriers to energy efficiency in Sweden and other EU countries within the segment of small and medium enterprises explain that the main obstacles are: lack of time, other business priorities, lack of knowledge, lack of information, lack of staff, high

 

investment, etc. [18]. Networking platforms could help to overcome these barriers by combining:

a) Energy audits using behavioural principle of providing the control over the result, and lectures on energy efficiency reflecting the individual needs to feel actively involved in the change,
b) Consultancy with experts meeting the principle of the authority,
c) Networking enabling to share the knowledge and providing the social proof [5] in meaning 'if others do it, I should also do it', 'I want to be among energy-efficient ones' or 'if it works for others, it will work for me'.

### *Friendly data as facilitator of desired changes in behaviour*

This study provides insight into the consumers' behaviour within electricity consumption based on the data from Bidgely technology, which currently belongs to major current disaggregation techniques. The service related to Bidgely includes obtaining regular reports on household consumption and recommendations on the household management areas such as space heating, refrigeration, lighting, and always on appliances.

Disaggregated information itself has two major impacts [14]:

- increased consumer engagement,
- reduced energy usage.

It additionally provides a great number of data, which is a valuable asset for designing effective informational and educational campaigns. Disaggregation technology can serve as a tool to reveal customer information that is relevant to optimizing energy efficiency programs of households. According to the study by Beckel et al., it is possible to infer 8 of the 18 characteristics of a household with an accuracy between 72 % and 82 %. The characteristics include for example number of inhabitants, the number of adults and children, and employment status (retired, employed, etc.). Then with accuracy, around 60 % follow characteristics such as the age of the house, type of the house, or income. [2]. Reports on disaggregation can be considered as part of digital marketing, which is most successful when personalized and well-targeted. The mailing list and targeting are considered to be the most important in terms of communication effectiveness. The impact of the mailing list's relevancy on the result of a campaign reaches 40 %, followed by an offer with 30 %, then layout and copy both presented by 15 % impact [4]. Therefore, the knowledge of the target group is essential.

### *Focus on age and type of agglomeration*

This study points at the particular areas of households' electricity consumption and investigates how households' consumption is influenced by their lifestyle shaped by:

1. the age of the property's owner;
2. the size of agglomeration where the property is located.

Based on the widely-accepted belief that aging is a multi-dimensional process and older people are likely to experience the various aging processes differently due to the wide variability across individuals [33], the age needs to be considered within the complex of factors, as changes in behaviour during a person's life are the results of adaptation and adjustments to life changes, not just aging itself. However, the age is easily accessible input being provided within standard interaction between supplier and consumer with the potential to cluster customers with similar needs into a reasonable number of target groups. Examination of consumer responses to marketer-controllable variables (e.g., pricing, sales promotions) of companies in different countries and specific industries, and how the various gerontographic segments respond to these variables, could provide useful guidelines for strategy development, as it has in the United States [25, 26].

Another interesting and easily accessible factor influencing the electricity consumers' behaviour is the size of agglomeration, where the dwelling is located [23]. Due to the study

 

by Buček [5] the size of agglomeration impacts lifestyle in terms of commuting and economic structure. The smaller the village is, the probability of prevailing residential over - production character is higher. This effect would be strengthened by the geographic proximity of larger agglomerations. The bigger the city or town is, the services sector becomes more significant. Another study by Debasish, Prusty [8] presents findings that social norms, traditions, caste, and social customs have a greater influence on consumer behaviour in rural areas than in urban ones. Their study indicates that rural consumers mostly use friends (45%), TV (17%), and mobile phone retailer (12%) as the source of information. The purchase decision is taken by self-decision (52%), with the help of family (29%) and friends (18%). This knowledge impacts the choice of the channel to effectively deliver the information.

The research uses data about customers in Slovakia. Currently, there is no limit towards volume of energy consumption for households in Slovakia. However, among governmental proposals for actions to deal with energy crisis, which has started in the end of 2021 and has been deepened by impact of war in Ukraine on the energy market, an idea related to consumption restrictions appeared. The proposal suggested that from the year 2023, 85 % of individual household's electricity consumption (based on the volume in previous period) would be subsidized by state, billed in prices valid in 2022 and consumption above the limit would be billed in higher prices [35]. This proposal didn't enter into force at last, but the idea has already appeared. Currently the activities leading to decrease in consumption are more of an educative character towards energy efficiency.

There are different electricity tariffs available for households. In case of households with the above average electricity consumption, usually over 4 MWh/year, the two tariff products with lower price of electricity during night hours are applied, which means that altering the operating time of selected devices would impact household's electricity bill.

Due to the knowledge of the Country-of-Origin aspect, the country where the product or service is produced impacts consumer behaviour and decision making [24]. When a product or service is complex such as services related to house management, the consumer is more likely to incorporate the Country-of-Origin aspect into their decisions [36]. Therefore, we consider the results of the study to have the potential of effectively covering at least the area of the Central European region regarding the common history and presence of several common cultural features. Market globalization and the appearance of similarities in consumers' behaviour have been supported in the last few decades due to factors, such as the collapse of communism, the global opening of previously closed markets in India, China, Eastern Europe, and Latin America, worldwide investment and production, increases in world travel and consumer sophistication, advances in telecommunication technologies, and the growth of global media [32].

## 3. DATASET DESCRIPTION AND METHODOLOGY

### *Dataset description and hypothesis*

We examined the datasets '*OV_data*' and '*peer_insight*', which contain the data from SMART meters of electricity consumers. The SMART meter measures the progress of consumers' consumption electricity continuously within various time intervals. Bidgely application recognizes the consumption of individual appliances separately due to their specific electric stamp. Bidgely records these data on each individual consumer into above listed datasets. The datasets include consumers meeting the legislative criteria for an obligatory instalment of smart meters, which has been proceeded in Slovakia sequentially since 2014. The consumers with smart meters have been offered a free application Bidgely and the datasets include the ones, who have activated it. The data have been anonymized and have the following structure:

 

OV_data contains attributes: OV (char), eic (char), bidgely_start_date (date), bidgely_end_date (date), consumption (int), age (num), postcode (char), town (char).

Peer_insight contains attributes: OV (character), etag (character), id_bidgely (char), id_user (char), id_appliance (char), type (char), start_date (date), end_date (date), last_modified (date), actual_usage_kwh (num), benchmark_usage_kwh (num), peer_radius_km (num), peer_user_count (int), size_bytes (int).

We merged the datasets in the R-studio environment using the "OV" attribute, which is common for both datasets. It provided comprehensive information about customers and their consumption trends for individual appliances during the monitored period.

The datasets examined, contain parameters that were not relevant for our research, therefore they were removed before processing as well as records with incomplete and extreme values. The output contained data of 33 095 electricity consumers within the household segment in Slovakia. The data analysed include the electricity consumption of the consumers during the period from June 2018 till August 2021. These consumers are primarily households using electricity for heating or equipped with electric water boilers.

This study examines customer behaviour related to electricity use in the following particular areas of the consumption:

- total consumption,
- lighting,
- water heating,
- air conditioning,
- space heating,
- refrigeration,
- always on appliances.

It focuses on the behaviour of households divided into categories due to their age as well as the size of agglomeration, where the property is located and compares their consumption. The dataset contains over 3 mils. records on the electricity consumption in the above-listed categories.

Our study links to research, which examined whether the increase of individuals' control over electricity consumption based on the access to personalized energy disaggregation reports leads to the changes in their consumption patterns [17]. The results confirmed the hypothesis that consumers' access to customized analysis of their electricity consumption, influences their behaviour and has an impact on the decrease of the electricity consumption. Another conclusion has been, that there are differences in the behaviour of consumers related to energy efficiency due to the demographic factor of age. This study dealt with the households' total consumptions, which in this case has been categorized into particular areas of electricity consumption to get more detailed picture needed to support the effectiveness of energy efficiency initiatives.

The motivation of our research was to provide in depth information on electricity consumption patterns of individual customers due to the demographic factor of age and the size of agglomeration, where the consumer lives. We established the following hypothesis and subsequently the research question.

The study examines the hypothesis:

**HYPOTHESIS 1** (H1): There is a statistically significant difference in electricity consumption within particular areas due to the demographic factor of age.

Following the proof of the H1, the study continues to examine the consumption in relation to the size of agglomeration, where the property is located.

Within the framework of the established hypothesis, we will analyze the correlation between the electricity consumption expressed in units of kWh and age. To analyse the correlation between these numerical variables, we use the Pearson correlation coefficient test [28].

 

Hypothesis H0: "There is no statistically significant difference in electricity consumption within particular areas due to the demographic factor of age.", we will test at a significance level of alpha = 0.01. If the p-value for a given consumption category is lower than 0.01, then H0 will be rejected, which means that there is a statistical relationship between age and consumption within the given consumption category.

If a statistical relationship between consumption and age will be proven, we will determine the nature of this relationship based on the Pearson Correlation coefficient (r), which will take on values from -1 to 1. A positive Pearson Correlation coefficient means positive linear relationship; a negative value means negative linear relationship. The higher the absolute value of the Pearson Correlation coefficient, the higher the linear relationship between the variables.

Based on results, the analysis of consumers' average electricity consumption will follow. The analysis will focus on comparing consumption in three areas:

- analysing electricity consumption in particular categories;
- analysing consumers' consumption related to age;
- analysing consumers' consumption related to the size of the agglomeration.

### *Methodology of analysing electricity consumption in particular categories*

The analysis compares consumers' monthly average electricity use within the categories of total consumption, lighting, water heating, air conditioning, space heating, refrigeration, and always on appliances. Even the average monthly consumption differs within the year because of the weather, which increases electricity consumption mainly due to the exterior temperatures (heating in case of low temperatures, air-conditioning in case of high exterior temperatures), for the purpose of our study, this aspect has been considered irrelevant as the study focuses on analyzing and comparing differences among different demography groups, not on electricity consumption trend in particular months throughout the year.

### *Methodology for analysing consumers' consumption related to age*

Following our previous research providing an outcome, that consumers' behaviour within electricity consumption differs by age, we've analysed how age impacts the consumption in particular areas. We divided consumers into 3 age categories:

a) 18 - 34 years
b) 35 – 54 years
c) 55 – 70 years

The categorization has been realized based on the following:

- The commodity consumption is usually billed to the property owner, which is restricted by the age of 18 years, when a person is considered an adult.
- Due to the study of different age groups' behaviour related to media consumption, this categorization reflects the lifestyle of the particular groups and the way they acquire information. It influences the selection of effective tools and relevant content to deliver messages related to education in energy efficiency, which is among the practical implications of our research.
- Our categorization also reflects the current society's lifecycle by considering the age when people start managing households of their own. In European union states, it is between 17,5 to 32,4 years [12].
- The insight listed above, impacts interval of the third category from 55 to 70 years. We assume that at this point of our lifecycle decreases the number of households' permanent residents, which influences the household management including the activities related to energy consumption. It is established on the data on the European union population starting a family in the age between 26 to 31 years [12] combined with the fact that the average age of leaving parental household is 26 years.

 

- Consumers aged above 70 years were not included in the dataset analysed as the decision-making process related to household management is realized with the strong influence of children or grandchildren of the property's owner. Therefore, online communication related to energy efficiency is targeted to people aged under 70. The reason also is, that the genuine dataset included consumers over 100 or 110 years, where we assume that the owner is deceased and the formal transfer of property hasn't been completed, the decision-maker is a relative.

### *Methodology for analyzing consumers' consumption related to the size of the agglomeration*

To categorize the agglomerations examined in the research, the Degree of Urbanisation (DEGURBA) was applied, as a classification method developed to facilitate international comparisons. The method is acknowledged by the UN Statistical Commission [10]. DEGURBA classification indicates the character of an area and is based on the share of the local population living in urban clusters and urban centres. It classifies local administrative units into three types of areas [13]: cities (densely populated areas), towns and suburbs (intermediate density areas), and rural areas (thinly populated areas).

1. **City** is defined as an urban centre consisting of contiguous grid cells of 1 km2 that have a density of at least 1500 inhabitants per km2. The contiguous cells should have a total population of at least 50,000. Gaps in these urban centres are filled and edges are smoothed.
2. **Town and semi-dense areas** are an urban cluster, that consists of contiguous grid cells with a density of at least 300 inhabitants per km2. The contiguous cells should have a total population of at least 5000.
3. **Rural area** is thinly populated area outside urban clusters.

Based on the above-described approach, agglomerations included in the research were divided into 3 following categories:

1. Rural - Size (No. of inhabitants) up to 5000
2. Town - Size (No. of inhabitants) 5001 – 50 000
3. City - Size (No. of inhabitants) over 50 000

## 4. RESULTS

This research has focused on analysing customer behaviour related to electricity use in individual areas of electricity consumption: total consumption, lighting, water heating, air conditioning, space heating, refrigeration, and always on.

The 1st part of the study has analysed the relationship between consumers' behaviour within energy efficiency in particular consumption categories and the demography factor of age. We attempted to confirm Hypothesis 1 stating, that there are differences in the behaviour of consumers related to energy efficiency within particular consumption categories due to the demographic factor of age.

The Null Hypothesis: There is no dependency between the variable of age and the amount of electricity consumption, was measured by employing the linear relation between the two scale variables.

The Pearson Correlation Coefficient was used [28] and according to its values presented in Table, the Null Hypothesis was rejected and the alternative Hypothesis on the dependency between variables was confirmed.

 

**Table 4.1.** Test of dependency between consumptions within categories and age

| Consumption category | Pearson Correlation coefficient | p-value | alpha | Hypothesis | Result |
|---|---|---|---|---|---|
| Space Heating | -0.11266 | <0.001 | 0.01 | rejected | Consumption depends on age |
| Refrigeration | 0.09867 | <0.001 | 0.01 | rejected | Consumption depends on age |
| Air Conditioning | -0.07248 | 4.16E-67 | 0.01 | rejected | Consumption depends on age |
| Lighting | 0.05971 | <0.001 | 0.01 | rejected | Consumption depends on age |
| Always On | 0.01983 | 1.96E-3 | 0.01 | rejected | Consumption depends on age |
| Water Heating | - | 1.46E-01 | 0.01 | not rejected | Consumption DOES NOT depend on age |
| Pool | - | 1.22E-01 | 0.01 | not rejected | Consumption DOES NOT depend on age |

The results show the negative linear relationship between age and amount of electricity consumption in the categories of Space Heating and Air Conditioning, which are among 3 categories with the highest average level of consumption.

Space Heating is the first, followed by Refrigeration and Air Conditioning. Water Heating and Pool are on a very similar level and there is not dependence on age. These two categories differ in terms of consumers' perception of necessity. Water heating is in Central European climate conditions closer to basic needs in comparison to Air Conditioning, which is considered to be an appliance providing extra comfort. The tendency of spending less electricity in the categories with the highest average level of consumption suggests higher cost sensitivity with the increasing age of consumers.

The results on categories related to physical presence in the property such as lightning or always on show the positive linear relationship between age and the amount of electricity consumption. It reflects the more active lifestyle of younger categories, on the other hand, lightning and always on belong to the categories with the lowest average consumption and therefore lowest impact on the cost of electricity consumption.

In the 2nd part of the study, we've attempted to extract more detailed insight into consumers' behaviour, which would support the potential of energy efficiency initiatives by improved targeting. Therefore, we've compared the areas with more and less significant differences in consumption behaviour. Consumption areas, where obvious differences in consumption have occurred among age and location categories, are dependent on the amount of time that residents spend in the household.

To achieve a higher tangibility of the results, the differences in selected cases are presented in euros. As appliances' consumption varies based on their energy class or model, the middle values were applied. The price in the table is the maximum commodity price for the households in Slovakia for the year 2022, set by the State regulatory authority. The price in the table does not include the fixed cost related to electricity supply e.g. distribution fees.

**Table 4.2.** The average electricity consumption of appliances and price in Slovakia for 2022

| Appliance | Average electricity consumption (kWh)* | Cost to use per hour (EUR) | Electricity cost per kWh (commodity cost)** |
|---|---|---|---|
| Fridge with freezer | 0,3 | 0,0183 | |
| Washing machine | 2 | 0,122 | |
| Dishwasher | 1,25 | 0,07625 | |
| LCD TV | 0,16 | 0,00976 | 0,061 kWh |
| Air conditioning | 3,5 | 0,2135 | |
| LED bulb 60 W | 0,01 | 0,00061 | |
| Water heater | 2 | 0,122 | |

We have visualized the results through the following figures exported from pivot tables.

 

***Total consumption***

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 410,8296727 | 338,611025 | 383,832007 | 377,7575681 |
| Middle | 472,7231584 | 439,700794 | 473,22596 | 461,8833039 |
| Older | 463,2863979 | 436,822543 | 445,503892 | 448,537611 |
| **Average value** | **448,9464097** | **405,044787** | **434,187286** | **429,3928277** |

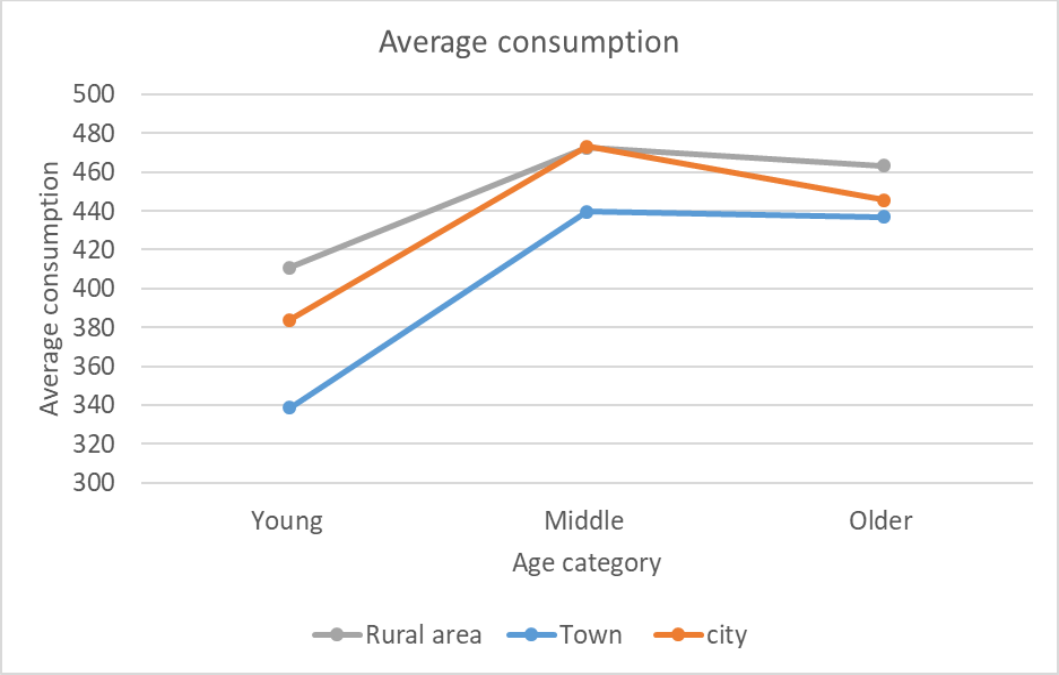


**Fig. 4.1.** Total consumption (kWh)

Consumers in rural areas have the highest average electricity consumption, followed by consumers in the cities. The lowest level of average electricity consumption is observed within the group living in the towns.

- This order applies to categories of young and older consumers. In the category of middle-aged consumers, consumption in rural areas and cities reaches a similar level.
- The highest consumption in all the types of agglomeration relates to middle-aged consumers (35 – 54 years).

***Lighting consumption***

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 27,78205703 | 23,39657635 | 23,56821858 | 24,91561732 |
| Middle | 38,2736304 | 36,68005287 | 34,96266095 | 36,63878141 |
| Older | 39,60238301 | 37,98430817 | 36,71322331 | 38,0999715 |
| **Average value** | **35,21935681** | **32,68697913** | **31,74803428** | **33,21812341** |

 

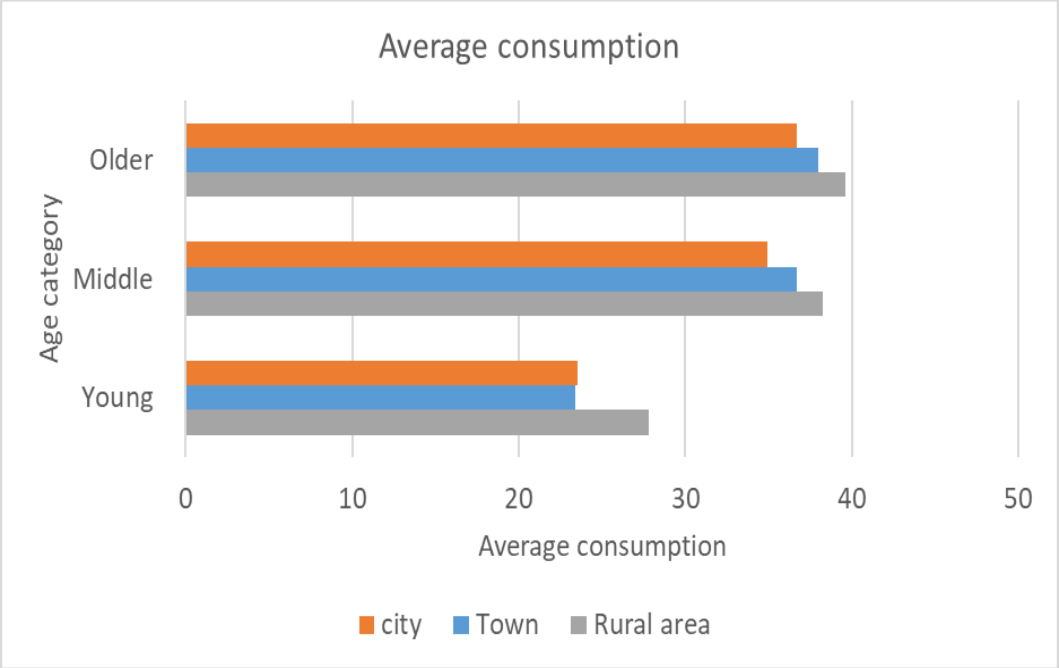


**Fig. 4.2.** Lighting consumption (kWh)

- Electricity consumption on lighting is dependent on the consumer's physical presence on the property.
- In each type of agglomeration, the biggest electricity consumption related to lighting is in the category of consumers aged 55 to 70 years (older), which establishes the dependency on a lifestyle of this category, which spends more time at their homes.
- In all age categories, consumption in rural areas is higher than in towns and cities. The difference reaches 3 to 4 kWh in average monthly consumption when comparing rural areas to cities. To increase the tangibility of the result, the following example would serve:
  - Led bulb consumption: 0,01 kWh
  - Using lamp with 3 lightbulbs: 0,03 kWh
  - 3 – 4 kWh difference in monthly consumption represents 100 hours of lighting monthly or approximately 3 hours daily.
- This supports the claim that different living habits and behavioural routines impact energy consumption. Consumers in bigger agglomerations have easier access to a wider spectre of out-of-home activities, which impacts the amount of their time spent on the property. There is a significant difference between the group of "young" consumers in comparison to categories of "middle" and "older" consumers. It is represented by the amount of 10 – 14 kWh in monthly average consumption, which equals approximately 250 to 500 hours monthly (based on the example above).

***Water heating consumption***

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 124,5838846 | 123,0391415 | 141,5799019 | 129,7343093 |
| Middle | 123,6553438 | 130,463145 | 128,8536727 | 127,6573872 |
| Older | 126,9154341 | 126,821314 | 134,834856 | 129,523868 |
| **Average value** | **125,0515542** | **126,7745335** | **135,0894769** | **128,9718548** |

 

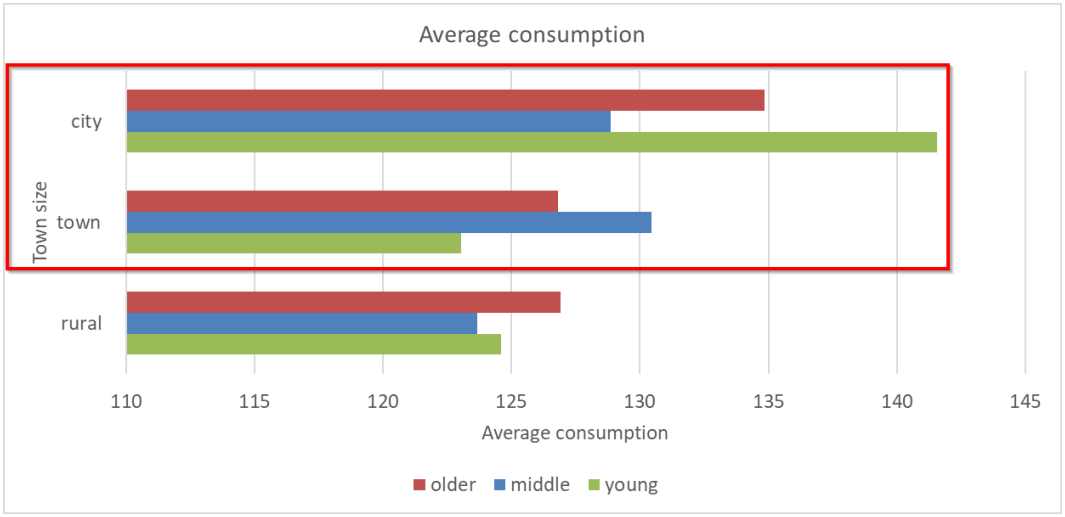


**Fig. 4.3.** Water heating consumption (kWh)

- The average electricity consumption for water heating is on a similar level. in rural areas and towns. It is higher by 7 kWh per month in the cities in comparison to rural areas and towns, but this difference represents heating of approximately 120 liters of hot water which equals, for example, one bathtub, therefore does not reflect the significant difference in consumption behaviour.

### *Air conditioning*

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 112,372785 | 111,3322813 | 109,3141469 | 111,0064044 |
| Middle | 123,3632023 | 127,2176276 | 133,2868927 | 127,9559075 |
| Older | 113,377211 | 121,3758597 | 126,5448923 | 120,4326543 |
| **Average value** | **116,3710661** | **119,9752562** | **123,0486439** | **119,7983221** |

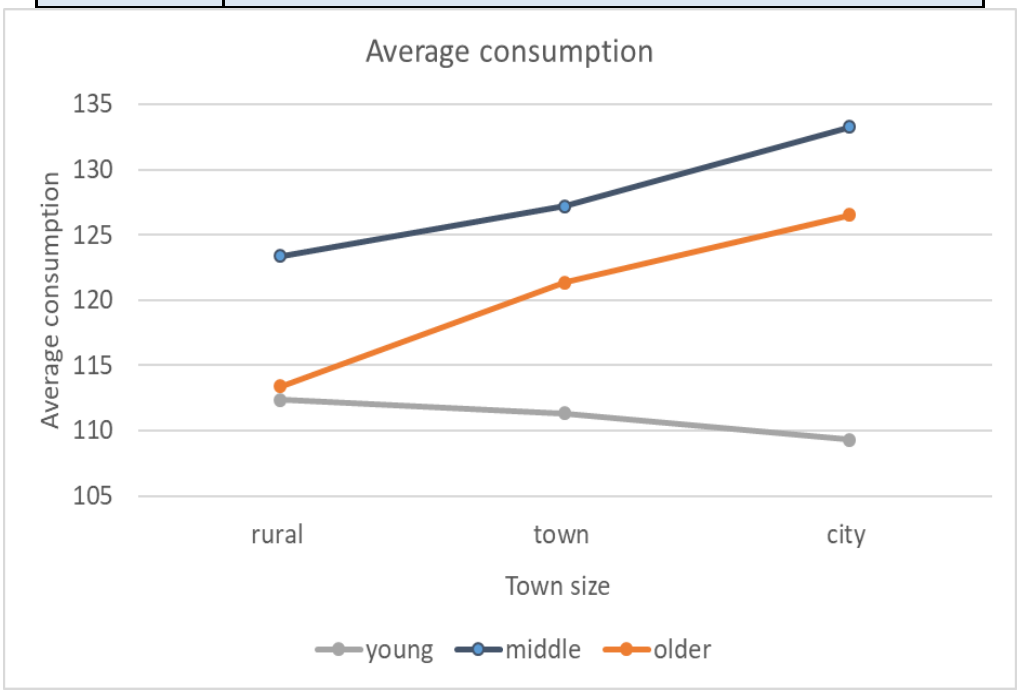


**Fig. 4.4.** Air conditioning consumption (kWh)

 

- The consumption in bigger agglomerations is higher as the temperature there can be up to approximately 2 or 3 times higher than in smaller agglomerations. Also due to air quality, the air ventilation through opening the windows would probably be less intensive.
- The highest consumption occurs in the category of middle-aged customers. Compared to other age categories, it represents the extent of 7 to almost 25 kWh monthly, which equals 2 to 7 hours of air-conditioning usage. The category of young consumers shows the lowest consumption related to air-conditioning with the most obvious differences in towns and cities reaching a difference of 10 to 20 kWh per month.
- This category is related to the amount of time spent at home – in the house, flat; and the results display a similar but less significant trend as the lighting category, where younger consumers in bigger agglomerations trend towards out of home lifestyle.
- Electricity consumption within the category also relates to the amount of money the person is able or willing to invest into her/his comfort and how intense is the discomfort (worse air quality in the bigger city vs. cleaner air and lower temperature in the rural areas). The willingness to spend more on comfort appears to be strongest in the category of middle-aged consumers, who seem to spend more time at home than younger consumers and are probably less cost-sensitive than the category of older consumers.

***Space heating consumption***

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 301,1342769 | 270,8408179 | 363,2576857 | 311,7442602 |
| Middle | 259,378239 | 262,5976718 | 325,4578095 | 282,4779067 |
| Older | 210,3373863 | 212,3748125 | 267,4037899 | 230,0386629 |
| **Average value** | **256,9499674** | **248,6044341** | **318,7064284** | **274,7536099** |

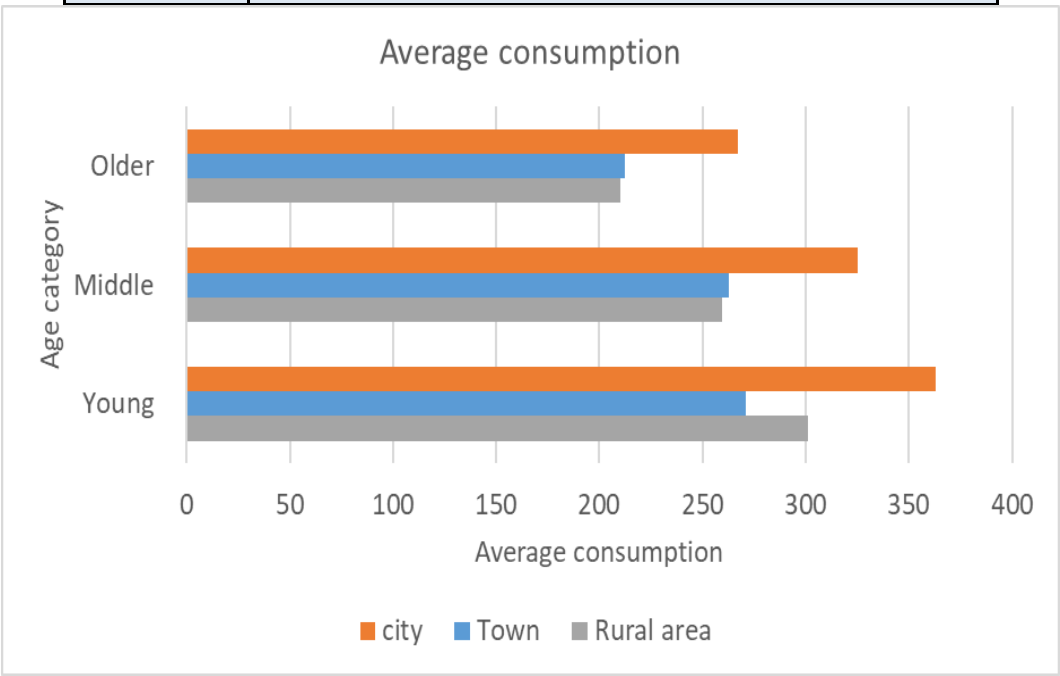


**Fig. 4.5.** Space heating consumption (kWh)

- Significant differences can be observed within different age categories, where there is a trend of younger consumers spending more energy. The difference between young and older consumers regardless of the size of agglomeration reaches approximately 80 kWh per

 

month, which means more than 900 kWh yearly equaling approximately 55 euros yearly (based on max. electricity price in Slovakia for households 0,061 Eur/kWh set for year 2022).

- As for the agglomeration categories, the most significant difference appears in the cities, where the average monthly consumption on space heating is approximately 60 kWh higher in comparison to rural areas and towns. The effect can be caused by a stronger tendency to combine electricity with wood as a fuel for space heating.
- This category is not related to the physical presence of a consumer in the household as it is in the case of for example lighting or air conditioning. Consumption related to space heating is more dependent on the financial effect on the consumer and her/his comfort. "I want to be warm, and I can pay for it". The group of people preferring lower temperatures at home due to the positive health effects or as a part of their lifestyle that includes winterization is still a minority. Another aspect of higher consumption within the young category would be the presence of small children and providing them with a comfortable environment.
- The consumption in the category of middle-aged consumers is closer to young consumers, they spend monthly approximately 30 kWh less than young customers. In comparison to older consumers, the middle-aged category spends monthly approximately 50 kWh more.
- In case of the middle-aged customers, the incentive towards this type of behaviour can be higher motivation for financial effectivity than in the category of younger consumers. The reason for prioritizing the financial effectiveness can come from the principle of not spending more than needed, but not at any cost as there is probably a lower willingness to decrease own comfort as in the case of older customers, where the energy bill needs to be controlled due to lower-income related to the retirement period.

### *Refrigeration consumption*

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 32,86679155 | 29,99534424 | 31,44946436 | 31,43720005 |
| Middle | 37,40352933 | 35,70179346 | 34,35879422 | 35,82137234 |
| Older | 39,85576864 | 38,22623818 | 37,2992759 | 38,46042757 |
| **Average value** | **36,70869651** | **34,64112529** | **34,36917816** | **35,23966665** |

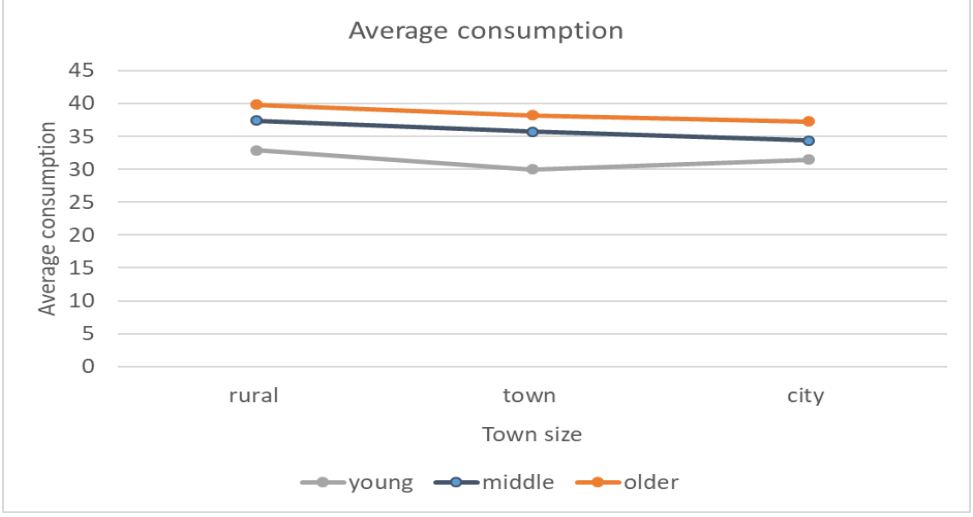


**Fig. 4.6.** Refrigeration consumption (kWh)

- The biggest difference appears between categories of older consumers in rural areas vs. young consumers in the towns. It is 10 kWh per month, which exceeds the yearly consumption of one A category refrigerator including the freezing section (approx. 110 kWh).
- The overall results indicate that:
  - these consumers have inefficient appliances (lower energy class);
  - at least 2 appliances – separate refrigerator and freezer (e.g. highest consumption occurs in the category of older-aged consumers in rural areas. The reason could be the intention to store special meet purchased from farmers, which are sold in bigger amounts, or to store the bigger amount of food and decrease the frequency of shopping, which influences the need for mobility and traveling to the nearby cities and costs some amount of time.);
  - their behaviour in the area of electricity consumption related to refrigeration is ineffective, probably due to low knowledge of efficient habits.

***Always – on***

| Average | Agglomeration category | | | |
|---|---|---|---|---|
| **Age category** | **Rural area** | **Town** | **City** | **Average value** |
| Young | 56,67039872 | 52,71637142 | 55,31790336 | 54,90155783 |
| Middle | 76,11951268 | 79,89100522 | 89,40651329 | 81,80567706 |
| Older | 80,72345299 | 87,25934023 | 98,02581712 | 88,66953678 |
| **Average value** | **71,17112147** | **73,28890562** | **80,91674459** | **75,12559056** |

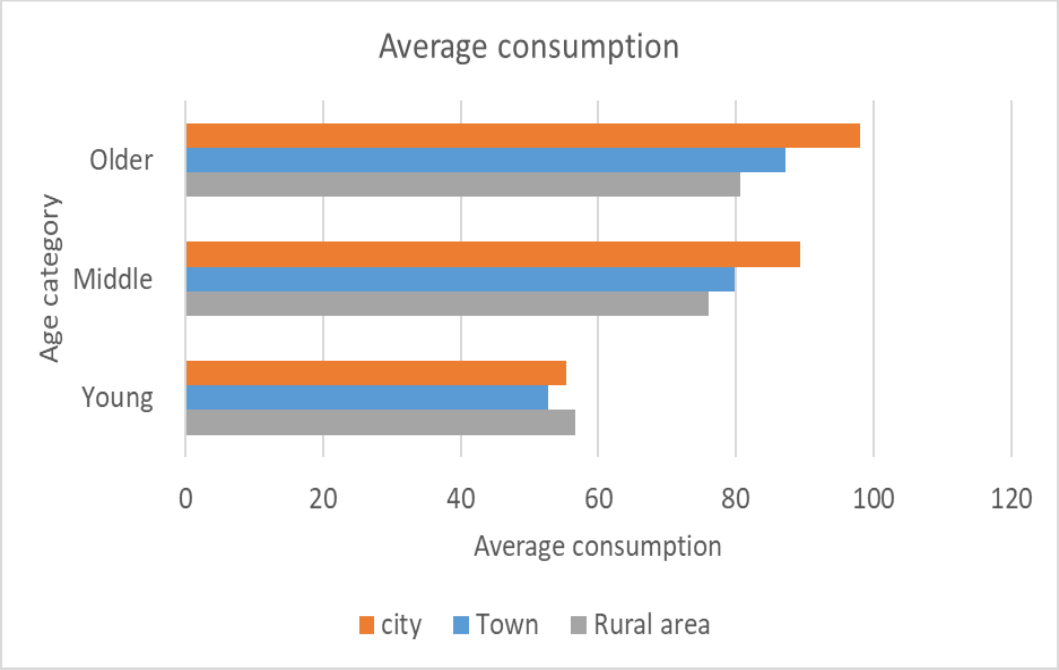


**Fig. 4.7.** Always – on consumption (kWh).

- Older aged consumers spend the most electricity within this category. The reason is probably they spend more time at home, which is observed in the category of lighting as well.
- Older consumers spend over 30 kWh more than the young-aged category, and middle-aged have the consumption higher by 25 kWh more than the young. At the consumption level of for example LCD TV, which is 0,16 kWh, the 25-kWh difference represents over 150 hours of watching TV.
- From the comfort point of view, the older people seem to prefer always on or entertainment appliances to higher temperatures and they tend to focus their energy-saving

 

activity more on heating, which generates multiple times higher costs than always on appliances.

- From the agglomeration size point of view, the level of consumption is similar in the category of young consumers. More obvious differences appear in middle-aged and older consumers, where the consumption of middle-aged consumers and older consumers rises with the size of agglomeration. Even though the category is related to consumers' presence in the household, it doesn't show the trends in lighting and air conditioning, where the consumption is lower in sizeable agglomerations with more opportunities for out of home activities. The reason would be, that the always on category includes more appliances therefore the average consumption is impacted by the number of always on appliances present on the property.

## 5. LIMITATIONS

Our current research has been accompanied by a few limitations, that need to be taken into account in the application of the results:

- The research confirms different patterns in behaviour in consumption related to age and size agglomeration, but further research to confirm the triggers causing differences in electricity consumption patterns is needed to reveal various motivators, which would be addressed to activate these groups of consumers in decreasing the level of consumption.
- For the further use of these results, we would like to point out, that we have worked with average values, which do not reflect the seasonality of energy consumption. But still, it hasn't been relevant in our study focusing on the long-term trend.
- The level of energy consumption and efficiency is a complex topic influenced by a group of factors. We focused on the impact of a tool based on behavioural principles and our study reflects the insight that energy consumption is highly influenced by climate as well as dwelling conditions, therefore we recommend the practical implementation of the results mainly in the Central European Region.
- We are also aware that the intrapersonal factor of "age" itself should not be considered a sufficient parameter to evaluate or predict customers' behaviour within household management, and consequently to improve targeting. But it is an easily accessible and precise type of data about consumers.

## 6. CONCLUSION AND PRACTICAL IMPLICATIONS

Among the most aggressive originators of environmental deterioration is electricity production by burning fossil fuels. Cutting down electricity consumption is a tough challenge during the period of the human race's existence, when electricity has become a candidate with the potential to revolutionize items in Maslow's pyramid. A relevant group of energy consumers are households as they are the source of more than half of the carbon dioxide emissions. Therefore, numerous initiatives have been established to address the problem.

Along with the initiatives to increase the level of energy produced by renewable resources, energy conservation, and energy efficiency are priorities for governments worldwide. They have motivated intensive research over the past decade into understanding how energy is consumed, and how to translate the knowledge into meaningful information to enable energy consumers to take responsibility over their energy consumption [31]. Strategies for realizing potential savings rely on informed decisions and rational actions of the consumers. Unfortunately, studies reveal existence of several economic, technological, and organizational barriers, that influence the level of consumer awareness and knowledge. Therefore, such strategies result in poor implementation rates of energy efficiency measures. [18].

 

To achieve the desired result, which is a sustainable behavioural change leading to permanent decrease in electricity consumption, a mastered mix of relevant information in an easily perceivable shape combined with effective tools grabbing the attention of households needs to be created. As targeting is the most influential factor, when it comes to the success of the communication campaigns, knowledge of consumers' desires or barriers to performing desired behaviour and actions is a topic of high relevancy.

The household segment is especially challenging due to its size and variability in habits or behaviour within household management. Energy consumption is influenced by the characteristics as for example the number of occupants and their age; type of occupants as consumption of households where there are no children or where couples work, consume energy differently than households with small children or older people. These characteristics multiply the level of difficulty in attempts to understand the energy consumers' behaviour and consequently increase the difficulty in addressing them successfully in an attempt to improve their energy efficiency.

The first part of this study concludes that age provides numerous insights into household lifestyle resulting in differences in electricity consumption. The outputs show both positive and negative linear relationships between age and amount of electricity consumption in the examined categories. The tendency of spending less electricity in the categories with the highest average level of consumption suggests higher cost sensitivity with the increasing age of consumers. The results on categories related to physical presence in the property such as lightning or always on, show the positive linear relationship between age and the amount of electricity consumption. It reflects the more active lifestyle of younger categories, on the other hand, lightning and always on belong to the categories with the lowest average consumption and therefore lowest impact on the cost of electricity consumption.

The second part of the study pointed at extracting more detailed insight into consumers' behaviour, which would support the potential of energy efficiency initiatives by improved targeting. It specifically dealt with the place of living as one of the causes of different behaviour in electricity consumption combined with the factor of aging as a reflection of lifestyle. The results have revealed possible significant inefficiency in the area of refrigeration, showed non-essential differences in the areas of air conditioning and water heating, and provided detail on relevant differences in consumption within lighting, always on, and space heating.

Disaggregation provides valuable insights for the improvement of energy efficiency campaigns and makes them applicable to the mass market as they scale to thousands or millions of customers with little additional effort. Energy efficiency appears to be a contra-productive activity to utility companies at first sight. But on the other hand, it reflects the already ongoing trend of digitalization and decentralization, which enables the expansion of the Peer-to-Peer (P2P) model within the energy market and makes end-users less dependent on utility suppliers. This probably leads to the same impact as Airbnb or Uber models have had on the accommodation or taxi sector, by creating a highly competitive way of satisfying related customer needs by cutting down costs, especially intermediary ones. Technologies allow this trend to enter the energy sector and develop pressure on energy companies' transformation and force them to search for new sources of income reflecting the needs of customers. One way is to transfer the income from the electricity supply to other energy-related services and products. Among the key preconditions of success is image and reputation, therefore proving it via consultancy and advice on energy efficiency within households appears as an effective option. [30].

More detailed information on customers also supports the improvement of customer retention, which is becoming more relevant in a liberalized energy market [30]. Utilities benefit from customer insights, which can they reveal using the proposed system to estimate household characteristics. The same information that helps to make energy-saving campaigns more effective, can help market products and services more successfully. The latter includes

 

identifying target households for specific offerings, e.g., promoting solar panels only to mid to high-income customers who live in a house rather than in an apartment and offering green tariffs preferentially to families with young children. The revealed household characteristics might also help to lower the cost of efficiency campaigns by targeting households with high potentials such as those that show a mismatch between household characteristics and energy demand. Other possible actions include tailoring behavioural campaigns with a strong presence of the crowdfunding principle, where every kilowatt-hour counts as a small change multiplied by 8 billion humans would make a change.

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