



Nudging consumers
towards energy efficiency
through behavioural science

ELECTRICITY OUTSIDE THE HOME

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TRANSPORT OF ELECTRICITY TOWARDS HOMES

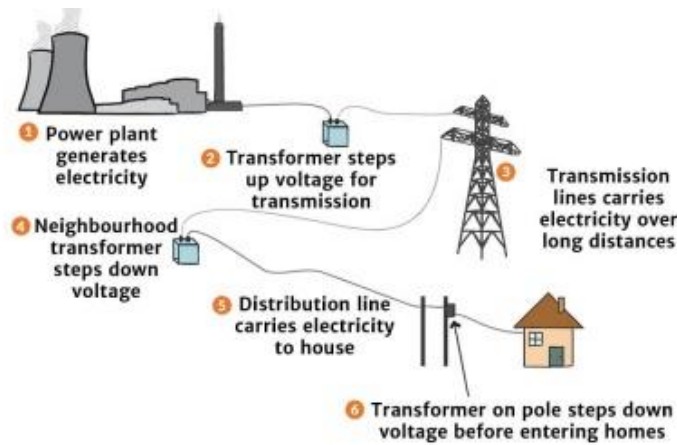


Figure 1: Representation of electricity transmission from a power plant to a house [1]

The transmission of electricity from a power plant to homes and businesses is organised in Belgium through three distinct networks that are interconnected (see Figure 1):

- The transmission network via high-voltage lines: from e.g. nuclear power plants, gas power plants, wind farms, etc., electricity is transported at high-voltage levels of 70 kilovolts (kV) and above.
- The local transmission grid via local high-voltage lines: this is a transitional grid that transports electricity at somewhat lower high-voltage levels of 36-70 kV, e.g. from wind farms, cogeneration plants, etc. It supplies industrial customers.
- The distribution network via underground cables: this transports electricity with a voltage between 230 volts (V) and 36 kV. It brings power to private customers. Installations with lower capacity are connected to it, e.g. some wind farms, solar panels at professionals and private individuals, etc.

Transformer houses in residential areas convert the medium voltage to low voltage of 230 V. This is the voltage that enters your home and can be used by appliances in your home. [1, 2]

What would be benefits of high-voltage power lines?

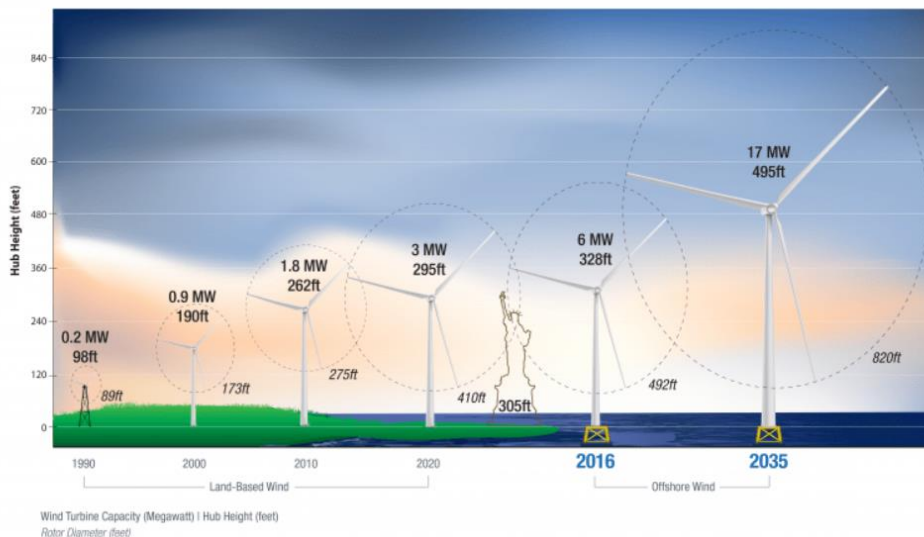
Can you think of any disadvantages?

What would be advantages of underground cables?

Do you know of any disadvantages?

Read the following article: 'Top 10 Things You Didn't Know About Offshore Wind Energy' [3]

10. Offshore Wind Resources Are Abundant: Offshore wind has the potential to deliver large amounts of clean, renewable energy to fulfill the electrical needs of cities along U.S. coastlines. Under conditions that foster offshore wind utilization, the National Renewable Energy Laboratory estimates that the **technical resource potential for U.S. offshore wind** is more than 4,200 gigawatts of capacity, or 13,500 terawatt-hours per year of generation.



9. Offshore Wind Turbines Can Be Extremely Tall: In order to capture the abundant wind resources available offshore, offshore turbines can be [scaled up](#) to one-and-a-half-times the height of the Washington Monument, with blades the length of a football field.

8. Offshore Wind Components Are Getting Larger: Offshore wind turbine components are transported by ships and barges, reducing some of the logistical challenges that land-based wind components encounter, such as narrow roadways or tunnels. These components enable offshore wind developers to build larger turbines capable of producing more electricity; however, working at sea presents its own challenges.

7. **The U.S. Offshore Wind Industry is Ready for Takeoff:** The U.S. Department of Energy (DOE) works collaboratively with industry and academia to [address research challenges that are unique to U.S. offshore wind](#) (like [hurricanes](#)), and to [understand and address market barriers](#) such as environmental impacts, logistical challenges, siting and permitting, and infrastructure development. Finally, DOE is also working to [demonstrate advanced technologies](#).
6. **Offshore Wind Farms Use Undersea Cables to Transmit Electricity to the Grid:** Electricity produced by offshore wind turbines travels back to land through a series of cable systems that are buried in the sea floor. This electricity is channeled through coastal load centers that prioritize where the electricity should go and distributes it into the electrical grid to power our homes, schools, and businesses.
5. **The Majority of U.S. Offshore Wind Resources Are in Deep Waters:** The bulk of the nation’s offshore wind resources, about 68 percent, are in areas where the water is so deep that conventional foundations—large steel piles or lattice structures fixed to the seabed—are not practical. U.S. offshore wind projects are developing a variety of different foundations suited to unique conditions at each site.
4. **Offshore Wind Turbines Can Float:** A number of companies are developing innovative floating offshore wind platforms for use in deep waters. Four kinds of floating platforms are spar-buoy, tension leg platform, semi-submersible, and barge. About 80% of projects plan to use semi-submersible platforms.
3. **Offshore Wind is Right on Time:** In many areas where offshore wind projects are planned, offshore wind speeds are highest during the afternoon and evening, when consumer demand is at its peak. Most land-based wind resources are stronger at night, when electricity demands are lower.
2. **Offshore Wind Resources are Near Most Americans:** Nearly 80 percent of the nation’s electricity demand occurs in the coastal and Great Lakes states—where most Americans live. Offshore wind resources are conveniently located near these coastal populations; for example, in the Northeastern United States where some of the nation’s first offshore wind projects are planned. Wind turbines off coastlines use shorter transmission lines to connect to the power grid than many common sources of electricity.
1. **Offshore Wind is Here in America:** In December 2016, Deepwater Wind completed the commissioning of the 30-MW [Block Island Wind Farm](#), marking a milestone as the nation’s first commercial offshore wind project. In 2020, the 12-MW Coastal Virginia Offshore Wind pilot became the second operational U.S. offshore wind project. Additionally, there are about 40 offshore wind projects in various stages of development across the United States.

How does one transport electricity from offshore wind turbines to land?

ENERGY SOURCES IN BELGIUM

We cannot find a source of electricity on earth. Other sources of energy are needed to generate electricity. There are several sources of energy in which energy can be converted into electricity. The most commonly used energy sources in Belgium that generate electricity are the following [4]:

- Non-renewable energy sources:
- Nuclear energy
- Gas (fossil energy)

- Renewable energy sources
- Solar energy
- Wind energy (offshore and onshore)
- (Biomass)
- (Hydropower)

What are offshore wind turbines? _____

What are onshore wind turbines? _____

Tip: look up what "shore" means: _____

See below the 2022 and 2021 electricity mix in Belgium in Figure 3.

Tip: Look carefully at the units in the title and look up what TWh means.

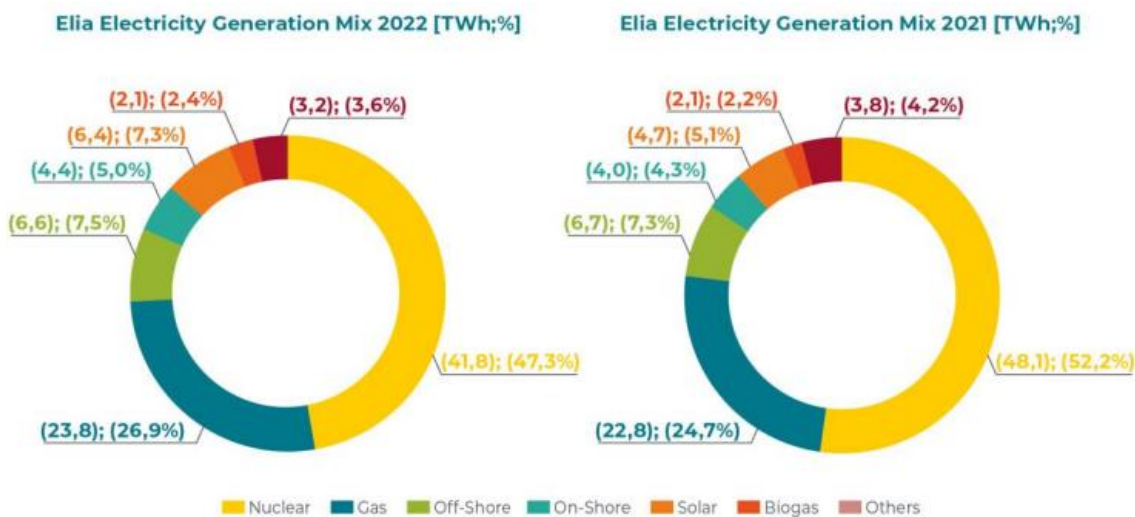


Figure 3: Electricity mix in 2022 and 2021 in Belgium [4]

What differences can you observe between 2022 and 2021?

What percentage of energy in Belgium in 2022 and in 2021 came from renewable energy sources?

What is the percentage increase or decrease in renewables?

Net electricity generation in Belgium in 2021 was 96.34 TWh.
Total electricity consumption in that year was 83.66 TWh. [5]
Calculate how much electricity Belgium could export in 2021.

The number of private households in Belgium in early 2022 was 2.89 million [6].
An average household consumes 3 500 kWh per year of electricity.
Calculate the share of households in Belgium's total electricity consumption.

The percentage of electricity in Belgium generated by renewable energy sources is increasing every year. In December 2022, electricity generation from renewable energy sources was 1 717 GWh. [7] Look up what GWh means.

Calculate the percentage of electricity generated by renewable energy sources if this electricity production were the same for 12 months.

Calculate how many days we can survive on 'green electricity' in Belgium.

'Grey day' is the symbolic day on which the amount of renewable energy produced in a country in one year is completely used up, counting from 1 January of that year. Calculate the day on which the 'green electricity' produced in Belgium is fully used up in Belgium.

Now look up when it is 'Grey day' in Belgium this year: _____
 On this symbolic day, not only electricity produced by renewable energy sources, but also other renewable energy is used up in Belgium.

What is an energy 'blackout'? Look this up on the internet.

What is the 'switch-off plan'? Look this up on the internet.

We now calculate how much electricity Belgium's four main energy sources can generate and look up the advantages and disadvantages of the different energy sources. For this, the class can be split into four groups so that each group studies one energy source.

1. Nuclear power plants

In figure 4, you can see a picture of the Doel nuclear power plant.



Figure 4: Photo of Doel nuclear power plant [8]

The steam coming out of the cooling towers of the nuclear power plant can be observed from afar. Many think that this steam contains radioactive radiation or disperses toxic fumes, but it is actually just water vapour.

Where does this steam come from?

The components of a nuclear power plant can be found in Figure 5.

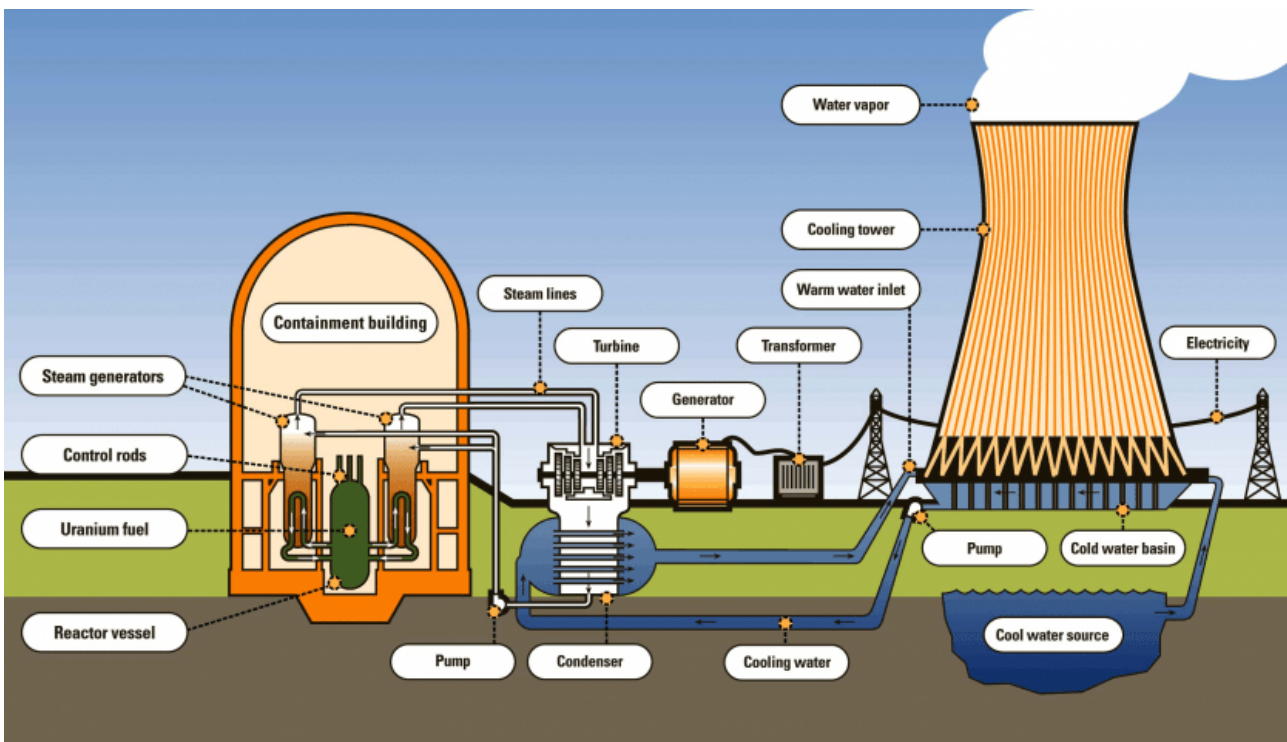


Figure 5: Components of a nuclear power plant [9]

Doel 4, the reactor that was last erected, has a net power (= energy use) of 1039 megawatts (= about 1 gigawatt).

How much electricity (expressed in megawatt hours = 1 megawatt produced in 1 hour) can Doel 4 generate per year?

A nuclear power plant cannot operate all year round: it also needs e.g. annual maintenance and breakdowns can occur. Assume that the reactor operates 96% of the time. Calculate how much electricity can actually be generated per year by the Doel 4 reactor.

Some of the energy generated is lost to e.g. heat. Calculate the core power (= total energy generated) of reactor 4 if you know that the efficiency is about 35%.

Calculate how many families per year can be supplied with electricity by this reactor.

Search the internet for the advantages and disadvantages of nuclear power plants. Read the information you find critically and note the advantages and disadvantages in the table below. Find reliable sources and note the sources below the table.

Advantages	Disadvantages
Advantages	Disadvantages

Sources consulted:

2. Gas power plants

In addition to the old gas plants, new gas plants were recently built to provide enough electricity in Belgium if the nuclear plants will no longer be used. In figure 6, you can see a picture of the gas power plant in Tessenderlo.



Figure 6: Photo of the gas power plant in Tessenderlo [10]

How much electricity can a new 875-megawatt gas-fired power plant generate per year?

A gas power plant also cannot operate all year round, e.g. because of annual maintenance or breakdowns. Assume that the gas power plant operates 90% of the time. Calculate how much electricity can actually be generated per year by this gas-fired power plant.

Calculate how many families a year can be supplied with electricity by this gas power plant.

Modern gas power plants achieve an efficiency of about 60%. Find out how it is that the efficiency is higher than nuclear power plants.

Find out on the internet what advantages and disadvantages gas power plants have. Read the information you find critically and note the advantages and disadvantages in the table below. Find reliable sources and note the sources below the table.

Advantages	Disadvantages
Advantages	Disadvantages

Sources consulted:

3. Solar panels

More and more people are putting solar panels on their roofs at home. In October 2020, Flanders had half a million solar panel installations: these provided a capacity of 3595 megawatts. [11]

The number of Flemings with a home battery to temporarily store electricity generated by the solar panels was still limited until 2020: from 19 batteries in 2019 to 116 in 2020. This number has been increasing sharply since then. By 2021, 11 174 home batteries had already been installed by 8 November and an additional 6 983 Flemings have applied for a home battery premium [12]. A home battery can store energy for a few hours to days (see lesson 'Electricity at home') [13].



Figure 7: Picture of solar panels on a roof [14]

Those who have their own solar panels can check the output of the solar panels on the EnergyID dashboard. In Figure 8, you can see an example of a family's electricity production from solar panels per month.

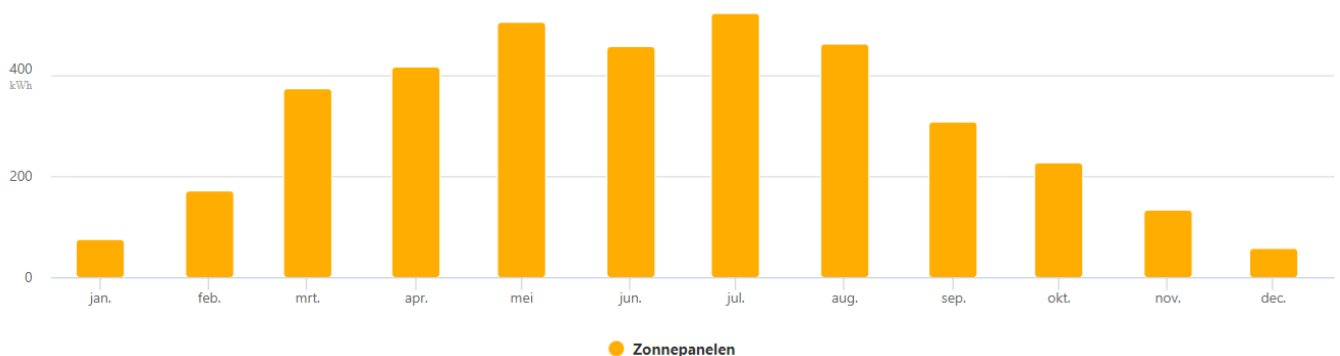


Figure 8: Electricity output of a household's solar panels per month [15]

The number of sunshine hours is not the same every day. On average, there are 1400 to 1700 hours of sunshine per year in Belgium [16]. Sunlight is not always equally strong. Therefore, the maximum power a solar panel can provide is expressed in watt peak (Wp). For example, a solar panel has an output of 300 watt peak [17].

Estimate how many kilowatt hours of electricity 12 300-watt peak solar panels would theoretically generate per year.

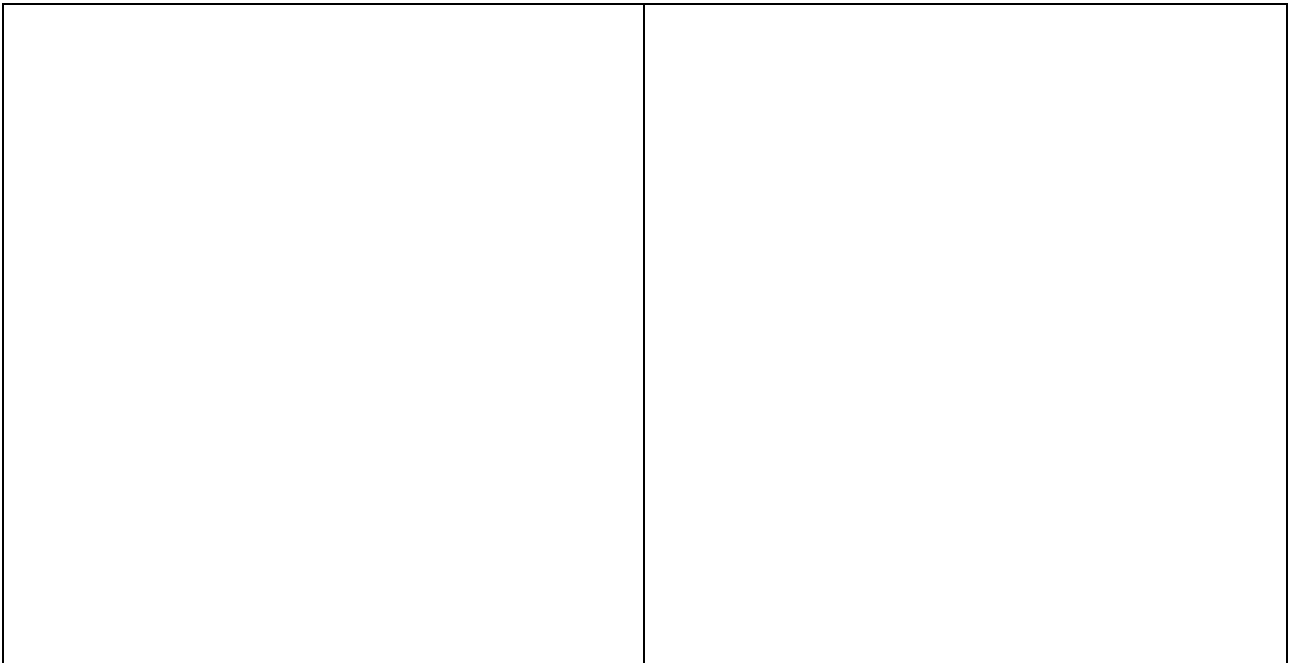
This peak power is only achieved under ideal conditions. In practice, about 85% of this peak power will be deliverable during sunny hours. Calculate how much electricity these 12 solar panels produce in one year on average in real life. Does this correspond to the amount of electricity consumed by an average family?

Suppose you want to supply all Belgian households with electricity from one energy source. How much surface area of solar panels would you then need in order to supply all Belgian households with electricity using solar panels alone? (Hint: one 300-watt peak solar panel has a size of about 2 m²).

What percentage of Belgium's surface area is this?

Search the internet to find out what advantages and disadvantages solar panels have. Read the information you find critically and note the advantages and disadvantages in the table below. Look up reliable sources and note the sources below the table.

Advantages	Disadvantages
Advantages	Disadvantages



Sources consulted:

4. Wind turbines

In order to switch to as many green energy sources as possible, wind (windmill) farms are also being built in several places in Belgium.



Figure 9: on-shore wind farm [18]



Figure 10: off-shore wind farm [19]

Today a standard wind turbine on land has a mast 100 metres high and blades of 55 metres long (or even larger). These wind turbines have a capacity of 3 megawatts (MW) [20].

Calculate how many megawatt hours of electricity are generated by this wind turbine in one year under ideal conditions.

The wind does not always blow hard and sometimes it does not. On average, a wind turbine produces in one year produces 23% of that optimal output.

Calculate how much electricity this wind turbine produces on average in one year in reality.

Now calculate how many families can be supplied with electricity by one wind turbine.

The ratio between the number of offshore and onshore wind turbines in Flanders is about 2/3. Wind turbines at sea are larger than on land with capacities of 6 MW (and more). The efficiency at sea is also higher, about 38% on average [21].

Which wind turbines generate the most electricity in Flanders, the wind turbines at sea or on land? Show how to calculate this.

How much surface area of wind turbines do you need to use wind turbines alone to supply all Belgian households with electricity? (Tip: Wind turbines should be at least five times the diameter of the rotors apart).

What percentage of Belgium's surface area is this?

Research on the internet what advantages and disadvantages wind turbines have. Read the information you find critically and note the advantages and disadvantages in the table below. Look up reliable sources and note the sources below the table.

Advantages	Disadvantages

Sources used:

5. Comparison of energy sources

Briefly evaluate (e.g. with +, - or +/-) the listed criteria for each energy source in the following table:

	Nuclear power plants	Gas plants	Solar panels	Wind turbines
Renewable energy source				
Security				
Waste and recycling of materials				
Climate impact (Co2 emissions, waste...)				
Flexibility and stability of energy supply				
Amount of electricity generated				
Impact on landscape				
Other				

6. Locations of energy sources

Find out where nuclear power plants, gas power plants and wind turbines were placed in Belgium. Why were these places chosen?

Class assignment:

Conduct a class discussion:

1. Each group defends one energy source. Argue with the advantages and disadvantages of the energy sources.
2. Together, decide on a plan for Belgium: how much of each energy source would you provide to power all Belgian households.
3. Where would you place these sources of energy? Draw the energy sources on the map of Belgium (see Figure 11). Make your own legend below the map.



Figure 11: Blind map of Belgium

Legend:

Fancy a game?

- Game from WWF from the energy box (Dutch, French and English) [22]
- DECIDE Power of Community game [23]

ELECTRICITY CONSUMPTION IN THE WORLD

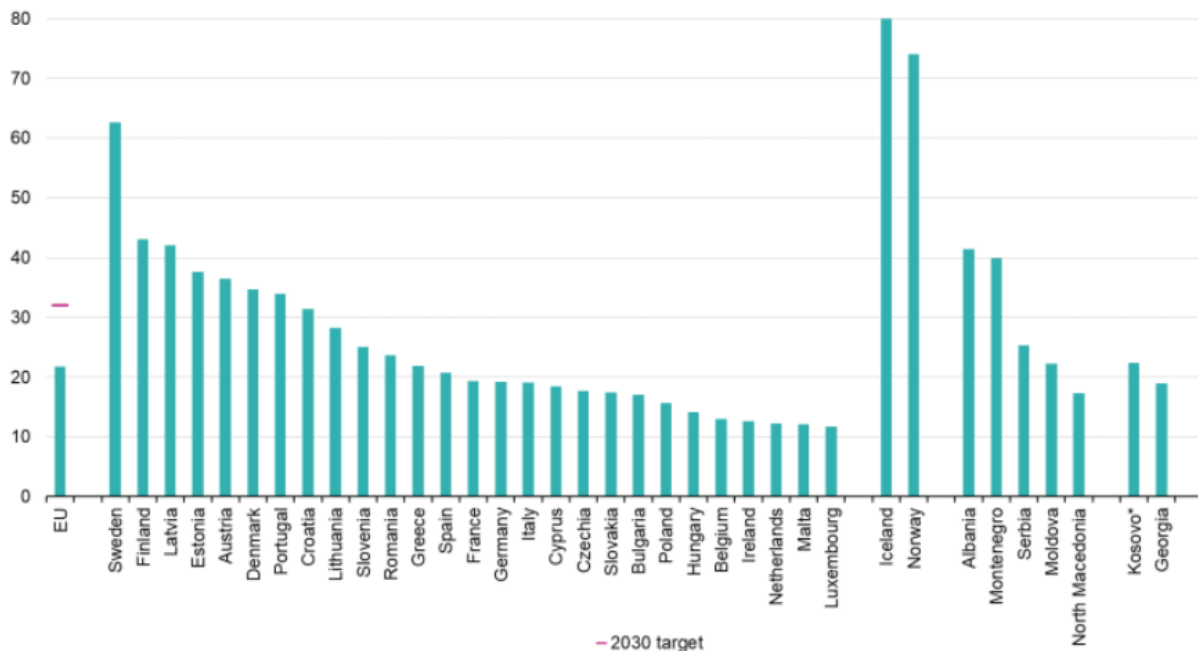
On the following website you can find out how much electricity is consumed per inhabitant:

<https://www.indexmundi.com/g/r.aspx?v=81000&l=en>

Belgium ranks 35th here. Which European countries consume more electricity per inhabitant? How could you explain these differences?

Compare Belgium's share of renewable energy with other European countries in Figure 12. What do you notice?

Share of energy from renewable sources, 2021
(% of gross final energy consumption)



* This designation is without prejudice to positions on status, and is in line with UNSCR 1244/1999 and the ICJ Opinion on the Kosovo declaration of independence.

Source: Eurostat (online data code: nrg_ind_ren)

Figure 12: EU renewable energy share in 2021 and 2030 target [24]

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