Inventory

ECONOMIC DEVELOPMENT ON THE BASIS OF RENEWABLE ENERGIES

Kraków Metropolis Association, June 2019

Notes on the research method

This Inventory arises at a special moment for renewable energy sources (RES) in Poland: on the eve of 2020, which closes the current perspective of energy transformation and the development of RES. Thus, we can already make some assessment of the adopted objectives, policies, plans, actions, and results. One should also draw conclusions and indicate directions that ought to be regarded in the perspective of the new horizons of 2030 and 2040.

The more ambitious goals of international policy reacting to the deepening climate crisis cause, also in Poland, the development of RES accelerated. Legislative changes and law adaptation, as well as technological progress, is so dynamic that monitoring and research do not always follow the dynamics of transformations. The institutions operating on the national level produce fresh statistics, but on the regional and communal scales, some recent data are dispersed whilst ones published a few years ago present a totally outdated state of affairs. In order to reflect the most up-to-date situation in Poland and Małopolska, we often used data collected and published by non-governmental and non-public organizations working for the development of RES, as well as press materials available in specialist industry websites. Local governments' websites have been the main source of information on current activities in the region.

The Inventory focuses on the use of renewable energy in the areas of production of electricity, heat, and transport. What needs to be additionally explained is our approach to cogeneration (CHP), which is becoming increasingly common in Poland. It is the process of the simultaneous generation of electricity and useful heating in a combined heat and power plant. Some of the CHP plants have an installation that enables the supply of RES, mainly biomass, which share in the total fuel stream fed to boilers, often reaching several dozen percent. In concessions from the Energy Regulatory Office (URE), CHP systems using biomass are classified as RES installations. Therefore, in such cases we decided to assume that these plants produce heat or electricity from RES and accounted for them in the RES balance sheets.

POLICY TARGETS

1. What are the policy objectives with respect to the use of renewable energies in the heat, transport and electricity sectors?

The current assumptions for the development of renewable energy in Poland are set out in the Act of 20 February 2015 on renewable energy sources (Dz. U. 2018 poz. 2389).

The most important strategic document in which the policy objectives for the use of renewable energy are indicated is the *Poland Energy Policy 2030* (M.P. 2010, No. 2, item 11). The main targets are, among others: increasing the share of RES in the final energy consumption to at least **15% in 2020** and **20% in 2030**; the **10% share of biofuels** in transport fuels, and the increased use of second-generation biofuels in 2020.

Pursuant to the Renewable Energy Directive (2009/28/EC), in 2010 Poland adopted the *National Renewable Energy Action Plan 2020* (KPD). The plan defines the targets in the sectors of electricity, transport, heating and cooling, and defines the measures to be taken to increase the share of renewable energy in the use of final energy.

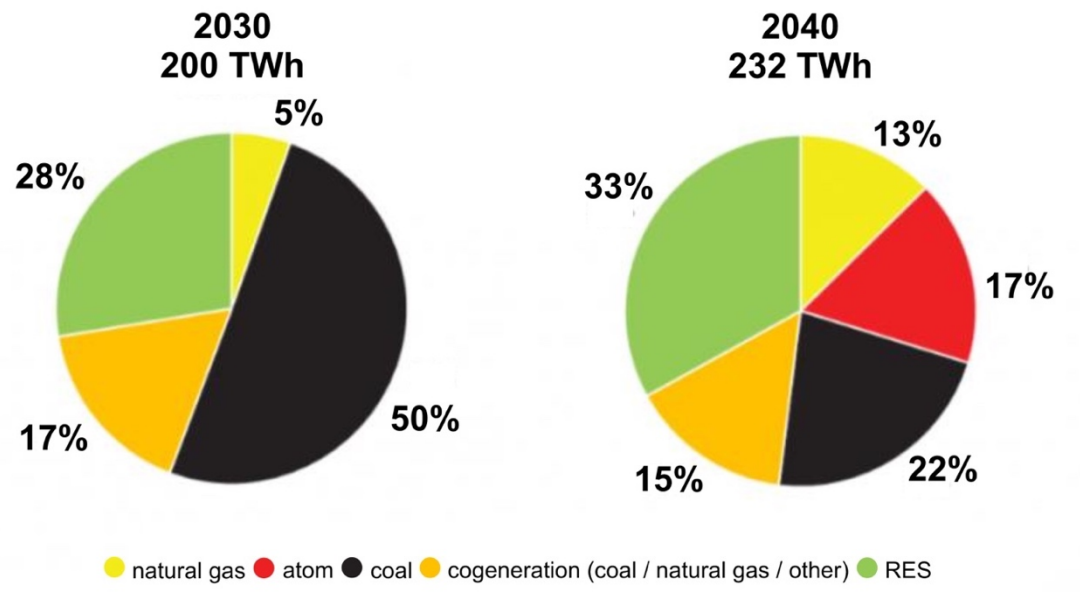
Currently, the *Poland Energy Policy 2040* is being prepared. As of June 20, 2019, the draft of this document, available for consultation (PEP 2019), was available on the Ministry of Energy's website. Simultaneously, the *National Plan for Energy and Climate 2021-2030* is being drafted, resulting from the Regulation (EU) 2018/1999 of the European Parliament and of the Council of 11 December 2018 on the Governance of the Energy Union and Climate Action (KPEK 2019).

As part of the EU target for 2030, Poland declares a **21% share of RES in final gross energy consumption**.

The main objective is the reduction of the emission intensity and the diversification of energy sources. Today, 80% of electricity in Poland is produced from **hard coal and lignite coal**. The draft PEP2040 assumes that, in 2033, the first nuclear power plant will be included in the system, and natural gas plants should be used as the system's stabilizers. The installed capacity is to increase from the current 42 GW to 72.6 GW in 2040. The annual production of energy is to increase from 165 TWh to 232 TWh.

The share of RES in Poland is to grow much slower than in the entire EU.

Fig. 1. Energy production by source according to draft PEP2040



The RES in heating industry targets

As they start difficult and expensive modernization processes, Poland's heating companies usually choose well-known, proven solutions based on waste and biomass incineration CHP. Their use of solutions that allow sustainably reduced dependence on fossil fuels, while eliminating environmental costs, is relatively rare.

According to the IEO (June 2019), despite the projects supported by **financial instruments and subsidies**, the Polish heating sector's pace of transition may be too slow; it could cause the entire power industry's inability to fully benefit from funds for innovation and general transformation through e.g.: intelligent microgrids, energy cooperatives, clusters, and RES communities, which will be supported in the EU after 2020 (IEO 2019a).

Technologies that, until recently were considered too expensive or not suited to Poland specifically, are becoming economically viable enough to support heating companies' development. First of all, these are investments in new RES and heat storages, as well as integrated multi-source solutions permanently reducing costs in heating.

The ElectroMobility Development Plan

EU regulations oblige Poland to achieve in transport a **10% share of renewable energy in 2020** and **14% in 2030**.

In 2016, the Ministry of Energy adopted the ElectroMobility Development Plan, which assumes that by 2025, a million electric cars will be used in Poland. The plan also includes the electrification of public transport. In 2020, there should be approximately 75,000 electric cars registered in Poland, of which 70% will be in agglomerations and densely populated areas. In 2025, half of the fleet used by the public administration is to be electric.

PGE, Energa, Enea and Tauron, the biggest power companies in Poland, appointed the ElectroMobility Poland company, which will contribute to the implementation of the plan.

Systemic objectives

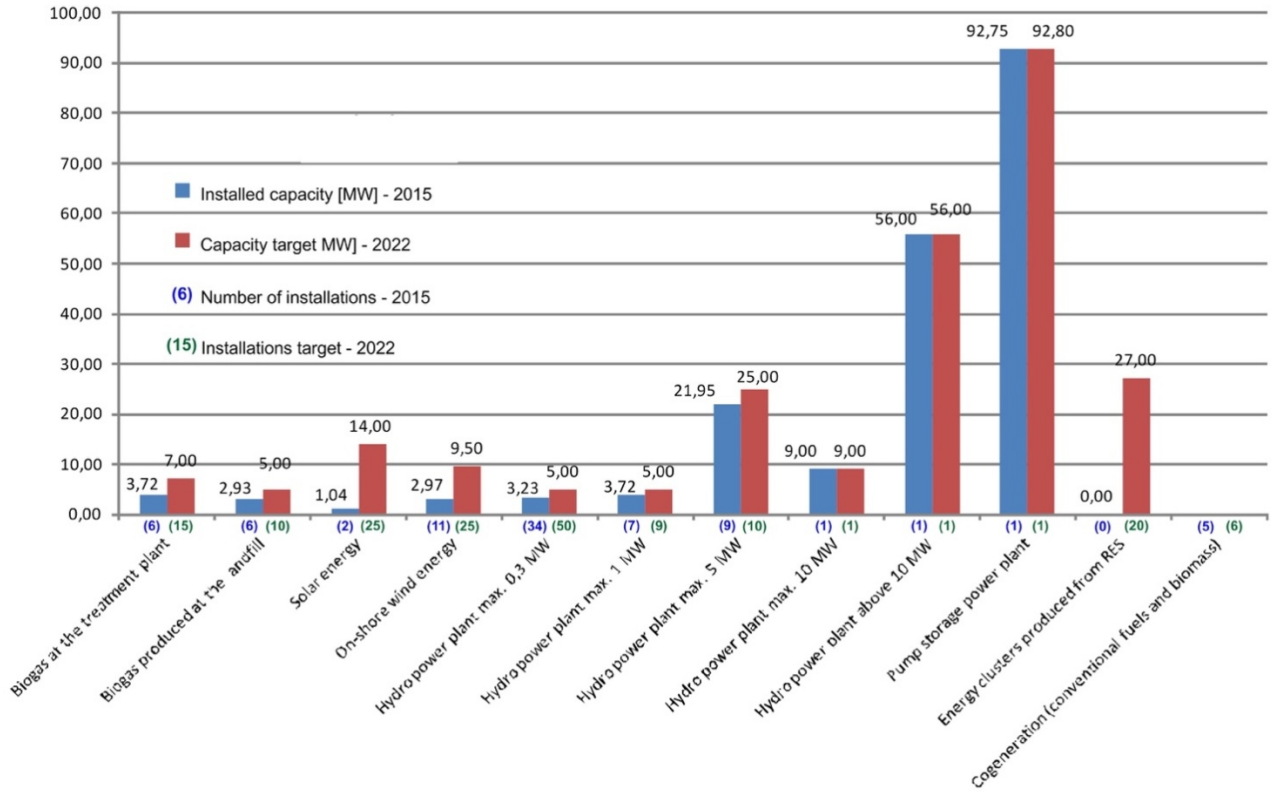
A significant part of generation capacity from renewable energy installed in Poland is based on unstable sources, dependent on atmospheric conditions, and working a low number of hours a year. In systemic terms, this has an adverse effect on the efficiency and cost of energy generation; it is necessary to maintain reserve power and a high flexibility of the entire system, which generates an increase in energy costs. The development of **energy storage**, **intelligent energy management** systems, and the creation of incentives to improve the **price flexibility** of energy demand will contribute to the use of energy from RES.

Regional policy of Małopolska

The Development Strategy of the Małopolska Region 2011-2020 (DSMR 2020; 121-122) recommends increasing the utilisation and promotion of RES substantially. The Strategy recommends identifying the existing and potential development barriers, and determining the direction of the regional policy of renewable energy development as one of the key actions.

The Małopolska Spatial Development Plan (PZPWM 2018; 76) indicates the need to shape **compact urban structures** that minimize energy demand and increase the use of RES. In the development scenarios, an increased demand for energy is expected, but also greater opportunities for prosumer energy and the use of RES. PZPWM therefore provides for a gradual increase in the share of energy from RES, but only to achieve the level assumed in Directive 2009/28/EC. The plan assumes creating conditions and mechanisms aimed at increasing the share of renewable energy generated in the region from 9.5% in 2015 to **15% in 2022**, in particular based on solar energy, biogas and biomass combustion, efficient energy use (including thermal modernization of buildings and RES heating), and improving the system of organizational, educational and financial solutions.

Fig. 2. The RES licensed installations in Małopolska according to plan 2022 in relation to 2015 (PZPWM 2018; 76)



Strategy for KrOF Integrated Territorial Investments [ITI]

Air pollution is a major problem in KrOF. In the Strategy for KrOF ITI (Noworól 2014), it is noted that the quality of air might be improved by the development of RES. This positive effect, however, does not apply to the combustion of biomass which often causes high emissions of Particulate Matter [PM]. For this reason, the total prohibition of all solid fuels, including biomass, will be introduced in Krakow in September 2019 (UM Kraków 2014).

One of the priorities of KrOF ITI that affects the quality of life is the transition to a low-carbon economy, including the thermal modernization of buildings, smart energy management, and the use of RES. However,

among the indicators adopted in the Strategy for KrOF ITI, there is none that would allow the direct control of RES development.

In the Environmental Impact Assessment of the Strategy for KrOF ITI (ATMOTERM SA 2014; 73, 108), the following indicators related to renewable energy were proposed for the annual control:

- Capacity of RES devices (implemented by KrOF projects) [MW];
- Low voltage electricity consumption per capita [kWh];
- Number of new RES installations in municipal facilities (implemented by KrOF projects).

2. What is the role of the different government levels in implementing these policy objectives?

The **central government** occupies the pivotal role in the development of RES. The state's policy so far has been characterized by the lack of a long-term vision (e.g. 25 years), ad hoc regulations, the instability of law and growing legislative uncertainty. These generate serious risks and impact the availability of project financing (especially for smaller investors) and, consequently, the scale of investment and RES costs.

The draft PEP2040 (as of 2019-06-20) contains provisions on the role of **local governments** in the implementation of specific objectives, i.e. ensuring conditions for the development of energy-sustainable areas at the local level (energy clusters, cooperatives – target: approx. 300 in 2030).

The involvement of local governments and **local energy planning** will have a special role in the implementation of the National Heating Plan. There are plans to activate **communes**, **poviats,** and **regions** in energy planning resulting in rational energy management, the development of clean energy sources, and the improvement of air quality. Planning should be based on real **cooperation between regional and local authorities**.

Municipalities and **bottom-up local initiatives** play a crucial role in building awareness and ecological needs, thus the combined sales, as well as various forms of financial support from public funds are to be used as incentives for using RES.

Regional and local authorities also are responsible for providing conditions for the development of clean and efficient heating systems. They are obliged to cooperate with the minister responsible for energy matters and the voivode in the planning and implementation of fuel and energy supply systems.[1]

The **regional government** participates in the planning of energy and fuel supply and examines the compliance of energy plans with the national energy policy.

Poviats are responsible for system security, public services, and citizens (Dz. U. 2019 poz. 511). This obligation is extremely important in dispersed generation systems.

The responsibilities of the **municipality** include planning and organizing the supply of heat and electricity in the commune; the rationalization of energy consumption; the promotion of consumption reducing solutions; and the assessment of the potential of local electricity generation.

[1]The role of particular local government levels is regulated in this context by the Energy Law Act (Dz.U. 2019 poz. 755).

3. Which country-specific conditions contribute to the choice of renewable energies?

There has been a slight upward trend in RES energy production in recent years. The share of renewable energy from RES in total primary energy in Poland increased between 2013–2017 from 11.9% to 14.1% (GUS 2018; 1). In 2017, energy obtained from renewable sources in Poland came mainly from:

- solid biofuels (67.9%),
- wind (14.0%),
- liquid biofuels (10.0%).

RES in Poland also includes biogas, water energy, and solar radiation, as well as ambient energy harvested by heat pumps and geothermal resources.

The structure of obtaining energy from renewable sources for Poland is regionally diversified, which not only results from the characteristic geographical conditions, but also to a large extent from the national energy policy and regulations that promote or inhibit the development of energy acquisition from particular sources.

With a very large share of energy from coal, the development of RES will be driven not so much by the regional specificities or decision-makers, but mainly by the increase in the prices of **CO_2 emission allowances**.

In the **power industry**, wind has the largest share in the RES branch (68% in 2018). The capacity of **hydroelectric** installations is almost constant, however in 2018, it slightly decreased. It is the only decrease in all the RES branch. **Biomass** and **biogas** have grown steadily.

Fig. 3. RES capacity in Poland by source from 2012–2018 [MW] (Rynek Elektryczny 2019)

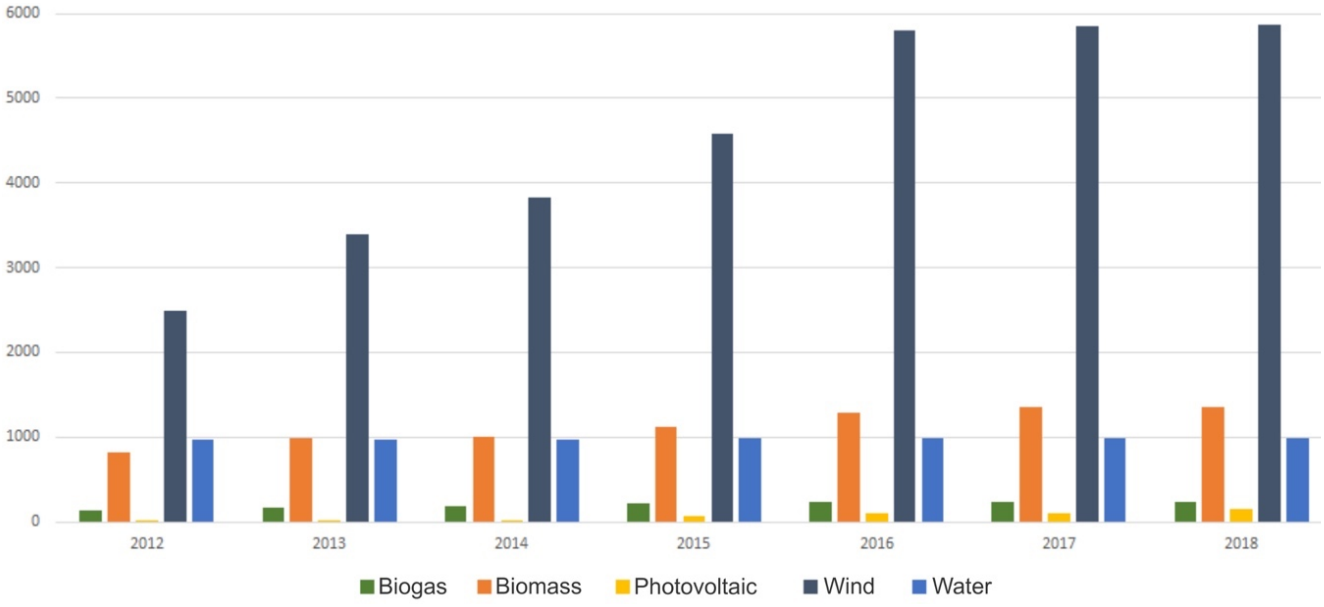
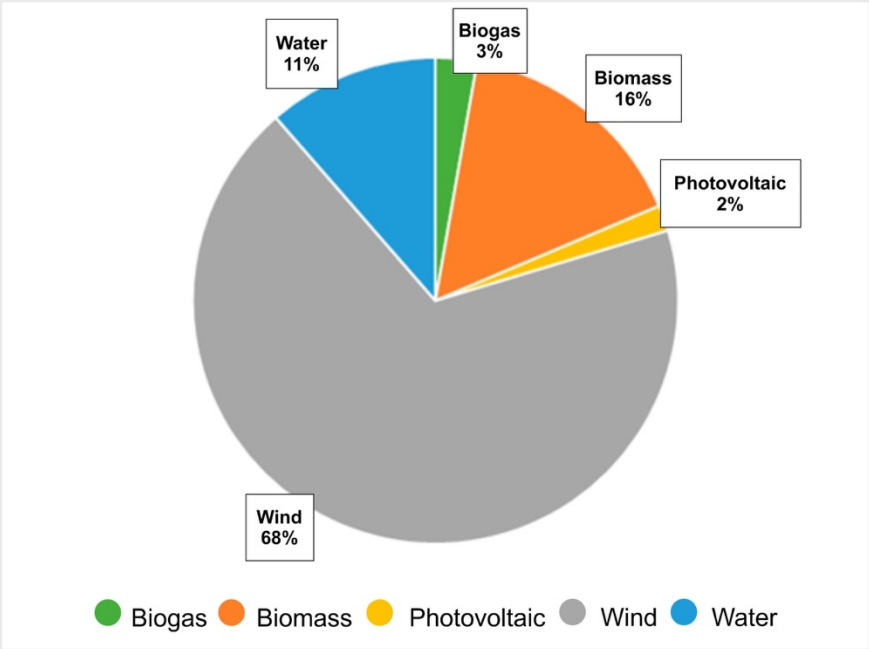


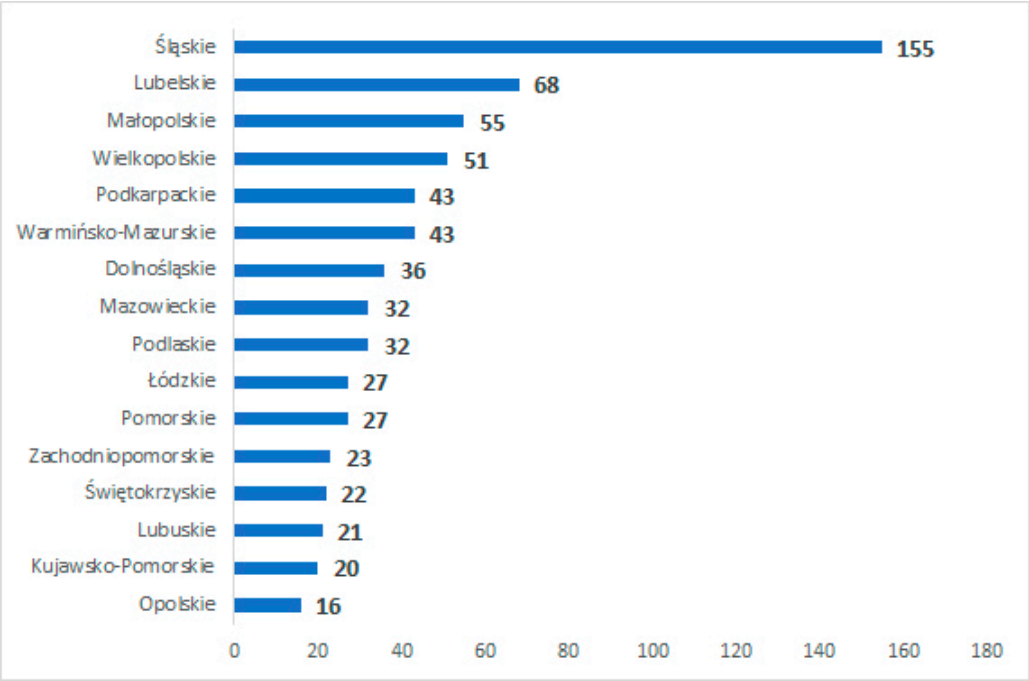
Fig. 4. RES in Poland by source in 2018 [MW] (Rynek Elektryczny 2019)



The dynamics of photovoltaics (PV)

The number of PV installations is strongly differentiated regionally. According to URE, the number of RES power installations at the end of 2018 amounted to 3017, of which 1198 are wind, and 671—PV. PV installations accounted for 22% of all RES installations. Most of them are located in Śląskie. Małopolska ranks third in Poland (Rynek Elektryczny 2019).

Fig. 5. The number of PV installations by region (31-12-2018) (Rynek Elektryczny 2019)



The largest increase in 2018 concerned PV. Its capacity increased by 43 MW compared to 2017. However, its share in the total amount of RES installed capacity at the end of 2018 was only 2%. Until now, the prosumer segment was the leading one in the development of PV in Poland, but since the first auction for solar installations in December 2016, the image of the PV industry has changed radically. According to current trends, at the end of 2020, the total installed capacity of PV should reach over 1.2 GW; as a result, it could become the second technology in Poland's RES branch in terms of installed capacity.

Alongside the ‘traditional’ household prosuments and energy companies, the commercial prosuments are becoming increasingly important. Considering the high prices of electricity and their forecasted continuous increase (in particular for industry and farms), the commercial prosumage of solar electricity seems very prospective.

According to PEP2040, further dynamic change is planned regarding installed generation capacities. By 2040, the PV is to become the dominant technology. The offshore wind energy sector also will grow significantly.

The dynamics of wind power generation

The last capacity auction for energy from RES in November 2018, after the amendment of the RES Act, showed the dominance of wind farms over photovoltaic power plants, with respect to the capacity above 1 MW. A large auction is planned for autumn 2019, in which the total capacity of new wind projects that will win 15-year contracts for energy sales at a guaranteed price, may reach 2.5 GW (IEO 2019e; 4).

In May 2019, 570 wind projects were being developed in Poland, 90% of which already had connection agreements.

According to the IEO, of the 570 currently implemented wind projects, only one is located in Małopolska.

Fig. 6. Locations of currently implemented wind projects in Poland’s regions (URE 2018)

Region of Małopolska

According to the Energy Regulatory Office (URE 2019a), by 2019-06-20, 81 licensed producers and small-scale commercial installations generating electricity in renewable energy installations were identified in Małopolska. Different types of installations have been located in areas where the specific environmental, economic and technical conditions might strongly influence decisions about running particular type of renewable energy production.

Among the 81 units, 15 use biogases generated in the process of sewage disposal or treatment, or biogas produced in landfills. Those units have been located mainly in major urban centres such as Krakow, Skawina, Oswiecim, Nowy Sącz, and Myślenice. Urban agglomerations produce large amounts of sewage and wastes so this ensures continued supplies of material for biogas production. Access to these waste products is also important for the operation of the unique thermal waste treatment plant in Kraków.

- **PV farms**

16 units in the Małopolska Region generate electricity from the photovoltaic farms. The biggest ones, of an installed capacity about 1 MW, have been located in the eastern part of Małopolska, in the Tarnowski Poviat (Wierzchosławice, Radłów) and the Bocheński Poviat (Gierczyce). Effective localisation of a photovoltaic farm requires non-shadow places and a dust-free area. It is also necessary to find a sufficiently large, flat area. Considering these, the eastern part of Małopolska is the most suitable for photovoltaic farms. The variable weather conditions and the mountainous topography makes big-scale photovoltaic investments less profitable in the southern part of Małopolska. The levels of urbanisation and air pollution make them less profitable in the northwest part of the region.

- **Wind farms**

Eleven units in Małopolska produce electricity from the wind. The units with the largest installed capacity have been located in the northern part of the region, in the Miechowski Poviat (Kalina Rędziny, Kalina Mała). The location of a wind farm must have a stable wind regime. Distances from the households, transport infrastructure, electricity networks, and environmental conditions – a wind farm should not be located in an area of nesting and migration routes of birds and bats – is just as important. Considering these, the northern and eastern parts of Małopolska are considered the best for wind farm investments. In those areas, weather conditions are more stable than in the mountainous, southern part of the region, and the vast agricultural areas allow the building of wind turbines in the proper distance from farmhouses and other buildings. Even more importantly, those areas are not often subject to nature protection.

- **Hydroelectricity**

In the southern part of Małopolska, thanks to its mountainous topography, water power developed as an industry. 35 hydroelectric power plants have been built mainly in the areas with great land slopes or in places where the water was dammed up. The largest ones are located on the Dunajec River (Niedzica, Rożnów, Czchów) and on the Vistula River (Kraków-Dąbie, Kraków-Przewóz, Kościuszko) barrages. The largest number of hydro power plants is located in the Poviats: Tatrzański and Nowotarski.

- **Geothermal sources**

In the southern part of Małopolska, a unique heating plant which uses geothermal waters in the temperature range above 80˚C (Geotermia Podhalańska) has been built. The main qualifying factors for geothermal heat or electricity production are specification of geothermal waters (e.g. temperature, mineralization), geological conditions (e.g. aquifer depth and its extension) and the heat customer structure. The compact type of urbanisation in the Podhale towns and villages favours the establishment of the heat network there. In the northern part of Małopolska, apart from the bigger urban centres, a dispersed type of urbanisation dominates. It can cause unfavourable economic and technical conditions for big-scale heat production from geothermy, even if the geothermal water parameters and other natural conditions are met.

Kraków Metropolitan Area (KOM)

Table1. Locations of the largest RES installations in KOM (installed capacity over 0,5 MW) by poviats (locations in KrOF are marked in red) (2018-12-31) (URE 2019a).

Type of RES	Poviat	Installed Capacity [MW]
Thermal waste treatment	City of Kraków	16,9
Hydro	Wadowicki	4,61
Hydro	Wadowicki	3,7
Hydro	City of Kraków	3,2
Hydro	City of Kraków	3,2
Mixed biomass	Wadowicki	3,15
Hydro	Krakowski	3,03
Wind	Miechowski	3
Hydro	Myślenicki	2,56
Hydro	Krakowski	1,6
PV	Bocheński	1,382
Landfill biogas	City of Kraków	1,341
PV	Miechowski	1
Wind	Miechowski	0,9
Hydro	Krakowski	0,76
Landfill biogas	Olkuski	0,73
Sewage treatment biogas	City of Kraków	0,557
Wind	Proszowicki	0,5

Kraków Functional Area [KrOF]

RES technologies, which dominate in KrOF, are based on biogas, multi-fuel combustion (with biomass) and thermal waste treatment. It is believed that installations based on these technologies should also be developed in the nearest future. On one hand, they cover the increasing demand for heat and electricity production, which is likely to occur as a result of the continuous development in KrOF. On the other hand, they help to manage the increasing amount of sewage and waste in Kraków and the neighbouring municipalities.

The PV farms and the wind farms need big areas of land to produce electricity on an industrial scale. It can cause difficulties for implementing these technologies in KrOF considering the dispersion of housing developments and the protection of forests, nature conservation areas, and the growing demand for recreational areas in Krakow and neighbouring communes. The photovoltaic plant needs to cover about 2 ha of land to produce 1 MW of electricity. The total installed capacity of heat and power plants in two communes: Krakow and Skawina equals 450 MW of electricity and 2 590.6 MW of heat. An equal electric capacity from the PV plant would need to ensure 900 ha of land, which is comparable to e.g. a half of the total area of the town of Skawina (2050 ha).

The existing hydroelectric power plants on the Vistula River probably use the maximum potential for the location of this type of plant in KrOF. But the development of this kind of energy source is still possible through the modernisation of electricity production technology and an increase in energy efficiency.

4. Who bears the costs of the energy transition and how are these distributed? Are there differences between the heat, transport, and electricity sectors?

There is a lack of discussion in Poland about the costs of energy transformation and who should bear them: households or other groups of recipients.

Some energy recipients, e.g. small and medium enterprises, large customers, including energy-intensive industry, can negotiate electricity prices and billing terms. Electricity sellers are required to submit for approval to the President of the URE only the tariffs and billing terms for household customers.

Tariff-protected households account for about 25% of annual energy consumption, while industry and small and medium enterprises consume about 75% (Prawo2019). If the increase in energy production costs is not transferred to individual recipients, i.e. households, a gap is created, which is compensated by raising prices in the low-voltage enterprises sector. Finally, the rise in energy prices is reflected in households due to the increase in costs of products and services.

Electricity production in Poland is based on conventional fuels, mainly hard coal and lignite coal. Currently, due to the growing global coal prices, electricity prices are expected to increase. In addition, the prices of CO_2 emission allowances are increasing, which in the case of conventional fuels also raises energy costs. The general dynamics of the fall in energy prices due to the costs of renewables going down does not actually affect Poland, where the share of RES in the fuel structure is still insignificant (Gazeta Prawna 2018).

The bill which a household pays for electricity consists not only of the price of energy, but also (in about 1/2) the cost of its distribution: fixed and variable fees and other costs including RES support. In addition, the increase in the share of the fixed fee in the distribution costs **reduces the attractiveness of investments in energy efficiency and prosumerism**.

The RES Act does not support the production of **heat** from RES, and almost entirely focuses on the production of electricity. Therefore, new legal and economic impulses as well as technological and market innovations are needed so that the enormous potential of renewable energy production in distributed systems could be widely and properly used.

The support for **electromobility** described below has for the time being a limited scale and a dubious impact on the reduction of energy transition costs.

5. Does the expansion of renewable energy systems face acceptance problems? If so, what are the citizens' motives?

In 2015, an opinion poll was carried out for IEO (TNS 2015), on the social attitudes of Poles towards microinstallations and prosumerism. The results have shown that every third household would like to use energy from renewable sources, primarily solar energy (40% of respondents indicated solar collectors). Every sixth respondent would like to invest in a small wind turbine, heat pump or PV. Unfortunately, the poll also showed the lack of awareness of mechanisms of prosumerism, and the expected payback times.

Another poll about RES on a macroeconomic scale (CBOS 2016) showed that RES is the expected direction of industry development in Poland. 50% of respondents shared this view; 39% were in favour of the balanced use of renewables and non-renewables.

On one hand, the acceptance of RES is high, but on the other, many respondents conservatively assume that Poland has large coal resources that should be effectively used. Poles are interested in energy issues, but their knowledge about energy systems is limited.

Low level of ecological awareness and a lack of knowledge about the operation of energy systems may be the main reason for the protests that might occur when a RES installation is considered in the neighbourhood (NIMBY). Wind farms are perceived negatively mainly due to environmental problems such as noise (wind turbines) and changes in the landscape (wind turbines, PV farms).

Among the social problems with RES, tensions about the distribution of benefits should be mentioned. A small group of investors and landowners significantly increase their incomes, while their neighbours have the sense of bearing the environmental costs.

The opposition by residents to the development of wind farms was the reason for the introduction of the Wind Farms Investment Act in 2016 (Dz. U. 2019 poz. 654) (the so-called Distance Act), which blocked most investments in wind farms and caused the withdrawal of many major investors from Poland.

Of all RES, the windmills trigger the most intense emotions. For example, in 2008, in the commune of Sułoszowa in the Kraków poviat, a foreign investor arrived to build a wind farm. Three years later, residents' protests began. The case was described in a detailed report (FME 2013). The arguments against the investment consisted of:

- the lack of wasteland and still cultivated agricultural land (the belief that the area loses agricultural value);
- the specific arrangement of narrow plots (a larger number of owners had to agree on the benefits);
- neighbourly jealousy about further economic benefits;
- distances from buildings and the potential impact of windmills on health;
- the landscape spoilage;
- shortages of knowledge and information;
- residents' sense of investment “behind their backs”.

The study revealed that the residents of Sułoszowa were generally sympathetic to RES. Their resistance was awakened by the way the investment was being prepared and the communication shortages. The outbreak of the dispute that led to the withdrawal from the investment resulted from factors such as:

- the low level of initial awareness about the hazards and inconveniences resulting from the windmills,
- the frequent repetition of imaginary threats,
- the investor’s insufficient communication activities,
- opponents' arguments referring directly to threats to people and the common good (health issues, risks to animals, noise, landscape disfiguration) which easily reached out to the stakeholders whilst the other side referred to private interests (profits from the provision of land) or general benefits (sustainability).

In the opinion of the authorities and people directly involved in the investment process, communication with the investor was good, but among the general public there was a lack of awareness of the investor's activity. The consultations were held only with people directly interested. Others did not have a care for the common good and the objective information about threats; hence, the rebellion against attempts to implement the investment "behind the backs" of the community.

The survey, although carried out in 2013, is still relevant to the dynamics of protests in other regions and against other types of investment, including biogas plants (Bio-gazownie 2019), and even solar farms. In the wake of increasingly common investments in RES, waves of protests follow. The main sources of information in conflict situations are local and industry media, often representing two poles of public opinion. There is a need for systemic solutions to improve communication and participatory approaches that better prevent and mitigate conflicts. It seems that spatial conflicts between the need to conserve nature and the landscape, and energy needs, could be minimized by a substantially strengthened planning system. The key element of such a system should be an early, broad, and professionally moderated public participation (Jeleński 2019).

6. What measures are taken to increase citizens’ acceptance?

The report presented by the Pro-Akademia R&I Centre (Pro-Akademia 2014) indicates a high level of acceptance of RES investments among municipal authorities. However, the promotion of RES knowledge should be increased to provide municipalities with comprehensive data. Currently, on the one hand, the investors' lobby is the main source of information for municipalities, while on the other the authorities are often afraid of community protests, particularly against biogas plants and wind farms.

There could be many arguments to convince the public to accept investments in RES (cleanliness, environmental and health benefits, reduction of energy prices, technological progress, new jobs, energy security, and income for the commune and residents).

Increased public acceptance may improve citizens' active involvement in energy transformation. For example, there are various ownership models in Germany so that only 5% of RES installations are owned by large energy companies. In Denmark, wind energy projects obtain a permit under the condition that the local community owns at least 20% of shares (Altas Energii 2018).

Regional and local measures

In Małopolska, activities aimed at promoting renewable energy and increasing citizens' acceptance appear primarily as a remedy for air quality problems, and in this context, citizens are encouraged to invest in RES (https://powietrze.malopolska.pl). In Kraków, the exchange of furnaces and boilers, due to the upcoming ban on solid fuels, has so far not contributed to the promotion of renewable energy as an alternative way to provide heat and electricity in households. Paradoxically, the effect of this ban may be a reduction in the use of renewable energy in domestic heating installations, since this prohibition concerns inter alia biomass (wood, pellets, briquettes), which when incinerated in installations without filters, contribute to PM emissions. It is important that the thermal modernization campaign accompanying the ban for solid fuels promotes the replacement of old boilers with RES installations, such as hybrids of PV and heat pumps.

The municipalities in Małopolska willingly engage in projects conducive to energy transition financed by EU funds. Such an efficiency of local governments might be appreciated. However, it should be noted, that with such a passive approach to RES investments, they are made only if any external financing is available.

In the promotion of energy transition in Kraków, universities and research institutes play a significant role. They organize conferences and events which aim not only at the professional exchange of knowledge, but also the popularization and promotion of RES.

The major universities (AGH-UST, CUT, UA) provide degree programmes related to renewable energy. Municipalities might use the potential of HEIs, R&D institutions and NGOs experienced in the transfer of knowledge, ones that enjoy the necessary capital of trust. There are few partner activities undertaken so far, such as the RES Day in Krakow (OZE Day 2018) or the cooperation between AGH and MPEC (MPEC 2019).

The example of Podhale, where geothermal waters are used as a source of heat, is one of the best practices of community involvement and multi-stakeholder partnerships in economic development based on RES in Małopolska. It brought a genuine economic, social and environmental benefit for the local communities and the region (Ślimak 2013) as a result of many years of involvement and cross-sectoral investment. It needs to be noted, however, that the scale of geothermal resources in Podhale is unique.

The prospects for transition in agriculture

According to the Central Statistical Office (GUS) (OZERISE 2013), approximately 6% of final energy in Poland is consumed in agricultural production, and almost 30% by households in rural areas. These are characterized by the highest percentage of coal consumption. In order to meet the requirements related to the 3x20% package, the use of renewable energy in agriculture should increase in Poland from around 50 PJ in 2005 to 85 PJ in 2030.

This particular model of energy demand and the unclear status of farmers in Poland (they are indirect consumers placed between households and small enterprises) cause farmers to pay proportionally more for electricity than both households and large industrial customers often supported by special tariffs.

The problem significantly concerns Małopolska, with over 135,000 farms (2017) on 687,600 ha total area of arable land (Urząd Marszałkowski 2018). The knowledge about practical solutions aimed at increasing the efficiency and reducing costs of energy for farms and producer groups through the use of RES and smart energy grids and micro-grids – including the rate of energy autonomy of farmers and rural areas – can be drawn from the project “Agricultural farms and smart grids integrated RES” (OZERISE 2013).

7. What renewable energy sources are mainly used for heat production?

Małopolska is one of the regions where over 90% of industrial heat is produced from coal (90.1%). Only 6.01% of the generated heat comes from RES. In particular:

- biomass (102 826.0 GJ, i.e. 7.2% share in the production of heat from RES in Małopolska in 2017),
- municipal solid waste (787 342.0, i.e. 55.6%),
- other renewable sources (525 733,7, i.e. 37,1%), including Geotermia Podhalańska which produces about 450,000 GJ of thermal energy annually.

Table 2. The structure of industrial heat production in 2017 r. [GJ] (URE 2018b)

Małopolska	**Coal**	**Gas**	**Oil**	**RES**	**Other**
23 554 728	21 218 403	772 469	1 394	1 415 901	146 561
100%	90,08%	3,28%	0,01%	6,01%	0,62%

In KrOF, five entities have a license for the generation of heat (Table 2). The total thermal power of 53 generating units located in the cities of Kraków and Skawina equals 1 581.310 MW.

Table 3. Licensed entities producing heat in KrOF (URE 2019c)

Licensed entity	**Location**	**Type of production**	**Fuel**	**Installed thermal power[MW]**
CEZ Skawina	Skawina	Multi-fuel combustion installation (ISW), steam boilers, cogeneration	Coal, Heavy oil, Biomass from products, waste and residues of industry processing agricultural products	946.600
Krakowski Holding Komunalny	Kraków	Thermal waste treatment installation (ITPO), steam boilers, cogeneration	Non-hazardous waste containing biodegradable fractions, Fuel oil	69.000
Miejskie Przedsiębiorstwo Energetyki Cieplnej	Kraków	Boiler rooms - 49 units	Natural gas, Fuel oil	27.710
TAMEH Polska	Kraków	Steam boilers, cogeneration	Blast furnace gas, Coal, Coke gas, Natural gas	538.000
PGE Energia Ciepła	Kraków	Water boilers, steam boilers	Hard coal, Light heating oil, Biomass from products, waste and residues from agricultural production and processing	1 644.000

None of the 53 units can be defined as an installation that uses 100% RES. Two of them partly produce heat in renewable energy installations:

- CEZ Skawina SA has a multi-fuel combustion plant (ISW), which is a cogeneration unit where the maximum weight fraction of biomass in the total fuel stream is 40.5%.
- Krakowski Holding Komunalny SA, in which heat is generated in a thermal waste transformation installation (ITPO), is also a cogeneration unit. The heat comes from the thermal transformation of non-hazardous waste containing biodegradable fractions of plant and animal origin, as well as fuel oil combustion.

It should be noted that for the most part, heat production in KrOF is based on the cogeneration process. The EU promotes this technology due to its energy efficiency, the ability to significantly reduce CO_2 emissions, and the possible utilisation of RES.

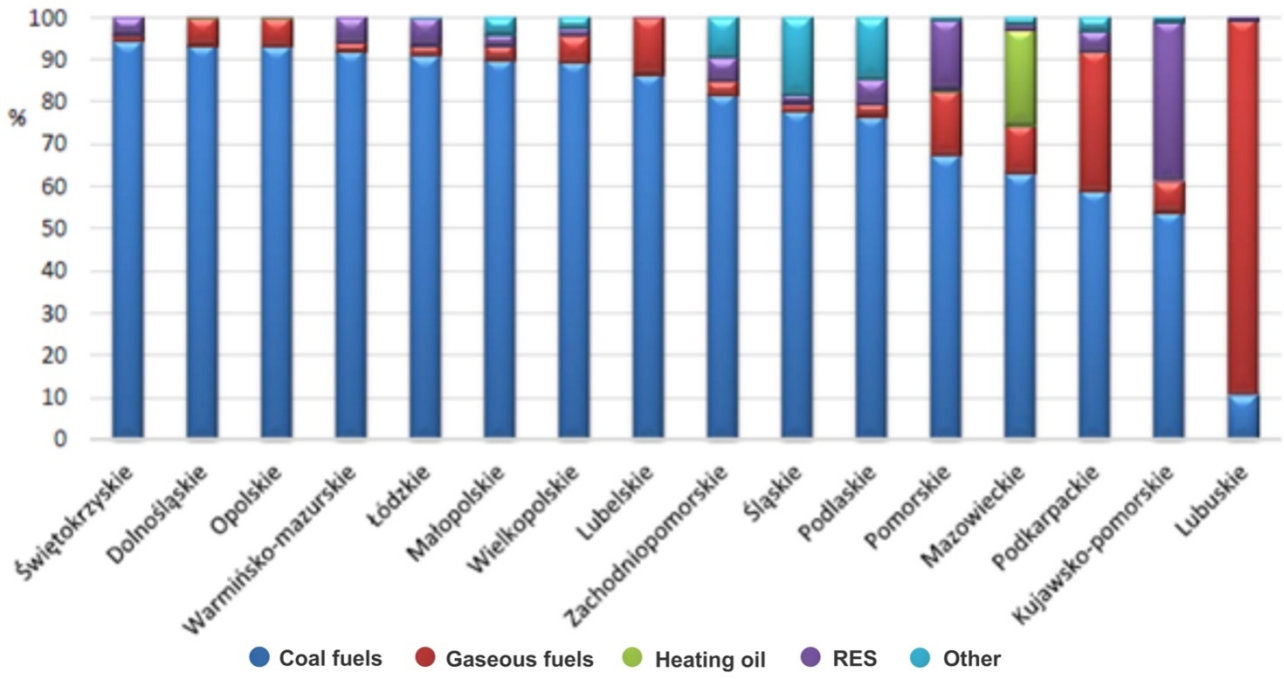
8. Which (mandatory) regulations or incentives encourage citizens/companies/municipalities to opt for a heating system based on renewable energy sources? Are there regional differences?

Context

Heat and cold account for 58% of the final energy consumed in Poland. By comparison, electricity accounts for only 20%. In residential buildings, the costs of heating and domestic hot water preparation exceed 80% of the total costs of energy consumption. Over 70% of approximately 5.5 million existing single-family houses are heated with solid fuel fired boilers (IEO 2015).

In Małopolska, 90.1% of heat is produced from coal (URE 2018). According to opinion polls on micro-installations and prosumerism, Poles would most likely replace coal-based energy sources with RES. As many as 35% of citizens declared not only support for the idea itself but also a wish to purchase RES installations. The main motives were: energy charges reduction, cleaner air, convenience, the possibility of using subsidies, promotion of innovation, prestige and image (IEO 2016).

Fig. 7. The structure of heat generation in Poland's regions by sources (URE 2018)



Despite such a positive attitude from citizens, the Act on Renewable Energy (2015) does not support the production of heat from RES, and instead focuses on electricity production. Therefore, appropriate legal and economic impulses are needed so that the enormous potential of renewable energy production in distributed systems will be widely and properly used.

What can be seen in Małopolska are the effects of the amendment to the Energy Law Act (2010) which was aimed at stimulating the development of cogeneration (CHP). The share of heat production from CHP in total heat production in 2017 was over 70% and is one of the highest in Poland (URE 2018). In KrOF, CHP is used, i.e. by the CEZ Skawina, an incineration plant in Kraków and a plant producing energy utilities for ArcelorMittal facilities in Kraków. The latest national documents begin to consider the measures to implement Directive 2018/2001 on the promotion of the use of energy from renewable sources (RED II) and the new climate and energy package. The Polish energy policy project (PEP2040) announces the popularization of heat storage, which is important in connection with unstable RES.

Heat networks and the diversification of sources

The low-temperature heat networks, which combine centralized heat production in district heating plants with the significant use of renewable energy and low temperature water systems (Jaworski 2016), are the direction currently preferred in the EU. To realize this concept, high-efficiency heat sources, heat transfer networks, and low-energy buildings are necessary. In urban agglomerations, the main constraints are heat networks and receivers designed for supplying water from networks with temperatures above 80˚C, whose modernization requires large financial surcharges.

New buildings should be designed for new heating technologies, including distributed heating. In small towns, there are more opportunities for network modernization and technological changes due to shorter sections of the heat network and a smaller number of facilities that need to undergo thermal modernization. However, in such places, heat is provided by municipal facilities which often have less opportunities to finance transition than facilities belonging to large energy concerns.

The above conditions forced the activation of funds supporting the introduction of RES into heating. In 2018/2019, the IEO prepared for the National Fund for Environmental Protection and Water Management [NFOŚiGW] the assumptions for the establishment of the "Heat from RES" Program in mid-2019 (IEO 2019c). The program is to help heating companies obtain the status of an effective heating system thanks to the simultaneous introduction of several types of renewable energy and heat storage. The expected form of support at the pilot stage is a subsidy.

NFOŚiGW, the Ministry of the Environment (MŚ) and the Ministry of Investment and Development (MIiR) recently announced programs aimed at supporting the use of renewable energy in heating, such as NFOŚiGW "Ciepło powiatowe" and grants for environmental projects, energy transition, climate change adaptation, and local development, all financed by EEA Funds.

Due to the increasing requirements for reducing emissions and the share of RES, diversification of generation sources, innovations in their integration in heating systems, and the expansion of heating technology towards various types of RES should be expected. Depending on local conditions, the following technologies and renewable energy sources are primarily considered (IEO 2019a):

- **Biomass**

Due to the excessive use of biomass in both electricity and the wood industry, its prices increased. In addition, the RED II Directive, after 2020, will reduce the range of renewable fuels from biomass, which change the costs of CO_2 emission allowances. New criteria for the environmental equivalence of biomass will be introduced, which will particularly affect biomass boilers with a nominal thermal power of 20 MW and more. Biomass as a "stable" source may therefore be a complement to heating mixes, but itself should not be the basis for the transition to RES.

- **Geothermal**

There are at least several dozen heating companies, preferably located in relation to locally available economic geothermal resources, which may consider the use of geothermal energy resources as a stable, yet still very expensive supplement in the heat generation. The RED II Directive states that the EU should facilitate the development of geothermal energy, because it has a low environmental impact compared to non-renewable sources.

PZPWM 2018 recommends the development of RES based on existing geothermal resources mainly in the "Górski Park" Functional Area. On the basis of analysis and the assessment of geological conditions of hydrogeological floors in Małopolska, 92 zones of possible use of geothermal energy have been indicated, including KrOF communes, such as Niepołomice, Kraków, Igołomia - Wawrzeńczyce, Zielonki, Kocmyrzów - Luborzyca, and Liszki.

- **Biogas**

Biogas has been used in KrOF and there are conditions for the further development of biogas plants that use the fermentation processes of:

- organic waste in landfills (including the Barycz landfill in Kraków),
- animal waste in farms,
- sewage sludge in wastewater treatment plants.

- **Solar**

Most heating companies in Poland have proper conditions for using large areas for solar collectors (access to undeveloped or post-industrial areas of the city, including areas owned by Thermal Energy Holding {PEC}, or roofs belonging to the heat consumers). The annual solar radiation sums in Małopolska amount to 950-1000 kWh/m^2. The average sun exposure is about 1,450 hours a year. Climatic conditions allow collectors to cover up to 70-80% of the energy needed to produce domestic hot water.

- **Unbalanced energy from wind farms (green power-to-heat) - P2H**

District heating can benefit from the use of unbalanced electricity from RES (P2H), in particular from wind farms whose generation profile is similar to the heating profile. Until now, cheap and unbalanced energy (with prices even below PLN 20 / GJ) from wind farms has not been used for heating purposes. Power (currently 6 GW) from wind farms will increase to 9 GW in three years as a result of the auction for RES energy.

There are also no limitations for heating companies investing in photovoltaic systems, both to cover their own needs in terms of electricity, as well as to use surplus energy for cooling or heating purposes.

- **Heat storage and a diversified heating mix**

RES's potential in heating, and their efficiency, are growing rapidly with the development of heat storage technologies. Thanks to the storages, one can fully use energy from the weather-dependent RES and facilitate the exploitation of geothermal sources, and improve the efficiency of biomass and coal boilers, which would become sub-peak or peak.

Additional energy efficiency measures in heating, which from 2021 will be introduced in Poland, will lower the required temperature levels, facilitating the integration of renewable energy in heating systems. Together with the new Regulation of the Parliament and the EU Council on the internal electricity market that increases the price dynamics (time of use), support will be provided for increasing the share of renewable energy, including weather-dependent, in heating.

Financial support for the modernization and optimization of heating systems

NFOŚiGW currently supports projects aimed at the modernization and optimization of heating systems, particularly by two programs: *Effective Heating and Cooling Systems* – implemented from domestic funds, and *Supporting RES Investments and their Connection to the District Heating* – under the OP IE.

Energy cooperatives

According to PZPWM 2018, in the perspective of 2025-2030, co-operatives and energy clusters based on cooperation between rural communes should gain importance. In their case, the main source of energy should be mainly biomass and biogas plants. This will allow the management of the remains of agricultural production and additionally allow for a more effective elimination of forest succession. The legislation on cooperation between the cooperatives (clusters) and currently operating energy companies requires further development and refinement. An example of the Energy Cluster Korona Północnego Krakowa is mentioned below as a good practice.

Distributed heating

In addition to district heating, the distributed RES installations have been supported in Małopolska, including: solar collectors, heat pumps, biomass boilers and micro-biogas plants which are particularly interesting for households that do not have access to a heat network.

Since March 2013, WFOŚiGW and BOŚ have been granting loans on preferential conditions, partially non-refundable, for non-commercial installations of solar collectors with a power maximum 10 kW. They also support the municipalities which install solar collectors with a minimum capacity of 10 kW. WFOŚiGW also co-finances the investments of companies and NGOs investing in biomass boilers, heat pumps, recuperators, solar collectors, photovoltaic installations, biogas plants and heat network connections (WFOŚiGW 2019).

The largest project which currently allows for co-financing RES in Małopolska is implemented by the Municipality of Krakow under the ROP Małopolska 2014-2020. Residents replace their old boilers and heating installations with modern sources and installations that meet current emission standards. The program funds up to 100% of investment costs (BIP Kraków 2014). It precedes the total ban on the use of solid fuels in Kraków. Unfortunately, the program actually does not promote the use of RES, nor the comprehensive thermal modernization reducing heat consumption. Gaseous fuels and light heating oil have been allowed, which may for years inhibit household investment in heating systems based on RES.

For comparison, within the same ROP Małopolska, the Commune of Niepołomice implemented investment in heat pumps and PV in its primary schools. The facilities have been equipped with complete low-energy heating installations and insulated. Smart control systems allow for the optimisation of the operation of heating devices depending on the weather and the needs of users.

Incentives for thermal modernization with RES

The tax relief introduced at the beginning of 2019, allows to deduct from the income tax the expenses on thermal modernisation of buildings, including the installation of solar collectors, PV and heat pumps. In the draft amendment to the law on supporting thermal modernization and renovation (May 2019), it is assumed that the premium will be increased if RES is used as part of the thermal modernisation project (Gram w zielone 2019a).

In the first place, the support will be directed to towns below 100,000. For larger cities, the details of the programme are to be agreed upon with the city authorities in cooperation with local NGOs dealing with air quality issues.

The budget for the implementation of the Act is estimated at PLN 1.2 billion. Part of the investment costs will be borne by the commune. In towns up to 100,000, the municipality's contribution should amount to 30%. The remainder will be financed from state funds including the recycling fee (Gram w zielone 2019a).

KrOF's own programmes

Among the **ITI** projects, particularly noteworthy is Action 1: Thermal modernization of public and residential buildings, intelligent energy management and use of RES in KrOF implemented as an element of PRIORITY 4; and the improvement of the KrOF environment though energy efficiency, intelligent energy management and renewable energy use. This activity includes the installation of RES devices in municipal and private facilities, as well as installing a solar farm in the commune of Wieliczka.

RENEWABLE ENERGIES IN THE TRANSPORT SECTOR

9. Which regulations or incentives encourage citizens/companies/municipalities to opt for alternative drives (like battery or fuel cell electric vehicles)? Are there regional differences?

Decisions regarding the choice of a particular means of transport arise from a number of sociological, cultural and economic aspects (Nosal 2012) and people's individual needs. "Soft" mobility management instruments, which are not obligatory but based on the information, consulting, organizational, educational and marketing activities, might be sufficiently effective. On the other hand, there are legal or financial instruments, i.e. planning regulations, fuel taxes, and fees, which contribute to limiting the use of conventionally fuelled cars.

The basic criteria for choosing the vehicle and the drive are still economic motivations, as well as the time and comfort of travel.

For economic reasons, natural gas drives are relatively popular in Poland, whilst the popularity of hybrids is quickly increasing. It seems, however, that in Małopolska, cars fuelled with gasoline and diesel will remain the basic mobility option for a long time due to - on the one hand - high costs of purchasing an electric car - and on the other - scattered development which limits the efficiency of public transport. From January 2019, a new emission fee in retail prices of fuels was introduced in Poland. The money raised in this way is to be allocated i.e. for subsidies for electric cars for state offices and local governments (Money 2019a). The emission fee, together with the basic excise, amounts now to over 50% of the retail price of fuel.

In January 2019, the first in Poland's Green Zone was introduced in the Kraków district of Kazimierz (Kraków 2019a). Over time, the traffic restrictions for cars with diesel engines that do not meet Euro 5 or Euro 6 standards should be expected in Kraków. A discussion on the introduction of such a ban has already started.

The Krakow Metropolis is an area of urban sprawl with all its consequences for mobility. Krakow remains one of the most congested cities in Poland. The spatial planning crisis is aggravated by the dysfunctional model of city development based on monofunctional housing estates and economic/office/commercial zones, and the chaotic development of dispersed houses on the outskirts of the city and in nearby villages. All these factors increase dependence on individual transport.

Among the factors that are indispensable to encourage residents to choose an alternative drive is an increasing range, the availability of charging points, and fast loading time. The responsibility to carry out information, education and marketing activities in order to encourage the public to alternative drives lays on the vehicle manufacturers and charging station networks. However, the electromobility market will not develop without active intervention from the state (Ministerstwo Energii [Ministry of Energy] 2018). In 2016, the ElectroMobility Poland company was founded. Its goal by 2050 is to produce one million electric cars in the country. Domestic production of electric cars should start by 2023 (Money 2019b). While the very idea of electromobility seems right, it needs to be remembered that electric cars in Poland are powered by the electricity produced mainly from coal combustion.

To stimulate the growth of alternative drives in Poland, the Act on electromobility and alternative fuels was introduced in 2018 (Dz.U. 2019 poz. 1124). Increasingly, also in Poland, vehicles driven by fuel cells are discussed, among which the most popular use hydrogen. In 2050, fuel cell vehicles can have a 20-25% automotive market (Kierunek energetyka 2018).

According to the KPMG and PSPA report (May 2019) (KPMG 2019), current legislation does not meet market expectations. Despite a positive assessment of some of the solutions, for example an increased depreciation limit for electric cars, nearly half of respondents did not find their significant impact on the development of electromobility in Poland. This shows how important it is to appropriately use the funds available under the Low-Carbon Transport Fund (FNT).

In June 2019, the government announced that the provisions of the Biofuels Act on support for the purchase of **electric and hydrogen cars** are to be amended. The support is to include individuals who do not run any business. The current regulations include only entrepreneurs and local government units (CIRE 2019).

Electric scooters, bicycles, and motorcycles gain popularity as alternatives to cars. Small electric vehicles are mainly used in cities, where the infrastructure is more suited to their users and the residents are more open to new mobility options. Kraków, an academic city with a student population of approximately 200,000, is a natural hub for mobility innovation.

10. Are regional concepts being developed to support a switch to alternative drives (like battery or fuel cell electric vehicles)?

Since the 1990s, Kraków has been a leader in sustainable mobility in Poland, with one of the world's oldest pedestrian, car-free areas (larger even than the famous Strøget in Copenhagen), the first extensive and still enlarged paid parking zone in Poland, a city bike first introduced in the 1990s, and a completely low-emission public transport fleet since 2000s. The Metropolitan Railway is being developed, combined with a bus network (bus lanes) and a bicycle network with park & ride interchanges. A feasibility study for the Krakow metro/premetro is being prepared. Carsharing is developing in the metropolitan area, and electric scooters are gaining in popularity.

In 2019, the City of Krakow was awarded the "Electromobility Friendly City" certificate, whereas Krakowski Holding Komunalny SA was awarded the "Electromobility Friendly Enterprise" certificate (Krakow 2019b). Krakow is the first city in Poland where a bus line consisting exclusively of electric buses has been launched. The plans are also to obtain cars and charging stations for the Municipality of Krakow fleet.

Electric cars are exempt from parking fees (Smart City 2018), while the monthly subscription for a hybrid car is 2.5 times lower than for a standard car (Kraków 2019c).

In 2017 and 2018, conferences devoted to energy, local government and transport were held at the Krakow AGH University of Science and Technology (Nowa Energia [New Energy] 2018). In attendance, among others, were representatives of the national government, local governments, energy groups, independent energy distributors, energy clusters, technical universities and student clubs, mass transport companies, companies offering solutions for the e-mobility industry, representatives of manufacturers, and dealers of electric vehicles.

The promotion of electromobility in Małopolska is fostered by events such as the Polish Rally of New Energy (RPNE 2018).

Tauron, a major energy holding company in the region, recently launched the Tauron Progress acceleration program for the development of an innovation ecosystem, based on the Strategic Research Agenda. The program is open to ideas from start-ups, academic centres, institutions and individuals; the chance to obtain 550,000 PLN to develop an innovative start-up project was offered by the Pilot Maker ElektroScaleUp. In this case, Tauron

seeks solutions in the field of sharing e-cars, scooters and bicycles, development and management of charging points, alternative vehicle power supply systems, big data, and the dynamic valuation of services and billing systems (Gram w zielone 2019b).

RENEWABLE ENERGIES IN THE ELECTRICITY SECTOR

11. Which renewable energy sources are mainly used for electricity production?

By 2019-06-20, 60 electricity generating units were identified in Małopolska (URE 2019c). The total installed capacity in all units was 1 887.790 MWe (Table 3), with electricity using conventional fuels accounting for 65% (1 226 287 MWe), while RES—35% (661.503 MWe).

Table 4. Production of electricity from different sources [MW] and their share [%] in Małopolska (URE 2019c)

Source of energy	Number of units	Installed capacity[MWe]	Share
Total electricity demand	60	1 887.790	100%
Non-renewable	24	1 226.287	65%
Renewable	**36**	**661.503**	**35%**
→ *Biogas*	6	6.147	0.3%
→ *Biomass (co-incineration)*	4	470.050	24.9%
→ *PV*	6	5.422	0.3%
→ *Wind*	4	4.900	0.3%
→ *Hydro*	16	174.984	9.3%
→*Geothermal*	0	0.000	0%

It needs to be noted, that four units included in the "biomass" category do not produce energy only from biomass. They use the process of burning various fuels (in cogeneration), in which in addition to biomass, also coal, natural gas, heating oil and other fossil fuels are co-fired. As a result, there is no possibility of defining the actual installed capacity based solely on fuel from a renewable energy source.

Of the above-mentioned units, 16 are located within KrOF, in the following communes: Kraków (12 units), Liszki (1 unit), Niepołomice (1 unit) and Skawina (2 units). Their total installed capacity equals 922,601 MWe, which is 48.9% of the installed capacity for the entire Region of Małopolska. This is due to the fact that in KrOF, the largest regional producers of electricity are located, such as a heat and power plant in Kraków; a heat and power plant in Skawina; a heat and power plant belonging to the ArcelorMittal Poland SA steelworks; and Krakowski Holding Komunalny SA.

Table 5. Production of electricity from different sources [MW] and their share [%]in KrOF (URE 2019c)

Source of energy	Number of units	Installed capacity [MWe]	Share
Total electricity demand	16	922.701	100%
Non-renewable	5	442.053	47.9%
Renewable	**11**	**480.648**	**52.1%**
→ *Biogas*	3	3.498	0.4%
→ *Biomass (co-incineration)*	3	466.900	50.6%
→ *PV*	1	0.060	0.0%
→ *Wind*	0	0.000	0.0%

→ *Hydro*	4	10.190	1.1%
→ *Geothermal*	0	0.000	0.0%

In addition to the licensed activities related to the industrial generation of electricity, it is also possible to run a business involving the production of electricity from RES in a small commercial installation which means a renewable energy installation with a total installed electric capacity of more than 50 kW and less than 500 kW.

The register of the producers using small installations is maintained by the President of URE. According to URE (2019b), 45 small installations were registered in Małopolska in 2018 (Table 6).

Table 6. Small RES electricity installations in Małopolska, 2018 (URE 2019b)

Source of energy	Number of units	Share
Biogas	9	20.0%
PV	10	22.2%
Wind	7	15.6%
Hydro	19	42.2%

12. Which (mandatory) regulations or incentives have been created for the expansion of renewable energy system for electricity generation? Are there regional differences?

Incentives and support mechanisms for the development of RES for electricity generation in Poland currently operate at the national level and are mainly prepared by the government. Instruments gratifying the generation of electricity from RES are mainly regulated by the Act on RES (Dz.U. 2018 poz. 2389). Support mechanisms include (KAPE 2018):

- Obligation of electricity companies to purchase electricity from entrepreneurial RES micro-installations.
- A system of discounts for prosumers, meaning that households can generate electricity in micro-installations, surplus it to the grid and collect up to 70-80% of the energy stored in this way at the time of their increased demand for electricity, and then settle accounts with the energy supplier from the balance sheet difference.
- Guaranteed electricity purchase prices for RES micro-installations and a system of subsidies to the market price for installations using hydropower and biogas.
- Green certificate system, meaning that for every kWh of electricity generated from RES, a certificate of origin issued by the President of URE is issued. Obtaining green certificates and their sale on the stock exchange is an additional profit for the producer, apart from profits from the sale of electricity or savings resulting from energy consumption for one's own needs.
- Auction system in which renewable energy producers can offer the amount of energy they undertake to deliver within 15 years.

The process of energy transformation can also be accelerated by the increase in electricity prices. In 2018, in Poland, energy consumers struggled with rapid price increases, the collapse of several electricity and gas suppliers, and legislative uncertainty related to energy prices. Companies operating in the industrial sector should take care of their **energy security** by starting active search for alternative solutions. It seems, therefore, that the difficult situation of enterprises, related to the lack of stability in the electricity markets, may mobilize them to invest in renewable energy installations.

At the regional level, an intensive **information campaign** is being conducted on the opportunities offered by RES. The knowledge zone financed from the EU LIFE program funds is kept and updated, e.g. on the regional government portal (Powietrze Małopolska 2019).

In the area of **financial support** for RES investments, the Regional Fund for Environmental Protection and Water Management in Krakow is active (WFOŚiGW 2019).

The competitions are organized as part of the Regional Operational Program 2014-2020 (RPO WM 2018) for the development of RES infrastructure. They have contributed greatly to the development of prosumerism.

However, across Poland, **regardless of regional differences**, PV has a very large and still unused long- and short-term potential, which is reflected in short investment circuits and in a large number of advanced PV projects (the IEO Database indicates more than 2 GW of power in new PV projects with conditions for connection granted) (IEO 2019d).

The national program Energy Plus announced by the Ministry of Entrepreneurship and Technology in January 2019, is particularly directed at the prosumer PV realized through investments in micro-installations by single-family house owners and SMEs (IEO 2019e).

In the wake of these activities, support instruments for the development of the domestic PV industry, intelligent energy network technologies and renewable energy-based mobility are expected in the new energy policy of Poland.

13. How will the additional costs for grid expansion be passed on to the citizens/municipalities/companies?

The current policy of the central authorities aims at transferring the costs of the national energy infrastructure development to the largest producers and consumers of energy. Protection of individual, public and small business consumers is based on freezing prices, that is, moving away from the rules of a free energy market. Independent experts predict that such a policy of central control of energy prices will lead to a sudden collapse of the market and the inevitable, the abrupt rise in prices, in the perspective of a few years maximum. Sooner or later, the final recipients and all taxpayers will be charged.

The development of renewable energy networks and distributed energy affects the work of distribution networks. From passive networks supplying energy to consumers, they become active, multi-directional grids (PSE 2018). As a result of the dissemination of prosumerism and distributed energy solutions, the management of the existing network, un-adapted to the multi-directional operation, will be increasingly expensive for Polskie Sieci Elektroenergetyczne - the network system operator in Poland.

The development of the Poland energy infrastructure, in the perspective of 2030, will have to meet, among others, the following challenges (KPZK 2030; 141-142):

- adaptation of power grids to receive energy from dispersed RES installations, including planned onshore and offshore wind farms (takeover of surplus power will require the construction of several hundred km of new transmission lines together with the accompanying infrastructure),
- development of the highest voltage transmission network for the connection of new generation sources, including RES,
- improving the efficiency of transmission, supply, and consumption of energy through the development of smart grids
- increasing the use of renewable energy through the construction of new capacities, which will improve energy security at the national, regional and local levels.

The rules for financing the network of offshore projects are unclear. Neither in the "Development plan for the current and future electricity demand for 2018-2027" prepared by PSE in 2018, nor in its supplement from March 2019, where the need to introduce HVDC technology is mentioned, is there any information on who would be responsible for covering the costs of construction and connection of the necessary infrastructure (IEO 2019b).

Prosumption and co-production grids and renewable energy communities

The development of prosumer energy will allow the reduction of energy costs of self-consumed PV electricity, but it may cause an increase in the operating costs of reserve power and networks (WISE 2014). Nevertheless, distributed energy remains one of the important directions of the development of the Polish power system. Currently, work is underway on the government project Energia Plus, which aims to provide households, small and medium-sized enterprises, and local government units with energy independence. An incentive instrument for investment in RES installations is tax relief, thanks to which one can reduce tax liabilities by spending on RES.

PKO BP and BOŚ provide loans to various entities for the purchase and installation of RES devices, whilst NFOŚiGW calls for subsidy applications under the priority program Energia Plus, which focuses on investment project support (NFOŚiGW 2019).

The first in Poland, a municipal power network has been run in Ostrów Wielkopolski since June 2019. The energy produced from biomass is to start flowing to inhabitants in January 2020. The project consists of launching a local green energy network, investments in various RES devices, and systemic energy management for local balancing. This innovative project of energy community is expected to bring significantly lower electricity costs, cheaper public transport, new jobs, development of alternative energy sources, as well as improvement of the environment. Thanks to the participation of several dozen significant entrepreneurs, about 50 million PLN a year may stay in Ostrów, which would otherwise be transferred away by local business and residents (Gram w zielone 2019c).

14. What incentives (e.g. for power to X) have been created or are in discussion for the potential temporary surpluses of electricity?

Recently, the largest suppliers and distributors of energy in Poland have accelerated modernization projects and allocations of funds allowing for the connection of a growing number of active network users, dispersion of the power system, and the development of energy clusters and cooperatives.

Prosumer energy

Pursuant to the Act on RES (Dz.U. 2018 poz. 2389), prosumers may generate electricity from RES in order to use it for their own needs, and the surplus is transferred to an energy network for its temporary "storage". This system is based on the so-called net-metering, or a periodic billing system, in the form of a discount on the invoice. For installations up to 10 kW, for each 1 kW produced, it is possible to receive up to 0.8 kW of energy delivered, and in the case of installations above 10 kW, for each 1 kW produced, up to 0.7 kW of energy can be recovered.

If a prosument wants to use surplus energy without having to put it on the grid, they should adapt their installation to the optimal utilization of the energy produced. This can be assisted by a smart home system, synchronising various devices with the PV installation to allow the higher use of electricity at the time when the cells give it the most.

From the prosumers' point of view, the issue of surplus energy does not appear to be complicated. However, the same issue on a macroeconomic scale is one of the most urgent problems to research. The surplus energy from RES may be stored in rechargeable batteries and pumped into hydroelectric energy storages (PHES) (Bartosik et al., 2016), as well as heat stores.

The first in Poland, and one of the world's first hybrid battery energy warehouses (BESS) with innovative safety automation for optimizing wind generation management, will be put into operation at the end of 2019 at Bystra Wind Farm (Pomorze region), owned by Energa Wytwarzanie. It is one of the largest such devices in the world. Its power will reach 6 MW with a 27 MWh capacity.

There are several hydroelectric energy storage plants in Poland; one of them is located in Niedzica, in southern Małopolska. Its power at pump operation equals 2 × 44.5 MW.

Another solution also considered (Chromik 2016) is a storage of surplus electricity in the form of hydrogen in caverns and rock salt deposits, which are many in Małopolska, including KrOF.

However, support for the development of heat storages seems more advanced.

Heat storage for the potential temporary surpluses of energy

Popularization and various forms of financial support from public funds for heat storages development were announced in PEP 2040. These storages allow for better use of energy from the so-called weather-dependent sources, i.e. heat from solar collectors and electricity from wind farms (P2H); and to facilitate the exploitation of geothermal and combustion sources including biomass. This is a particularly advantageous solution for balancing the demand for electricity in clusters. In a system equipped with a heat storage, also non-renewable sources can be used continuously and gradually turned off.

Seasonal heat storage, which allows for the equalization of supply and demand, is considered a key element, conditioning a wide introduction of renewable energy into the heating sector with RES over 50% (IEO 2019a, 14). At present, a pilot support program, “Heating systems cooperating with RES and heat storage” is being prepared at NFOŚiGW.

15. Give a good and a bad example of how the economic development of the use of renewable energies takes place. Briefly describe the reasons why it is a good/bad practise.

	Good practice
Name	Energy Cluster Korona Północnego Krakowa
Context	In 2017, five communes of KrOF: Kocmyrzów-Luborzyca, Igołomia-Wawrzeńczyce, Michałowice, Wielka Wieś, Zielonki, together with the Local Action Group of the Crown of North Kraków, signed an agreement on the establishment of the Energy Cluster of the North Crown of Krakow. The Cluster aims to: Limit air pollution through investment in RES; Increase energy security through the diversification of energy sources; Develop RES with a particular emphasis on the development of dispersed prosumption. The structure of the energy cluster is to help i.e. in obtaining funds for RES installations (solar collectors and panels, and heat pumps).
Main stakeholders involved	Central government: Ministry of Energy, Ministry of Development Financing institutions: National Fund for Environmental Protection and Water Management and regional government (Urząd Marszałkowski) Municipalities, R&D centres, Entrepreneurs and prosumers Energy recipients NGOs
Web links	Public Information Bulletin (BIP 2017) of the Kocmyrzów-Luborzyca Commune: https://bip.malopolska.pl/ugkocmyrzowluborzyca,a,1366844,uchwala-nr-xxxii2492017-z-dnia-20092017-r-w-sprawie-wyrazenia-woli-przystapienia-do-porozumienia-cyw.html
Why is the practice considered “good”?	Energy clusters aim to provide local energy security with the use of local potential, improve the local natural environment, create conditions for the development of renewable energy and increase the competitiveness and economic efficiency of the local economy. A cluster allows for close cooperation between individuals, entrepreneurs, HEIs and research institutes, and local governments to engage in searching for the best, network solutions, projecting and financing. The solutions concern the generation of energy, balancing of energy demand, distribution, and trading of energy, in particular from RES.

	Bad practice
Name	Lack of a specific indication of which local government institutions would be responsible for the implementation of energy transition and to what extent.
Context	Currently, issues related to RES investments are regulated by a number of Acts (including energy regulations, the Act on RES, the Act on investments in wind farms, etc.). All of these provisions open the way to the development of RESs, but do not oblige local governments to take specific actions. This is important, for example, in the context of strategic documents, such as the draft Poland Energy Policy 2040, which included provisions for the involvement of local governments and local energy planning. These are to play a crucial role in implementing state policy e.g. in the field of district heating.
Main stakeholders involved	Central government Legislature Regional government (Urząd Marszałkowski) Sub-regional institutions (e.g. ITI operators) Local governments (municipalities)
Web links	https://www.gov.pl/web/energia/polityka-energetyczna-polski-do-2040-r-zapraszamy-do-konsultacji
Why is the practice considered "bad"?	Too many scattered legal acts concerning RES and the lack of clear competencies of local governments may cause, above all, legal interpretation problems. Another problem is the passivity of local governments, which are not obliged to take specific actions and do not have specific instruments that they could use to mobilise society for the involvement in energy transition.