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"Mój Prąd" as an example of the photovoltaic one-off grant program in Poland

Abstract: There are many financial ways to intensify the construction of new renewable energy sources installations, among others: feed in tariff, grants. An example of photovoltaic grant support in Poland is the "Mój Prąd" [My Electricity] program created in 2019. This program, with a budget of PLN 1 billion, is intended for households in which installations with a capacity range of 2–10 kWp have been installed. During its first edition 27,187 application were submitted. Over 98% of installations cost less than PLN 6,000/kWp. The total installed capacity is 151.3 MWp, which gives the average amount of co-funding per unit of power at the level of PLN 884.7/kWp. The average power of the installation on the national scale is 5.57 kWp, the indicator per 1000 inhabitants is 3.94 kWp, and per unit of area is 0.484 kWp/km^2. These installations will produce around 143.5 GWh of electricity annually, contributing to the reduction of CO_2 emissions by approximately 109,800 Mg per year. Most applications came from the Silesian Province (3855), which translated into the largest installed capacity of 21.82 MWp, as well as 4.81 kWp/1000 inhabitants and 1.77 kWp/km^2 (over

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3 times higher than the average in Poland).The installed capacity in the individual province was closely correlated with the population of the province (correlation coefficient – 0.95), while the installed capacity indicator per 1,000 inhabitants with insolation (0.80). The highest power ratio per 1000 inhabitants was achieved in the Podkarpackie Province and amounted to 5.05, and the lowest in the West Pomeranian Province (2.41).

KEYWORDS: renewable energy sources, renewable energy, photovoltaics, renewable energy policy, "Mój Prąd"

Introduction

In Poland, the development of installations using renewable energy sources (RES) has been observed for years. Among the newly installed RES electrical capacity until 2016, wind energy was the leader, and since 2019 photovoltaics has taken over the lead (URE 2020). The main barriers to the development of photovoltaics are technological aspects, including those related to energy productivity, as well as security, economic and legal aspects (Mirowski and Sornek 2015). In each of these aspects, research and scientific analyses are conducted both in the world and in Poland (Olczak et al. 2020; Zdyb and Gulkowski 2020). Both global (Calise et al. 2019; Thür et al. 2018) and Polish research (Kreft et al. 2020; Sornek et al. 2018; Żołądek et al. 2019) to a large extent focus on the productivity of this type of installation (Olczak et al. 2018; Talaat et al. 2019), as well as increase of energy security (Szczerbowski 2013), including the construction of energy storage (Burgio et al. 2020; Krupa et al. 2018) and the modelling of the energy network (Böckl et al. 2019; Hansen et al. 2020; Wróbel et al. 2019). In the economic and legal aspect, bigger differences can be found between what is occurring in the world and in Poland – these are energy prices, subsidies, required building permits, and the variability of legal conditions.

Polish subsidy programs (intended for renewable energy) may be a kind of incentive for investors to build installations, and size selection depends, among others, on the size of the installation and the type of investment (Benalcazar et al. 2020; Kuchmacz and Mika 2018; Trela and Dubel 2017). Support in these programs can take various forms: feed-in-tariff, grants, and auctions. Micro-installations (up to 50 kWp) have the smallest barriers (especially legal ones). There is no need for a building permit for them, while settlements can be made under the Prosumer program for both households and companies (Kuchmacz and Mika 2018; Pepłowska and Olczak 2018). Under this program, installations with a capacity of up to 10 kWp, where energy can be given to the national grid and 80% of this value can be taken (on an annual basis) by the investor (Pepłowska and Olczak 2018) are particularly privileged. Both micro and larger installations can benefit from the Regional Operational Programs of individual Provinces (financed from the European Regional Development Fund). In this case, households can apply for a subsidy only through local government units (e.g. municipalities) that want to increase the share of renewable energy in their area and this depends on their effectiveness in providing funds in the given area.

In addition to the above aspects, the local meaning differentiates in terms of access to solar radiation. The values of annual insolation calculated on a plane inclined at an angle of 45° for individual province in Poland have been plotted on Figure 1 – left side. As can be seen in Figure 1 – right side, the value of insolation for 30° and 45° inclination (south side) does not differ by more than 1% (Ministry of Development 2019).

In 2019, as a type of co-financing for investments in photovoltaics, the "Mój Prąd" program organized by the National Fund for Environmental Protection and Water Management was launched (call No. 1 lasted from August 30, 2018 to December 20, 2019). Currently (2020), the call for the second edition of the "Mój Prąd" program is underway (NFOŚiGW 2020). Co-financing of the installation is possible after its completion by investors and takes the form of a refund (reimbursement) of part of the incurred costs. The article contains an analysis of data derived from individual ranking lists during the first recruitment (2019), the results of which are posted on the website: www.mojprad.gov.pl.

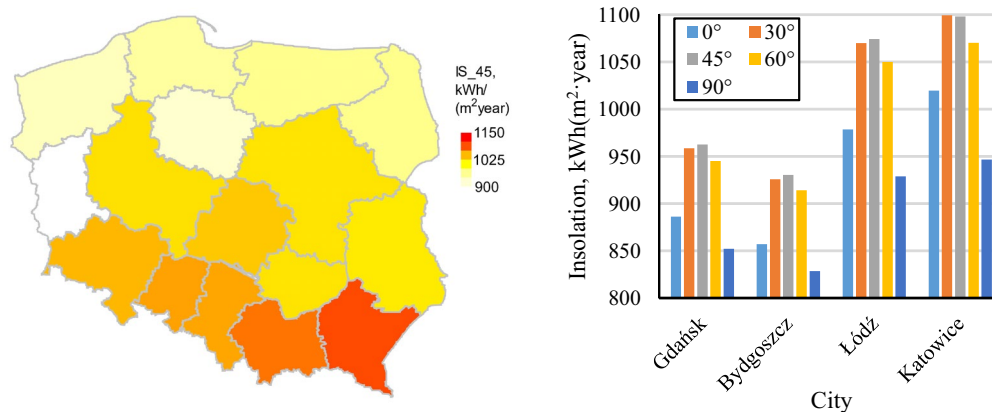

Fig. 1. Insolation (slope 45° south direction, I_S45) in Poland per Province capital city – left side, Insolation in some cities as a function of slope – right side
Source: own study based on Typical Reference Year (Ministry of Development 2019)

Rys. 1. Nasłonecznienie (kąt 45° kierunek południowy, I_S45) w Polsce w stolicy województwa – strona lewa, nasłonecznienie dla wybranych miast w funkcji kąta nachylenia – prawa strona

1. The "Mój Prąd" Program

Under the program, households could apply for a grant to partially cover the purchase and assembly costs of solar installations with a capacity of 2–10 kWp. As part of the first call for proposals, 27,187 applications classified into 99 ranking lists were submitted (Fig. 2). Information on program participants is provided on separate websites by list number. This information

includes the first and last name, province, installation capacity, scoring, awarded grant amount. The number of scores (from 1 to 4) depended on the installation cost calculated in PLN/kWp. Four scores were awarded for costs below PLN 6000/kWp, while one point was awarded for costs above PLN 7000/kWp.
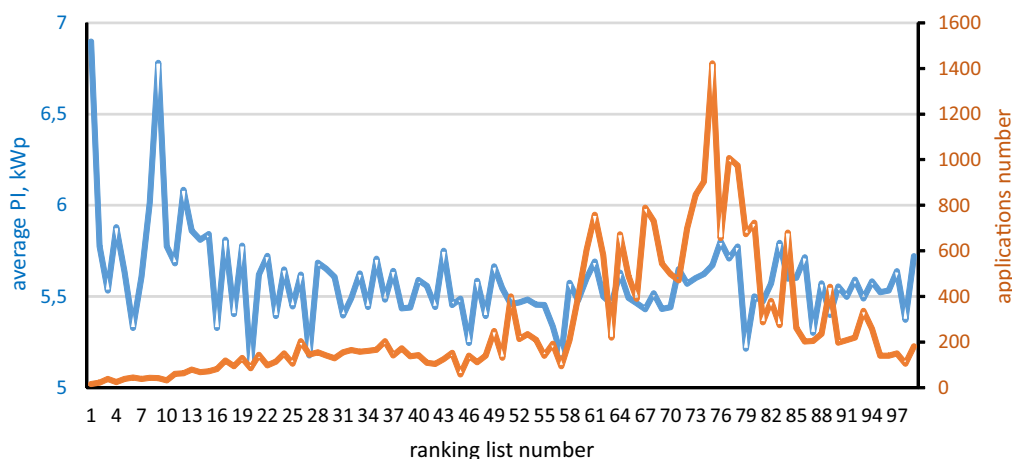

Fig. 2. Average installation power (average PI) – left scale and the number of applications in each of the 99 following ranking lists – right scale
Source: own study based on (NFOŚiGW 2020)

Rys. 2. Średnia moc instalacji (PI) – skala lewa oraz liczba wniosków w każdej z 99 następujących po sobie list rankingowych – prawa skala

The frequency dependence of a given number of points from the installed capacity (4 curves) is shown in Figure 5. In 98%, the grant awarded is a maximum value of PLN 5,000, with the grant amount not exceeding half of the installation costs. The total budget according to the ranking lists was PLN 133.8 million (some installations, however, did not receive a grant), which, with the total installation capacity in 151.3 MWp in program, gives a grant index of PLN 884.7/kWp (Fig. 4, right side). There have been some installations (less than 0.1%) which was built without dotation. Taking the average installation costs per kWp as PLN 4600/kWp (Derski 2019) into account, this ratio is submitted to the average co-financing in approx. 19% of the installation costs. Also, an additional form of support is the possibility of cost deduction from income during tax settlement. The volume of installed capacity under the program accounted for over 10% of all existing PV installations in Poland at the end of 2019 (URE 2020).

Among the total set of submitted applications, grouping by provinces has been made. The separated subsets were characterized in a numerical way. Results as number of installations (NI) and installation power (PI) are shown in Figure 3. Most applications were submitted in the Silesian Province, i.e. 3855, and the least in the Lubuskie Province 644. The total capacity of installations included in the submitted applications is 21.8 MWp in the Silesian Province and

3.8 MWp in the Lubuskie Province. For individual provinces, the highest average installation power (avg. PI) has been achieved for the Opolskie Province – 6.13 kWp, and the lowest for the Podkarpackie Province – 4.80 kWp.
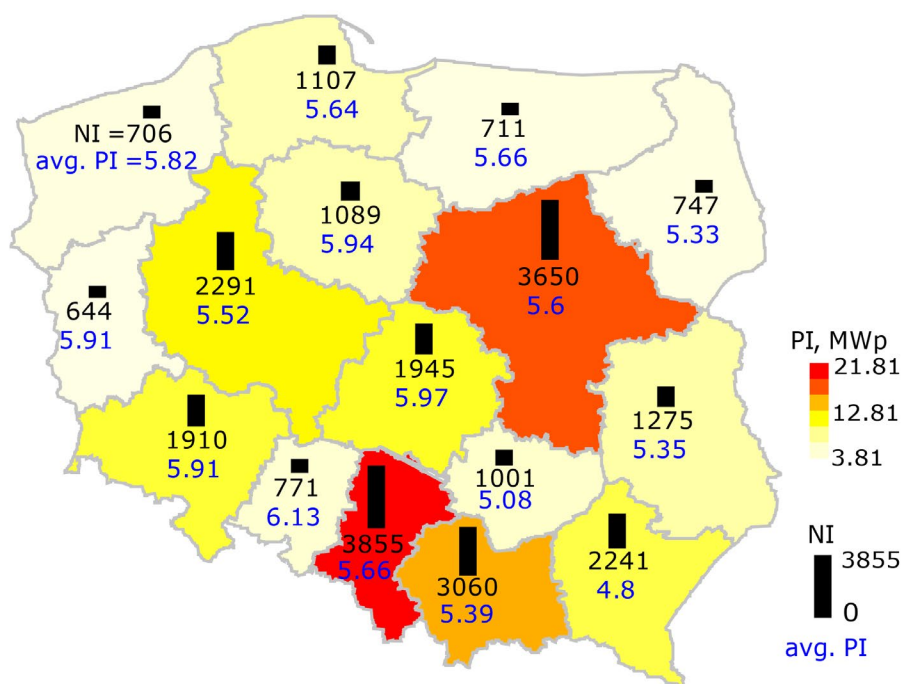

Fig. 3. Number of applications (and built installations – NI) in the 1st call of "Mój Prąd" per province; total installation capacity in the provinces (PI); average installation capacity (avg. PI) in the provinces
Source: own study based on (NFOŚiGW 2020)

Rys. 3. Liczba wniosków (i wybudowanych instalacji – NI) złożonych w 1. edycji "Mój Prąd" na województwo; całkowita moc instalacji w woj. (PI); średnia moc instalacji (avg. PI) w województwach

On a national scale, the largest number of installations were reported in the range of 4–5 kWp (Fig. 4, left side), and the average obtained 5.57 kWp.

In each point group, the frequency depends in a similar way on the power of the installation, except that for installations with a four-score installation where the highest frequency occurred at a slightly higher power (Fig. 5). In addition, it can be seen that from an economic point of view (grant intensity in PLN/kWp) there are quite a lot of installations (Fig. 4, right side and Fig. 5) with a capacity above 9 kWp for which the subsidy is relatively low, i.e. PLN 500–600/kWp .

The frequency of a given installation size reported in the "Mój Prąd" program was compared to data for 2015 (limiting the installation's power range to 10 kWp – 2015). The results are shown on Figure 6. An increase in the numerical proportion of installations in the 5–10 kWp range over those in the 2–3 kWp range can be seen. However, it should be remembered that installations
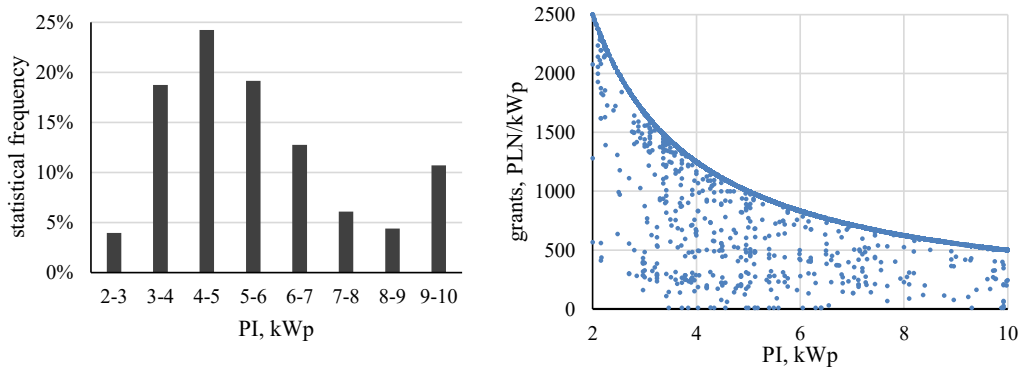
Fig. 4. Percentage of installation groups by installed capacity ranges – left side. Co-financing amount per kWp of the installation as a function of installation capacity (PI) – right side
Source: own study based on (NFOŚiGW 2020)

Rys. 4. Udział procentowy grup instalacji według przedziałów mocy zainstalowanej – strona lewa. Wysokość dofinansowania na kWp instalacji w funkcji mocy instalacji (PI) – strona prawa

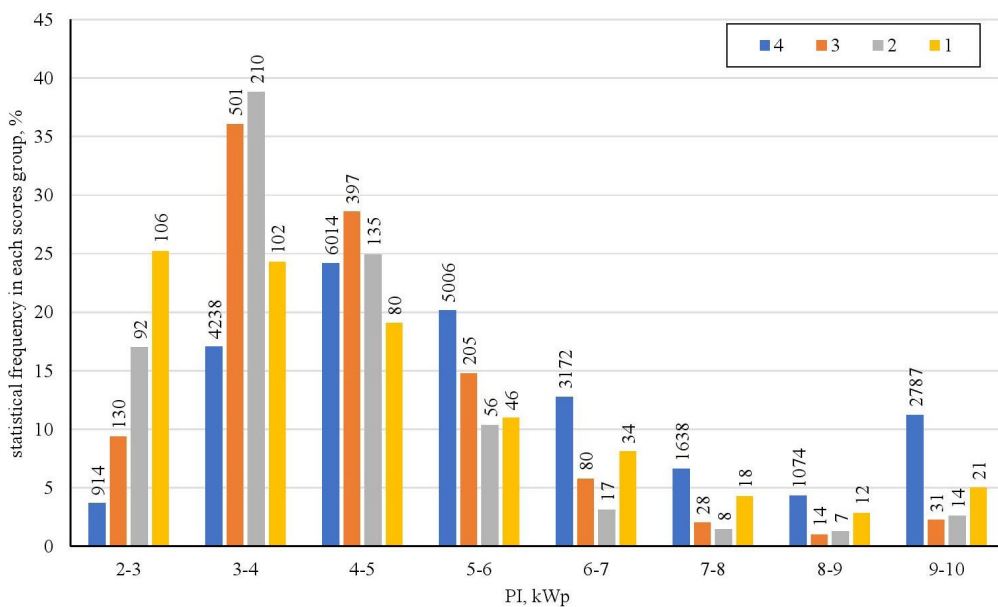Fig. 5. The frequency dependence of scores on power ranges along with the number of installations
Source: own study based on (NFOŚiGW 2020)

Rys. 5. Zależność częstości występowania punktów w przedziałach mocy wraz z liczbą instalacji

covered by the "Mój Prąd" program are not the only recently created installations in Poland. In addition, the total number of installations in 2015 was several times smaller than in 2019.
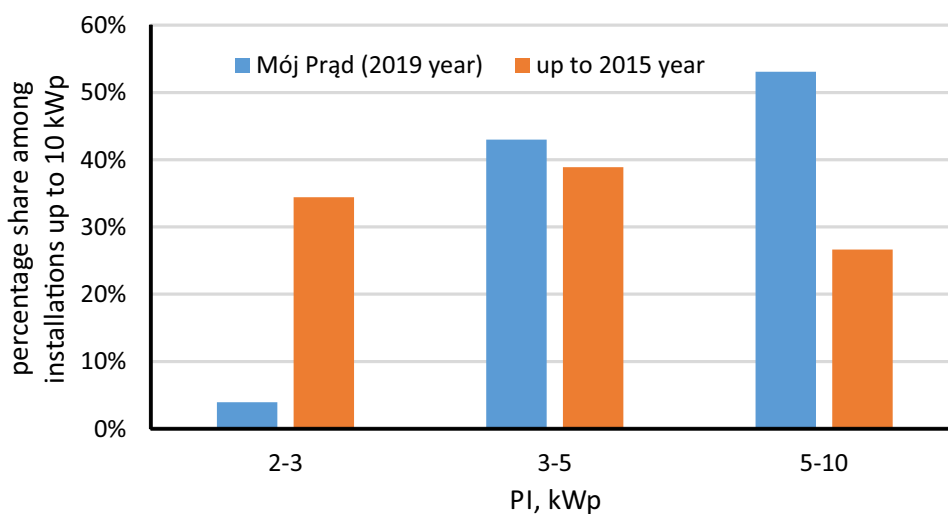
Fig. 6. Comparison of the share of the number of installations in the power ranges between the state of 2015 and implemented in connection with the "Mój Prąd" recruitment No. 1
Source: own study based on (NFOŚiGW 2020; Polska PV 2016)

Rys. 6. Porównanie udziału liczby instalacji w przedziałach mocy pomiędzy stanem z roku 2015 i zrealizowanych w związku z programem „Mój Prąd" nabór nr 1

2. Calculations

Correlation 1.

The authors set themselves the goal of estimating the impact of various parameters (characteristic for the province) on the amount of power installed under the program. To select the method of calculating the unit quantity, correlation analysis for selected parameters has been used (Table 1).

The highest linear correlation coefficient was achieved for the value of the population of the province and the installed capacity in the province (0.95), the detailed relationship is shown in Figure 7 (left side). The lowest correlation coefficient was achieved for the area of the province and installed power (0.24), however, it carried values associated with the density of installations in a given area (Fig. 7) (right side). The highest power density of the installation was achieved in the province. 1.77 kWp/km^2 in Silesia, and the lowest in the Warmian-Masurian Province (0.17 kWp/km^2). In further analyses, the relation resulting from the highest value of the correlation coefficient has been used (which allows the date to be free from the burden of the difference resulting from different population number of provinces) and calculated according to the equation:

TABLE 1. Correlation coefficients between selected quantities and installation capacity
for individual provinces

TABELA 1. Współczynniki korelacji pomiędzy wybranymi wielkościami a mocą instalacji
w poszczególnych województwach

Parameter	Linear correlation Pearson coefficient
The Province population (INH (prov.))	0.95
Population – cities (prov.)	0.90
Population density (prov.)	0.83
Insolation (I_S45(prov.))	0.60
Population – villages (prov.)	0.50
Insolation (prov.) · Province area (prov.)	0.36

Source: own work based on (CSO 2019a; Ministry of Development 2019).

$$PPI\left(prov.\right)=\frac{PI\left(prov.\right)}{INH\left(prov.\right)}\cdot1000 \quad [\text{kWp/1000 inhab.}] \tag{1}$$

where:

PPI – installation power indicator per 1000 inhabitants [kWp/1000 inhab.],

PI – power installed under the program in the province [kWp],

INH – population in province.
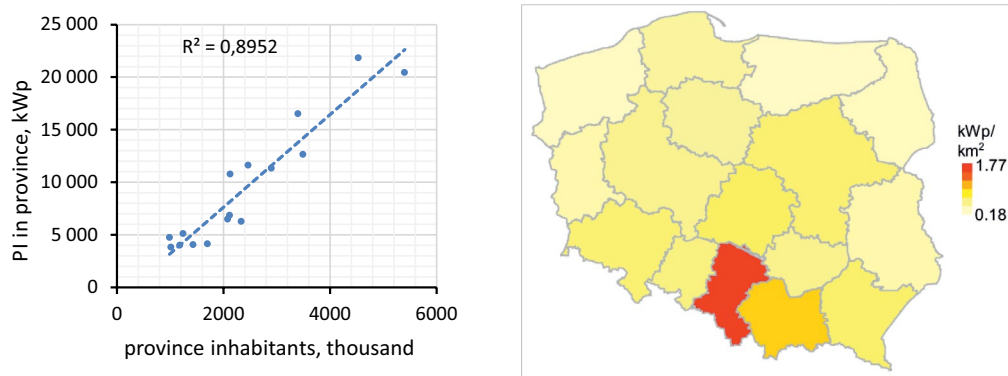
Fig. 7. Installation power in the province as a function of population – left side. Installation capacity/km^2
for provinces – right side
Source: own study

Rys. 7. Moc instalacji w województwie w funkcji liczby ludności – strona lewa. Moc instalacji/km^2
dla województw – strona prawa

The highest PPI (Fig. 8) was achieved in the Subcarpathian Province, i.e. 5.05 kWp/1000
inhab. and the lowest in West Pomeranian Province 2.41 kWp/1000 inhab. To be able to compare

these values in relation to the average value in Poland, the FPPI indicator was used (Fig. 8), calculated according to formula No. 2. In the Subcarpathian Province the FPPI index reached the value of 1.28, and in the West Pomeranian Province 0.61.

$$FPPI\left(prov.\right) = \frac{PPI\left(prov.\right)}{PPI.POLAND} \tag{2}$$

where:

FPPI	–	the power factor ratio per 1000 inhabitants in province to the power indicator per 1000 inhabitants in Poland.
PPI.POLAND	–	power indicator per 1000 inhabitants in Poland 3.91 kWp/1000 inhab.
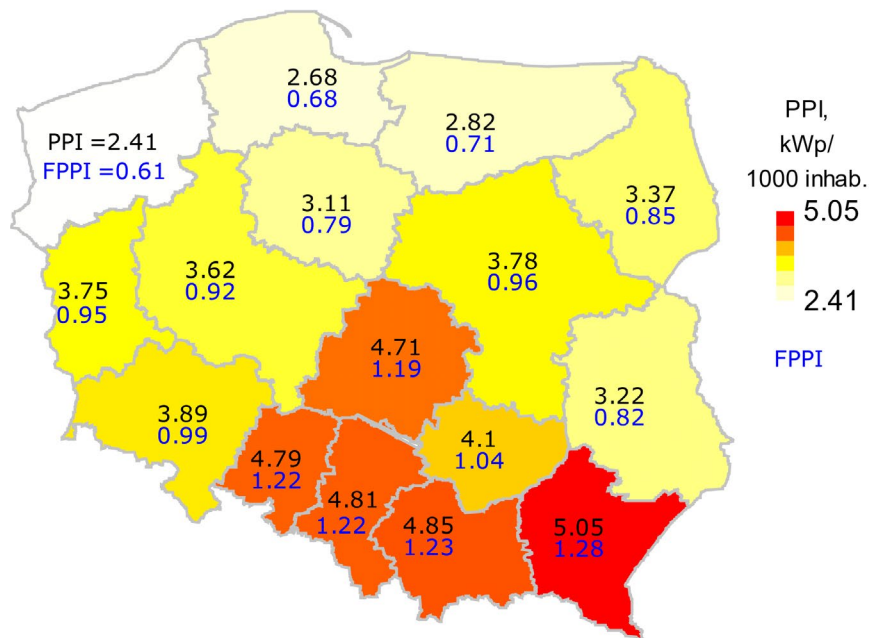
Fig. 8. PPI indicator for provinces and FPPI indicator for provinces
Source: own study

Rys. 8. Wskaźnik PPI dla województw oraz wskaźnik FPPI dla województw

Correlation 2.

The PPI indicator specified above was used to search for parameters on which the program popularity among household's investor depends on. The following were selected for analysis:

◆ IncF(prov.)/IncF.POLAND – disposable income ratio in relation to the national average in 2018 per one person in the household.

◆ I_S45 (prov.) – insolation to the south-facing plane and inclined to the horizontal plane at an angle of 45°.

- ◆ AvInc (prov.) – average monthly gross salaries in the national economy in the third quarter of 2019.
- ◆ Households energy poverty indicators by provinces in 2018:
  - ◆ LIHC – Low Income High Costs,
  - ◆ 2M – Twice the median share of energy expenditures,
  - ◆ Bills – The ability to pay bills on time (Bills).

Data was collected in Table 2 and the results are presented in Table 3. The highest correlation coefficient was achieved for PPI and insolation, equal to 0.80.

Table 2. Selected data (in columns) for provinces

Tabela 2. Wybrane dane (w kolumnach) dla województw

Province name	PPI (prov.)	IncF(prov.)/ IncF.POLAND (2018) [%]	I_S45 (prov.) [kWh/ (m^2·year)]	AvInc (prov.) [PLN/ year]	Household energy poverty indicators by provinces in 2018		
					LIHC [%]	2M [%]	Bills [%]
Lower Silesia	3.89	104	1 086.1	5 311.3	9.39	16.12	2.65
Kuyavian-Pomeranian	3.11	95	930.3	4 640.7	9.67	19.42	1.36
Lubelskie	3.22	91	1 049.8	4 602.36	14.8	18.07	1.33
Lubuskie	3.75	99	891.9	4 605.26	9.8	16.77	2.98
Łódzkie	4.71	96	1 074.2	4 863.68	8.77	19.76	1.96
Lesser Poland	4.85	96	1 130.5	5 155.7	8.45	16.58	0.69
Masovian	3.78	120	1 055.3	6 158.84	7.28	14.75	1.32
Opolskie	4.79	94	1 101.4	4 787.81	13.04	16.66	1.73
Subcarpathian	5.05	80	1 151.6	4 462.73	13.31	17.79	1.58
Podlaskie	3.37	95	974.8	4 644.56	13.21	14.39	0.85
Pomeranian	2.68	103	962.8	5 289.88	10.2	16.96	2.15
Silesian	4.81	104	1 098.4	5 200.35	6.14	15.89	2.72
Świętokrzyskie	4.10	92	1 054.8	4 529.34	8.86	19.86	0.76
Warmian-Masurian	2.82	92	973.6	4 376.11	10.91	16.99	1.81
Greater Poland	3.62	96	1 057.3	4 756.32	10.47	18.63	1.64
West Pomeranian	2.41	102	942.8	4 871.71	7.01	22.27	1

Source: own work based on (CSO, 2019b, 2019c, 2019d; Ministry of Development 2019).

Productivity and effects of PV installations

For the calculation of the average annual productivity of photovoltaic installations, the value of annual insolation at the installation site is considered (Fig. 1). The weighted average insolation value was calculated for the entire "Mój Prąd" program according to the following formula:

TABLE 3. Correlation coefficients between selected values from Table 2 and PPI

TABELA 3. Współczynniki korelacji pomiędzy wybranymi wielkościami z tabeli 2 a PPI

Parameter	Linear correlation Pearson coefficient
Insolation (I_S45)	0.80
Bills	0.11
AvInc	0.07
LIHC	−0.03
IncF(prov.)/IncF.POLAND	−0.21
2M	−0.24

Source: own study.

$$IAW.POLAND = \frac{\sum_{prov.} I\_S45(prov.) \cdot SPI(prov.)}{PI.POLAND}[\text{kWh/(m}^2 \cdot \text{year)}] \tag{3}$$

where:

IAW.POLAND	–	weighted average insolation in Poland [kWh/(m^2 · year)],
*I_S*45	–	insolation, on the S45 plane [kWh/(m^2 · year)],
SPI	–	sum of installation power in province [kWp],
PI.POLAND	–	total installation capacity in Poland in the "Mój Prąd" program (151 300 kWp).

Weighted average insolation on the S45 plane (south direction, angle 45°) for participants of the "Mój Prąd" program was 1061 kWh/(m^2 · year) with average insolation weighted by Province surface in Poland 1031 kWh/(m^2 · year). It proves that the "Mój Prąd" program is more popular in regions with higher than average solar exposure in Poland.

After multiplying the value of average insolation by the installation's power expressed in kWp (PI.POLAND = 151,300 kWp) and taking into account 10% for additional losses (transmission efficiency, inverter (Arbab-Zavar et al. 2019) and efficiency drops at high temperature of PV panels). And also, the fact that not all installations could be placed at an angle of 45°, a correction factor of 0.99 was adopted (the value of south side insolation for 30° and 45° inclination does not differ by more than 1% – Fig. 1, right side).

The annual productivity of the PV installations (1st call of the "Mój Prąd" Program) was obtained at 143.5 GWh of electricity. Considering the CO_2 emission factor for electricity according to KOBiZE (0.765 kg CO_2/kWh$_{electricity}$ (Institute 2019)) these installations will avoid CO_2 emissions of 109,800 Mg CO_2/year.

Conclusions

As part of the first edition of the "Mój Prąd" Program in Poland (2019), 27,187 applications were submitted with a total capacity of 151.3 MWp, which gives 3.94 kWp per 1000 inhabitants of Poland and 0.484 kWp per km^2. The largest installed capacity was achieved in the Silesian Province 21.81 MWp, where the highest power density was also achieved 1.77 kWp/km^2, as well as the highest number of submitted applications (3855). The lowest installed capacity was obtained in Lubuskie Province (3.8 MWp), while the lowest power density was achieved in Warmian-Masurian Province (0.17 kWp/km^2), and there were the lowest number of PV installations (644). The highest power ratio per 1000 inhabitants (PPI) was achieved in the Subcarpathian Province and amounted to 5.05 kWp/1000 inhab. (despite the lowest average installation capacity). The lowest value of PPI was achieved in West Pomeranian Province – 2.41 (kWp/1000 inhab.). The installed capacity in individual provinces was closely correlated with the population (with a correlation coefficient – 0.95) and the installed capacity index per 1000 inhabitants with insolation (0.80).

Installations reported in the first edition of the program will allow for the production of approximately 143.5 GWh of electricity per year, which corresponds to avoided CO_2 emissions in the form of 109,800 Mg/year. PLN 134 million was spent on submitted applications, which gives a co-financing rate of PLN 885/kWp. In Polish conditions, the presented method of subsidies meets economic barriers and is a good way to intensify investments undertaken by households in renewable energy.

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„Mój Prąd" jako przykład programu dotacyjnego na fotowoltaikę w Polsce

Streszczenie

Istnieje wiele finansowych sposobów na intensyfikowanie budowy nowych instalacji OZE, m.in.: taryfa gwarantowana, dotacje. Przykładem grantowego wsparcia fotowoltaiki w Polsce jest powstały w 2019 roku program „Mój Prąd". Program ten, z budżetem 1 mld zł, jest przeznaczony dla gospodarstw domowych, w których zostały zainstalowane instalacje z przedziału mocy 2–10 kWp. Podczas jego pierwszej edycji zgłoszonych było 27 187 instalacji. Ponad 98% instalacji kosztowało mniej niż 6000 zł/kWp (z czteropunktową punktacją). Całkowita moc zainstalowana to 151,3 MWp, co daje średnią wielkość dofinansowania w przeliczeniu na moc na poziomie 884,7 zł/kWp. Średnia moc instalacji w skali kraju to 5,57 kWp, wskaźnik na 1000 mieszkańców to 3,94 kWp, a na jednostkę powierzchni 0,484 kWp/km^2. Instalacje te pozwolą na wyprodukowanie ok. 143,5 GWh energii elektrycznej rocznie, przyczyniając się do redukcji emisji CO_2 o ok. 109 800 Mg rocznie. Najwięcej wniosków pochodziło z woj. śląskiego (3855), co przełożyło się na największą moc zainstalowaną 21,82 MWp oraz wskaźnik 4,81 kWp/1000 mieszkańców i 1,77 kWp/km^2 (ponad 3-krotnie wyższy niż średnia w Polsce). Zainstalowana moc w poszczególnych województwach była ściśle skorelowana z liczbą ludności województwa (współczynnik korelacji – 0,95), a wskaźnik mocy zainstalowanej na 1000 mieszkańców – z nasłonecznieniem (0,80). Najwyższy wskaźnik mocy/1000 mieszkańców (PPI) został osiągnięty w woj. podkarpackim i wyniósł 5,05, a najniższy w woj. zachodniopomorskim (2,41).

SŁOWA KLUCZOWE: fotowoltaika, odnawialne źródła energii, OZE, „Mój Prąd", OZE polityka