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## THE IMPACT OF PROSUMER PHOTOVOLTAIC INSTALLATIONS ON SHAPING THE PROFILE OF THE POWER DEMAND IN POLAND

**Summary:** The paper discusses the impact of prosumer photovoltaics installations on shaping the profile of the KSE power demand in Poland at different times of the year. Predictions were made on the basis of the partial data from photovoltaic installations operating in Poland in 2014. The analysis was performed in accordance with new regulations contained in the Renewable Energy Act.

**Keywords:** photovoltaics, prosumer installations, power demand, renewable energy

## WPŁYW FOTOWOLTAICZNYCH MIKROINSTALACJI PROSUMENCKICH NA KSZTAŁTOWANIE PROFILU KSE W ŚWIETLE NOWEJ USTAWY O OZE

**Streszczenie.** Artykuł omawia wpływ fotowoltaicznych instalacji prosumenckich na kształtowanie profilu zapotrzebowania na moc KSE w różnych porach roku. Predykcję wykonano na podstawie rzeczywistych danych pochodzących z części prosumenckich instalacji fotowoltaicznych działających w 2014 roku. Analizę wykonano z uwzględnieniem nowych regulacji prawnych zawartych w Ustawie o Odnawialnych Źródłach Energii.

**Słowa kluczowe:** fotowoltaika, instalacja prosumencka, analiza profili KSE, zapotrzebowanie na moc, odnawialne źródła energii

### 1. INTRODUCTION

In February 2015, the Polish Parliament (Sejm) passed new regulations on renewable energy sources, introducing novel support measures for prosumer microinstallations. The deputies initiated regulations which made it possible to apply guaranteed rates for microinstallations rated below 10 kW; all such installations are now classed in accordance with two defined power levels (which qualify for support). These powers have been specified as 3 kW and 10 kW and backing has been differentiated for these power ranges. In case of prosumer installations rated up to 3 kW, the guaranteed rate has been given as 75 gr per 1

kWh; at the same time, the maximum power of all such supported installations has been stated as 300 MW. The second group of installations, i.e. those ranging from 3 kW to 10 kW has been assigned to so-called fit rate, i.e. 40 gr to 70 gr per 1 kWh, depending on the RES type used. In case of photovoltaic (PV) installations with rated power ranging from 3 to 10 kW, a guaranteed rate equal to 65 gr per 1 kWh has been proposed. At the same time, total power limit for all installations belonging to fit group and rated at 3-10 kW has been set to 500 MW. Establishment of this law will instigate dynamic development of prosumer installations in our country. It is predicted that majority of new installations will be photovoltaic. This paper presents analysis of the impact of developing PV prosumer installations on shaping national power grid (KSE) power demand at different times of the year. It has been assumed here that during next few years, power limit defined by the Legislature will be attained. This means that c. 100 000 PV prosumer installations rated at c. 3 kW will be operating as well as 50 000 such installations rated at c. 10 kW. When power limits used in qualifying prosumers for guaranteed rates are exhausted, further development of PV prosumer installations is still predicted; by 2030, number of such installations may be 2 million or more.

## 2. SOURCE DATA

Analysis of PV prosumer microinstallation impact has been conducted on the basis of data collected by web portal <http://pvmonitor.pl>. The portal makes it possible to record (in real-time) measurements run in different types of prosumer installations; however, PV installation data is prevalent. Due to universal communication interface, data acquired from different devices using different standards of data exchange may be integrated by [pvmonitor.pl](http://pvmonitor.pl). Data may be sent and recorded in real time; aggregated data import is also possible and utilized by portal users. By February 2015 86 installations have been logged in [pvmonitor.pl](http://pvmonitor.pl) portal; in February, 55 of these installations were operating. Their rated power ranged from several hundred Wp to 40 kWp. During analysis we have used data acquired in different regions of Poland (Fig.1) by non-commercial prosumer PV microinstallations with rated power up to 10 kWp. This power rating is typical of household prosumer installations; such installations have been accorded guaranteed rates.

As portal [pvmonitor.pl](http://pvmonitor.pl) progressed, number of installations subjected to analysis in successive time periods grew; average nominal power changed, but usually fluctuated around 3-4 kW. These values have been taken into account during rescaling profiles and outputs of installations registered at [pvmonitor.pl](http://pvmonitor.pl) into equivalent total equal to 100000 installations rated at 3 kW and 50000 installations rated at 10 kW (such amounts are supported under relevant Bill). Analysis has been run for summer, winter and transitional season data; a representative day for each season has been chosen. A typical PV installation has been selected for each

season as an averaged one from amongst those registered at pvmonitor.pl. Output profiles of installations operating during a chosen day have also been averaged and then rescaled in accordance with support limits determined by RES Bill. Such profiles have been subsequently used for correcting national power grid (KSE) power demand profile.

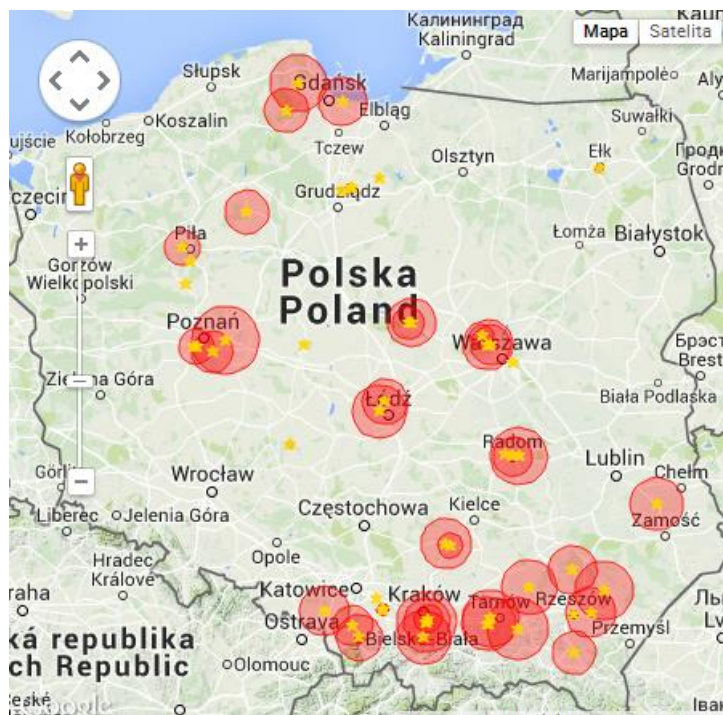


Fig.1. Geographical distribution of the prosumer installations monitored by the portal pvmonitor.pl on 2015/02/14

Rys.1. Rozmieszczenie fotowoltaicznych instalacji prosumenckich monitorowanych przez portal pvmonitor.pl w dniu 2015-02-14

In accordance with National Census of Population and Housing of 2011 (Narodowy Spis Powszechny Ludności i Mieszkań) [11], number of all houses in Poland was 6.1 million; single-family homes share was more than 90 % (5.5 million in 2011). Now, if we assume a fast development of prosumer microinstallations in Poland starting with 2016 and if we compare such expansion with that seen in Germany several years ago (Fig.2 – by end of 2014 nominal power of prosumer installations was 38.5 GW and number of installations exceeded 1.5 million), we may safely presume that by 2018 number of PV microinstallations in Poland will be high enough to use up limits of fit rates (800 MW); number of constructed microinstallations will exceed 150 thousand. This will correspond to some 2.75 of single-family homes. If we take into account world tendencies in distributed power engineering and emission goals defined by European Parliament, we must assume that PV installation market in Poland will dynamically grow and it may attain 2 million PV installations by 2030. It will correspond to less than 36% of houses and 33% of total buildings. That is why in the paper we have analysed the impact of 150 thousand microinstallations (total power 800 MW, within

and expending limits set by the Legislature) on national power grid (KSE) power demand profile as well as similar impact of 2 million of prosumer PV microinstallations constructed in more distant future.

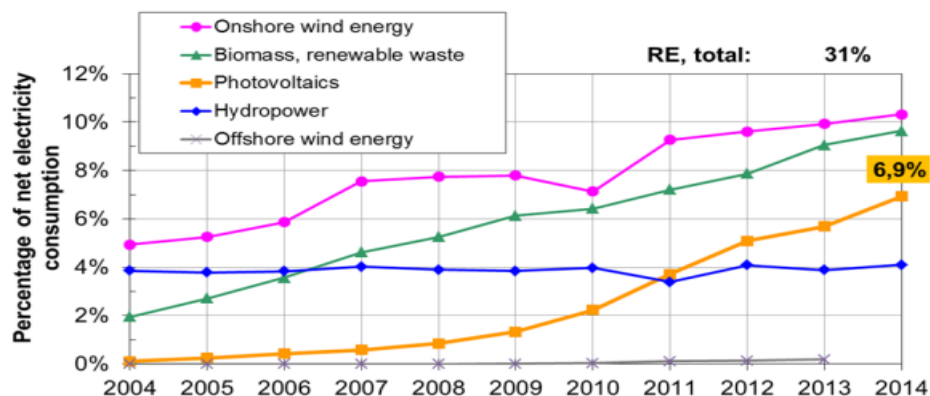


Fig.2. The electricity consumption in Germany by the source type [2]

Rys.2. Udział energii pochodzącej z OZE w konsumpcji energii elektrycznej końcowej w Niemczech [2]

It may also be assumed that when measures supporting construction of oversized prosumer installations (within power limits defined by the Bill) are expended, further development of prosumer installations will favour installations adapted specifically to prosumer demands; on the basis of data from pvmonitor.pl portal we may evaluate these demands as slightly exceeding 3 kW at present. However, if we predict future increase in electrical energy demand (caused e.g. by abandoning fossil fuels used nowadays for heating purposes in favour of clean technologies such as heat pumps, mass air-conditioning installations i.e. air-to-air heat pumps, which may also work as auxiliary heating sources in intermediate seasons, promotion of local energy storages), it may be assumed that average rating of prosumer microinstallation may rise at least to 4-5 kW by 2030. However, in this paper we have assumed that by 2030 average power of prosumer installation will be equal to 4 kW and number of such installations will attain 2 million.

### 3. ANALYSIS OF IMPACT OF PROSUMER PV INSTALLATIONS ON KSE DEMAND PROFILE

#### 3.1. Summer

Summer season is characterised by best possible conditions for operation of PV installations due to length of the day, sun's altitude and frequency of sunny days. During summer the daily and monthly effectiveness of PV installations is highest. Also during

summer the KSE demand changes in relation to other periods, since due to long days the evening peak demand is less (necessity of using artificial lighting is diminished). On the other hand, the antemeridian peak is much more evident and it is often higher than the evening peak. In addition, any power shortage during summer peak in Poland may be caused by lower productivity of coal power units at high ambient temperatures; this is due to difficult operating conditions of cooling systems, which is true in particular in case of open cooling circuits [3].

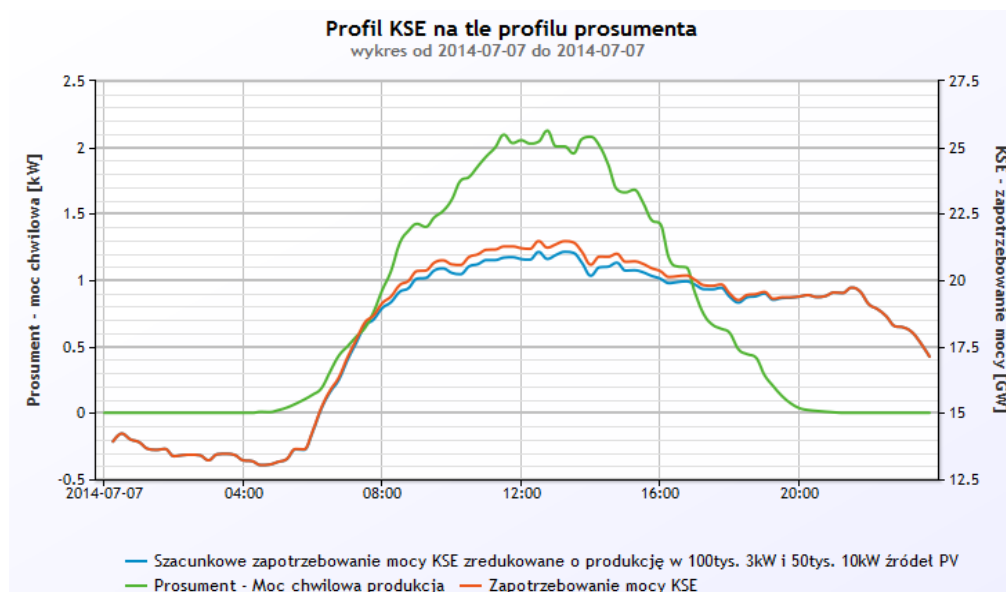


Fig.3. The KSE energy demand profile in July with 100 000 3kW and 50 000 10kW PV installations  
Rys.3. Profil KSE na tle 100 tys. 3kW i 50 tys. 10kW instalacji prosumenckich w lipcu

The KSE demand in Fig.3 for 7<sup>th</sup> July, 2014 is marked in red (scale located at right-hand vertical axis). Averaged and rescaled instantaneous power of 29 non-commercial prosumer installations rated up to 10 kW is marked in green (scale located at left-hand vertical axis); these are installations installed in different regions of the country, covered by monitoring conducted by portal <http://pvmonitor.pl> and operating on 7<sup>th</sup> July, 2014. Power of these installations has been re-scaled down to 5.33 kW, this is average power of RES installations corresponding to upper support limits defined by RES Bill. Power demand of KSE (scale at right-hand vertical axis) modified by predicted power supplied by 100 thousand installations rated at 3 kW and 50 thousand installations rated at 10 kW (total productivity 800 MW) is marked in blue. In summertime we may observe the impact of microinstallations demonstrated by lessening and flattening of antemeridian peak by c. 0.4 GW.

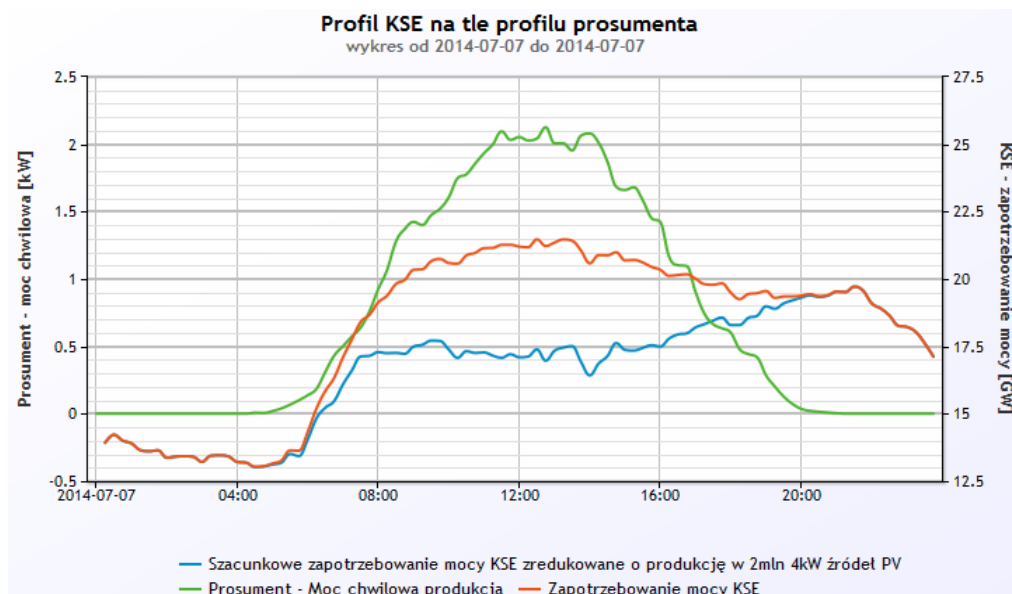


Fig.4. The KSE energy demand profile in July with 2 000 000 4kW PV installations

Rys.4. Profil KSE na tle 2 mln 4kW instalacji prosumenckich w lipcu

Similar simulation has been run for 2 million PV installations predicted for 2030 (Fig. 4). Total elimination of antemeridian peak is distinctly seen in the chart; demand for KSE power at noon decreases from 21.20 GW to 17.09 GW.

### 3.2. Winter

Winter is characterised by entirely different KSE power demand profile. In this season the total power demand in the country increases, which is due to intensive use of artificial lighting and higher need of power for heating purposes. In addition, as the days grow shorter, the evening power peak is more evident; its values are highest in the year. In wintertime PV installation operation is weak, and in case of snow cover generation of electrical energy is practically nil; consequently, impact on shaping KSE profile during winter is very, very insignificant. However, some days may occur when production of electrical energy in PV installations increases greatly, but such occasions are not numerous.

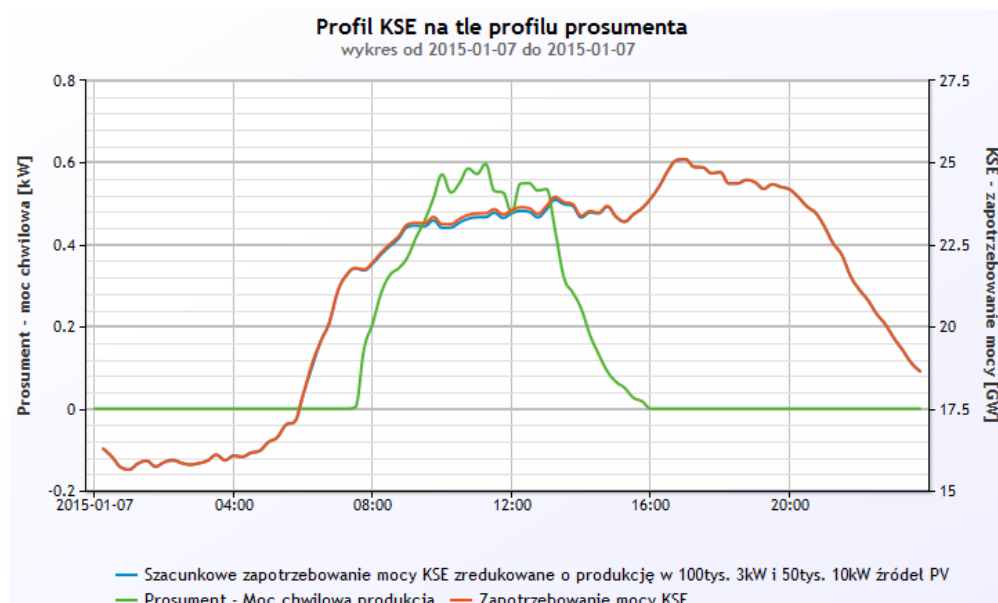


Fig.5. The KSE energy demand profile in January with 100 000 3kW and 50 000 10kW PV installations

Rys.5. Profil KSE na tle 100 tys. 3kW i 50 tys. 10kW instalacji prosumenckich w styczniu

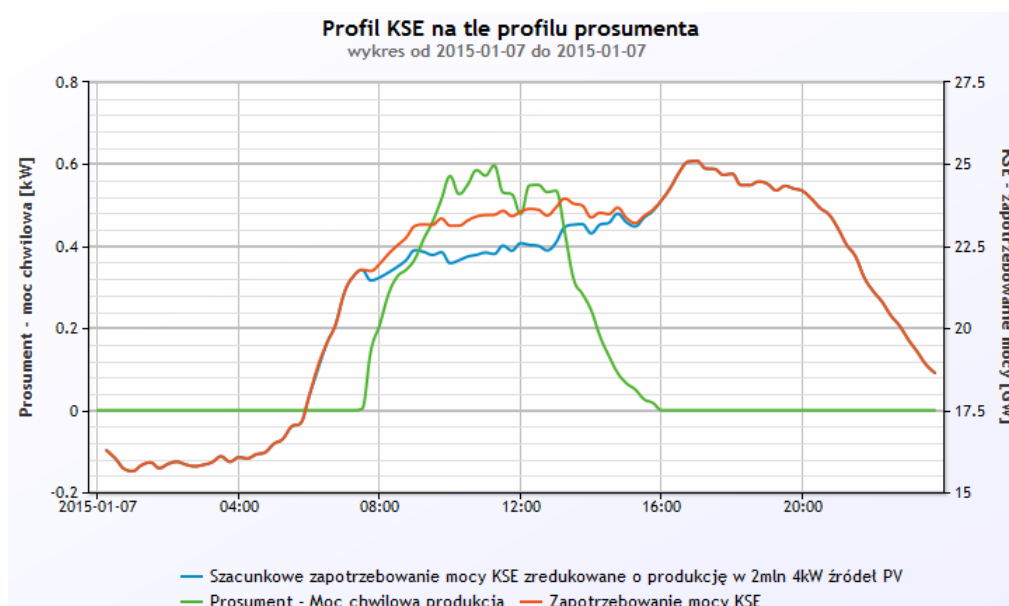


Fig.6. The KSE energy demand profile in January with 2 000 000 4kW PV installations

Rys.6. Profil KSE na tle 2 mln 4kW instalacji prosumenckich w styczniu

The KSE demand in Fig.5 for 7<sup>th</sup> January, 2015 is marked in red (scale located at right-hand vertical axis). Averaged and rescaled instantaneous power of 45 non-commercial prosumer installations rated up to 10 kWp is marked in green (scale located at left-hand vertical axis); these are installations installed in different regions of the country, covered by monitoring conducted by portal <http://pvmonitor.pl> and operating on 7<sup>th</sup> January, 2015. Average nominal power of these installations is 2.9 kWp, but it has been re-scaled down to 5.33 kW. Power demand of KSE (scale at right-hand vertical axis) modified by predicted

power supplied by prosumer PV installations with total productivity 800 MW is marked in blue. The impact of these installations on KSE power demand is practically insignificant at a discussed time.

In wintertime we may observe the growing impact of 2 million prosumer PV installations (Fig.6) rated at 4 kW each. It would lessen the antemeridian peak in KSE power demand by *c.* 0.7 GW at noon, 7<sup>th</sup> January 2015.

### 3.3. Transitional season

Transitional season is characterized by features specific to both summer and winter. When days shorten, the KSE power demand profile starts to resemble winter profile with significant stress on the evening peak. During this time, number of sunny days permits quite effective operation of prosumer installation, even though monthly output may be halved in relation to summer maximum output. This effect may be noted in October and November of 2014 for numerous PV installations (Fig. 7).

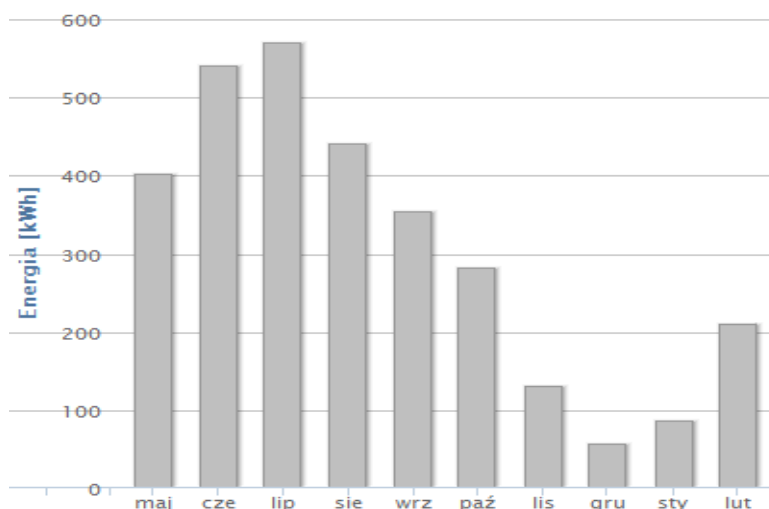


Fig.7. Performance of the photovoltaic 4.4kWp installation during the years 2014, 2015

Rys.7. Wydajność przykładowej instalacji fotowoltaicznej o mocy 4,4kWp w poszczególnych miesiącach w latach 2014, 2015

Even though sun conditions become more and more unfavourable, we may still observe a quite significant impact of PV microinstallations on KSE antemeridian power demand. Chart shown in Fig.8 demonstrates the predicted influence of PV prosumer microinstallations (total power 800 MW) on KSE power demand profile on 7<sup>th</sup> October, 2014.



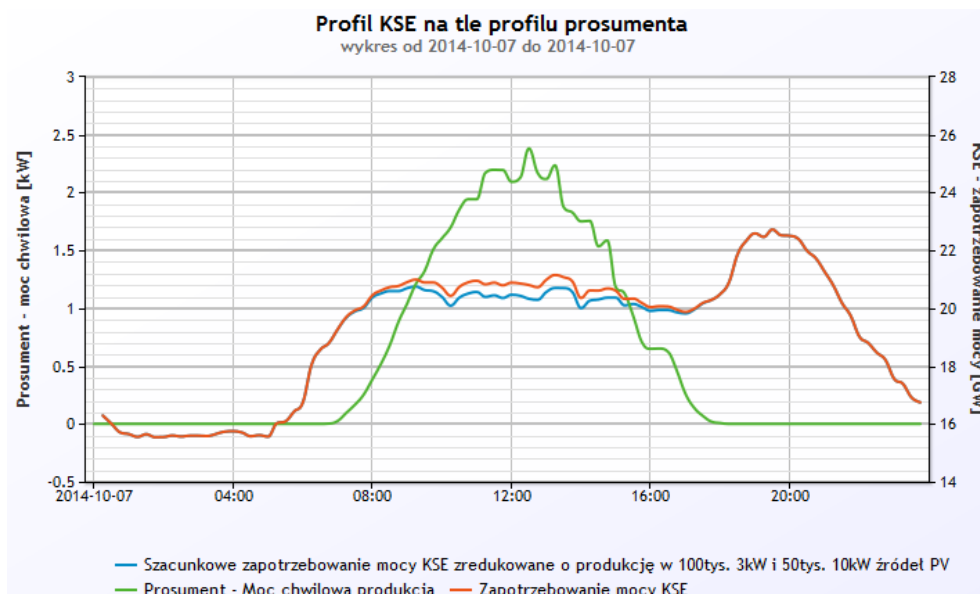


Fig.8. The energy demand profile in October with 100 000 3kW and 50 000 10kW PV installations  
 Rys.8. Profil KSE na tle 100 tys. 3kW i 50 tys. 10kW instalacji prosumenckich w październiku

The instantaneous power of PV prosumer installations has been calculated as the average of 38 non-commercial installations with rated power less than 10 kWp and operating at 2014/11/07, monitored by the portal <http://pvmonitor.pl>. Real profile of national power grid (KSE) on 7<sup>th</sup> November, 2014 (red and blue line) exhibits a significant evening peak lasting from 17:30 to 21:30; minor antemeridian peak would be somewhat flattened by activity of prosumer PV installations (lower blue line).

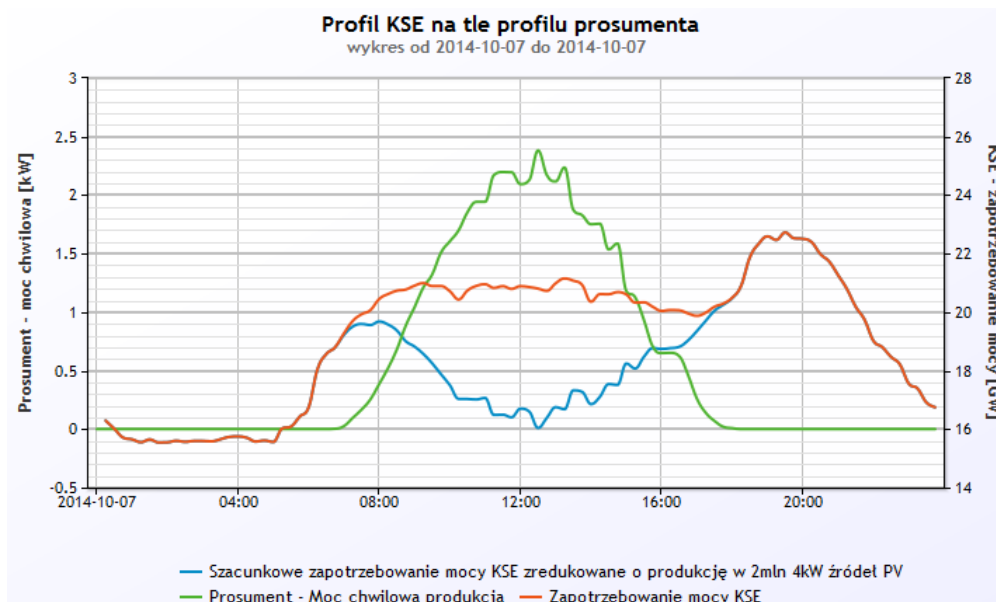


Fig.9. The KSE energy demand profile in October with 2 000 000 4kW PV installations  
 Rys.9. Profil KSE na tle 2 000 000 4kW instalacji prosumenckich w październiku

Similar simulation has been run taking into account 2 million of PV microinstallations; we may observe a complete elimination of antemeridian peak in Fig.9. On the other hand, close to 8:00 a.m. a morning peak is seen, it is produced as a result of shortened day and a delayed start-up of photovoltaic installations.

#### 4. CONCLUSION

The analyses presented above show that prosumer PV installations provide interesting opportunities, in particular they make it possible to reduce significantly antemeridian peaks (Table 1), especially during summer. This is due to characteristics of PV sources: the output is greatest in summer during sunny weather. Long summer days facilitate the output, since operation of installation from early morning till late evening is possible. PV output is highest during the identical time period, when the demand for electrical energy is also increased, since air-conditioning devices consume lots of energy and popularity of such appliances in Poland continuously grows. The increased demand for electricity is also exhibited by other refrigerating devices, those operating on continuous basis during sunny and hot summer weather in particular. Among such devices we may list all types of industrial refrigerating units, fridges, freezers, also refrigerating household appliances and those working in shops, cold stores, warehouses etc.

Table 1.

Redution in KSE power demand at noon [GW]			
<b>Power demand</b>	<b>2014/07/07</b>	<b>2014/10/07</b>	<b>2015/01/07</b>
KSE	21.20	20.89	23.55
KSE reduced by 800 MW PV	20.79	20.47	23.45
KSE reduced by 2 million of 4kW PV installations	17.09	16.70	22.85

In transitional periods the impact of prosumer PV installations may also be significant (Fig. 8, Fig.9), even though the evening peak is then most perceptible, since without energy storage facilities PV installations are not able to reduce this peak. However, after 2020 the evening peak will probably be less, since the mass advent of energy-saving LED lighting is in progress; this technology is nowadays fast replacing traditional and more energy-consuming lighting devices. Moreover, the KSE peak demands will be modified by emerging energy storage systems.

The least impact of prosumer PV installations on KSE power demand profile is exerted in winter. Even in this case we may observe some decrease in power demand during

antemeridian peak. This is especially well evident when impact of 2 million installations is analysed.

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