WEATHER IMPACT ON THE HOUSEHOLD ELECTRIC ENERGY CONSUMPTION

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Abstract
The aim of the article is to ascertain the interaction between weather conditions and electric energy consumption in the Latvia household. The electric energy consumption data in the Saurieši village, Riga region, Latvia, for the year 2012 were collected, and the climate data for the same period including the duration of the sun-shine, ambient air temperature, precipitation intensity, and wind speed were obtained. The research hypothesis that there is strong relation between weather conditions and electric energy consumption was proved partially – there is rather strong correlation between household electric energy consumption and air temperature (r = 0.91), and medium correlation between household electric energy consumption and precipitation (r = 0.61), as well as between household electric energy consumption and duration of the sunshine (r = 0.67).
Correlation found between weather conditions and electric energy consumption in the household allows to forecast the trends in energy consumption based on weather measurements, and even to use the weather forecasts for electric energy future demand trends development. The equations developed explain the household energy consumption patterns in Latvia with its geographical location and economic conditions, but the methodology developed can be applied for any region if necessary data are available.
Key words: electric energy consumption, weather impact, ambient air temperature, duration of sunshine, precipitation, wind speed, seasonal changes.

Introduction

New electric energy supply line development is rather complicated task, because of several factors influencing the final decision. One of them is electric power consumption regularity – if power consumption fluctuates, the electricity supply line must be established at the maximum power level. The main question for power line designer is – when to acquire the energy consumption data which will be used for the calculations. The same problem arises for electric energy producer – it would be nice to have possibility to forecast electricity consumption beforehand. In order to ease the life for both electric net designers and electricity suppliers, it was decided to find out, how the weather conditions influence the power consumption. If there is a clear trend observed, then this relation can be used for power consumption forecasts.

Common sense tells us that electric appliances use is somehow – directly or indirectly, linked to external conditions, especially to the weather conditions outside of a human being living space. One can call electricity as the supplier of the comfort in the household, because almost all devices used in the kitchen, living room or bedroom (lighting appliances – lamps, communication devices – phones, computers with internet connection, entertainment devices – TV and radio sets, processing devices – mixers, microwave and convenient ovens, grinders and cookers, etc.) use electric power, and they increase comfort level. At the same time current living standards state that lack of these devices will be recognized as discomfort, and almost inappropriate conditions for living.

Geographic location on the globe sets specific conditions for weather – there are countries and states, where the average annual temperatures are well above 0 °C, at the same time large part of mankind is living in the conditions where there are four different seasons – dark winter, which is cold and snowy, spring with rising temperatures and high precipitation, sunny, dry and rather hot summer, and windy and wet autumn. These conditions lead to different patterns in electric appliances use in household, which could be revealed.

If trends in electric energy use have substantial correlation with weather conditions, this can help electric energy suppliers and producers to forecast consumption, and thus organize and manage production of electric energy, which at the end will lead to much more stability in energy supply.

Previous research (Jakusenoks & Laizans, 2015b) substantially raising the electric energy consumption in private sector. On other hand, serious technological developments like luminescent (fluorescent also revealed that the number and variety of electric appliances used in Latvia household have been increasing substantially within the last decade, which leads to serious changes in electricity supply grid operation quality and efficiency. Power factor is particularly affected by this trend, and any result which could support energy consumption forecasting would also lead to more efficient quality management in the electric grid.

Current power factor forecasting model developed (Jakusenoks & Laizans, 2015)and the research revealed that the power factor there has visually recognizable repeated daily (day/night allows to describe the dependence of power factor from the time period during the year only by 86 %. If substantial correlation with other factors besides date in the calendar will be revealed, the power factor forecasting quality could also be improved.

Human behavior is being affected by seasonality - if it is cold and dark, people will rather stay home, and use lot of energy to provide heat and light (inside and outside lights – to reduce darkness depression). Rainy and windy conditions can also increase household energy consumption – because of drying and house heating needs. While staying at home people will more extensively use local entertainment devices (TV, radio, etc.,) and use kitchen appliances to prepare food and drinks. As the opposite – when days are sunny and hot, people tend to get out of their houses, and try to spend as much as possible time having rest near water.

Research shows that people feel comfortably when the room temperature is 19 – 22 °C (winter period) and 22 – 25 °C (summer period) – values established by bioenergetics processes in the human body and thermodynamic heat exchange between the human body and external environment (Dwyer, 2007). The temperature level, which is recognized by human body as neither cold nor hot, is 23 – 24 °C, (‘Human Comfort and Health Requirements,’ n.d.).

Extensive use of electric ovens is one of the reasons for substantial increase in household electric energy consumption – data of Latvia Central Statistic Bureau for 2010 show that electric ovens and other food processing appliances (18.7% of all electric devices used at home) consumed 11.4% from total annual household electric energy (Latvia Central Statistical Bureau, n.d.-a), but 79.5% of electric energy were used to produce comfortable temperature at home – for heating and conditioning (‘Types of energy resource consumption (%),’ n.d.).

Materials and Methods

The research and data collection took place in Latvia – a country with wide set of weather conditions, which is growing its electric energy consumption in the household sector, but still is rather far from EU average annual electric energy consumption, because of economic conditions.

The research object chosen was the village Saurieši, which is located in Riga county, Latvia. This village is a private individual and multistore house area, inhabited by people working nearby and in Riga city. Economic conditions of the inhabitants are rather homogenous, with above-the-average income and medium class living conditions, which have also a particular set of household electric appliances.

Some of common features for this environment are the following:

- Set of electric appliances rather homogenous;
- There is a variety of house design used in Saurieši, and the insulation/heat losses level fluctuates from house to house substantially;
- No particular household behavior trends are recognized in Saurieši;
- Although this might be the fact that different people have different comfort settings, the average behavior trends do not differ from the behavior of people from other Latvia regions with similar economic conditions too much;
- Results revealed can be adapted to the energy consumption trends in other villages in the countryside of Latvia.

Electric energy consumption data for the village Saurieši were collected from the commercial electric energy measuring and counting device belonging to

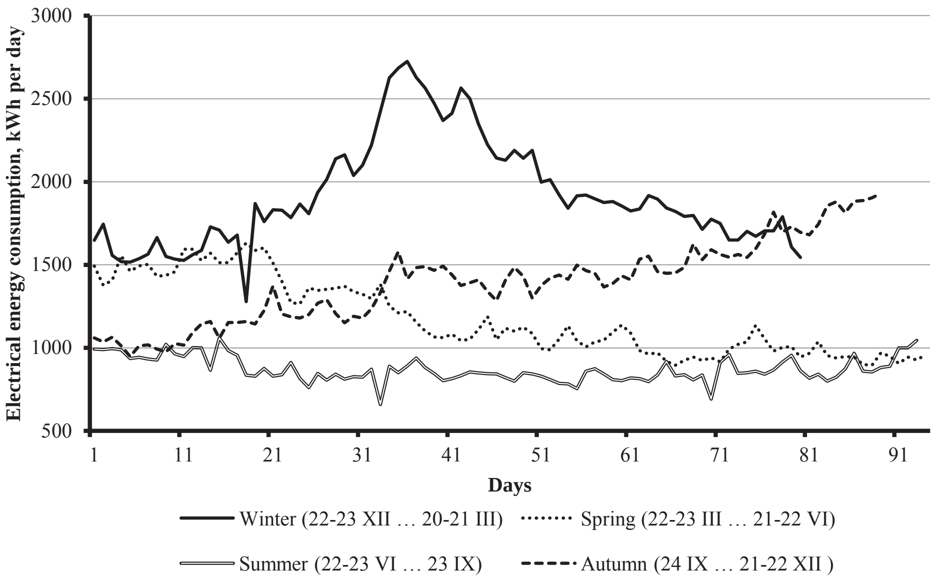

Figure 1. Electrical energy consumption in calendar seasons.

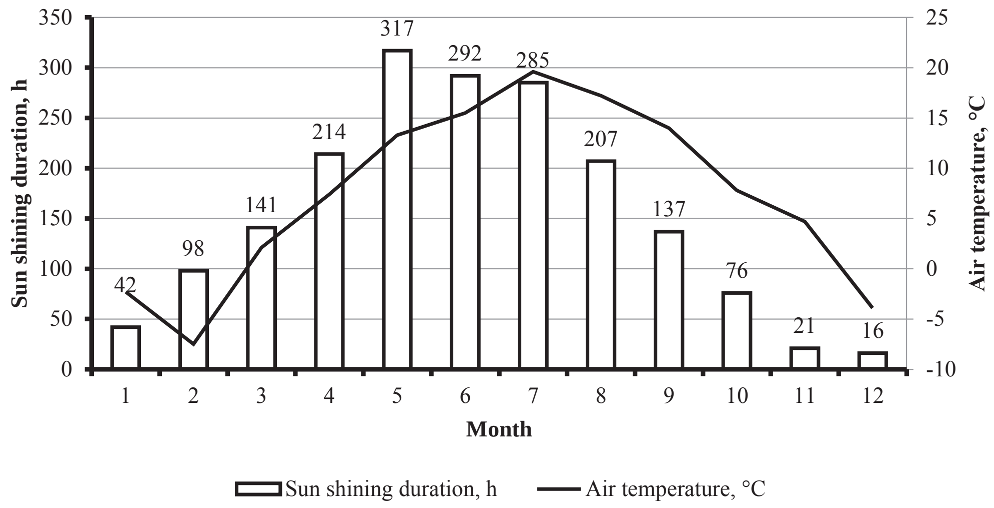

Figure 2. Sunshine duration and air temperature monthly data, 2012.

JSC 'Sadales tīkls' using the automatic electric energy counting system and particular data reading and collecting device. Electric energy consumption data with time step 10 minutes were obtained.

Weather data (monthly air temperature, precipitation, sun shining time, and air moisture content) for the year 2012 were used in this research, because the available weather conditions were available for this year (Latvia Central Statistical Bureau, n.d.-b).

Results and Discussion

Electric energy consumption data were divided in four parts based on annual seasonality ('Gadskartas (Anniversary),' n.d.) – spring, summer, fall and winter (Fig.1). Visual graphical data analysis revealed that there is a substantial difference in energy consumption between these time periods. Also, colder the season, more electric energy consumption took place in the village Saurieši.

Weather data obtained were presented graphically in order to make visual observation of trend and correlation presence between different weather conditions. Monthly based sun shining duration and air temperature is presented in Fig. 2, showing common trends of temperature and sunshine over the year.

Statistical analysis revealed rather strong positive correlation, which was calculated for these two variables - r = 0.76, which means that 76% of air temperature changes can be described by the sunshine duration at a particular month of the year (Table 1). As the Sun is the main energy supplier to the Earth in general, this positive correlation makes sense. Variations in this relation can be described by local temperature changes due to air mass movement from North and South.

Average (medium strong) negative correlation (r = -0.617) was revealed between air temperature and precipitation intensity. This can be described by the fact that snowfalls take place at temperatures below zero, and strong rains – in spring and fall, as well as in summer, so this could not be revealed by statistical analysis as a positive relation between temperature and precipitation.

Table 1

Weather data and electrical consumption data correlation

	Electrical energy consumption, kWh per month	Air temperature, °C	Precipitation, monthly sum, mm	Sun shining duration, monthly sum, h
Electrical energy consumption, kWh per month	1			
Air temperature, °C	-0.875	1		
Precipitation, monthly sum, mm	-0.617	0.609	1	
Sun shining duration, monthly sum, h	-0.670	0.755	0.210	1

Medium strong negative correlation (r = -0.57) was revealed between air temperature and relative air humidity – with increase in air temperature air humidity decreases (result not included in Table 1). This is usual condition in Latvia in summer, but this correlation does not describe the air humidity decrease in cold winter days, so this relation should be researched more deeply, and was not analyzed further in this article. The same was found for wind speed and electric energy consumption in the household.

The trend-line describing the relation between sunshine duration and ambient air temperature is presented in Fig. 3. This is linear regression – with the increase in sunshine duration ambient air temperature increases.

Monthly changes in electric energy consumption and air temperature (Latvijas vides, geologijas un meteorologijas centrs (Latvian Environment, n.d.) are presented in Fig.4. Visual analysis reveals negative correlation, and statistical data analysis proves this hypothesis - r = -0.875, showing a strong negative correlation.

Trend line and the equation describing electric energy change based on air temperature change is presented in Fig.5.

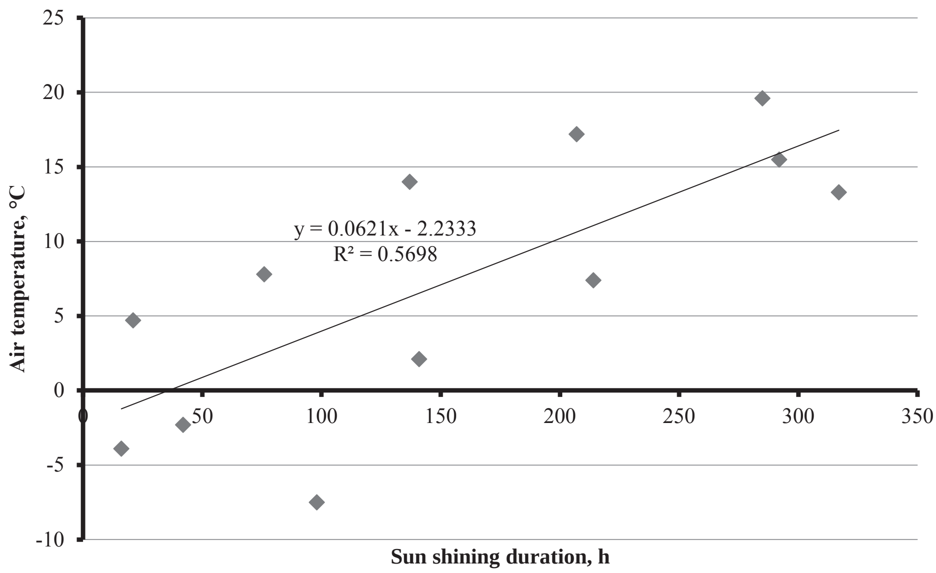

Figure 3. Sunshine duration and air temperature month data correlation.

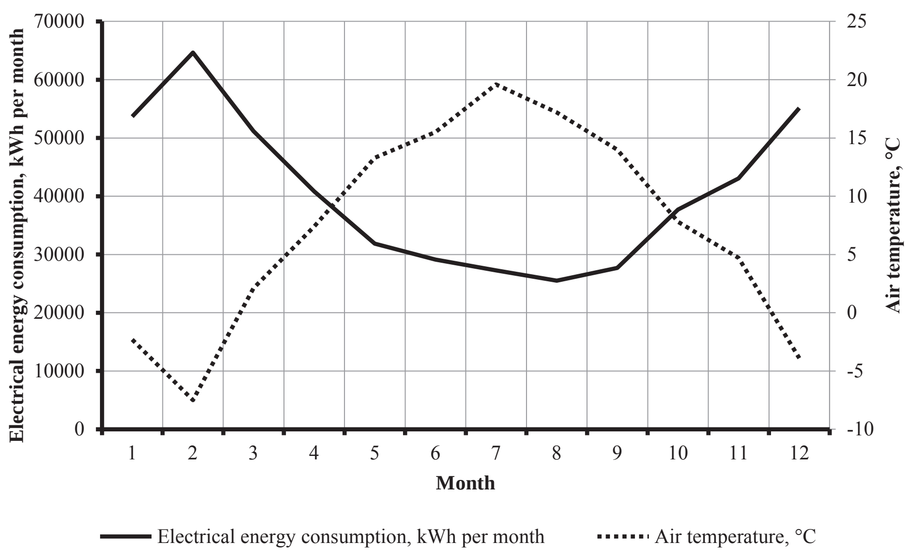

Figure 4. Ambient air temperature and electrical energy consumption monthly trends, 2012.

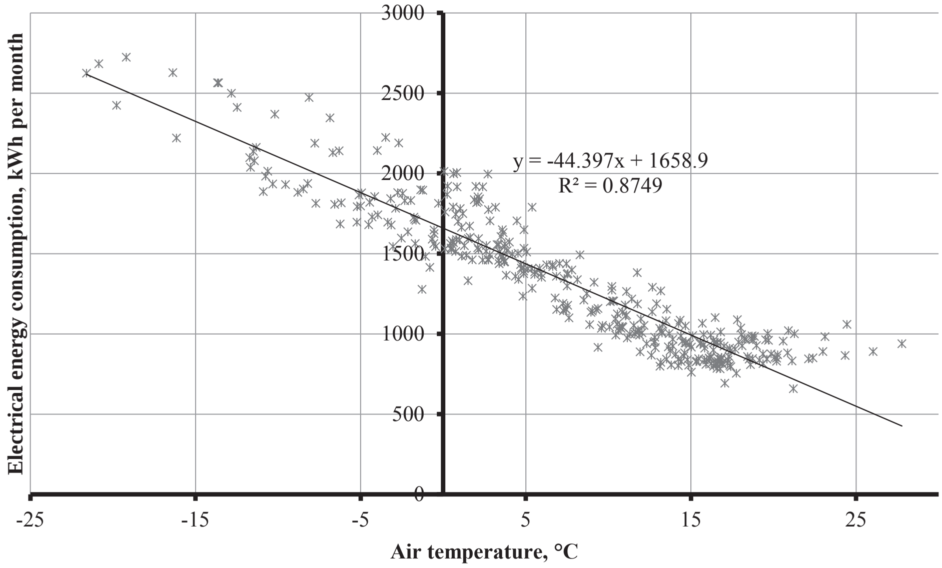

Figure 5. Electric energy consumption and average air temperature data correlation, 2012.

Monthly changes in electric energy consumption and monthly sunshine duration are presented in Fig. 6.

Visual analysis reveals negative correlation, and statistical data analysis proves this hypothesis - r = -0.670 – the correlation is medium to strong. As this variable has lower correlation with electric energy consumption, and both air temperature and sun shining duration are related, showing positive correlation, only the one – the strongest correlation showing variable, can be used for the model development. In this case ambient air temperature substantially better describes the electric energy consumption trends in household in Saurieši village.

As a result, mathematic model of village Saurieši electric energy consumption dependence on ambient air temperature can be described by the linear regression formula 1:

$$E = 1658.9 - 44.397 \cdot T, \qquad (1)$$

where E – energy consumption, kWh · month^{-1};
T – temperature, °C.

In order to use this model, the ambient air temperature forecast results can be used.

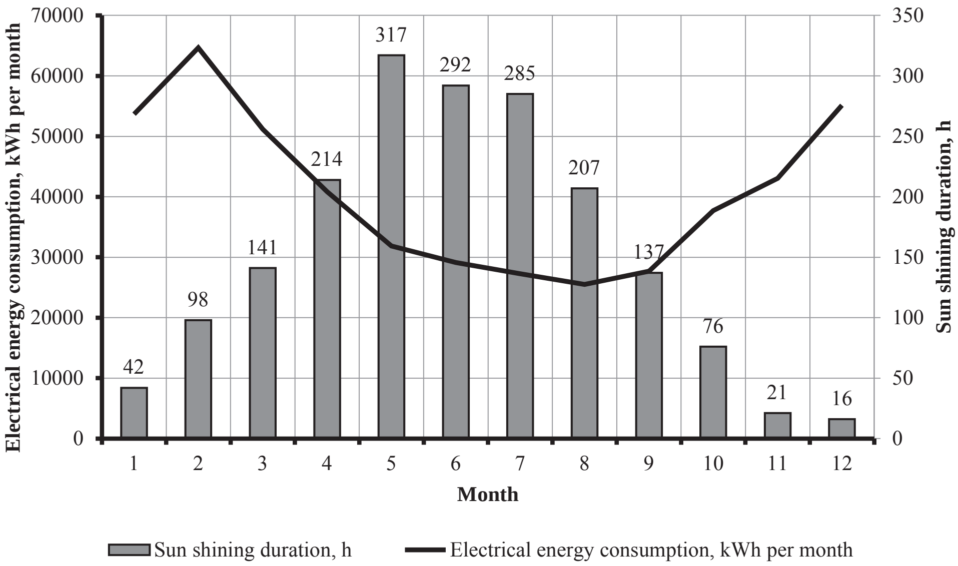

Figure 6. Sunshine duration and electrical energy consumption monthly data.

Conclusions

- Annual electric energy consumption data splitting by seasons showed significant difference in household electric energy consumption.
- Statistically significant evidence was revealed that the electric energy consumption in household is affected by weather conditions:
  - It is possible to forecast the electric energy consumption using ambient air temperature – the model explains 87.5% of variation;
  - Sunshine duration data can explain 67% of household electric energy consumption variations.
  - At the same time there is a strong correlation (r = 0.755) between sunshine duration and ambient air temperature, the model developed should include only one variable – the one with the strongest impact;
  - Precipitation intensity and wind speed have substantially smaller impact on electric energy consumption – more information is needed to include these weather conditions in the model.
- Electric energy consumption and weather data from more places and for longer time must be collected in order to improve model validity.

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