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The Development of Photovoltaics in the Visegrad Group Countries

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Abstract: The countries of the Visegrad Group (V4) face serious challenges related to increasing the share of renewable energy sources (RES) and the energy mix. One of the elements connected with the achievement of higher use of RES is the development of photovoltaics. The countries of the Visegrad Group still have untapped potential to increase energy production based on photovoltaic installations. However, this will require the implementation of solutions that will, on the one hand, encourage investors to choose this type of RES, and on the other hand, invest in obsolete transmission networks and energy storage. The aim of the article is to analyse the conditions related to the development of photovoltaics in the Visegrad Group countries, with particular emphasis on the further development of RES until 2030. The article also demonstrates the potential of solutions associated with the adaptation of industrial networks to the changing conditions in this sector (e.g. the growing number of prosumers). Moreover, the importance of storing energy from photovoltaic installations was emphasized, which will allow the stabilization of the energy system.

Keywords: photovoltaics; low-carbon development; economy; the Visegrad Group countries

JEL Classification: O11; Q28; Q56

1. Introduction

Recent years have brought an increase in the importance of photovoltaics as one of the fastest growing renewable energy sources. The development of this RES had a significant impact on the achievement by the Visegrad Group countries of the targets for the share of energy from renewable sources set for 2020 in the final gross energy consumption (Directive 2009/28/WE, 2009). The national targets for the share of energy from renewable sources in gross final energy consumption for 2020 set out in Directive 2009/28/EC was already achieved in 2019 by all Visegrad Group countries except Poland (Figure 1).

It should be noted that Poland committed that in 2020 the share of renewable energy sources would be 15% in gross final energy consumption (Dzikuć & Tomaszewski, 2016), in the case of Hungary and the Czech Republic it was 13%, and in Slovakia 14% (Table 1). Ultimately, Poland reached the 2020 target, which was largely due to the dynamic increase in the number of photovoltaic installations and the economic slowdown caused by the coronavirus pandemic (Rokicki et al., 2022). The limitations related to the epidemiological situation in Poland resulted in a reduction in energy consumption in 2020 (Mik et al., 2021). This reduction occurred mainly during the production of energy based on conventional

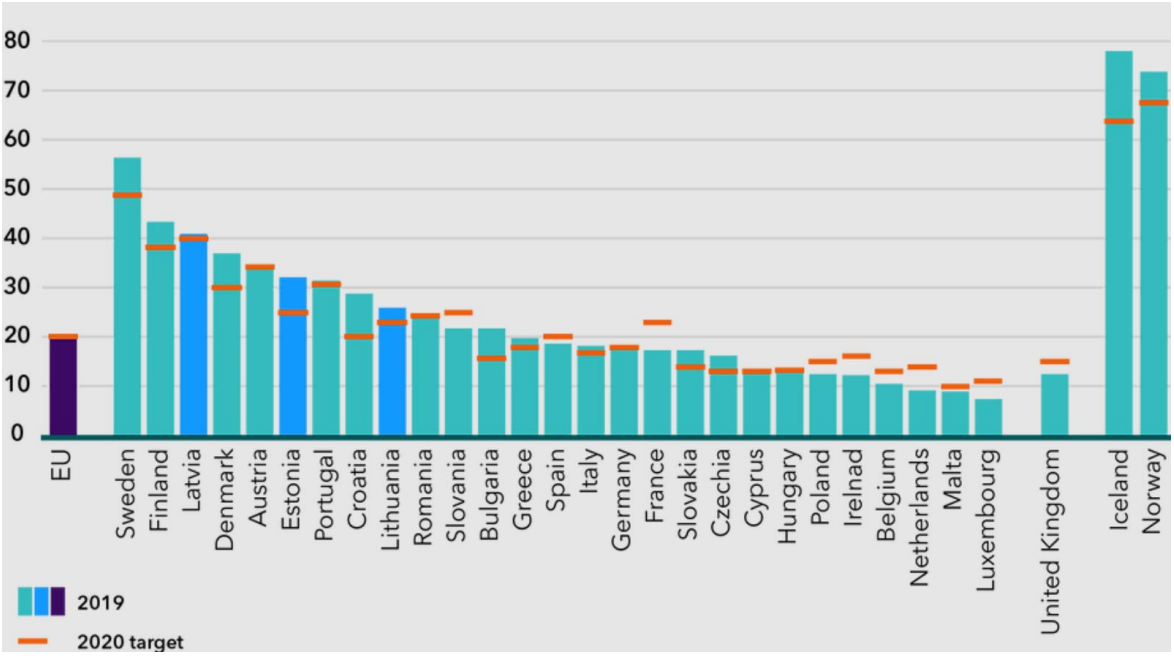

Figure 1. Overall share of energy from renewable sources 2019 (The European Bank for Reconstruction and Development, 2022)

energy resources such as lignite and hard coal. It should be emphasized that the development of RES, including photovoltaic installations, is consistent with the idea of low-carbon development (Zarębska & Dzikuć, 2013).

2. Methodology

The aim of the article is to analyse the conditions related to the development of photovoltaics in the Visegrad Group countries, with particular emphasis on the further development of RES until 2030 (Janda, 2018). The article also demonstrates the potential of solutions associated with the adaptation of industrial networks to the changing conditions in this sector (e.g. the growing number of prosumers). Moreover, the importance of storing energy from photovoltaic installations was emphasized (Kuceba et al., 2021), which will allow the stabilization of the energy system (Olczak et al., 2021).

The methodology of own research is closely related to the purpose of the analyzes. The indicated research goal was a determinant of the use of methods that are characteristic of social sciences (Poór et al., 2015). In order to effectively achieve the research goals, the following research methods were used:

- deductive method,
- analysis of source documents,
- analysis of the literature on the subject,
- methods of descriptive and mathematical statistics,
- tabular and descriptive charts.

The collected data was helpful in analyzing the development of photovoltaics in the countries of the Visegrad Group. The conducted research was helpful in trying to define the prospects for the development of photovoltaics in the coming years. Data obtained from the

central authorities of individual countries were used during the analyzes. The article analyzes statistical data and other important information related to the development of photovoltaics. The statistical data and other information used during the research were the basis for the economic characteristics of the analyzed renewable energy source (photovoltaics). The research methods and techniques used in the manuscript made it possible to achieve the assumed goal.

3. Analysis of Factors Influencing the Functioning of Photovoltaics in the Countries of the Visegrad Group

The countries of the Visegrad Group have a lower share of renewable energy in the total energy balance than in the entire European Union (Gnatowska & Moryń-Kucharczyk, 2021). Compared to other countries of the Visegrad Group, Poland generates the most energy based on RES (Figure 2). However, Poland is by far the largest country of the entire Visegrad Group, and if the number of inhabitants of individual countries is taken into account, these differences become blurred (Olczak & Komorowska, 2021). The Czech Republic and Slovakia in 2019 achieved the share of renewable energy planned for 2020, which may have contributed to the fact that the authorities of these countries were not willing to create conditions for the development of, among other things, photovoltaics (Duda et al., 2022).

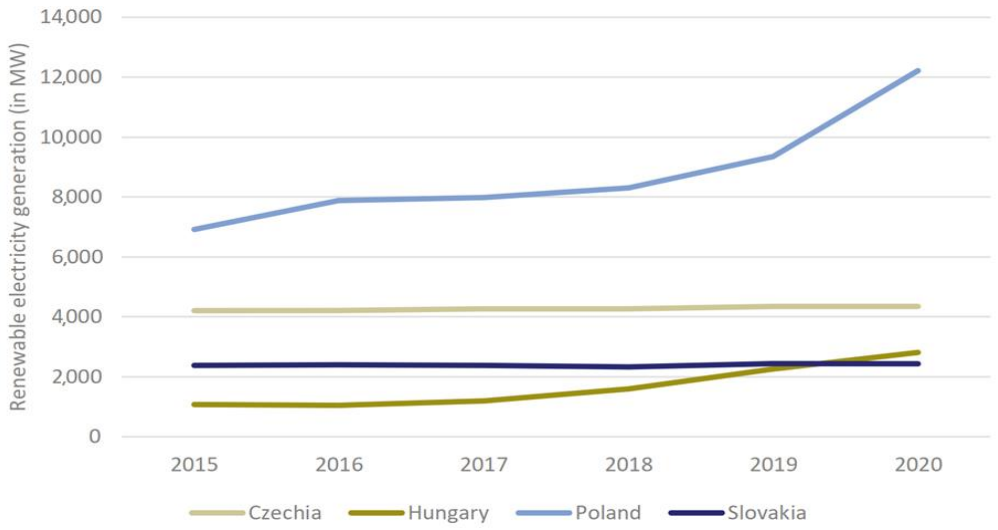

Figure 2. Production of electricity from renewable sources in the countries of the Visegrad Group in 2015-2020

Hence, the development of photovoltaics in recent years in the Czech Republic and Slovakia has been moderate. On the other hand, Poland and Hungary in 2019 were in a worse situation. In 2019, Hungary was close to the target of RES share in the energy balance for 2020, and Poland had a significantly lower share of RES and was forced to take measures that would lead to faster RES development. On the other hand, Poland and Hungary in 2019 were in a worse situation. In 2019, Hungary was close to the target of RES share in the energy balance for 2020, and Poland had a significantly lower share of RES and was forced to take measures that would lead to faster RES development. Therefore, Poland and Hungary were

exposed to sanctions by the European Union in the event of failure to meet the commitments made. Possible penalties that could be imposed on Poland and Hungary for failure to achieve the assumed share of RES could constitute a serious burden for these countries. It should be noted that increasing the installed capacity in photovoltaics, due to the relatively short period of investment implementation (Franz & Piringer, 2020), was one of the best solutions allowing Poland to achieve and Hungary to maintain the assumed RES share in the total energy balance (Hałacz et al., 2020).

The climatic conditions in the Visegrad Group countries related to the possibilities of obtaining electricity through photovoltaic installations are varied. The most favourable are in Hungary and in the southern part of Slovakia (Figures 3 and 4). However, they are less favourable in the Czech Republic and Poland (Figures 5 and 6). Yet, this does not mean that the climatic conditions in the Czech Republic and Poland lead to the lack of profitability of the operation of photovoltaic installations (Solargis, 2022). Maps showing data related to Photovoltaic Power Potential (PVOUT) for the Visegrad Group countries have been published by Global Solar Atlas, the World Bank and by Solargis. PVOUT maps provide the estimated power generation potential and provide information on the long-term average daily and annual potential electricity production from a grid-connected PV plant with a peak power of 1 kWp (kWp – the amount of electricity at the peak, i.e. at the peak of production). When estimating the potential of photovoltaics in individual countries, it was assumed that the configuration of the photovoltaic system is made of ground-based, free-standing structures that consist of photovoltaic modules made of crystalline silicon and are mounted in an optimal inclination position to maximize the annual energy production (Angowski et al., 2021). The estimates also take into account the use of inverters with optimal efficiency. Furthermore, the simulation assumes that the losses in energy production by photovoltaic installations due to their contamination amount to 3.5%. At the same time, it is assumed that the influence of the remaining losses due to cabling and shading is 7.5%. When estimating the photovoltaic potential, it was also assumed that the availability of the photovoltaic installation is 100%. When developing maps of the photovoltaic potential for the Visegrad Group countries, the temperature of the air above the ground was also taken into account (Solargis, 2022).

It is assessed that the average number of sunny hours in Hungary is around 2,000 per year. For Budapest it is approx. 1,990 hours, while for Bratislava (the capital of Slovakia) the number of sunny hours per year is similar and amounts to approx. 2,040. In the Czech Republic and Poland, however, the number of sunny hours is lower, usually in the range of 1,400-1,800 hours during the year. As previously noted, all countries of the Visegrad Group have good weather conditions for the production of energy by photovoltaic installations (Solargis, 2022). On the other hand, the most favourable weather conditions are from April to September, when the vast majority of energy is produced. It should be emphasized that the differences between Poland and the Czech Republic and southern Slovakia and Hungary are significant (Global Solar Atlas, 2022).

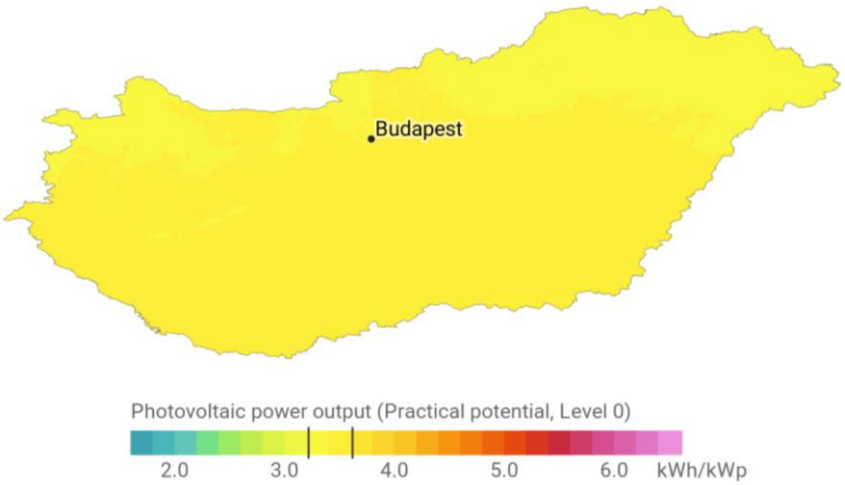

Figure 3. Photovoltaic power output in Hungary (Global Solar Atlas, 2022)

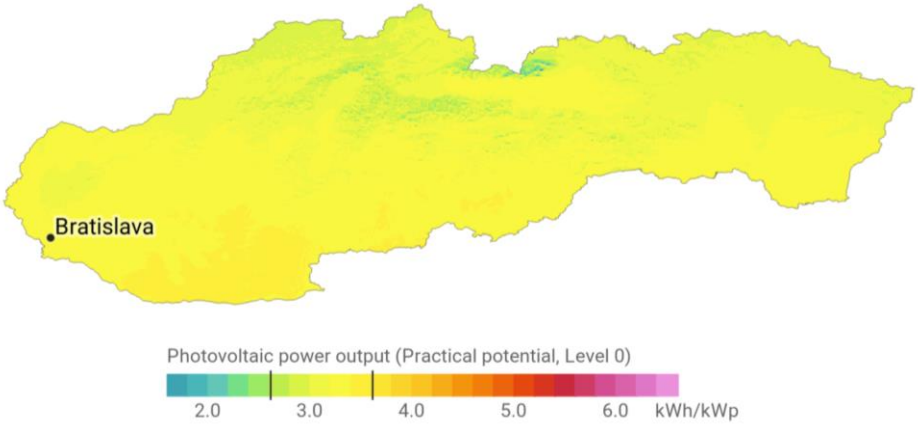

Figure 4. Photovoltaic power output in Slovakia (Global Solar Atlas, 2022)

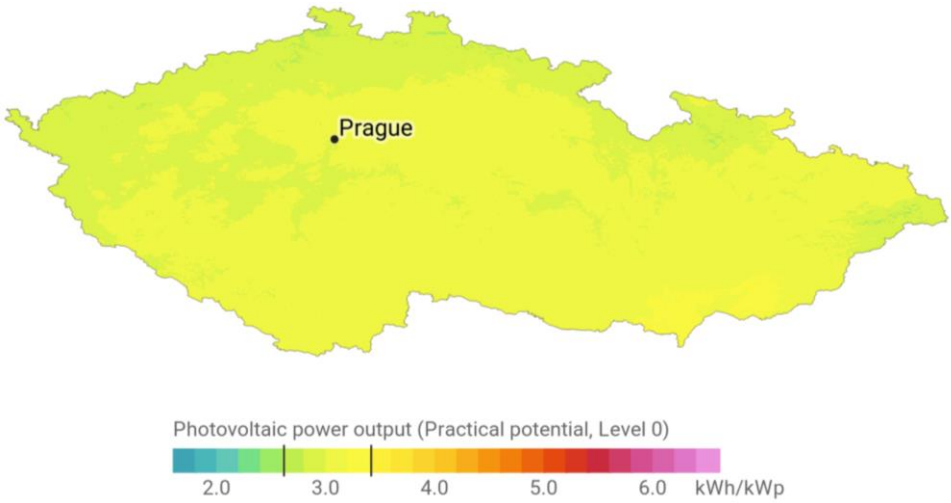

Figure 5. Photovoltaic power output in Czech Republic (Global Solar Atlas, 2022)

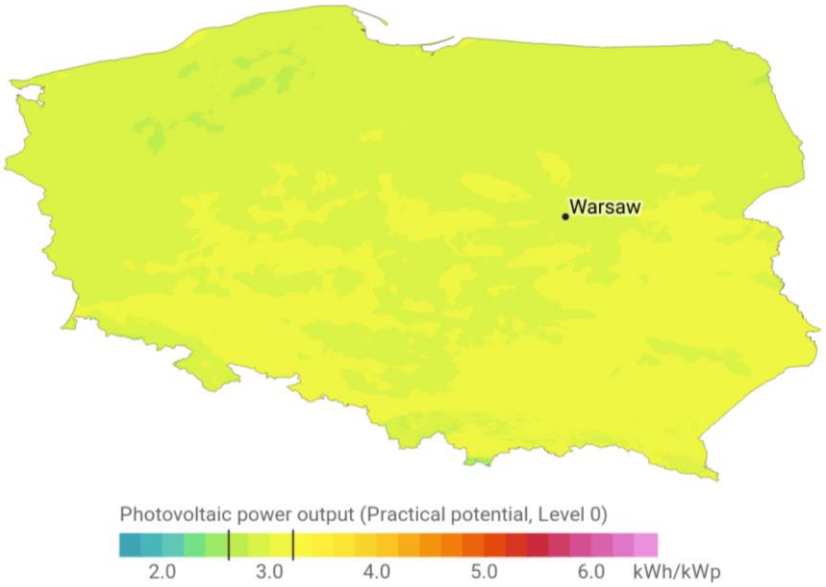

Figure 6. Photovoltaic power output in Poland (Global Solar Atlas, 2022)

4. Prospects for the Development of Photovoltaics in the Visegrad Group Countries

The state authorities of the Visegrad Group countries independently develop a national policy for the development of RES. In line with the assumptions for the National Energy and Climate Plan, Poland envisages an increase in the maximum capacity of photovoltaic installations to approx. 7.3 GW in 2030 and approx. 16 GW in 2040 (Kulpa et al., 2022). National contribution for energy efficiency (primary energy consumption and final energy consumption) of most Visegrad Group countries should be assessed as modest or low ambition. Apart from Hungary, whose national contribution for energy efficiency should be estimated as very low (Table 1).

When planning the future development of photovoltaic installations, the authorities of individual countries should take into account climatic conditions in order to maximize the efficiency of using the potential of solar energy. The example of Hungary shows that photovoltaic installations could be located in the southern part of the country, which is the area with the most favourable solar conditions (Figures 3 and 7).

It should be emphasized that the appropriate legal solutions that existed, among other things, in the Czech Republic more than ten years ago and the favorable conditions in Poland in the last few years allow us to achieve a dynamic increase in installed capacity in photovoltaic installations. However, in the case of Poland, the dynamic development of photovoltaics may weaken after April 1, 2022 due to the introduction of less favorable legal regulations, when the owners of newly built photovoltaic installations will not be able to use the energy system as a virtual energy storage (as has been the case so far). Prosumers in Poland who build photovoltaic micro-installations by April 1, 2022 will be able to use up to 80% of the energy that they sent to the energy system early. Nevertheless, after this period, they will sell unused electricity to the energy system. Currently, the prices at which prosumers will be able to sell surplus electricity produced are not known yet, but most likely

Table 1. Objectives, targets and contributions under the Governance Regulation of countries of the Visegrad Group (European Commission, 2021; European Union, 2018)

National targets and contributions	Countries of the Visegrad Group	**Latest available data**	**2020**	**2030**	**Assessment of 2030 ambition level**
Binding target for greenhouse gas emissions compared to 2005 under the Effort Sharing Regulation (ESR) (%)	Czech Republic	**4% (2018)**	**9%**	-14%	**As in ESR**
	Hungary	-10%	10%	-7%	As in ESR
	Poland	21%	14%	-7%	As in ESR
	Slovakia	-5%	13%	-12%	Ambitious (national target of -20%)
National target/contribution for renewable energy: share of energy from renewable sources in gross final consumption of energy (%)	Czech Republic	**15% (2018)**	**13%**	22%	**Unambitious (23% is the result of RES formula)**
	Hungary	12.5%	13%	21%	Unambitious (23% is the result of RES formula)
	Poland	11.3%	15%	21-23%	Unambitious (25% is the result of the RES formula)
	Slovakia	11.9%	14%	19.2%	Unambitious (24% is the result of the RES formula)
National contribution for energy efficiency: a) primary energy consumption (Mtoe) **b) final energy consumption (Mtoe)**	Czech Republic	a) **40.4 (2018)** b) **25.3 (2018)**	a) **43.3** b) **23.9**	a) **41.43** b) **23.65**	a) L**ow ambition** b) M**odest ambition**
	Hungary	a) 24.5 Mtoe b) **18.5 Mtoe**	a) 24.1 Mtoe b) **14.4 Mtoe**	a) No target set **785 PJ** b) **(18.7Mtoe)**	a) **Very low** b) **Very low**
	Poland	a) 100.9 Mtoe b) 71.8 Mtoe	a) 96.4 Mtoe b) 71.6 Mtoe	a) 91.3 Mtoe b) 67.1 Mtoe	a) Modest b) Modest
	Slovakia	a) 15.8 Mtoe b) 11.1 Mtoe	a) 16.4 Mtoe b) 9.0 Mtoe	a) 15.7 Mtoe b) 10.3 Mtoe	a) Low ambition b) Low ambition
Level of electricity interconnectivity (%)	Czech Republic	**26.6% (2018)**	**29.6%**	**44.1%**	**N.A.**
	Hungary	50%	55%	60%	N.A.
	Poland	4%	4%	8.7%	N.A.
	Slovakia	43%	59%	52%	N.A.

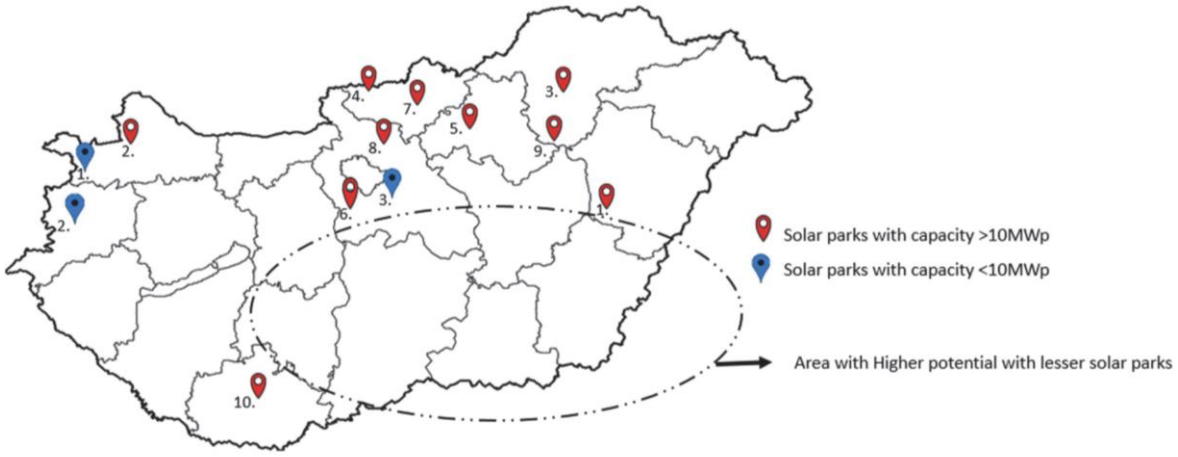

Figure 7. Solar park presence in various regions of Hungary based on power capacity (Kumar et al., 2021).

it will be a price much lower than the price they will have to pay for the electricity taken from the grid (Wciślik & Kotrys-Działak, 2021).

It should be emphasized that public economy is related to the development of photovoltaics. Central authorities decide on the co-financing of individual RES. In addition, the government authorities set the conditions for the sale of the energy produced from the photovoltaic installation (Klepacki et al., 2021). These solutions have a large impact on the decisions of investors, because they affect the economic efficiency of the operation of photovoltaic installations.

5. Conclusions

Geospatial analyses demonstrate the potential of the Visegrad Group countries in the further development of photovoltaics. Even though the climatic conditions are not identical in all analysed countries. In the southern part of Slovakia and in most of Hungary (especially the southern region of Hungary), there is the greatest potential for locating solar PV installations.

It should be noted that the factor influencing the increase in the share of renewable energy by the Visegrad Group countries may be the increasing fees for CO_2 emissions, which in December 2021 reached a price of approx. EUR 90 per ton. This may be particularly important in the case of Poland, which has the highest share of coal in the energy mix of all the countries of the Visegrad Group. Moreover, for the development of photovoltaics to be possible, actions will be needed to stabilize energy networks, which are often outdated.

In addition to the obvious solutions consisting in the modernization of power grids, it will be necessary to build local energy storage facilities that will help to relieve the power grid during summer days, when the largest amount of energy is produced by photovoltaic installations. The countries of the Visegrad Group are moderately decisive in their approach to a significant increase in the share of energy from RES in the energy mix.

The development of photovoltaics is closely related to public administration. An example may be the decisions of the central authorities in Poland, which led to the

creation of 850,000. micro-installations within three years. Similar examples of the influence of governmental decisions on the development of renewable energy sources (including photovoltaics) can be found in other EU countries.

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Conflicts of Interest: none

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