Fossil fuels and renewable energy sources

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1. Fossil fuels and renewable energy sources

Energy

Energy is the basis of all processes that take place around us and is the most critical factor influencing the development of society. Energy is a phenomenon without which life is inconceivable today. Without energy, we could not use most of the production facilities and household appliances, set vehicles in motion and we would not have heat and light. If we look at today's world through the prism of the main and priority areas on which we should focus, then there is certainly a question of ensuring low-cost and sustainable forms of energy. Yes, it is necessary to find, transform and utilise these forms of energy, but it is necessary to do it ecologically. So, let us try to extend the phenomenon of energy into the phrase "energy and environment".

How has the humankind changed in the last 100 years? How have production technologies changed during that time? How has the range of manufactured products changed over that period? How has the people's view of the need for energy and its use at their work and in their daily life changed? And how has our environment changed in the context of energy production and subsequent manufacturing activity? How long will the basic fossil fuels last? Will we be able to replace these fuels completely? These are the questions we could answer at length, but also with a simple and short sentence: "We live in dynamic times – with high energy consumption". Those who see the threat of basic energy sources depletion and climate change associated with greenhouse gas emissions know the meaning and the importance of finding new forms of energy. Some traditional energy sources are being gradually consumed and are increasingly expensive. Therefore, we have searched for alternative forms of energy sources for decades. Maybe it is appropriate to ask a question, whether it would not be better to find and develop such technologies and products that would require minimum energy instead of searching for alternative forms of energy sources. Or to implement effective energy saving, which represents the cheapest "source of energy".

Energy sources

Non-renewable and renewable energy sources are used in various technological processes in the production of the required forms of energy. The non-renewable energy sources include mainly fossil fuels based on coal and hydrocarbons. Fossil fuels may be present in solid (e.g. coal), liquid (e.g. petroleum products) or gaseous (e.g. natural gas) form. The non-renewable energy sources also include nuclear energy, ***Fig. 1.***

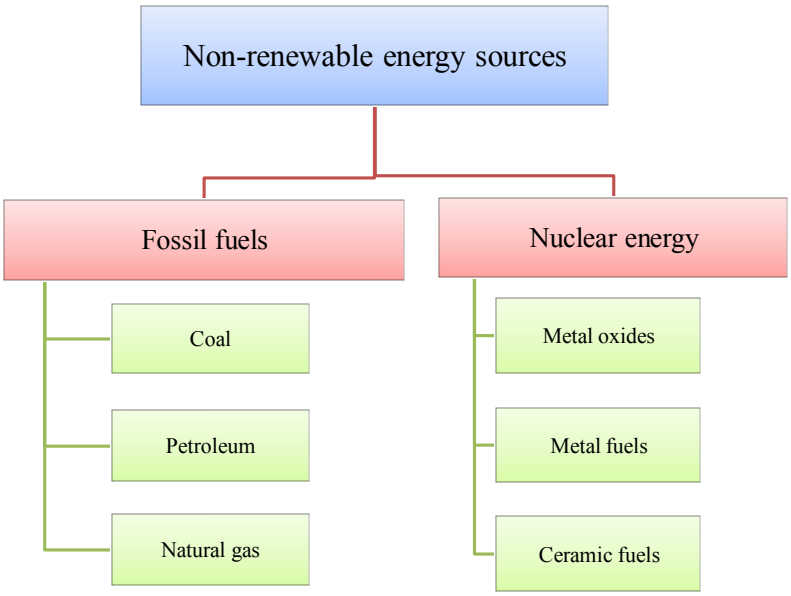

Fig. 1 Non-renewable energy sources

Currently, the most important renewable energy sources are hydropower, biomass and solar energy, Fig. ***2*** [1–3].

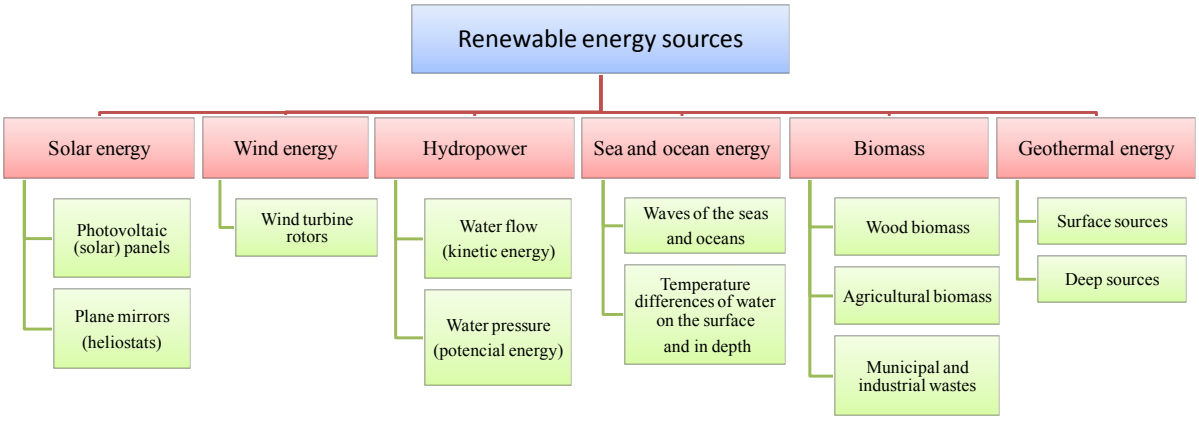

Fig. 2 Renewable energy sources

Fig. 3 shows a graphical view of the energy consumption according to the energy sources used in the world. Apparently, the consumption of traditional fossil fuels was considerably predominant in the last 40 years. Fossil fuels are the predominant source of energy, and they account for total world energy consumption of around 87 % (in 2013). Hydropower has the highest representation among the renewable energy sources. So far, biomass has only a minimum share in the total energy production and consumption.

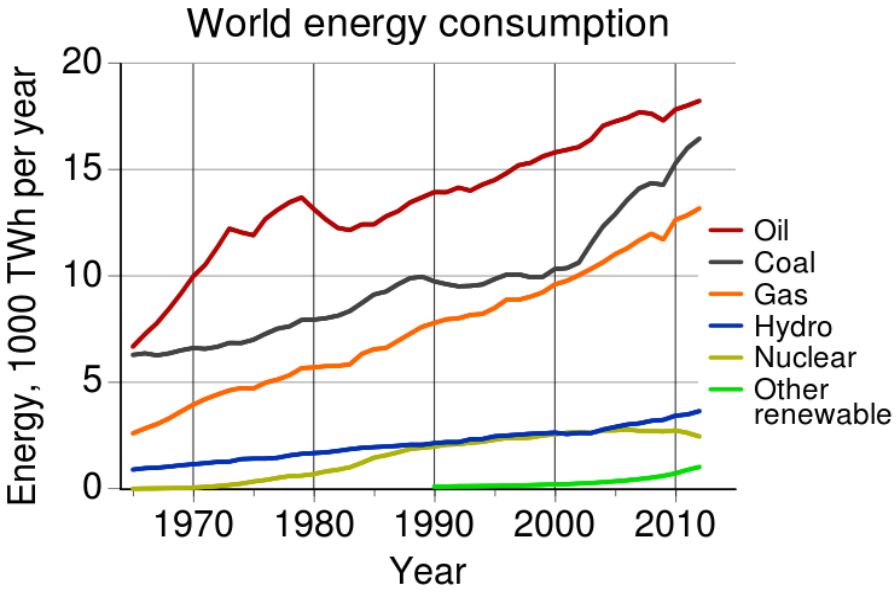

Fig. 3 World energy consumption through various forms of energy

The genesis of fossil fuels

The basic solid fossil fuels include peat, brown coal, lignite, bituminous coal (***Fig. 4***) and anthracite (***Fig. 5***). Coke is the special type of fossil fuel (***Fig. 6***). Coal, coke, petroleum products and natural gas represent the highest quality sources of fossil fuels and are among the most important sources of energy that are currently used.

Fig. 4 Fossil fuel – bituminous coal

In terms of raw material energy, there is a significant potential in so-called unconventional fossil fuels like petroleum and coal shale, biomethane, heavy oil sands, asphaltenes and the like. [4–7].

Let us look in more detail at the processes of the genesis of individual fossil fuels. Peat is formed from plant residues on the surface of Earth, while the coal formation takes place in the depth of Earth. Peat is the predecessor of coal, as it is the first step of converting plant matter into coal. In the long term, peat is primarily formed by biochemical processes, whereas coal is formed by geochemical and physical processes [5]. Peat is divided by prevailing botanical composition into moss and wood, and by soil admixture into pure and natural. Peat has high water content (65 to 85 %). Therefore, it is processed before use by pressing and drying to the water content below 25 %. Coal is a non-renewable fossil fuel, which was created by means of natural geological processes from plant residues. They were most commonly accumulated in swamps,

Fig. 5 Fossil fuel – anthracite

lakes or seas. Coal is a brown or black combustible rock composed of heterogeneous components with different physical and chemical characteristics. Coal retains the information of plant material and the environment in which the plants grew and accumulated [8, 9]. Most of the world's coal reserves began to form 300–400 million years ago by anaerobic biochemical reactions at high temperature and pressure acting for a long time. Temperature and pressure are factors that affect the geochemical and physical processes. Coal and hydrocarbons began to form from the original organic material, represented mainly by cellulose ($C_6H_{10}O_5$) and asphalts, by peatification and gradual coalification in marshes without access of air [5]. Gradual descent and covering of peat layers by clay and sand led to the formation of brown coal. Bituminous coal and anthracite have been formed by the action of strong tectonic pressure and high temperature. The whole carbonification process is characterised by diagenesis (a change that results in the conversion of loose materials into a compacted rock) and metamorphosis (rock transformation changing its physical-chemical properties) [5]. The hydrogen and oxygen content decreases and the carbon content increases. The carbon content in the combustible increases from 35 % (content in peat) to more than 92 % (content in anthracite). Coke has even higher carbon content in the combustible – about 94 %.

Fig. 6 Fossil fuel – coke

As mentioned above, individual types of fossil fuels differ by the degree of coalification and chemical composition, ***Fig. 7*** and ***Tab. 1***. ***Fig. 7*** also presents the factor of coal deposit depth, showing, e.g. that brown coal is located at the depth of 4–6 km, bituminous coal at 6–8 km, and anthracite at up to 10 km.

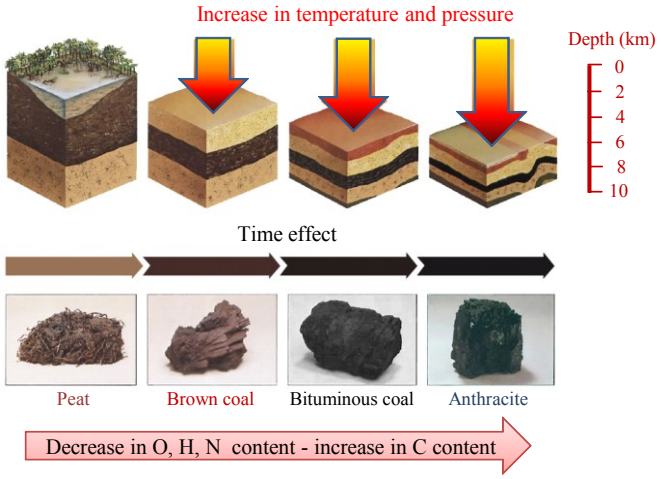

Fig. 7 Impact of factors on the formation of solid fossil fuels [modified by authors according to 10–12]

As already mentioned above, we include coke among fossil fuels. Coke is actually a processed fuel that is industrially produced by the carbonisation of coal, without access of air in so-called coke batteries. Carbonization of coal enables the more economical use of coal by producing better quality fuels and at the same time also raw materials for metallurgical and chemical industries.

Tab. 1 Typical composition of solid fossil fuels

	Type of fuel	H_2O [%]	Ash [%]	Volatile matter in combustible [%]	Carbon in combustible [%]	Sulfur [%]
	Peat	> 60	1–20	70–90	35–40	0.1–1.0
	Lignite	40–50	5–15	50–60	50–60	0.2–1.5
	Brown coal	20–40	5–25	40–60	60–75	1.0–3.0
	Bituminous coal	2–15	2–15	10–40	70–90	0.1–2.0
	Anthracite	1–5	5–12	3–8	87–94	0.3–1.5
	Coke	1–3	8–14	1–3	92–97	0.3–0.8

Crude oil as the basis of liquid fuel products is also included among fossil fuels and is composed of liquid hydrocarbons produced by the decomposition of organic material on the bottom of seas. Natural gas is a gaseous form of fossil fuel. It is a mixture of gaseous hydrocarbons (mainly methane – CH_4), enclosed in the ground or escaping from it.

Renewable energy sources

Renewable energy sources are defined as continuously replenished energy sources of various forms. This energy comes directly or indirectly from the Sun or the heat generated deep inside the Earth. Individual renewable energy sources are produced from the Sun, wind, water (watercourses on the land, water of the seas and oceans), biomass and geothermal sources [1].

Solar energy is the basis of almost all renewable energy. This energy has a crucial impact on the weather conditions on Earth. It is inexhaustible and environmentally clean. The Sun as one of the stars in our galaxy is a highly stable and highly powerful energy source. The energy of the Sun originates in the proton-proton fusion reaction. The reaction takes place at temperatures of 14 million degrees Celsius while the surface temperature of the Sun is about 6000 °C. Solar radiation can be used to generate electricity using photovoltaic (solar) panels (***Fig. 8***) and flat mirrors (i.e. heliostats). At present, photovoltaic cells are used the most, which are made of crystalline silicon in the form of monocrystal or polycrystal. Efficiencies of photovoltaic cells are at the level of about 12–20 %. The highest amount of energy from solar panels in the world is produced in Germany and Italy.

Fig. 8 Photovoltaic (solar) panels

The Sun warms the Earth's surface and atmosphere and therefore layers with different temperatures and pressures are created in the atmosphere. This causes the flow of air, creating wind that can be used as a renewable source of energy in rotors, ***Fig. 9***. The highest utilisation of wind energy occurs at airflow speeds around 12 $m.s^{-1}$. Efficiencies of rotors at wind farms are at about 40–45 %. Wind power is used the most in the USA, China and Germany.

The Sun radiation evaporates water of the rivers, seas and oceans. The water vapour condenses in the upper atmosphere and falls back on the surface of Earth in the form of raindrops. It is, therefore, another renewable energy source, where the energy of water flowing in watercourses is used. The energy of water is recovered in hydro power stations not only through its flow (kinetic energy) but also by utilising its pressure (potential energy), ***Fig. 10***. The advantage of hydro power stations is their ecological nature and safety. The efficiency of hydroelectric turbines is about 95 %. China, Brazil and Canada produce the highest amount of energy in the world using hydropower.

Fig. 9 Wind turbine rotors

The gravity of the Moon causes the tide of the oceans and wind creates waves on the seas and oceans. Temperature differences of water on the surface and in the depths of the oceans can also be utilised. All of these forms of energy can be used and represent another source of renewable energy – the energy of the seas and oceans.

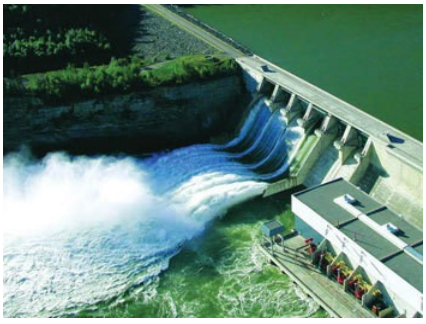

Fig. 10 Hydro power station

All plants use carbon dioxide (CO_2) from the atmosphere, and water from the ground for growth. These are converted into organic biomass matter (cellulose $(C_6H_{10}O_5)_n$ or glucose $C_6H_{12}O_6$) through photosynthesis. The photosynthetic reaction can be expressed by the chemical equation (1):

$$12\ H_2O + 6\ CO_2 + \text{sunlight} \rightarrow C_6H_{12}O_6 + 6\ O_2 + 6\ H_2O \qquad (1)$$

Solar energy, due to which photosynthesis takes place, is present in chemical bonds of the hydrocarbon material that is called biomass. By burning biomass, we obtain energy, while carbon dioxide (CO_2) and water are formed. The process is cyclic, continuous and renewable because resultant carbon dioxide (CO_2) is the input component for the growth of a new plant,

i.e. new biomass. Although the combustion of biomass releases environmentally unacceptable carbon dioxide into the atmosphere, it is only the quantity that has been accumulated by photosynthesis in plants. Therefore, we say that biomass combustion is "CO_2 neutral", ***Fig. 11***. In relation to the zero balance of CO_2 in the production and management of biomass, it is necessary to note that it is only a comparative term. In fact, taking care of growing biomass, its subsequent treatment, transport and processing are activities releasing carbon dioxide. A neutral balance of CO_2 in connection with the processing of biomass is therefore never achieved. However, the contribution of biomass processing to the overall balance of CO_2 in the energy production compared to fossil fuels is incomparably smaller.

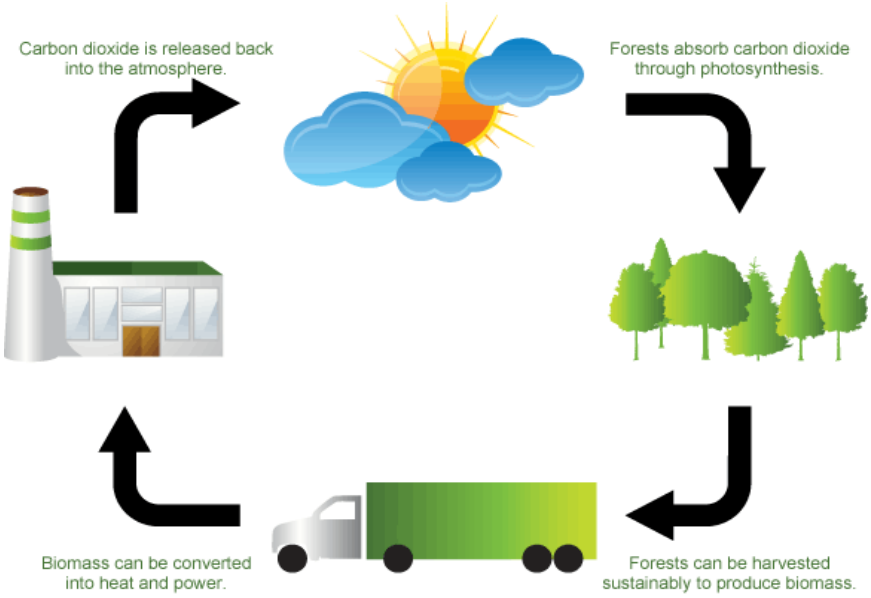

Fig. 11 Cycle of carbon dioxide (CO_2) in nature

In this context, it is perhaps appropriate to ask why carbon dioxide is perceived as harmful to the environment. Everything that happens in nature should be in balance. Also, the amount of CO_2 that enters the atmosphere through various processes (including production processes) should be consistent with the absorption ability of other chemical processes. Besides carbon dioxide and water, plants need also oxygen and other biogenic elements (e.g. phosphorus, potassium, calcium, magnesium, sulfur and iron) for life in the form of minerals. If the amount CO_2 in the atmosphere is above the limit, the amount of vital oxygen in the air decreases. Thereby it disturbs the balance in nature and the ability of plants to process these excess amounts of carbon dioxide through photosynthesis.

Fig. 12 Biomass – wood products

In this publication, we will focus on biomass and its use much more. First, it is necessary to define what biomass is. Biomass is a material of organic origin, which includes wood (***Fig.***

12) and plant biomass grown in soil and water, livestock biomass and organic waste [1, 13]. The USA, Germany and Brazil produce the highest amount of energy in the world using biomass.

Although geothermal energy is not really the renewable source, it is classified as a renewable source, because of its inexhaustible supply. Geothermal energy originates in the hot Earth's core, the temperature of which is estimated at about 4000 °C. A large amount of thermal energy is released by radioactive decay of substances and gravitation forces. The movement of magma brings this thermal energy to the upper layers of the Earth's crust where heating of rocks and groundwater occurs. Geothermal energy can be recovered directly from hot springs of geothermal water, steam discharge or by means of boreholes in rocks near the Earth's crust

Fig. 13 Steam discharge as a part of geothermal energy

Fig. 13. Geothermal energy is used the most in the USA, Italy and Iceland.

It is obvious that there are many various forms of energy, but not every energy source is consistent with current technological, economic and environmental criteria for specific application. For example, in the metallurgical sector, non-renewable fossil fuels are the most important and most widely used – particularly coal, anthracite, coke, oil products and natural gas.

At the beginning of this chapter, the concept of energy and forms of energy were explained. But what is the fuel? We will come across this concept quite often in the following chapters of this publication. Fuel is the common name for a chemical element, chemical substance or a mixture of substances, which can react in chemical reactions of combustion under certain (precisely defined) conditions. In these reactions, the chemical energy contained in fuel is released and transformed into thermal energy.

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