Current Aspects of Decarbonisation in the Czech Republic and Possibilities of Replacement of Coal Energy Sources by Renewable Sources of Electric Energy

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Abstract

The European Green Deal is a set of policy initiatives by the European Commission with the overarching aim of making Europe climate neutral in 2050. An impact assessed plan will also be presented to increase the European Union´s greenhouse gas emission reductions target for 2030 to at least 50% and towards 55% compared with 1990 levels. The European Green Deal has goals extending to many different sectors, including construction, biodiversity, energy, transport and food. For the European Union to reach their target of climate neutrality, one goal is to decarbonise their energy system by aiming to achieve net-zero greenhouse gas emissions by 2050. Article deals with current aspects of decarbonisation in the Czech Republic and possibilities of replacement coal energy sources by renewable sources of electric energy. Paper describes present situation in branch of production of electric energy and possible scenarios for reduction of coal energy sources in the Czech Republic.

Keywords: *greenhouse effect, the European Green Deal, decarbonization, renewable sources of electric energy, coal energy sources*

Introduction

The concept or phenomenon of the greenhouse effect is commonly used to describe two different things: the natural greenhouse effect, which is the greenhouse effect that occurs naturally on Earth, and the additional (anthropogenic) greenhouse effect, which originates in human activity and is most likely causing the global climate change [1].

Current scientific knowledge proves that human activity (greenhouse gas production) affects the Earth's climate system. Greenhouse gases are multi-atomic gases that absorb the Earth's thermal radiation, which is causing the heat up of the lower layer of atmosphere and the Earth's surface. These are carbon dioxide (CO_2), methane (CH_4), nitrous oxide (N_2O), partially and fully fluorinated hydrocarbons (HFC, PFC) and sulfur hexafluoride (SF6). And last, but not least we cannot forget the water vapor [1].

Because each of the greenhouse gases has a different ability to influence the climate, there is a so-called global heating potential for each greenhouse gas, and for comparison purposes, the greenhouse gas content is given in terms of CO_2 equivalent (CO_2, eq.).

Today the statistics are used to prove the global warming and its consequences, before that the statistics were used to prove the coming of another ice age. It therefore depends on which data and from which period we select. However, it also depends on the interpretation of this data. The greenhouse effect allows the Earth to reach a temperature at which life is possible. Nevertheless, in the different geological periods the Earth naturally faced the cold and warm periods. The problem seems to be elsewhere: Colder periods are repeated at regular intervals (less than a quarter of a billion years) and are many times shorter than warm periods. According to experts, the ice ages in the Quaternary were mainly caused by interventions from space. At the same time, the temperature fluctuated and in the interglacial times it was often even higher than it is today. We currently live in an interglacial period, which is longer than the previous ones. And about 6,000 years ago, it was a few degrees Celsius warmer than it is today which was one of the most important reasons why the humanity was able to switch from hunter-gatherer culture to modern agricultural one.

One of the major multi-atomic gases that causes the greenhouse effect, is already mentioned carbon dioxide. It enters the atmosphere during the volcanic activity, respiration of organisms, decomposition of organic matter and also during the combustion of fossil fuels, from other industrial activities and from road transport (anthropogenic influence). Recent research shows that 10.9 Gt of carbon is released annually from so-called "dead" wood. These are the dead trees whose wood is left in its original place and not processed. Part of the carbon is released into the soil and another part into the atmosphere. The amount of carbon released from this "dead" wood roughly corresponds to global emissions from fossil fuels [5].

Tab. 1. Global average greenhouse gas emissions by electricity generation technology (source ICCT)
Tab. 1. Średnie globalne emisje gazów cieplarnianych według technologii wytwarzania energii elektrycznej (źródło ICCT)

	gram eq. CO2 / kWh	gram eq. CO2 / MJ
coal	1001	278
oil	840	233
natural gas	469	130
nuclear energy	16	4
bioenergy	230	64
geothermal energy	45	13
solar (photovoltaic)	46	13
solar (concentrated)	22	6
wind energy	12	3
marine energy (waves etc.)	8	2
water power	4	1

Fig. 1. NordLink power cable [15]
Rys. 1. Kabel zasilający NordLink [15]

On the other hand, the carbon dioxide level in the atmosphere decreases during the growth of organic matter, deposition of organic substances in the sediment and during the forming of calcium shells (coral reefs, etc.). It is therefore a natural carbon cycle in nature. Through human activity, its content in the atmosphere rises.

Before the Industrial Revolution, the concentration of carbon dioxide in the Earth's atmosphere reached about 280 ppm (parts per million). It was a good amount - good in the sense that we were used to it. The molecular structure of carbon dioxide holds the heat near the planet's surface. The heat which would otherwise return to space. That means that the civilizations developed in the specific heat conditions thanks to this specific concentration of carbon dioxide. The average global temperature was about 14°C. That decided where we build our cities, what crops we will grow and consume, on which water sources we will be dependent, and even how we will respond to changing weather and changing seasons in the higher latitudes. [2].

As soon as the coal, gas and oil began to be burned for energy purposes, the carbon dioxide level began to grow. In the first measurements in the late 50s of the last century, the concentration of CO_2 was already increased to 315 ppm. In 2007, it was about 380 ppm and the CO_2 content in the atmosphere was growing roughly by two ppm per year [2]. It is assumed that the extra heat (a few watts per square meter of land surface), captured by the CO_2, is enough to warm the planet considerably [2].

The effects of a further increase in the concentration of carbon dioxide in the atmosphere cannot be precisely determined, however, some experts assume that the temperature will continue to rise because the warming will not show up in the atmosphere until after time. However, that would mean that we are unable to stop the global climate change.

In the last few years, a number of studies have emerged that tell us that we should not exceed the level of 450 ppm of CO_2. If this value is exceeded, in the following centuries the ice sheet in Greenland and West Antarctica will probably melt down and the ocean levels will then rise dramatically. We have to point out that 450 ppm is still an estimate (which does not include a varied mix of others less significant gases such as methane and nitrogen oxides). However, the 450 ppm of CO_2 will become a point which humanity will try to avoid. A point that is fast approaching. If the concentrations continue to rise by two ppm per year, we only have 35 years left [2].

In 2011 the concentration of CO_2 in the atmosphere was 390.9 ppm, today it is already 419 ppm. While maintaining current trends, the concentration of CO_2 in the atmosphere will increase to 560 ppm by the end of the 21st century [3].

Greenhouse gas emissions from various technologies of electricity production, decarbonisation of energy production

According to the latest report of the Intergovernmental Panel on Climate Change (IPCC), which was published on August 9th, 2021, a global temperature rise will reach 3 possibly 4°C in comparison to the temperature before the beginning of the industrial era [6]. Therefore, it seems that the temperature rise will be higher than 1.5°C presented in so-called Paris Agreement (2015) six years ago. In 1997 which is 24 years ago, the so-called Kyoto Protocol was adopted, under which the world community has committed itself to reducing the greenhouse gas emissions by 5.2% per year 2010 compared to the 1990 level. Unfortunately, this goal was not achieved, and the greenhouse gas emissions including the carbon dioxide are still rising.

Developed countries, especially the European Union, are aware that specific actions must be taken. The European Commission is proposing a "Green Deal" (the European Green Deal), which turns out to have its passionate supporters and opponents. But both groups believe that it will be possible to reduce the current, high consumption-oriented way of life. However, some experts do not believe in this [3] and argue that it is too late to prevent a 2°C increase in temperature. According to them, this should have started about 50 years ago, when the first warnings which were published in the reports of so-called "Club of Rome" came [3].

According to qualified estimates of climatologists, when the temperature rises by 2°C, it will cause the large droughts every 10 to 12 years in our latitudes (the so-called millennial summer will appear, which we faced, for example, in 2003, then in 2015 and 2018). If the temperature rises by 4°C, then a great drought appears in our latitudes every 3 to 4 years.

It should be noted that increasing the temperature by 1°C will reduce the world's production of four basic crops (rice, corn, wheat, soybeans) by 5%, the temperature increase of 2°C will reduce the worldwide production of these crops by 7 to 10%.

It is assumed that if the European Union reaches the climate neutrality in 2050, the result will be only a small reduction in global temperature. In 2050, it could be in the range of 0.02–0.05°C and in 2100 then 0.05 to 0.15°C [4].

Let's have a look at how electricity generation contributes to greenhouse gas emissions from various sources (CO_2 equivalent per kWh or MJ was used). Table 1 lists the global average greenhouse gas emissions by electricity generation technologies. Obviously in our conditions (as a landlocked country we do not have marine energy) the lowest emissions of greenhouse gases in the production of electricity are generated by using the water resources (4g CO_2,eq./kWh, or 1 g CO_2, eq./MJ), using the wind energy (12g CO2, eq./kWh, or 3g CO_2, eq./MJ) and by using the nuclear energy (16 g CO_2, eq./kWh, or 4g CO_2, eq./MJ). The production of electrical energy from photovoltaic solar power plants is equal to 46g CO_2, eq./kWh, or 13g CO_2, eq./MJ. The highest greenhouse gas emissions arise from the production of electricity in coal power plants (1001g CO_2, eq./kWh, or 278g CO_2, eq./MJ), when using natural gas, it is then 469g CO_2,eq./kWh, or 130 g CO_2, eq./MJ.

The European Green Deal and its implementation in the Czech Republic

However, despite the rather grim above forecasts of some experts, that certainly are not optimistic, there are a number of measures (proposed under the European Green Deal) which should reverse the above adverse development.

It should be noted that Europe accounts for only about 9% of greenhouse gases from the total world production of these substances, however, introduces the strictest measures against production of these emissions in the world.

The European Green Deal is a set of policy initiatives of European Commission, whose main goal is to make Europe climate neutral by 2050 [8, 9]. It contains the plan with evaluated impacts, whose goal is to reduce the emissions of European Union greenhouse gases by 55% by 2030 compared to 1990 [10]. The deal was introduced on 11th December 2019, approved by the European Parliament on 15th January 2021. It contains measures to reduce emissions, investments in cutting-edge research and innovations and protects the natural environment of the European continent [10]. The second goal of the agreement is the transformation of European economy so that it is sustainable in the long run, and the growth is possible without increasing the usage of natural resources [11].

The agreement aims to incorporate legislation that will make Europe the first climate-neutral continent in the world by 2050. The European Commission also wants to present a strategy in biodiversity by 2030, a new industry strategy, European Union action plan for the circular economy, a strategy for sustainable food production "from the farmer to consumer" and proposals for a Europe without pollution [12]

To achieve the Agreement's goals in the climate and energy areas by 2030, approximately 260 billion euros of additional annual investment (1.5% of gross domestic product) will be needed.

The European Commission submitted the investment plan for sustainable Europe which helps to meet the investment needs. At least 25% long-term EU budget should be dedicated to climate measures and the further support will be granted by European Investment Bank [12]

According to the European Commission, the Green Agreement has the following main elements [10]:

1. increasing the European Union's climate ambitions for 2030 and 2050,
2. supply of clean, affordable and secure energy,
3. clean circular economy in industry,
4. construction and renovation with efficient use of energy and resources,
5. accelerating the transition to sustainable and smart mobility,
6. "farmer to consumer" strategy: creating a fair, healthy and environmentally friendly food system,
7. protection and restoration of ecosystems and biodiversity,
8. ensuring a toxic-free environment through an ambitious zero pollution target.

The European Green Deal assumes the gradual inclusion of sustainability element into all European Union policies. The tools should be [10]:

1. promoting the green financing and investment and ensuring fair transformation,
2. greening of national budgets and sending the right price signals,

3. mobilizing research and promoting innovation,
4. involvement of education and professional training.

The plan also includes a number of other policies, such as carbon import duties, emission allowances introduction for air and sea transport or a new climate law that resets the rules of European investment policies [13, 14].

On July 14th, 2021, the European Union announced that the target within the framework of "European Ecological Package" will be reducing the greenhouse gas emissions by 55% by 2030 and achieving carbon neutrality by 2050. By 2030, 40% of electricity should be generated in the EU from renewable sources and in 2035 in EU the sale of passenger cars powered by internal combustion engines should end.

With principles of the European Green Deal project corresponds the NordLink, project which is set to be a new milestone in electricity supply in Europe as well as an important step towards a vision of a carbon-neutral system in Europe. NordLink project represents a high-voltage submarine cable line through the North Sea (see Fig. 1) between Norway (Tonstad) and Germany (Wilster) [15]. NordLink cable has a total length of 623 km, of which 520 km is under the sea. NordLink was officially opened on May 27th, 2021, and has been in trial operation since December 2020.

Electricity in the NordLink cable flows in both directions. In case of surplus energy generated by wind farms in northern Germany (in case of strong winds) the electricity flows through the power cable north to Norway where it is either distributed to the grid (it is purchased during the surplus at low prices) or used in pumped-storage power stations [15].

When the German wind farms production is low, Norwegian side can send the stored energy from pumped-storage power stations south to Germany and prospectively further to Europe. Electricity can only flow through the cable in one direction at a time, but the direction can be switched operatively.

Some energy concepts in the Czech Republic are also considering the above-mentioned possibilities of obtaining the electricity from Norway. However, this year the assumptions about using the NordLink cable line were not fully reflected because there was very little wind in Germany this year which led to less water pumping in Norwegian pumped-storage power stations. As a result, the energy systems in both countries had to face the electricity shortages [15].

The European Green Deal, which is also binding for Czech Republic, imposes a gradual shift away from the production of electricity in solid fuels thermal power plants, in our case coal. This means the decarbonisation of our energy sector.

It is expected that in the Czech Republic the renewable sources of energy will represent 23.8% of electricity production by 2025. The current share of renewable sources in the production of electricity is about 12 to 13%, of which 7% is produced by hydropower plants.

In order to achieve the goals of decarbonization, the Czech Republic established the so-called Coal Commission of the Czech Republic, consisting of 21 members. The members of the commission are biologists, climatologists, doctors, technicians, citizens living close to active mines, etc. The members are also representatives of the Rainbow Movement and Greenpeace CR. The Commission is chaired by the Minister for the Environment and the Minister of Industry and Trade. At its meeting in December 2020, the Commission decided to shut down of thermal power plants in the Czech Republic will take place by 2038 (Germany will shut down its thermal power plants during 2038). For the sake of completeness, it should be recalled that the years 2033, 2038 and 2043 were originally considered. It should also be noted that if the new nuclear power plant block in Dukovany is build it will remain operational until 2036.

In 2019 the coal-fired thermal power plants represented 9,800 MW of the installed electrical output in the Czech Republic, while they produced 33.8 TWh of electricity. According to the Bloomberg model NEF the Czech Republic should reduce the electricity production from coal to 52% by 2030, that means that only 17.6 TWh of electricity would be produced by coal-fired thermal power plants (at installed electrical output of 5,100 MW). The electricity generation in gas power plants should decrease from 7.8 to 3.1 TWh in the Czech Republic by 2030 [16].

The new amendment to Act No. 165/2012 Coll. on Supported Energy Sources was proposed in Czech Republic in 2020 (submitted on 30th March 2020 to Chamber of Deputies of the Parliament of the Czech Republic, approved on 18th October, 2021 as Act No. 382/2021 Coll.). This amendment states that in the period from 2021 to 2030 the share of energy from renewable sources in the final energy consumption should be at least 6% (compared to the current situation, but more is desirable). This amendment that has already been discussed in the Chamber of Deputies of the Parliament of the Czech Republic, therefore regulates instruments and measures through which this objective should be achieved.

The mentioned amendment to the Act No. 165/2012 Coll. assumes that the support for electricity from renewable sources will apply to plants put into operation in the coming years, that are power plants that use water energy up to an installed electric capacity of 10 MW, wind, landfill, and sludge gas.

The above-mentioned support could encourage faster construction of wind farms in the Czech Republic, which, despite the resistance of the local population, is necessary for the realization of the goals of European and Czech decarbonisation strategies. The development of community energy production based on renewable electricity sources (rooftop photovoltaic power plants on residential and communal buildings) is also expected.

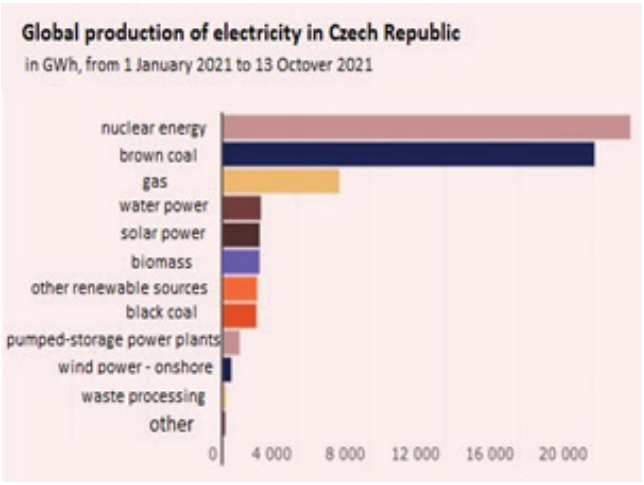
Potential possibilities of replacement of coal energy sources by renewable sources of electric energy in the Czech Republic

It is therefore necessary to ask the question of how to ensure the carbon neutrality in the Czech Republic, that means the balance between carbon emissions and their absorption into the atmosphere. To make things worse all of that must be achieved in a relatively short time frame. Current developments show how difficult it will be to achieve this goal even for Germany, which has huge installed capacity of renewables, in order to the fight against the climate change.

At the time when the Coal Commission of the Czech Republic was preparing its opinion about decommissioning of domestic thermal power plants (this should happen by 2038, although voices are rising to end mining before 2035, or even in 2030), several expert studies about the Czech Republic's

Fig. 2. How much did the emission allowance cost? – EURO/t CO_2 [15]
Rys. 2. Ile kosztowały uprawnienia do emisji? – EURO/t CO_2 [15]

Fig. 3. Total electricity production in the Czech Republic [16]
Rys. 3. Całkowita produkcja energii elektrycznej w Czechach [16]



transition to renewable energy sources were published [18]. The purpose of the expert studies was the support of the Coal Commission in deciding about the decarbonization of the Czech Republic (more precisely about the speed of its implementation).

For example, the study from company called EMBER (see below), envisages a complete cessation of coal dependent energy production in the Czech Republic by 2030, all of that at a relatively low cost and with a large investment for the future.

Company called McKinsey & Company published its study [19] in October 2020. The study [19] models an ideal plan to meet the so-called climate commitment, which means carbon neutrality in the year 2050, including the intermediate step in 2030 (closure of coal-fired power plants in the Czech Republic). The carbon neutrality (which is binding for the Czech Republic) is the reason why the entire coal business will most likely be retired.

A study [19] states that obsolete coal-fired power plants are already on the edge of market economic sustainability. The study assumes that the system of emission allowances that the EU imposes to fulfill the carbon responsibility, will make them a distant memory in the coming years. The price of emission allowances has now risen to an incredible 65 EURO per 1 ton of emitted CO_2 equivalent (see Fig. 2 below, Ember-Climate.org, SZ Business). For example, in May 2017 the price for the emission allowance was 4.95 EURO/t CO_2. This situation significantly affects the current price of electricity in Europe because it extremely increases the price of electricity produced from coal. This electricity is still vital for EU and we cannot do without this electricity at this moment. However, it should be noted that the current high price of emission allowances is largely caused by market speculation.

We should mention that the model made by McKinsey primary targets the question how to reach the carbon neutrality in the shortest possible time and by the most effective way (with minimal losses) and how to replace the electricity previously supplied by thermal power plants. This model is not aiming for just bare shutdown of thermal power plants but for the shutdown which will meet all the above-mentioned requirements.

The presented analysis shows that the reduction of greenhouse gas emissions by 55% by 2030 would in the Czech Republic require additional investments of 500 billion CZK (in 2020 prices). However, most of these investments should pay off, or even bring a profit in the long run, because the newly introduced technologies will reduce operating costs. And the main tool to reduce emissions is to reduce coal mining and burning.

Under a cost-optimal scenario, the reduction in electricity production from coal-fired power plants by 2030, will be

offset by the increase in electricity generation from renewable sources, namely 3.2 GW from new solar and wind power plants, and by increase in production from natural gas [18].

With a cost-optimal solution in mind, the electricity and heat from decommissioned coal-fired power plants would be partially replaced by solar energy, gas and wind energy. The problem will probably occur in case of gas, because the gas is currently scarce, and its price is rising.

Nevertheless, the most economically advantageous McKinsey model [18] predicts that in 2030 about 40% (compared to 2017) of coal-burning power plants will still be operational. This model also utilizes the electricity import from cheaper sustainable sources from abroad. Electricity import is (at least from the current point of view) still somewhat problematic both in terms of high price and in terms of sole capability to import the electricity (for example NordLink power cable faced difficulties this year).

A study made by company called BloombergNEF states that the key elements are so-called breaking points [18], which signalize when the renewable energy (with the initial investment in mind) becomes cheaper than the energy made from fossil fuels. For the solar power plants made by the Bloomberg company this point is expected to come in 2024 and for wind power plants in 2029.

BloombergNEF says that by the 2030 (according to the most economically advantageous scenario) the renewable sources of energy should produce about 12 GW of electricity [18]. About half of that should be produce by wind power and the other half by photovoltaic. The energy production of coal-burning power plants will decrease (by 9,5 GW), mainly due to bad economical rentability (the price of the emissions allowances rise – see Fig. 2, and so do the price of coal)

Predicted cost for building the new renewable energy facilities is (by the most economically advantageous estimates) about 140 billion euros (3 640 billion CZK), but this estimates, does not include the investments to the infrastructure.

The study made by the EMBER company has more ambitious goal. The study wants to prove that complete shutdown of coal power plants in Czech Republic is possible by 2030. The problem with „reliability" of the wind and solar power plants is solved by increasing the capacity of steam-gas power plants.

On top of that the study made by EMBER company [18] presupposes the investment of about 300 billion CZK every year for period of ten years. This investment into the transformation of energy production should create about 45 000 jobs predominantly (90%) in renewable sector. The study therefore states that the end of coal powered power plants will be positive for the whole economy.

The coal shutdown by 2030 would allow to Czech Republic to meet the EU targets in the field of climate. Outage in electricity sources should by compensated by wind and solar power plants. Safety net in case of low output by wind and solar power will be formed by steam-gas power plants.

The model states that the envisioned energy system has the regulating capacity of 13.3 GW, and the consumption during the peak hours (as stated in the model) is 12.6 GW. The Czech Republic should by therefore self-sustainable even in if the output from wind and solar power plants is low. Outage in heat production should be compensated by heat pumps together with waste heat recovery.

This study also counts on the import of electricity to the Czech Republic from abroad (but only in negligible amount of about 1% of entire consumption).

Most likely the situation around the coal-fired power plants shutdown will evolve by one of the above-mentioned scenarios. The coal powered energy production should end (by those scenarios) by 2033 or by 2038 (which is the same as Germany) or eventually by 2043. For the long time the preferred variant of the shutdown was the second one (2038). The same conclusion was made by so-called Coal Commission of the Czech Republic in December 2020. The government of the Czech Republic noted the commission's conclusions (that means the conclusions of the commission were not approve by the government)

Current energy situation in the Czech Republic and real possibilities of decarbonisation in electricity production

By 2038 (which was the original date of the coal-fired power plants shutdown given by the Czech's Coal Commission) about 9,800 to 12,000 MW of installed electrical power from the coal-fired power plants should be shut down. Nowadays when the much earlier date of coal shutdown is being consider (2030), the only one thing is clear – that it will not be easy.

As we already mentioned the renewable sources of energy should produce about 12 GW of electricity. About half of that should be obtained by wind energy and the other half by photovoltaic.

To fulfill the demanded requirement on installed capacity of wind power plants (6,000 MWe) in the Czech Republic, we will need to increase the installed capacity of wind power plants for about 5,660 MWe (current installed capacity is 339.4 MWe). It is very hard to predict if this very ambitious project will be successful, but in any case, we should at least try.

However, it is necessary to ask a question, how we will be able to sustain the production of electricity and heat (to keep light and heat in our homes) if in some days, for example in January when the temperature plummets to let say -10 and the sunlight and wind will not be available? In the case of the Czech Republic, we also have to consider the fact that the Czech Republic has the most industrial capacity per citizen in Europe (industry if of course more power intensive that other forms of production)

For example, on Friday, October 8th this year the wind stopped blowing in Germany. The giant installed capacity of Germany's wind power plants which is whopping 65 GW on land and sea was able to use only one gigawatt (GW) of its installed capacity. The photovoltaic power plants of which Germany has about 50 GW of installed capacity did not produce at all at that time! Combined installed capacity of Germany's wind and solar power plants equals to hardly believable 58 nuclear power plants similar to Temelín Nuclear Power Plant in the Czech Republic [20].

The construction and maintenance of these power plants cost tens of billion euros per year and all of that is paid by German taxpayers. The above-mentioned incident proved that the renewable sources of energy are very unreliable and unstable in real life. German grid manager had to call back to action about 48.5 GWe of conventional coal power and nuclear power plants also worked around the clocks (which should

be, according to the plan shut down by 2022 in Germany, even though some of them could easily stay operational up to 2036). The most serious deficits during the peak hours were covered by very expensive gas power plants (12 GWe), which are operated off market by the grid manager. [20]

All the unexpected costs caused by this situation mend that at 9 am the price o of one MWh skyrocketed to 393.1 euros (9,984 CZK). Then after the photovoltaic power plants started to feed the power to the grid the price dropped, but after the sunset the price skyrocketed again even more to 442 euros (11,227 CZK) for one MWh [20].

Current situation therefore shows that reaching the carbon neutrality (in order, to fight with climate change) will be very challenging even for Germany.

The Czech Republic should lower the production of CO_2 by 55% (in comparison with year 1990) by 2030. Specifically, we should reduce our production of CO_2 from 199 million tons to 89.5 million tons, but we have to mention that for example in 2017 the Czech Republic produced just 129 million tons of CO_2 emissions. Last year we lowered the CO_2 emissions by 40%. To meet the goal of Fit for 55, we have to lower the emissions by another 15% (the energy production is responsible for 38% of total emissions of CO_2) [21].

We have to point out that the management of the electricity production system with the high percentage of renewable energy sources is vastly different to the management with mostly conventional sources of energy like for example coal. For example, in the summer the system could produce surpluses of about 3,000 to 5,000 MW, which have to be exported or regulated. On the other hand, in winter, we could face a huge lack of power, which will be on the edge of transmission capacity. So, the control power will not be sufficient in the Czech Republic, and we will risk the dependence on imported electricity. The dependence on import may occur when we reduce the production of electricity from coal to about 60% of current production [21].

It is therefore clear that the Czech Republic will have to face many technical difficulties in order, to reach the carbon neutrality. It will also take the considerable amount of time. Carbon neutrality is possible through so-called technological neutrality in electricity production, which means large scale usage of nuclear energy supplemented by natural gas or hydrogen.

If we really want to reduce the effects of the climate change and fulfill the obligations from climate agreements (Kyoto, Paris 2015, Glasgow) and protect the atmosphere which is the common asset belonging to the whole world, then we have to, according to report of Intergovernmental Panel of Climate Changes (IPCC) from 2018, keep the nuclear power plants in our inventories. And not only that, the number of operation nuclear reactors have to be 2 to 5 times higher than today by 2050. Without the nuclear energy it is not possible to reduce the effects of the climate change, because the nuclear power is the only non-fossil fuel that is not dependent on weather, time of the year or time of the day. [22]

Czech Republic joined forces with eight other member states and together we supported the proposition made by France. France wants to replace a high number of obsolete nuclear reactors by new ones and therefore need to convince the European Commission to add the nuclear energy to taxonomically supported emission-free resources [20]. At the latest meetings of European Commission about energy production the possibility of adding the nuclear power (and natural gas) to supported emission-free resources category was discussed. The latest information from European Commission suggests that the nuclear energy was indeed added to supported category.

After all, there was no reason not to include the nuclear energy into the supported emission-free sources category. The global average greenhouse gas emissions of this technology are only 16g CO_2, eq./kWh, during the production of electricity from photovoltaic power plants it is 46 g CO_2, eq./kWh and in the case of wind energy it is then 12g CO_2, eq/kWh. On the other hand, the highest greenhouse gas emissions occur during the production of electricity in coal-fired power plants (1001 g CO_2, eq./kWh - see Table 1 above [7]).

And how expensive is the production of electricity from Czech sources? Last year (2020) the nuclear Power plants produced 37% of total electricity production, coal sources produced 43%, solar sources 3% and the wind sources just 1% of total electricity production. This year (2021) from the beginning of January to October 13th, 2021, nuclear power plants produced the most electricity from all sources (total electricity production in the Czech Republic in 9.5 months of 2021 is evident from Fig. 3).

As entrepreneur Pavel Tykač recently stated, his coal sources produce the electricity for 0.15 CZK per kWh [16]. If we add, the emission allowance, the price increases by 1.60 CZK per kWh (nowadays the increase is higher – see Fig. 2 above). Although the prices of electricity production from the nuclear power plants are well-guarded trade secrets, at the conference of the Equilibrium institute (October 18, 2021) Hynek Beran from ČVUT (Czech Technical University in Prague) showed the prices of nuclear electricity at around 0.25 CZK per kWh [20].

It will be necessary (at least, in the near future) to use the electricity not only from the renewable sources, but also from the nuclear power plants, gas power plants or even hydrogen power plants (at least for limited time). And the very expensive gas-fired power plants should cover only the most significant deficits at peak times.

In conclusion, it should be noted that the investment needed to reduce greenhouse gas emissions in the Czech Republic in accordance with the European Commission's plan are estimated to around 4.5 trillion CZK, which is approximately three times the revenue of the Czech Republic's budget for the whole next year. This estimate roughly corresponds with the estimates made by Bloomberg NEF and EMBER in their studies (see Chapter 3 above).

Recently the interest in small modular reactors (SMRs) has risen dramatically. This type of reactor could ensure the access to nuclear power for decentralized production of electricity and heat.

Small modular reactors are reactors with an electrical output of approximately10 to 300 MWe. None of these limits (lower or upper) is defined exactly. For the upper limit, the International Atomic Energy Agency states an electrical output of 300 MWe and the US Department of Energy (DOE) states the heat output of 1,000 MWt as the upper limit. These definitions roughly agree with each other, heat output may be

more significant in this specific category of reactors, because this type of small reactor is often considered for heat supply or water desalination. The lower limit is defined even less precisely. Reactors with lower electrical power output than above mentioned 10 MWe are referred to as minireactors or microreactors [23].

The major obstacle to the development of nuclear energy in today seems the fact that construction of conventional nuclear power plant is huge one-time investment and therefore the need for a loan is usually inevitable. If we succeeded to implement the small modular reactors, these investments could be spread over the time, which would reduce the risks for investors.

Small modular reactors can be technically divided into two groups [23]. The first group includes conventional light water reactors (pressurized or boiling), which are based on known types of reactors, developed for example, for use in the icebreakers or submarines. The second group includes completely new innovative concepts, mostly belonging to IV. generation of reactors. This is often an attempt to get something like long-lasting battery. The entire reactor would be brought to the place of use in a compact form. It would remain operational without the fuel replacement for decades and then it would be decommissioned. The development however is mostly at its infancy. Prototype reactors of this type will probably not be ready until after 2030 [23]. Therefore, we will not be able to use this device as an alternative source of energy in the initial stages of reduction of electricity production in coal-fired power plants.

Apparently, a significant turnaround could occur if we will be able to construct working fusion power plants. Mankind has been trying for decades to control the energy source of the stars - nuclear fusion. It is stated that the first nuclear fusion reaction under "controlled conditions" was done in Argentina on March 24th, 1951 (about 71 years ago!) [24]. In the end, it turned out to only be one of many dead ends in our long-lasting endeavor to transfer the energy source of the stars down to Earth.

However, this report attracted attention and sparked a wave of interest in fusion research in both the US, Great Britain and the then Russia (former USSR). At the time, it was mainly a matter of proving that "thermonuclear fusion" works.

The largest fusion reactor ever built is the European Union's ITER Tokamak. This reactor will have the vacuum chamber with a volume 10 times larger than today's largest European tokamak JET in the UK. ITER should start operating in 2025. Maximum output should be reached in 2035 [24]. So far, the plan is that when ITER proves successful, the construction on real prototype of fusion power plant will begin. This power plant will be called DEMO and will grow near the French city of Cadarache. The main advantage of fusion power plants is the very low fuel consumption, which will be a fraction of the volume of fuel needed to operate a conventional (fission) nuclear power plant. According to the European plan, the construction of the DEMO project could start around 2040. The start of electricity production around 2050 seems to be a relatively optimistic, but still realistic estimate [24]. Therefore, it will also not be possible to use these devices as alternative sources within the initial stages of decarbonization in the Czech Republic.

Conclusions

It is clear that the Czech Republic wants to ensure carbon neutrality, i.e. balance between the carbon emissions and their absorption into the atmosphere.

However, in the near future, we will have to achieve the technological neutrality first. This means to use not only the renewable energy sources but also the nuclear energy, gas (at least for a limited time) or hydrogen in the production of electricity. After all, other countries in the European Union (for example France) want to achieve this, too. This is probably the only way for the Czech Republic. Otherwise, we will not be able to achieve the stable electricity production at such a level that we can continue to operate our industry (the Czech Republic has the largest share of industry per capita in the European Union), which is the backbone of our economy and needs considerable amount of energy for its continued existence (despite that there is a maximum effort to save the energy in industry wherever it is possible).

Equally important, is to provide the electricity for the population. However here it is necessary, to resolve the cardinal question: How to ensure the production of elektricity and heat in some days in the winter if there will be no wind nor sun light and the tempreature will plummet to let say -10 ° C? Again, the best solution for the near future (with the current technical possibilities in mind) seems to be the use of nuclear energy and gas (at least for a limited time), or hydrogen.

It should also be noted that there is currently no plan of energy industry transformation in the Czech Republic. This plan must be based on a society-wide contract, and it is not possible to change it every four years after the parliamentary elections.

The current conflict in Ukraine is leading the energy debate in the Czech Republic primarily to the question of how to deal with the real risk of a natural gas outage from the east. The list of possible solutions includes the accelerating of development of renewable energy sources or energy consumption reduction programs. The Czech Republic's long-term solution for fossil fuels replacement is to invest to the nuclear reactors building programs, but this solution will take some time. Therefore, it will be necessary to secure supplies of natural gas in the near future (from new sources like Qatar, United States, Algeria), which, in addition to energy production, is also an irreplaceable raw material for some industries. Most of this gas will most likely be delivered by special cargo ships to the terminals in the European Union ports in the form of LNG - liquefied natural gas and then the transport will continue by existing or newly built pipelines.

Literatura – References

1. LAPČÍK, Vladimír. Environmental Impact Assessment (monograph). VŠB-Technical University of Ostrava, Ostrava, Czech Republic. 2011, 217 p. (in Czech)
2. McKIBBEN, Bill. Carbon. New Numbers. National Geographic, 10/2007, pp. 59-63. (in Czech)
3. People´s Newspaper (Lidové noviny), 17.09.2021, p. 13. (in Czech)
4. Study calls for European nuclear renaissance. World Nuclear News, 05.02.2021.
5. BALDRIÁN, Petr. Communication. Institute of Microbiology of the Academy of Science of the Czech Republic. (in Czech)
6. Intergovernmental Panel on Climate Change, 08/2021. (in English)
7. KRÝŽOVÁ, Sofie. The study dispels the myth of electric cars. Do they really produce less emissions? SZ Byznys, 10/2021. (in Czech)
8. Europe's Green Deal plan unveiled. POLITICO [online]. 2019-12-11 [cit. 2021-09-09]. Dostupné online. (in English)
9. SIMON, Frédéric. EU Commission unveils 'European Green Deal': The key points [online]. 2019-12-11 [cit. 2021-09-09]. Dostupné online. (in English)
10. Green Deal for Europe. European Commission [online]. [cit. 2019-12-20]. Dostupné online. (in Czech)
11. ZAMOUŘIL, Jakub. What is the European Green Agreement? CZECHSIGHT – All about Czech and foreign technology [online]. 2019-12-15 [cit. 2019-12-20]. Dostupné online. (in Czech)
12. Green Deal for Europe sets out how to make Europe the first climate-neutral continent by 2050, how to revitalize the economy, improve health and quality of citizen´s lives and to take care of nature so that no one is left out. Ekolist.cz [online]. [cit. 2019-12-20]. Dostupné online. (in Czech)
13. KUBALA, Radek. European green deal – too late, too little, no justice. Daily Referendum. denikreferendum.cz [online]. [cit. 2019-12-20]. Dostupné online. (in Czech)
14. Green Deal for Europe. Wikipedia. (in Czech)
15. ŠTĚPÁNEK, Vít. The new underwater line connected Germany and Norway. Underwater high voltage cable NordLink shows the way of future for the green energy. People´s Newspaper, 28.05.2021, p. 7. (in Czech)
16. KUBÁTOVÁ, Zuzana. Foreign bankers must not dictate to us. Dostupné online. (česky) www.seznamzpravy.cz/clanek/cizi-bankeri-nam-nesmi-diktovat-chci-silnou-ceskou-banku-rika-tykac-177717. (in Czech)
17. Amendment to Act No. 165/2012 Coll., on Supported Energy Sources, as amended of regulations (approved on 18th October, 2021 as Act No. 382/2021 Coll. in the Chamber of Deputies of the Parliament of the Czech Republic). (in Czech)
18. GAVRINĚV, Vojtěch. The end of coal may come soon, sooner that we can imagine, say the scientists. SZ, 21.10.2020. (in Czech)
19. Climatically neutral Czechia – Ways to decarbonise the economy. McKinsey&Company. SZ, 10/2020. (in Czech)
20. SMUTNÝ, Milan, VONDRÁŠ, Jan. Comment: German energy transition is responsible for expensive electricity, SZ, 22.10.2021. (in Czech)
21. KRÝŽOVÁ, Sofie. What do we need fossil fuels for? We need them to save the forests, says the geologist Cílek. Dostupné online. (česky) www.seznamzpravy.cz/clanek/ceka-nas-energeticka-chudoba-odpoved-nabizi-konference-o-energetice-177960). (in Czech)
22. ENTLER, Slavomír, HORÁČEK, Jan, MÁLEK, Jiří. New sources of nuclear energy. Energetika, No. 4, 2021, vol. 71, pp. 227-231. (in Czech)
23. WAGNER, Vladimír. Current state in the field of small modular reactors. Energetika, No. 4, 2021, vol. 71, pp. 232-235. (in Czech)
24. LÁZŇOVSKÝ, Matouš. An endless source of energy is still not in sight. How far are we from functioning fusion power plants? Online: www.seznamzpravy.cz/clanek/nekonecny-zdroj-elektriny-porad-nikde-jak-daleko-jsme-od-fuznich-elektraren-179417. (in Czech)

Aktualne aspekty dekarbonizacji w Czechach i możliwości zastąpienia węglowych źródeł energii odnawialnymi źródłami energii elektrycznej

Europejski Zielony Ład to zestaw inicjatyw politycznych Komisji Europejskiej, których nadrzędnym celem jest uczynienie Europy neutralną dla klimatu w 2050 r. Przedstawiony zostanie również plan oceny wpływu, aby zwiększyć cel redukcji emisji gazów cieplarnianych w Unii Europejskiej do 2030 r. do co najmniej co najmniej 50% i około 55% w porównaniu z poziomami z 1990 roku. Europejski Zielony Ład ma cele obejmujące wiele różnych sektorów, w tym budownictwo, bioróżnorodność, energię, transport i żywność. Aby Unia Europejska osiągnęła swój cel neutralności klimatycznej, jednym z celów jest dekarbonizacja ich systemu energetycznego poprzez dążenie do osiągnięcia zerowej emisji gazów cieplarnianych netto do 2050 r. Artykuł dotyczy aktualnych aspektów dekarbonizacji w Czechach i możliwości zastąpienia energetyki węglowej źródła przez odnawialne źródła energii elektrycznej. Artykuł opisuje obecną sytuację w branży produkcji energii elektrycznej oraz możliwe scenariusze redukcji węglowych źródeł energii w Czechach.

Słowa kluczowe: *efekt cieplarniany, Europejski Zielony Ład, dekarbonizacja, odnawialne źródła energii elektrycznej, węglowe źródła energii*