Models of individual consumers load versus standard profiles; MS Excel – aided study

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In the paper, the results of comparative analysis for electrical energy consumption by the household group individual consumers settled according to the G (LV) tariff and the standard profiles elaborated PTPiREE are reported. In analysis, the special tailored IT tool using the MS Excel has been applied.

1. Introduction

Since the introduction of the TPA rule to the retail market (individual consumers), the approach to the electrical energy market has significantly changed. The tracking of the yearly cycle of energy consumption by individual consumers became a figure of merit and the standard profile of electrical load has been constructed referring to the observations [1].

A new born (in July, 2007) electrical energy market in Poland at the level of the consumer fed on the LV side shows that the energy consumption measuring data for former years is missing [2]. Thanks to the works on the data acquisition, saving and processing conducted by PTPiREE (*Polish Association for Electrical Energy Transmission and Dispatch - Polskie Towarzystwo Przesyłu i Rozdziału Energii Elektrycznej*), a catalogue of the electric energy consumers' characteristics has been developed and the standard profiles (for consumers with defined features) have been constructed [3].

When constructing the standard profiles, a definition of the proper number/list of the consumer groups, i.e. the proper number of standard profiles for a specific consumer type (for example, the consumers included into the household group settled acc. to the G tariff) is an important task. To accomplish the task, a high number of the load profiles of individual consumers with various features has to be acquired and adequate analyses are to be carried out. The main goal of the research is to indicate the groups of consumers with strongly diverse graphs. For this task, the investigation and determination of the impact of the substantial factors on the load graphs in specific groups as well as on the difference between them are helpful.

In the paper, the chosen results from analysis of the load graphs for individual consumers settled according to the G tariff as well as those for two standard profiles developed by *PTPiREE* for such consumer type are reported. The research

aims to evaluate the mentioned profiles and to indicate the reasons of the would-be discrepancies between the standard profiles and the load graphs for consumers encountered by the specific profiles.

Regarding the great number of consumers and the wide scope of research, a specific tailored IT tool (Excel spreadsheet) has been developed to accomplish the task as described above [4].

2. Tested consumer's characteristics

Division and the most important features of the individual consumers groups covered by the study are presented in Table 1 [5, 6].

Table 1. Characteristics of the consumer groups under consideration

Tariff group	Consumer localization	Electric heating of rooms	Electric heating of running water	Group name
G11	City	No	No	**G11 M1**
G11	Rural			**G11 W1**
G11	City		Yes	**G11 M2**
G11	Rural			**G11 W2**
G12	City	No	No	**G12 M1**
G12		No	Yes	**G12 M2**
G12		Yes	Yes	**G12 M4**

In Table 2, the list of three load profiles for the household-type individual consumers (settled acc. to G tariff) developed by PTPiREE, aggregated by the type of the used electric power tariff and by the type of heating applied in the household are presented.

Table 2. Standard profile acc. to PTPiREE

Profile name	Tariff group	Electric heating
A Profile	G11	No data
B Profile	G12	No
C Profile	G12	Yes

Among the presented standard consumers graphs, the A profile is the most general. The only criterion of the consumer's assignation to the A profile is Tariff group – G11 (single-zone consumers) which the actual consumer belongs to. The analysis has shown that there is neither splitting according to the consumer's administrative localization (town, village) nor according to the water and room heating type (electric, non-electric). Other presented profiles (B, C) have been elaborated for two-zone consumers (G12), and the main criterion of the consumer's assignation to the profile was the water and room heating type (electric, non-

electric). In Table 3, extreme and average values of daily power normalized per one consumer within specific profile groups developed referring to data from 2008 are presented.

Table 3. Extreme and average values of daily power for profiled consumers

		$P_{d\ min}$ kW/consumer	$P_{d\ śr}$ kW/ consumer	$P_{d\ max}$ kW/ consumer
A Profile	MAX	0,490	0,708	0,872
	AVG	0,277	0,450	0,585
	MIN	0,210	0,322	0,396
B Profile	MAX	0,611	0,770	0,986
	AVG	0,378	0,533	0,714
	MIN	0,265	0,426	0,556
C Profile	MAX	1,541	1,894	2,486
	AVG	0,596	0,890	1,241
	MIN	0,213	0,452	0,616

The average values explicitly depend on the group type. The higher level of electric equipment in the group, the higher values of the power.

3. Analysis results – selected examples

3.1. A profile consumers

In Fig. 1 the yearly averaged daily load curves for the consumer groups under consideration as well as their total daily curve (G11 graph) and the daily load curve for the A profile found for working days in 2007 are presented.

On these curves, two specific extreme values appearing between 5 A.M. and 6 A.M.(minimum – morning off-peak period) and 6 P.M. and 10 P.M. (maximum – evening peak) can be perceived. The daily load variability analysis for successive month of the year have shown that in wintertime the evening peak is more evident than in summertime (the curve reaches higher values). Such a rise is related to intensive use of electricity for lighting purposes.

Further investigation of the consumer groups indicated that the morning off-peak appears nearly at the same hours, both in winter and in summer; however, it takes slightly different values for different groups. The times when the extreme daily loads occur are close to each other (T_{dmin} – 5A.M. till 6 A.M., T_{dmax} – 7 P.M. till 10 P.M.).

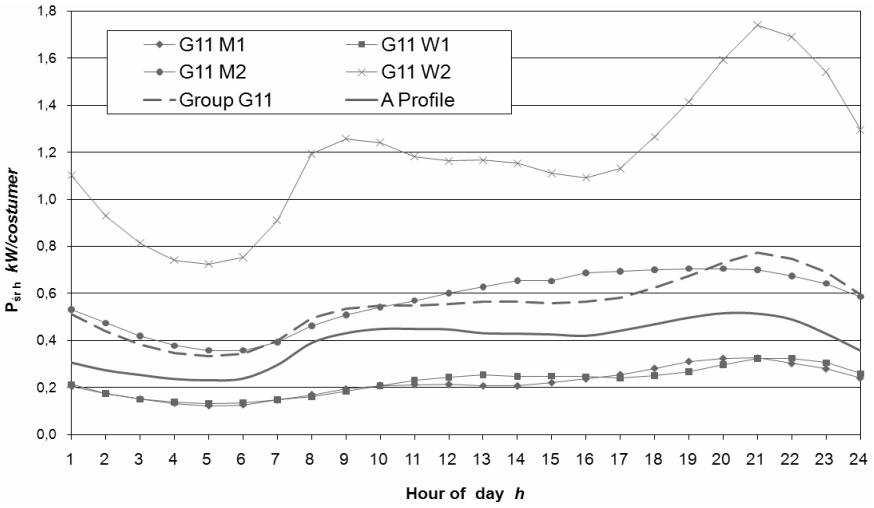


Fig. 1. Daily load variability averaged per year for tested consumer groups

Regarding the A profile construction, the choice of the individual consumers to the group seems to be important. In Fig.1, the total waveform which is the average waveform for the consumers under consideration (Group G11 graph) is shown. In the constructed group, the total waveform is mostly affected by the consumer living in rural area and using the electric water heating (the average daily consumption is twice higher than that in the total waveform).

In Fig. 2, the PTPiREE yearly average of daily load for the A profile which was compulsory in the period 2007-2009 is presented. The curves has been plotted referring to the measuring data for individual customers from the overall area of Poland. The A profile for 2007 and 2008 have been constructed referring to the data acquired from about 600 consumers of electrical energy whilst the profile 2009 – for 700 recorded waveforms. The analysis has shown that the selection of the consumers for an actual profile is rather a random process and can result in the different shape of the curves. Total curve depends on the percentage of the consumers belonging to specific groups (Table1).

Basing on the authors' expertise in the graphs analysis, the conclusion can be drawn that in the case of the G11 tariff group's consumers, the shape of the graph is mostly affected by the sunset time (T_{zach}). Among the consumer groups under consideration, such influence is the most evident by the consumers using the non-electric sources for heating rooms and water [5].

In Fig. 3, the variability of the monthly average power consumption ($P_{m\ śr}$) versus the monthly averaged sunset hour for the , G11 M1 group and the A profile 2007 are compared.

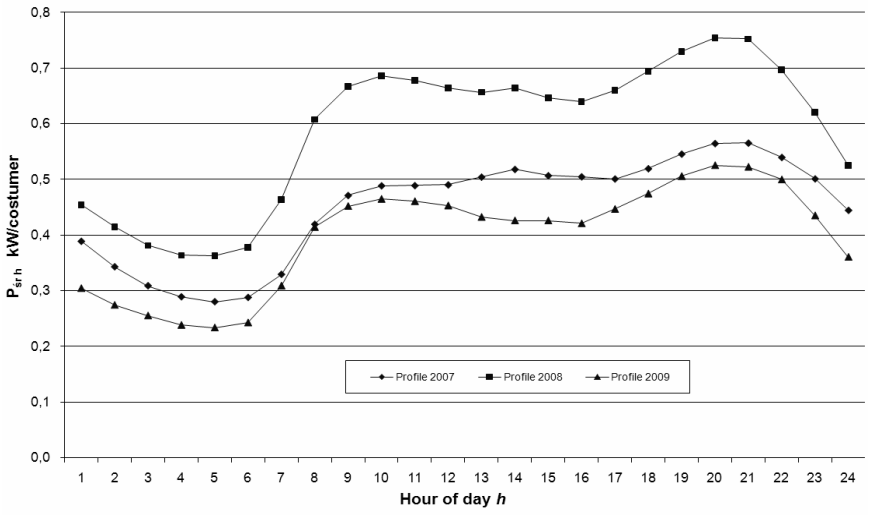


Fig. 2. Yearly average of daily load for A profile worked for 2007-2009

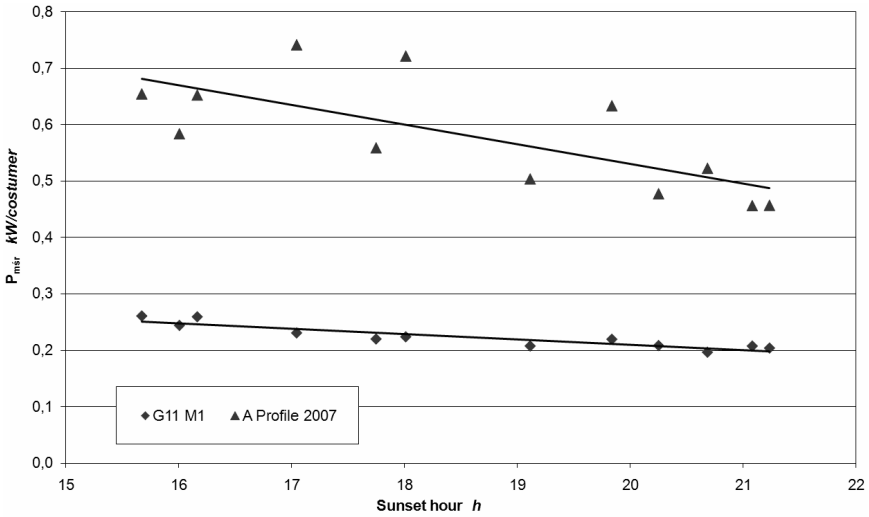


Fig. 3. Variability of the monthly average power consumption *versus* the monthly averaged sunset hour (2006)

The graph for consumers belonging to the G11 M1 group (Fig. 3) can be described by the linear function in the form:

$$P_{śrm} = 0{,}4 - 0{,}01 \cdot T_{zach\ śrm} \tag{1}$$

where $T_{zach\ śrm} \in (15^{42} \div 20^{16})$.

Matching coefficient is relatively high ($R^2 = 0{,}89$).

For the A profile, the relation between the monthly averaged power consumption and the sunset hour is much more weak (R^2 = 0,62) when comparing to the G11 M1 group.

Detailed investigation of the variability of the power load for A profile(2007 – 2009), have shown the light influence of the air temperature ϑ on the value of energy consumed during a daytime. The situation is changing during night time when the profiled consumer can use the completing electrical heating of rooms. The impact of temperature is more explicit when $\vartheta_{śr}$ attains daily the values below 10ºC (Fig. 4).

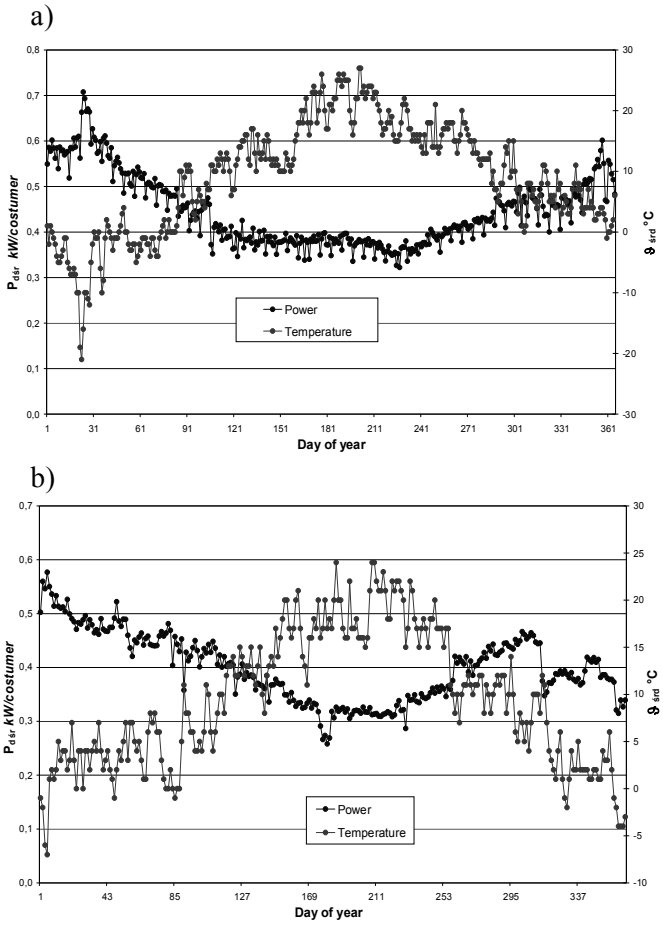
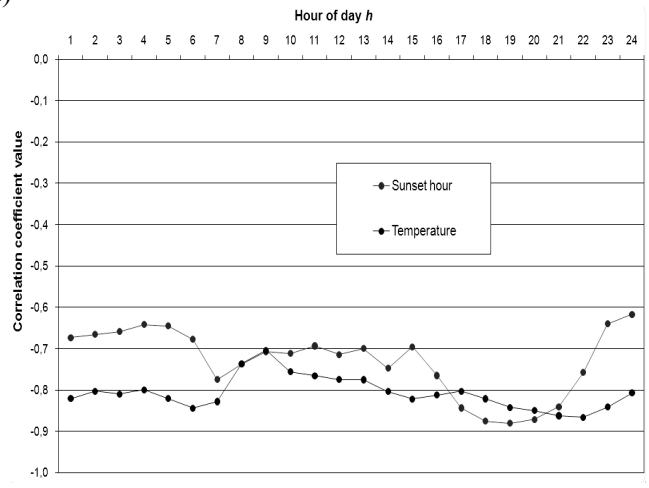


Fig. 4. Annual variability of temperature and average powers for :(a) A profile 2008, (b) A profile 2009

More detailed analysis of the curves shows that the impact of the sunset time and temperature on the A profile load in different years is different. Such conclusion is confirmed by the study of the correlation coefficient between the

hourly power consumptions for 24 hours and the external factors found for years 2007 and 2008 (Fig. 5). There is high correlation between the considered factors (T_{zach}, $\vartheta_{śr}$). The shape of curves for 2008 (Fig. 5a) indicates higher impact of the temperature, whilst in 2009 the explicit impact of the sunset hour can be observed (lighting loads).

a)



b)

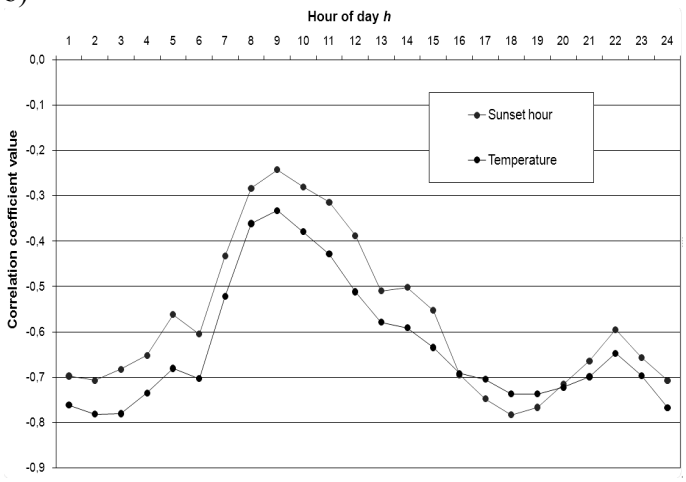


Fig. 5. Variability of correlation coefficient values :(a) A profile 2008, (b) A profile 2009

Impact of the sunset hour on the consumed power is perceptible in after dinner and evening hours when the consumers use the electric lighting.

In sum, the A profile consumers group includes the consumers of diverse specific characteristics and with different external conditions which significantly affect the shape and values of the electric power consumption graphs.

3.2. Consumers included into C profile

The Consumers assigned to the C profile are those settled according to the G12 tariff using the electric heating of rooms and water, like the G12 M4 consumers. The significant impact of the temperature on the consumed power value should be expected

In Fig.6, a case of the annual variability of average load ($P_{dśr}$) and daily average temperature ($\vartheta_{dśr}$) found for working days, C profile 2007 (recording 2006) and the two-zone consumers living in town and using electrical heating of rooms and water (G12 M4) is presented (data for 2006). The characteristics of these groups are very close to each other.

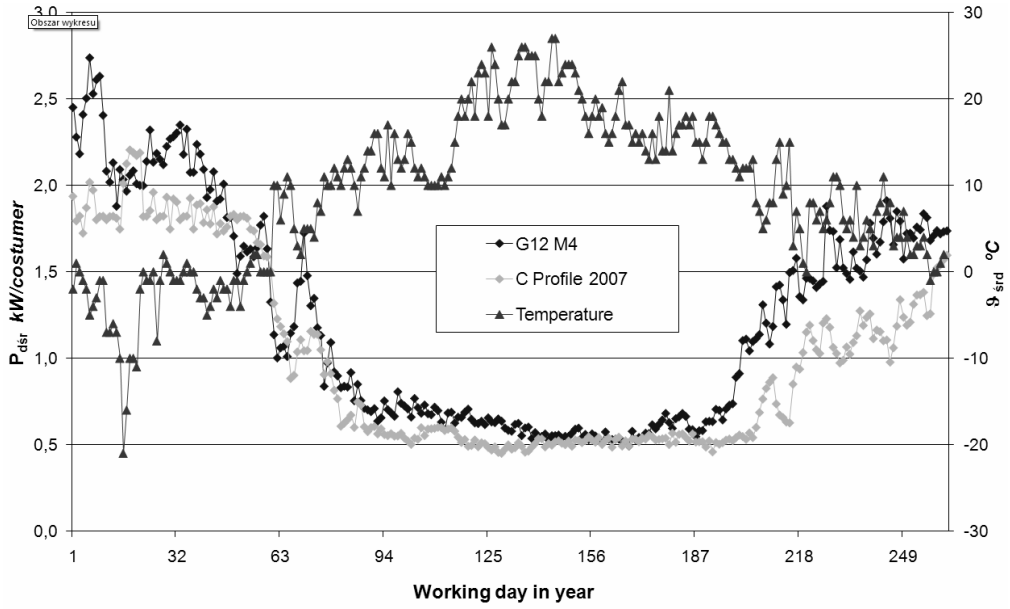


Fig. 6. Annual variability of average load and temperature in 2006

Preliminary analysis of graphs in Fig.6 has shown small differences in the consumed power values in the summertime. Perceptible differences in the waveforms occur in the wintertime when the electric heating is working.

In addition, the study on the impact of temperature (ϑ) on the consumed electric power univocally shows that the influence of this factor is the most evident during the heating period (from October till March). In other months it is weaker but still significant. Moreover, in the summertime (June- August) in the P.M. zone with higher energy prices, a slight influence of the T_{zach} on the consumed energy value is observed [6].

In Fig.7, the annual variability of the power correlation coefficient in specific hours of the day at the average daily temperature for the G12 M4 type consumers and C profile 2007 are reported.

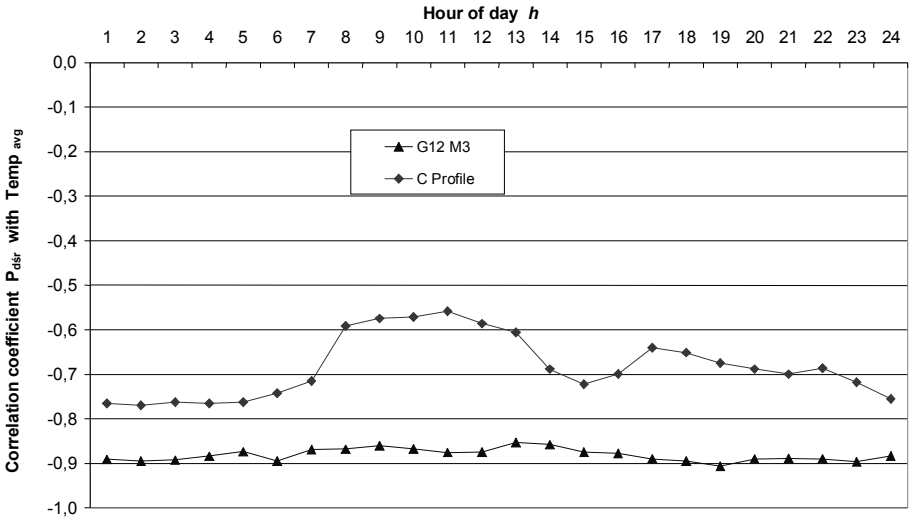


Fig. 7. Annual variability of average load and temperature in 2008

Tracking of the correlation coefficient (Fig. 7) in tested groups confirms a strong relation between the consumed power and the temperature. For the G12 M4 group, higher values of the correlation coefficient can result from the consumers character i.e. room and water heating by the electric energy. The directives concerning the selection of consumers for the C profile do not distinguish the consumer using the electrical heating either for room or for water from that heating the both at the same time. Like in the A profile, the straightforward criterions of the consumers' selection for the profile become primordial.

On the base of the annual variability shown in Fig.6 and respective temperature variability for the heating period, the relationship can be established:

− for G12 M4 consumers:

$$P_{d\ śr} = 1{,}89 - 0{,}069 \cdot \vartheta_{śrd} \qquad (3)$$

$$(R^2=0{,}88)$$

− for C profile:

$$P_{d\ śr} = 1{,}38 - 0{,}032 \cdot \vartheta_{śrd} \qquad (4)$$

$$(R^2=0{,}82)$$

where: $\vartheta_{śrd} \in (-19{,}5 \div 10)°C$.

Formulas (3) and (4) are similar for successive years of observations.

In Fig. 8, the power consumption average values in month in so called *lower price zone of energy* (zone II) are compared to the average temperature in month, for the consumer groups under consideration (C Profile 2007 and G12 M4 – 2006).

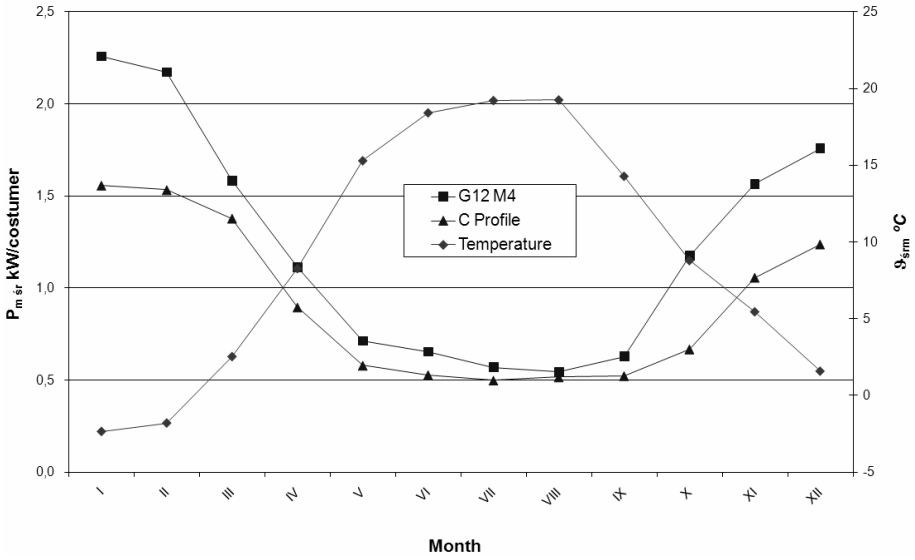


Fig. 8. Annual variability of average load and temperature in successive months, 2006

There is strong relation between the power consumed in the II zone (lower price of energy) and temperature. The relation can be expressed by formulas:

- for G12 M4:

$$P_{II\ m\ śr} = 21{,}1 - 8{,}27 \cdot \vartheta_{śrm} \tag{5}$$

- for C profile:

$$P_{II\ m\ śr} = 20{,}14 - 10{,}6 \cdot \vartheta_{śrm} \tag{6}$$

where: $\vartheta_{śrm} \in (-19{,}5 \div 6)°C$.

3.3. Evaluation of profiles' significant features

In our research, the impact of defined factors on the values appearing in the load graphs has been analyzed and the extraction of significant features in specific groups and standard profiles has been carried out.

In Table 4, the features of the energy consumers settled according to the G11 tariff and the A profile consumers are listed.

A profile has been constructed for consumers settled according to G11 tariff which are differently equipped with electrical devices and differently localized. Then, the total graph (A profile) depends on the percentage of the specific consumer groups classified for its construction.

Table 4. Impact of external factors on the shape and values of the G11 graphs

Group	T_{zach}	$\vartheta_{śr}$	$P_{dśr}$ [kW/consumer]
G11 M1	strong	no	0,218
G11 W1	strong	no	0,224
G11 M2	weak	no	0,568
G11 W2	weak	weak	1,175
A profile	strong *	?*	0,394÷0,579

* - depending on the year of observation

In Table 5, features of the consumers encountered to the G12 M4 group and the C profile consumers are specified.

Table 5. Impact of external factors on shape and values of G12 graphs

Group	T_{zach}	$\vartheta_{śr}$	$P_{dśr}$ [kW/consumer]
G12 M4	weak*	strong	1,25
C Profile	weak*	strong	0,82÷1,24

* - at certain times of the day (16-22)

In groups compared in Table 5, a significant impact of temperature on the daily consumption of energy is observed. However, the strongest relationship power – temperature has been observed in the hours of the lower price of energy.

Opposite to the G12 M4 consumer group, in the description of the C profile consumers the latter using the electric power for the water and rooms heating (generalized profile) are not distinguished.

4. Final remarks

To acquire a thorough knowledge on characteristic parameters and their properties in the electric load graphs for individual consumer groups, a series of analyses is required. Coexistence of some factors affecting the graphs significantly hampers the research. Construction of the specialized IT tools simplifies the investigations and becomes a precious source of information on the factors significantly affecting the electrical consumption curves by the consumers.

The carried out analysis has shown that precisely formulated criterions of selection of individual consumers to the profile group when constructing the standard profiles should be precise; too general criterions introduce a great spread of the energy consumption by specific consumers from the average value for the group. A standard profile should be constructed from the consumers of similar or very close features. However, it should be kept in mind that too detailed criterions of selection of the consumer to the profile can complicate the construction and application of profiles in true practice.

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