Use of energy sources.

Program module: ENERGY USE IN ELECTRICITY PRODUCTION

History of the use of electricity.

Static electricity has intrigued people for centuries. About 2,500 years ago, the Greek philosopher Thales noticed that when you rub amber with silk, it starts to attract silk and other light items, such as feathers. It is now known that this attraction occurs because rubbing takes part of the electrons from the surface of the silk to the surface of the amber. The negatively charged amber, however, attracts light objects as it tries to get rid of its excessive electrons.

In 1831, Michael Faraday discovered the law of electromagnetic induction, which allowed developing and designing electric motors and generators. The first electric generator was built in Paris in 1832, and the first usable electric generator was made in Germany in 1867 – on the basis of the dynamo-electric principle, the German industrialist Ernst Werner von Siemens constructed a direct current generator, which was also called a dynamo.

The hydroelectric power plant in Cragside, England, built by Lord Armstrong (1810–1900) in 1868, where he used the dynamo by Siemens, is considered the world's first power plant.

The world's first public power plant was opened in London in 1882 (Edison Electric Light Station). In the same year, the first power plants were opened in America. Electricity was produced by a steam engine mainly for lighting. Telegraph stations were also among the major clients.

History of electricity in Estonia.

The first industrial power stations in Estonia were built at the end of the 19th and at the beginning of the 20th century. The rapid development of energetics began in major cities and industrial centres: in Tallinn, Tartu, Narva, Pärnu, and Kunda. Initially, electricity generation and consumption were directly related to industry. One of the first public power stations that supplied electricity to private consumers and the city, as well, mainly to illuminate the streets, was built in Pärnu in 1907. Some years later, this also happened in Tallinn. Electricity was first supplied to the inhabitants of Narva as late as in 1918, when the hospital and the homes of the city's highest officials were connected to the electrical power network of the woollen mill. In the same year, the first high voltage power line in Estonia was built, which transmitted electricity from the Kunda power plant to the city of Rakvere, located about 16–17 km away.

The main sources of energy used to produce electricity were water from rivers and peat, which was better-known. Though early in the century, it was known that there were fairly large oil shale deposits in the subsoil plots of Estonia, little research was carried out on the properties of oil shale and its production was still in its infancy.

The next bigger step in the electrification in Estonia began with Estonia's independence. By that time, many major cities had their own industrial power plants and numerous small power plants were built in small towns and rural settlements. For as long as the output of larger power plants was relatively small and their distribution networks were poorly developed, these small power plants played an important role in the development of electrification in Estonia. In the first half of the 1920s, the largest power plants of the first Republic of Estonia were introduced: Ulila, which started to supply the city of Tartu and southern Estonia, and Ellamaa, which transmitted electricity to Tallinn and Haapsalu through high voltage lines. These stations used local peat for fuel. Over time, the capacities of Ulila and Ellamaa stations grew, and new areas were connected to their networks, which led to the rapid development of high-voltage networks in the second half of the 1930s.

The Second World War was a big step back for electrical power networks and power generation. Many power plants were destroyed and vandalised. For example, Tallinn's power plant lost 70% of its pre-war capacity.

In the era of the Estonian SSR, electrification continued at a rapid pace and people's demand for electricity increased steadily. The 1950s marked the beginning of designing of one of the most powerful oil shale power plants in the world of that era – the Balti Power Plant. The construction of the power plant began in 1956 and the first boiler started operation in 1959. The plant reached its full capacity in 1966, when the entire Narva city was equipped with thermal energy and its nearby industrial plants were provided with steam. Before the completion of the Balti Power Plant, plans of a new and more powerful power plant were already underway. The construction works of the Estonian Power Plant, which is still the world's most powerful oil shale based-power plant, started in 1964, and its full capacity was achieved in 1973.

Today, 8 TWh of electricity is consumed per year in Estonia. The total capacity of Narva Power Plants – Balti Power Plant, Estonian Power Plant, and Aovere Power Plant, which was built in 2015 – however, is 12 TWh. Thus, Estonia sells electricity to other Baltic States as well as to the Nordic countries via a submarine cable.

**Methods of power generation.**

**Thermal power plant.**

Thermal power plants convert thermal energy into electricity. The thermal energy is either generated from the nature, produced in the power plant itself, or is a by-product of another process. About 80% of the world's electricity production is produced in thermal power plants. The most common fuels for combustion in thermal power plants are fossil fuels – coal, brown coal, and natural gas. As a rule, thermal power plants are built in mining areas where the required fuel is cheap, because it is much cheaper to transport electricity than fuel.

Power plants work on either steam turbines, gas turbines, or internal combustion engines.

The **steam turbine** is a heat-powered machine where superheated steam is directed to the circular rotating blades on the turbine shaft through nozzles or circularly arranged turbine blades. The power affecting the rotating blades forces the turbine impeller to rotate and transforms into mechanical force.

Steam turbines are rotary machines, consisting of a standing body or a stator and a rotary motor inside of it, to which one or more impellers with blades have been attached.

In terms of construction, the **gas turbine** is similar to a steam turbine. The difference is that instead of steam, high-pressure gas from the combustion fuel causes the turbine motor to rotate. The fuel is burned in a combustion chamber where both fuel and air are added under high pressure. The initial pressure of gas is usually 0.6 to 1.2 MPa (megapascal) and initial temperature up to 900 °C. The temperature (up to approximately 500 °C) and speed of the gas exiting the turbine are usually so high that it can be used efficiently – for example, in the production of thermal energy.

**Internal combustion engines** can be used for the co-generation of electricity and heat or only for the production of electricity. To avoid overheating the engine, it must be cooled, which allows using heat to generate warm water. The recovery of exhaust gas heat is also implemented, which increases the efficiency of the conversion of fuel energy even further. The electrical efficiency of the engines is 35–42%. In combined power generation, it is possible to achieve efficiency of up to 92%. In combining combustion engines with steam turbines, it is possible to produce additional electricity, which results in electrical efficiency of up to 50%.

The efficiency of thermal power plants usually ranges from 30–45%.

In Estonia, about 85% of all electricity produced is produced in thermal power stations that use oil shale as fuel.

Nuclear power plants, solar thermal plants, and geothermal power plants are the exceptions. In nuclear power plants, heat is generated by the decomposition of nuclear fuel, not in combustion, and in solar power plants, a heat-carrying container is heated with solar energy concentrated with mirrors. Geothermal stations use energy found in the ground. The largest geothermal power plants are in California; Iceland uses plenty of the power stored below the Earth's surface, as well.

**Alternative sources of energy**

**Hydropower**

In Estonia, the power of water has been used since at least the 13th century, when people started building watermills. The first hydroelectric power plant in Estonia was built in Kunda in 1893. Before the Second World War, the proportion of water power in the overall energy balance of Estonia was quite large: the production of hydroelectric power stations (including the station on the Narva River) was 28,770 MWh, which accounted for 28.6% of the total production of power plants.

Even though Estonia is considered an area relatively rich in water in terms of medium drain per 1 $km^2$ (250,000 $m^3$ per year) and per capita (8,000 $m^3$ per year), the energetic use of water resources is complicated because the water areas are fragmented between many small and rivers relatively low on water (except the Narva River), as well as the fact that rivers have a small average slope due to a relatively flat surface. Therefore, the hydroenergetic potential of Estonia is modest and there are no opportunities for building larger hydroelectric power plants. Theoretically, the hydropower resource in Estonia is estimated to be up to 30 MW, of which 10 MW is practically usable. By 2020, with the introduction of new planned hydroelectric power stations, this resource of about 10 MW can also be largely exhausted. The transboundary water body of Narva River is considered separately – a 30 MW hydroelectric power plant could be built on the rapids on the Estonian side.

A hydropower plant is an electricity plant in which the potential energy of water is converted into electrical energy. As a rule, hydroelectric power stations are built on large rivers, where the falling water, collected with a dam, makes the hydro turbines rotate with power generators. Their construction is time-consuming and costly (voluminous earthworks and concrete work in the construction of dams), but the manufacturing cost of electricity is relatively low, as the operating costs are small.

**Wind power**

People have been using wind energy in sailing boats for thousands of years, and architects have used wind for just as long as natural ventilation in houses. The windmill of the Greek engineer Heron from the 1st century is said to have been first used to make a machine work. Windmills were very popular in Estonia as late as at the beginning of the 20th century. The first wind turbine generation systems were introduced in the last quarter of the 19th century, when several inventors constructed wind turbines for their own households. In the mid-1920s, 1–3 KW wind turbine generation systems were industrially manufactured in USA. As the lack of electricity in Estonian rural areas was a big obstacle in the general development of farms and rural areas and the construction of power lines was very slow, the wind generator was a good solution. The first tests on using wind power for electricity production were carried out in the late 1920s. The first patented wind generator in Estonia was completed in 1937; it was also manufactured industrially.

Wind energy is a type of renewable energy during which the kinetic energy of wind is transformed into mechanical or electrical energy. Wind turbines, for example, transform wind power into mechanical energy and wind generators or wind turbine generation systems transform it into electricity. Wind power comes from the energy of the movement of air, which, in turn, comes from solar energy.

**Solar energy**

Solar energy is generally understood as using solar radiation for the production of thermal energy or electricity. Solar radiation is characterised by randomness and periodicity, which in turn is also affected by geographic location. The total solar radiation in Estonia may differ several times on a clear and a cloudy summer day, which has a significant effect on the amount of energy produced. It must also be taken into account that the output capacity of solar panels in Estonia is greater in summer than in winter. Therefore, households often generate more energy in the summer than they can use. In winter, however, we do not create enough solar energy for two main reasons: the length of the day is much shorter than in summer, and the consumption load is much higher than in summer.

Solar power is converted into electricity by using solar cells that convert solar energy directly into electricity. As sunlight is evenly distributed, each building can potentially produce electricity locally.

Solar cells are widely used to supply spacecraft with energy and in commonly used low-power devices like calculators. Solar panels do not pollute the environment during their entire lifetime. However, it takes a lot of energy to produce solar cells, because they are made of high-quality material.

**Geothermal energy**

Geothermal energy or the heat of the Earth occurs when solar energy is stored in the earth or as the warmth spreading from deep within the Earth. It is a cheap and renewable energy resource which is highly valued in developed countries (e.g. Sweden, Iceland, Germany, etc.). In Estonia, it is possible to apply low-temperature geothermal energy at a depth of about 1 metre in the ground. Geothermal energy occurring at a depth of up to 200 m is considered ground-level geothermal energy. At this depth, the temperature is too low for the heat to be used for direct heating or for the production of electricity. Geothermal heat pump systems are used to extract or store the surrounding energy.

In the 20th century, the first power plants were built that use the warmth of Earth's thermal water or warm groundwater. The temperature of thermal water can reach over 200 °C and in this case, it is not liquid, but in a gaseous state as steam.

**Biomass energy**

Bioenergy has been used for thousands of years. Bioenergy or biomass energy is a type of renewable energy which is derived from the use of organic matter from organisms – usually from combustion.

Combustion of biomass for heat does not endanger atmospheric processes as long as the combustion is balanced with the amount of biomass created.

Definitions:

*Electricity* – electricity is a type of energy generated by the movement of ultra-small particles referred to as electrons.

*Static electricity* – the charge stays on the charged object – in the case of amber, a comb, or a human – until the electricity finds some way to flow or create an electrical solution. Lightning is a grandiose example of a natural electrical solution. Rising and falling air currents cause droplets to collapse and break in the cloud. This causes accumulation of gradual charges within the cloud. From time to time, the charge becomes large enough to cause an electric solution in the form of a lightning bolt reaching the surface.

*Electric current* – the current of electrons from an area where there are too many electrons, to an area where there are too few electrons; just as water flows from higher places to lower places.

*Electromagnetic induction* – a phenomenon in which an electromotive force is generated in a wire due to a magnetic field. If the cable ends are connected, i.e. the circuit is closed, it will create an electric current.

*Electric generator* – an electric machine that converts mechanical energy into electrical energy.

*Non-renewable resources* – natural resources that are not created in nature anymore or are created very slowly, so that we may run out of them as a result of continuous use. These include, for example, oil shale, oil, and iron ore. In order to preserve non-renewable resources for as long as possible, people try to re-use materials.

*Fossil fuels* – or organic fuels of fossil origin – are organic substances used for energetic purposes and extracted from the subsoil plots. They are sedimentary rocks into which carbon compounds that have exited the circulation in the biosphere have deposited. Fossil fuels are combustible minerals that are formed by the fossilisation of organic remains.

*Biomass* – a natural source of energy that is created every year. For example, willow thicket and animal manure.

*Summarised solar radiation* – the sum of direct and diffuse solar radiation that has fallen on a horizontal surface. The proportion of direct and diffuse radiation in the summarised solar radiation per year is approximately equal. During summer months, direct radiation is predominant in the summarised radiation, and in winter months, diffuse radiation is predominant. Like direct and diffuse radiation, summarised solar radiation also depends on the Sun's height, cloudiness, atmospheric transparency, and the reflection capability of the surface.

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