CZYSTA MOC ENERGII

LESSON PLAN

How do renewable energy sources work?

LESSON DURATION 45 min HIGH SCHOOL CLASS

Students will learn what renewable energy sources are, what physical phenomena they are based on, and how they operate within the power system.
The lesson helps students understand the key advantages of renewable energy sources, debunks common myths about them, and shows the challenges associated with the development of renewable energy. The content is based on the attached lesson plan.

By the end of the lesson, students should be able to answer the following questions:

1. What are renewable energy sources, and how do they differ from fossil fuels?
2. How do photovoltaics, wind turbines, hydropower plants, and geothermal energy convert energy from the environment into usable energy?
3. Why do renewable energy sources have a low carbon footprint and low marginal cost of energy production?
4. What does the variability of renewable energy production mean, and why must the power system be flexible?
5. What are the most common myths about renewable energy sources, and how can they be verified?
6. Why are recycling, lifespan, and energy payback time of renewable energy installations important when assessing their environmental impact?
7. What role do energy storage systems, pumped-storage power plants, and demand-side management play in a system with a high share of renewables?
8. What is a prosumer, and how do distributed energy sources change the traditional energy model?
9. What technical, social, and spatial barriers hinder the development of renewable energy sources?
10. How can the development of renewable energy be reconciled with the need for stable, affordable, and secure electricity supply?

5 min

SEGMENT 1

Introduction to renewable energy technologies

Renewable energy sources (RES) are energy sources that utilize natural, constantly renewing processes occurring in nature, such as solar radiation, air movement, the water cycle, and the Earth's internal heat.

Unlike fossil fuels, RES **do not rely on burning resources** but on converting energy already present in the environment, which means there are no direct CO_2 emissions during energy production or that they are offset (e.g., in the case of biomass, which is still classified as RES). As a result, renewable technologies have a virtually negligible carbon footprint — for example, generating 1 kWh from onshore wind turbines results in a carbon footprint of just 11 grams of CO_2. By comparison, 1 kWh generated from a lignite-fired power plant results in an emissions cost of **1,200 grams of CO_2**

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Renewable energy technologies are based on various physical mechanisms: photovoltaics convert light into electricity, wind and hydro turbines convert the kinetic energy of air and water movement into mechanical and then electrical energy, and geothermal installations use heat to produce energy or heating;
For this reason, renewable sources have a **very low marginal cost** of energy production, independent, for example, of fluctuations in raw material prices, as is the case with gas or coal-fired power plants

The development of renewable energy sources (RES) is currently one of the main directions of the energy transition, driven by climate, strategic, and industrial factors. At present, there is approximately 5,100 GW of installed renewable energy capacity worldwide.

20 min

SEGMENT 2

Myths about renewable energy sources

The myth of unmanageable waste disposal and environmental pollution: Opponents of renewable energy claim that, for example, used wind turbine blades and old solar panels are waste that cannot be recycled. In reality, even in Poland there are already companies specializing in the processing of wind turbine blades, and photovoltaic panels are approximately 90–95% recyclable (most of a PV panel's mass consists of glass and aluminum). The renewable energy industry is striving toward a circular economy model, which the fossil fuel sector is unable to achieve.

The myth of harm to health and animals: wind turbines are sometimes accused of killing vast numbers of birds or generating infrasound harmful to humans. Statistics show, however, that cats, noise barriers, and glass-walled office buildings pose a threat to birds that is several to over a dozen orders of magnitude greater. In turn, the infrasound generated by wind turbines is comparable in level to the sound of the sea or wind in the trees and has no proven negative impact on health when appropriate distances are maintained.

The myth of short lifespan and rapid degradation: Renewable energy sources are often accused of having a short lifespan; it is claimed that solar panels and wind turbines break down after just a few years, becoming useless scrap. This is a misconception. Modern photovoltaic panels are designed so that their efficiency after 25 years of operation is at least 80–85% of their initial power. The same applies to wind turbines, which have a projected lifespan of 20–30 years. As a result, renewable energy is a long-term investment, not a temporary solution

The myth of instability leading to a total blackout: A common argument against renewable energy sources is the claim that a system based on these technologies can easily collapse when the wind isn't blowing and the sun isn't shining. Modern energy solutions address this issue through diversification of sources (e.g., a mix of wind, solar, and nuclear), the development of energy storage (batteries, pumped-storage hydroelectric plants), and demand-side response (DSR).

The myth that renewable energy exists only thanks to subsidies: this is one of the most common arguments, suggesting that without public funds and generous subsidies, renewable energy would not have emerged. The truth is that solar and wind power are currently the cheapest energy-generation technologies capable of competing in the free market without any support. Moreover, it is the fossil fuel sector that has been receiving massive, often hidden subsidies for decades (e.g., support for mining, failure to fully cover health costs resulting from smog). Subsidies for renewable energy act as an accelerator for the transition, not a life support system propping up an unprofitable business

The myth of unpayable energy and carbon debt: in discussions about renewable energy, the argument often arises that the production of photovoltaic panels or wind turbines consumes more energy and emits more CO_2 than these devices are capable of producing or saving over their lifetime. This is not true; the socalled Energy Payback Time (EPBT) for a photovoltaic 20 min.installation operating in Europe is typically between 1 and 2 years, and its Carbon Payback Time is approximately 1 year. For onshore wind farms, these figures are 6 months and 6–9 months, respectively. Meanwhile, the lifespan of these systems is 25–30 years.

The myth of a negative impact on property values: in local discussions, it is often argued that wind or solar farms mar the landscape and lower the prices of adjacent plots of land. However, market research conducted, for example, by the Polish Wind Energy Association or investors from individual companies does not confirm a sustained decline in property values in the vicinity of such projects. Moreover, in municipalities investing in renewable energy, local government budgets are funded by taxes on installations, which allows for better infrastructure (roads, schools, community centers), thereby increasing the attractiveness and quality of life in the area.

Possible discussion questions:

Why are myths about renewable energy so popular?
This stems, among other things, from the anchoring effect (people cling to outdated information they have heard once) and fear of the unknown. Additionally, renewable energy changes the landscape and way of life (e.g., solar panels on roofs), which provokes natural resistance from conservative social groups, often fueled by misinformation or polarizing political actions.

How can you tell if a message is disinformation?
To identify disinformation, you should first and foremost remain vigilant toward messages that evoke extreme emotions, such as fear or anger, and avoid sources that do not provide specific, verifiable data from reputable institutions.

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5 min

SEGMENT 3

How do renewable energy sources work within the power grid?

Traditional systems resemble a system based on a single, massive heart (power plants) pumping blood (energy) into the vessels (consumers). A renewable energy system consists of hundreds of thousands of small producers (e.g., wind farms, hydroelectric plants, residential solar panels), many of whom are prosumers - that is, entities that both produce and consume energy.

the most common RES (wind and solar power plants) generate energy in a **predictable but uncontrollable** manner. You cannot "turn on" the wind or the sun when you happen to need more electricity—but you can predict when it will be windy or sunny. Managing a larger number of such sources requires the system to have sufficient flexibility and coordination, as well as careful planning.

When RES produce too much or too little electricity, the system operator (in Poland: Polskie Sieci Elektroenergetyczne) must manage this somehow.

A system incorporating RES requires **additional capacity** in the form of energy storage facilities, pumped-storage power plants, or flexible conventional sources (e.g., gas-fired), which can quickly make up for shortfalls.

To manage thousands of renewable energy units efficiently and effectively, the **system must become smart,** i.e., it must use digital technologies to forecast weather and automatically control electricity flows.

At every moment, the amount of energy fed into the grid **must equal** the amount of energy consumed by users. If this balance is **disrupted**, the frequency of the electricity in the outlets changes, which can lead to damage to devices or a failure of the entire system. That is why it is so important to properly manage all the power sources operating within the system.

Possible discussion questions:

Are renewable energy systems more prone to blackouts?
Not necessarily. A blackout is a widespread power failure that is more often caused by outages at large conventional power plants or damage to transmission grids than by problems with renewable energy sources. However, systems with a high share of solar and wind power require a different approach to management. If this management is sufficiently flexible and based on solutions that facilitate the operation of renewable sources (energy storage, gas-fired power plants, international interconnections), the system remains stable.

Does it often happen that there is no wind and no sun at the same time?
This phenomenon is called Dunkelflaute (dark calm) in German. In Poland, this mainly occurs in winter, when days are short and cloudy, and a windless high-pressure system lingers over the country. This is not an everyday occurrence, but statistically it happens every year for several to over a dozen days. At such times, other power sources—such as nuclear power, energy storage facilities, biogas plants, or gas-fired power plants—must take over the role of renewable energy generation.

Who oversees the operation of the power grid?
In Poland, this is the company PSE (Polskie Sieci Elektroenergetyczne).

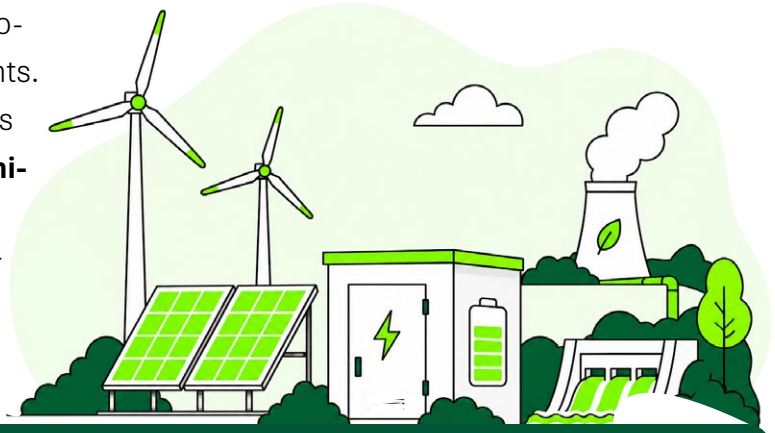
10 min

SEGMENT 4

Challenges in the development of renewable energy sources

The operation of the most common renewable energy sources depends on the weather. When the wind suddenly stops blowing or the sun goes behind the clouds, the system must react instantly. The lack of sufficient alternative power sources, energy storage, and flexible backup sources is currently one of the biggest technical barriers to the development of renewable energy plants;
Most existing power systems were designed **decades ago** for a few large gas or coal-fired power plants, and less commonly, nuclear plants. Connecting thousands of distributed sources requires massive investments in the **modernization and construction** of new transmission lines and system flexibility solutions, for which there is often a lack of funds or political will;

The construction of certain renewable energy sources—such as wind turbines -often faces **resistance** from local communities (the so-called **NIMBY** effect: Not In My Backyard). People fear noise, changes to the landscape, or other issues, which significantly prolongs investment processes and sometimes even blocks them;
Compared to traditional power plants, renewable energy sources require significantly **more land** to produce the **same amount of energy.** For example, to replace a single unit of a large coal-fired power plant, thousands of hectares of solar farms or hundreds of wind turbines are needed. This sometimes leads to conflicts over land use and also necessitates the search for innovative solutions, such as agrovoltaics (combining agricultural crops or livestock farming with photovoltaic panels).



Possible discussion questions:

How can we convince the local community to support the construction of a wind farm in their neighborhood?
Public participation and financial benefits are key. If residents become, for example, co-owners of the farm, or if the municipality can use taxes from the wind turbines to fund a modern school and roads, resistance usually diminishes. It is also important to provide accurate information about the lack of negative health impacts from modern turbines.

Isn't importing renewable energy technology a new form of dependency?
Europe currently produces only a small fraction of photovoltaic cells or battery components. China's dominance in this sector, for example, poses a political risk, but does not constitute a critical threat to Europe's energy security, because renewable energy technologies, unlike fossil fuels, rely on installed capacity rather than on continuous supplies of raw materials.

Are renewable sources truly clean?
Renewable energy sources, while incomparably cleaner than fossil fuels during operation, are not entirely free from environmental impact, as their "cleanliness" must be assessed over their full life cycle. Nevertheless, the carbon footprint of electricity from, for example, wind turbines is the lowest in the entire energy sector.

5 min

SEGMENT 5

Wrap-up Discussion

If you were to design Poland's energy system for the year 2050 - one that is affordable, secure, and clean - how would you balance the development of renewable energy with today's challenges?

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