Powering Cities without harming the Climate: An introduction

Energy is a matter of course for us. Often we do not even realize what we are using it for. We are permanently dependent on electricity. It begins in the morning with making coffee, brushing our teeth, and listening to music on the way to school. This list could be continued for the whole day. In addition, we heat our apartment in winter, cool our food in the refrigerator, and go by cars and trains. We fly by plane and light up our rooms and so on. Furthermore, all economic sectors such as agriculture, industry, trade, services and public institutions do also depend on energy.

What exactly is energy?

Energy is fundamental to all activities. Our body takes the energy we need to live from the food we eat. Energy, in the form of electricity, is also needed to charge the smartphone. In pre-industrial times, people used energy sources such as water, wood, and coal from their natural environment. Today, the development of new sources of energy enables us to have a modern economy and the technological progress we know. The newly developed energy sources include oil products such as petrol, diesel or heating oil, but also natural gas.

Physical basics

Energy is a physical quantity that can be measured and can therefore be clearly determined. In our everyday life, we use the term energy in various contexts that do not always agree with the definition of energy used in physics. For example, many will agree with the claim: "It costs me a lot of energy to get up in the morning". In fact, this means something completely different: "I have to outdo myself getting up in the morning because I would actually much rather continue sleeping". Physically speaking, getting up actually requires energy because the center of mass of the body has to be raised, i.e. the body changes its position. The energy created by lifting the body is called **potential energy**. The amount of energy required to do this is minimal. For an average person, it corresponds to the **chemical energy**, i.e. the energy taken from our food, contained in about 0.05 g of wheat mixed bread, i.e. about the amount of energy in one crumb of bread.

There are other forms of energy besides potential and chemical energy, for example:

- **Kinetic energy**, the energy of motion.
- The **thermal energy** or simply heat.

In short, energy is the ability to do work. In the physical sense, work is always performed when energy is converted from one form to another. In the example above, work is done when chemical energy is converted into potential energy while standing up.

In thermodynamics, two main laws play an important role:

1. The law of conservation of energy: Energy can be transformed from one form into another, but it can neither be generated nor destroyed. Even though it is often said

that we consume or generate energy, it is always just a matter of converting it from one form into another.

2. The second law states that certain processes are irreversible: Heat can only flow from a warmer to a colder body, never the other way around. Mechanical energy can be completely converted into heat energy, but the reverse process is impossible.

Sources of energy

Energy is obtained from various sources. A distinction is made between renewable energy sources and non-renewable energy sources. **Non-renewable energy sources** are finite; they are only available as long as natural reserves last. The use of these energy sources pollutes the environment, as these materials are usually burnt to generate energy. This produces carbon dioxide (CO_2), one of the greenhouse gas responsible for climate change on earth. More about this below.

Non-renewable energy sources include fossil fuels such as **oil**, **natural gas**, **lignite** and **hard coal**. They were formed over many millions of years from dead plants and animals and today are often located deep below the earth's surface. **Nuclear power** is also one of the non-renewable energy sources. Here atoms are split, releasing energy. The starting material is often the radioactive element uranium. The problem is that, in addition to energy, radioactive radiation is also released. This is harmful to humans, animals and plants. Common to all these energy sources is that first thermal energy is released, which is used to heat water. The resulting water vapor then drives a generator, which works like the dynamo of a bicycle.

Task: Have you ever heard of Chernobyl? During an accident in a nuclear power plant, radioactive radiation leaked out and contaminated the environment. If you are interested in this, you can research the consequences of the accident on the internet.

Renewable energy sources are those, which are "refilled" automatically. They include **water power**, **solar radiation**, **wind power**, **wave power**, **geothermal energy** and **bioenergy** from sources like wood, pellets and straw. The first law of thermodynamics states that energy is neither generated nor consumed, but is converted. In the case of water, wind or wave power, for example, the kinetic energy is converted into electrical energy - i.e. electricity. In the case of geothermal and bioenergy, as with fossil fuels, this is accomplished via heat. Only solar radiation can be converted directly into electricity.

The share of renewable energies in the total energy used varies greatly between countries. Figure 1 shows this for the EU countries.

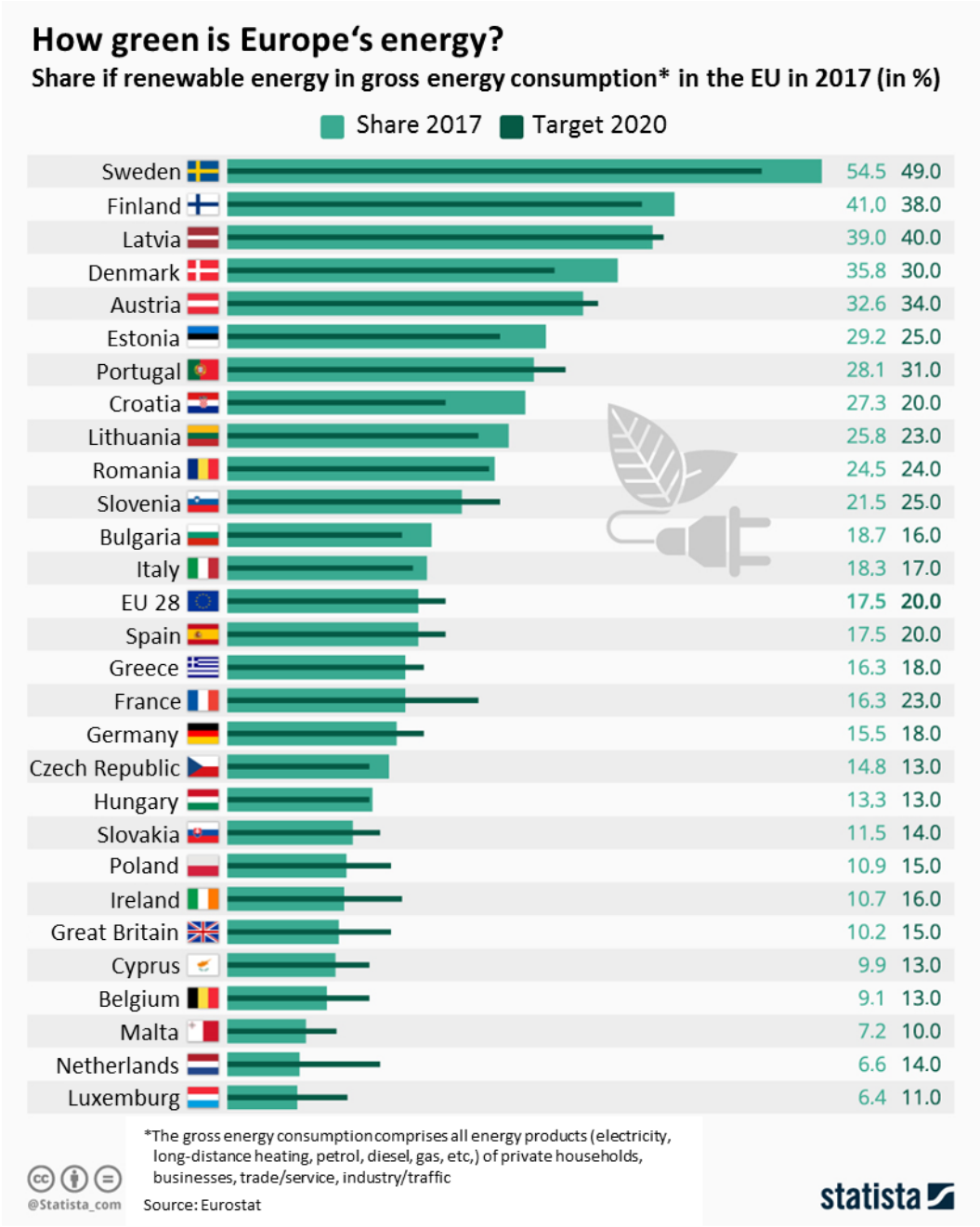

Figure 1: How green is Europe's energy? (Translated from: Statista: https://de.statista.com/infografik/18785/anteil-erneuerbarer-energien-am-bruttoendenergieverbrauch-in-der-eu/)

Tasks: How long will the system based on fossil fuels actually be able to withstand our high energy consumption? Oil, natural gas, uranium and coal deposits are finite. However, the financial, political and ecological costs are also increasing and are provoking tensions. In the long term, it is therefore essential to switch completely to renewable energies. Do research on the following questions:

- How has the share of renewable energy changed over the last 20 or 30 years?
- Why isn't the share of renewable energy greater?
- What needs to be changed in the area of energy supply and energy consumption in order to use 100 % renewable energy?

Electricity, electric energy and power

Every day we use electricity in the form of electric current. This current consists of electrons, small negatively charged particles. If too many negative charges are accumulated in one place and there is an electrical connection to a place with too few electrons, the particles move to balance the imbalance. This is what we call electric current.

Task: You can generate electrical energy yourself by rubbing a wool sweater with a ruler, for example. In this way, the kinetic energy causes the ruler to be charged electrically and you can pick up pieces of paper with it.

How does the electricity get into our socket now?

The socket is connected to the power grid. The electricity that comes out of our sockets is generated in a power station. You can compare a power station to a dynamo on your bicycle. When you pedal hard – that is, when you apply force and do work – kinetic energy is converted into electrical energy and the light on your bicycle is illuminated. From the power station, the electricity is transported at high voltage via high-voltage lines. Transformer stations reduce the voltage and from there the electricity is transmitted to your home.

What does my socket have to do with the climate?

The greenhouse effect

We regularly charge our smartphone, our laptop, even our toothbrush via the sockets. Nowadays we need electricity for almost everything and the energy demand is constantly growing. Nevertheless, we quickly forget that conventional energy production is associated with emissions of greenhouse gases such as carbon dioxide (CO_2). Sustainable energy production therefore plays a central role.

Surely, you have heard of the **anthropogenically caused greenhouse effect**, the man-made greenhouse effect. Here is a short explanation: It is important that there is a **natural greenhouse effect**, which ensures that we on earth have pleasant temperatures to live in. This works because most of the radiation that the sun emits is short-wave. It penetrates the atmosphere and hits the surface of the Earth. The surface is heated, which causes the emission of long-wave thermal radiation. Various gases in the atmosphere, including carbon dioxide, absorb part of the long-wave radiation and radiate it back to Earth. In this way, it stays nice and warm on our planet. However, it becomes warmer when more greenhouse gases enter the atmosphere and thus more radiation is radiated back to Earth. One reason for the increasing amount of greenhouse gases in the atmosphere is, for example, the generation of energy by burning fossil fuels.

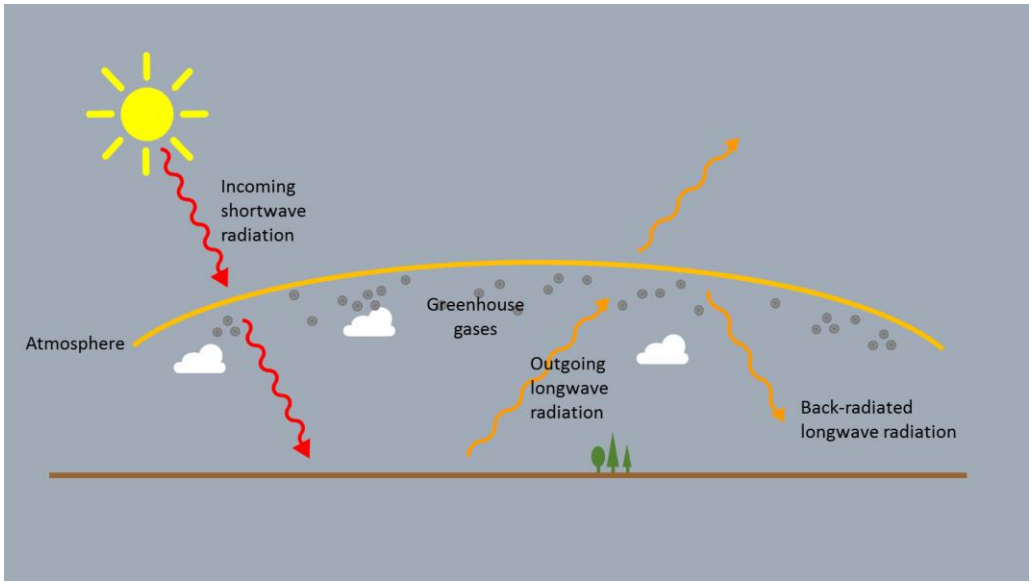

Figure 2: Greenhouse effect (simplified)

Tasks: The amount of CO_2 emitted into the air by a person is called the carbon footprint. How do you estimate your own carbon footprint? Create a CO_2 profile at

https://footprintcalculator.henkel.com/en

https://www.foe.ie/justoneearth/carboncalculator/

https://uba.co2-rechner.de/en_GB/

City climate

The climate in cities differs significantly from the climate in the surrounding area. On the one hand, the supply of fresh air and the exchange of air masses is hindered by dense housing, and on the other hand, radiation plays a special role. Sunlight is reflected several times by the walls of houses. Building materials typical of cities, such as asphalt and concrete, heat up quickly and store the heat, which is emitted later. In addition, the waste heat from households, industry and traffic contributes to the warming of the urban climate. Furthermore, the air in cities is particularly contaminated with trace gases, carbon monoxide, carbon dioxide, water vapor, soot particles and fine dusts. The long-wave thermal radiation emitted from the city surface can poorly penetrate the haze above the city and is radiated back. This results in an **urban greenhouse effect**.

Energy in my school and in my surroundings – What can we do?

Energy itself remains invisible, but we can realize it by its effects. Also at school, we constantly use energy. But where do we do that?

Tasks:

- Look around your classroom. Where is energy being used at the moment?
- What is the source of electrical energy in your school?
- How could your school save energy? What can the students do to help saving energy?
- You do not only use energy at school but also at home and when you are under way. Are there options to save energy there?
- Are there any disadvantages that arise from saving energy? How could these be compensated?

Apart from households, energy is used in many other places in the city. This leads to the release of heat and causes CO_2 emissions. This will also have to change in the future in order to keep the anthropogenic greenhouse effect within limits and to keep the city climate tolerable. The measures required here do not only affect private households but also the city's infrastructure. Here, major conversions always involve high financial costs. Therefore, it must first be investigated where energy can be saved particularly well. This information is then evaluated in a political process in which the needs of various groups such as residents, the economy and the companies responsible for energy supply must be taken into account.

Tasks:

- How much energy is needed to "run" a city?
- What is the energy used for? Who are the biggest energy consumers in a city?
- Where can energy be saved particularly well? Also, take into account who could have disadvantages as a result.

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