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Renewable Energy Sources as Part of a Green Deal

Renewable energy aims at reducing greenhouse emissions, supplying the growing demand for electricity, and diminishing consumption of fossil fuels – these are the basic elements of the New Green Deal, heading towards carbon neutrality. However, renewables have negative impacts on the electricity network's operation, leading to reduced power system stability.

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The EU's list of renewable energy sources includes energy generated by (i) on- and offshore wind turbines, (ii) solar energy, mainly from photovoltaic (PV) panels, (iii) biomass and biogas, and (iv) wave and tide power. Currently, solar and wind power are the primary sources of renewable energy. They have similar technical characteristics: the energy is dispersed and not always available. The use of biogas can be beneficial to agriculture, utilizing its waste. Biomass as a renewable resource is controversial as it leads to deforestation.

The minimum shares of renewables in the European energy production set by the European Commission stimulate new investments despite high costs and limited dispatch ability. The current limit of renewables for 2030 is 32%, possibly increasing to 50% towards 2050.

The main drawback of renewables from the continuity of supply point of view is their limited availability. Onshore wind farms' operation with rated power does not exceed 2,300 hours annually, while offshore wind farms' electricity production time amounts to 3,500 hours at the Baltic Sea and 4,500 hours in the North Sea. Such periods of wind farm operation are relatively short, as compared with the need for 8760 hours of continuous electricity supply.

The maximum theoretical efficiency of a wind turbine does not exceed 59%, and it strongly depends on the area circled by its propellers. In practice, the efficiency of wind turbines is about 40–45%. Advancements in wind turbine technology have led to larger towers, reaching 220m for 9–12 MW plants. Onshore wind towers are significantly smaller, generating 3 MW at over 100m with blade lengths between 60 m and 70 m. Most turbines in Poland are low-power, with the size of their towers not exceeding 40–50 m.

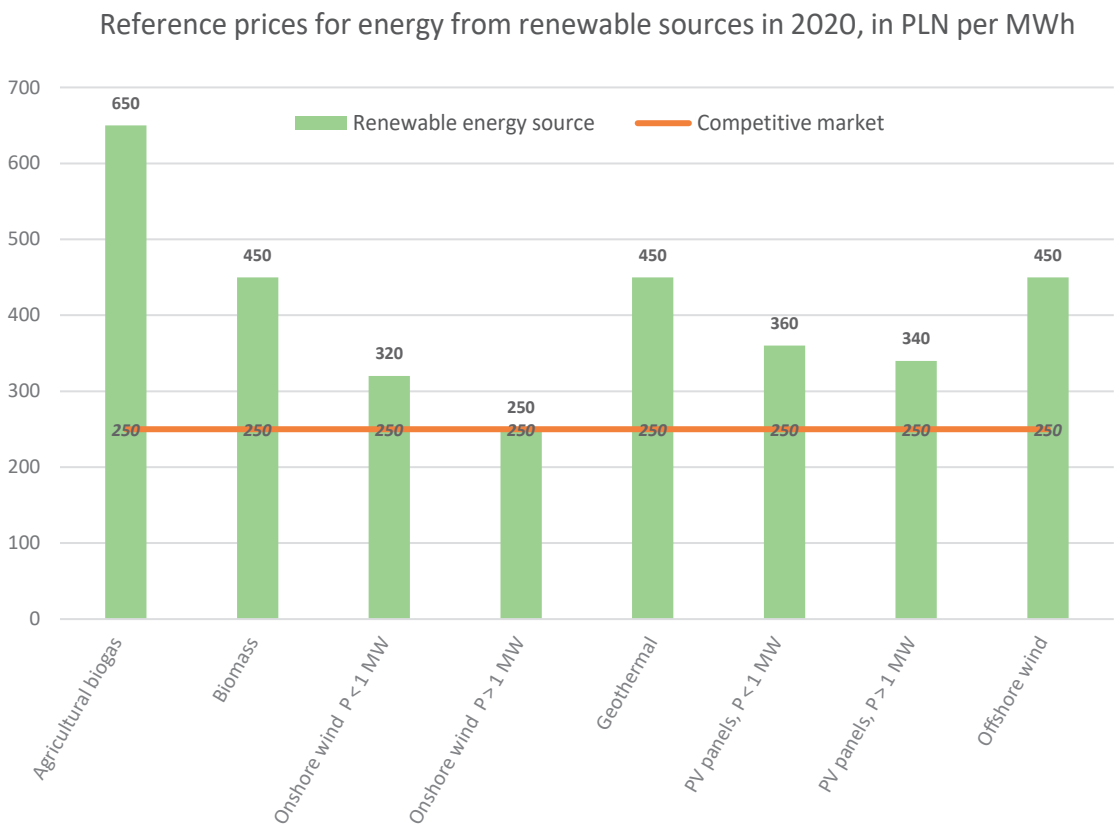

Fig. 1
Reference prices for renewable energy auctions

They are mainly imported, second-hand, from Western Europe, much like used cars.

Solar-powered electricity generation is dominated by mono- and polycrystalline PV panels. Black monocrystalline cells can reach an efficiency of up to 20% with the maximum theoretical value of about 30%, while distinctive blue polycrystalline panels have smaller efficiency, amounting to 15%. In Central Europe, effective operation time with the rated power by PV panels does not exceed 1000 hours per year. Solar energy in the region is around 1 kWh/m^2, which means large power PV installations require significant land area. In addition, this technology is highly sensitive to cloud levels, with PV electricity generation being low in the autumn and winter months.

While wind farms are almost entirely commercial installations due to their size, PV panels can also be commercial plants when their rated powers exceed 50 kW, but there are also small household installations operating in the prosumer model (see below).

Renewable energy in Poland

The development of renewable energy sources (RES) in Poland is dependent on subsidies. From 2005 to 2015, the green certificates issued for renewable energy production provided additional income for RES producers, which could also sell all electricity produced to the distribution companies at competitive market prices. Such double revenue, reaching 200% and more of market prices, allows for very profitable production. Significant profits from RES businesses attracted new investments leading to a boom in RES construction projects and consequently a rapid increase in subsidies, which place a significant burden on consumers, amounting to more than 5 billion PLN per year.

Since 2015, the new subsidy system has been in operation, based on auctions conducted with the use of reference prices. A renewable energy producer can obtain a 15-year contract with auction prices usually well over market prices (Figure 1). The RES subsidies have been increasing year by year to reach the mounting targets of the European Union. Estimates indicate that Poland's average annual direct subsidies for renewable energy sources will amount to 8–10 billion PLN (approx. €1.75–2 billion). The total costs of renewable energy include direct subsidies and costs of maintaining power reserves, which provide electricity when renewable sources are unavailable because there is no wind or sunshine.

Fully dispatchable electricity production plants include only three conventional technologies: (i) coal power plants, (ii) gas-fired power installations, and

(iii) nuclear power generation. However, increasing renewable production causes conventional power plants, on which energy security depends, to produce less and less energy, mainly serving as a power reserve for renewables.

Hence, reduced output of conventional power plants and lower sales revenues lead to new subsidies for dispatchable installations, including coal power stations. These new subsidies introduced in 2015 are called the *capacity market* and will operate in Poland until 2030, charging approximately €1.2 billion per year to energy consumers (2021). Furthermore, contracts established at the capacity market will remain in effect until the early 2040s. Therefore, the capacity market is an indirect subsidy for renewable energy paid to conventional power plants for reserving RES production.

Prosumer programs

Another way to increase production from renewables involves prosumer programs. These allow anyone who owns installations of PV panels to enter subsidy schemes. Prospective prosumers should also have the ability to finance PV installations. These subsidy schemes target the wealthiest groups of energy consumers, owners of houses, able to participate in upfront costs amounting to about 20,000–30,000 PLN (approx. €4,000–7,000).

> It is estimated that the average annual direct subsidies for renewable energy sources in Poland will amount to 8–10 billion PLN.

The main difference between a renewable energy producer and a prosumer is that a professional producer must have an appropriate license to generate electricity and operate as a registered business entity, as a VAT payer. The producer's income comes from the electricity sold at preferential prices obtained in renewable energy auctions (Figure 1).

A prosumer, in turn, is a person who produces energy for his or her use and has received appropriate subsidies, such as Poland's "My Electricity" or "Clean Air" schemes. These subsidies amount to around 8,000 PLN (€1,750), with an average installation cost of 25,000 PLN (€5,500). Thus, prosumers profit from energy cost-savings while professional producers gain from large-scale electricity sales at favorable prices compared to the competitive market.

Since PV panels can generate power only during daylight, prosumers still have to be connected to electrical networks allowing for energy purchase from outside sources for the rest of the day, especially in winter. Furthermore, the energy produced during daylight has to be stored for evening hours. Energy storage is very expensive. Therefore, a prosumer receives yet another subsidy covering the additional costs of energy storage.

Such a subsidy is called *net-metering*, allowing for the injection of prosumers' energy into the power grid during energy excess from PV panels in daylight and its withdrawal during evenings and nights. Conventional power plants are employed to perform the function of electricity storage. Thus, such installations reduce production when prosumers have energy overplus and increase generation when they withdraw electricity from the grid. The fee paid by prosumers for such storage equals 20% of the electrical energy fed into power networks.

Despite the numerous subsidies, prosumer programs are not cost-effective, and professional economic calculations using the discounted flow method show prosumer losses of 30 percent compared to the case when they solely purchased electricity from the grid. However, the government supports prosumer programs as they provide more RES electricity production. In addition, a certain role in the decision to become a prosumer may be played by a desire to be a part of fashionable trends, including a wish not to stand out among neighbors who have already purchased such RES installations.

Impact on the National Power System

The major renewable technologies such as wind and solar power depend on weather conditions, so they cannot be included in power balances that determine energy security. Although RES cannot be dispatched on-demand, wind farms and PV panels are easily controlled power sources. PV and wind power plants have output inverters operating in a pulse modulation mode, capable of shaping the frequency, amplitude, and phase of electric currents fed into the grid. Additionally, wind turbines can change the pitch angle of propellers, thus regulating the amount of energy taken from the wind.

While large wind installations are equipped with appropriate inverter controllers, prosumers' PV panel inverters generally have inadequate controllers, usually adapted from electric drives due to their low

costs. In addition, the inverter controllers of prosumers' PV plants are not designed to work with power systems that experience continuous voltage fluctuations. As a result, when larger fluctuations happen, which occur frequently, PV installation inverters shut down their operation, cutting off power supply from these plants. This can lead to serious failures of power systems.

Seeking to cope with such uncontrolled operation of prosumers' PV installations, grid operators have proposed new rules for response to fluctuations in frequency and voltage levels. However, these new operation rules for prosumers' inventers are still waiting at the Polish Ministry of the Climate and Environment office to be introduced as legal regulations. Moreover, their introduction is being slowed down because of the expected significant increase in the cost of inverters for prosumers' PV plants, which would necessitate more subsidies.

Another problem is that renewable energy installations lack natural inertia, an element of stabilization in power system operation. In the case of energy excess in the conventional power system, e.g., a line outage, steam turbine generators weighing hundreds of tons can increase their rotational speed, converting the electricity surplus into kinetic energy of the rotating masses. Conversely, conventional generators slow down their rotation when there is an energy shortage, transferring energy stored in kinetic energy of rotation back into the power system.

The ability to vary the generators' speed is the main advantage of conventional power stations when stabilizing electric grid operation. Unfortunately, renewable sources do not possess inertia ability, and during fluctuations in power systems, they quickly shut down their operation, causing failures in the electric energy supply. The rising installed capacity of renewable sources impels transmission grid operators to search for new inertia sources in power systems – for instance, proposing to employ the generators and steam turbines in old power plants after their coal furnaces are decommissioned, as rotating masses operating in the motor mode. However, this is a highly debatable solution.

Blackout in East England

On 9 August 2019, the power system in the East of England experienced a major failure, leaving more than 1,152,000 consumers disconnected from the grid and without power – including vulnerable consumers such as Newcastle Airport and Ipswich Hospital. Thousands of travelers were trapped in rail carriages, many in underground tunnels. Rail operation was not restored until the following day. The failure's nature and its speed came as a surprise to the grid operators. Something that should never have happened has become a real threat.

The failure was initiated by spontaneous shutdowns of distributed generation, mainly small PV panels. At the first stage, 500 MW of PV installations disconnected themselves in response to voltage fluctuations in the power grid. Afterward, the Hornsea One offshore wind power plant reduced its power from 799 MW to 62 MW. In the subsequent failure step, the gas-fired power plant in Little Barford (STC1 – 244 MW) shut down its operation because of excessive steam pressure, and then, anticipating that the safety mechanisms would operate, the dispatchers also disconnected the second steam turbine (GT1B – 187 MW). The resulting rapid drop in voltages across electric networks caused spontaneous and uncontrolled shutdowns of subsequent renewable installations, mostly PV panels, leading to a serious outage in the power supply.

The installed capacity of renewable sources, including PV panels, increases every year, resulting in a higher probability of system failures. Additionally, the power industry's energy transformation and closure of conventional power plants lead to diminishing inertia with stabilizing features. Little progress has been noted in artificial inertia research, leaving an open question of whether it is possible to replace natural inertia.

New Green Deal

The New Green Deal is the EU's political program leading to carbon neutrality, which means the ability to balance emission of greenhouse gases with its absorption, including the forests' ability to capture carbon dioxide. Initially, the green deal was expected to be achieved only by renewable energy sources. However, since this has been proven impossible, as RES cannot operate on demand, intensive research is being carried out to develop large-scale energy storage in the form of so-called *green hydrogen* produced from renewable energy. However, more than a century of experience with hydrogen in the energy industry shows that this gas easily escapes through the walls of storage tanks and pipelines, burning explosively. Thus, the hope of achieving carbon neutrality through the widespread implementation of hydrogen in power generation seems to be wishful thinking.

Renewable energy is an important part of energy transformation; however, it is expensive and requires power reserves provided by conventional power generation. Increasing costs of renewables lead to a new *modus operandi* in power systems, in which electricity is a luxury good with limited access. This new way of functioning power systems will be a big challenge for the economy and societies. ■

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