THE ENVIRONMENTAL IMPACT OF POWER PLANTS IN SLOVAKIA

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Abstract: *The aim of this paper is to evaluate the impact of different types of power plants on the environmental indicators in Slovak Republic. We begin with overview of some of the previous studies of power plants types and their impact on environmental indicators, including water use and withdrawal and CO_2 emissions. The second part of the paper analyses the data from the reports of The Ministry of the Environment of the Slovak Republic on the environmental impact of different types of power plants in Slovakia. The paper compares the current research with the data from Slovakia and compares the environmental impact of different types of power plants in regard to different environmental goals.*[371]

Keywords: *power plants, environmental indicators, Slovakia*

1. INTRODUCTION

The environmental impact of human activities is gaining growing attention in recent years, especially in connection to climate change and extreme weather events. As the scientific community agrees that human activities, especially emissions, are an important contributor to these events, international organizations are calling for coordinated international effort in climate change mitigation.

Slovak Republic, as one of the member states of the European Union, is also part of this effort. In addition, the global trend of more sustainable economic growth is influencing not only emissions, but also other activities that may have harmful effects on the environment or human health.

In this paper we focus on the shift towards more environmentally sustainable practices in energy sector in Slovak Republic and the accordance of Slovak energy sector with the objectives set by the European Union and other international organizations relevant for the country. The objective of the paper is to evaluate the impact of different types of power plants on the environmental indicators in Slovak Republic. The paper first describes the state of research in environmental impact of different types of power plants, with special focus on water resources. The second part of the paper is based on the data from the Ministry of Environment of the Slovak Republic. We analyze the changes in energy sector related environmental indicators.

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2. ENVIRONMENTAL IMPACT OF POWER PLANTS

Electricity is regarded as relatively clean source of energy, which is not necessarily true when we take into account the whole process of electricity generation. Different power plant types have different adverse impact on environment, but no type of power plant is harmless during the whole process. Power plants represent physical footprint, require considerable amount of fossil fuels, biomass or waste to burn, produce greenhouse gases and other waste and have other disruptive effects on environment. [1] Public Service Commission of Wisconsin [2] lists these areas that can be adversely affected by power plants: air, global climate, water quality and quantity, wetlands, soil and land, vegetation, wildlife, protected species and historical and archaeological sites.

Environmental protection consists of many different fields, but the most vocal public debate is held in the field of greenhouse gases emissions and their impact on climate change. This topic is closely linked to energy sector as electricity and heat production is the largest single source of global greenhouse gas emissions with 25% share. [3] The emissions of CO_2 and greenhouse gases emissions are one of the main differentiating factors of the evaluation of environmental impact of each power plant type. Meta-analysis published by World Nuclear Association [4] compares 21 scientific studies on the emissions of greenhouse gases by different power plant types. On average, lignite power plants emit the highest amount of CO_2 per 1 GWh of electricity produced (1069 t), followed by coal (888 t), oil (735 t) and natural gas (500 t) power plants. Other types of power plants emit significantly lower amounts of CO_2. The highest average amount of CO_2 emitted was recorded by solar photovoltaic power plants (85 t); however the range recorded by studies is great, reaching as high as 750 t. Other power plants recorded even lower average values: 45 t for biomass, 28 t for nuclear, 26 t for hydroelectric and 26 t for wind power plants.

The emissions of CO_2 are not exclusively connected to the electricity generation, as the emissions are also a result of electricity transmission and use. Center for Climate and Energy Solutions [5] suggests these opportunities to reduce carbon emissions: shifting from coal to natural gas, improving plant efficiency, using biomass as fuel, adding renewables, increasing transmission and distribution efficiency and reducing industrial, commercial and residential energy demands. Additionally, IPCC report [6] suggests the implementation of CO_2 capture and storage facilities and wider use of nuclear power as ways of reducing emissions.

Power plants do not only emit CO_2, but also other gaseous emissions (CO, SO_x, and NO_2), particulate emissions and trace elements (e.g. mercury, lead or cadmium). These other emissions can be successfully managed and avoided by available technology. [7] The main contributors to other emissions are coal power plants. Zhao et al. [8] studied the emissions of coal-fired power plants in China, focusing on SO_2, NO_x and particulate matter. They conclude that although emissions are growing, there are initiatives to mitigate the problem in China by employing new technologies. However, the authors claim that the emissions of NO_x will continually present a problem in for Chinese air quality.

Water resources and water in general are important elements in the production of electricity, not only for hydroelectric power plants. Almost all other types of power plants, including some types of power plants using renewable sources, contribute to water withdrawal and water use in the electricity production process. The basic process that that causes water withdrawal and water use in the power generation is the production of steam. Most power plants produce steam to power turbines that produce electricity. After steam passes through the turbine it is cooled, condensed and reused. The water used by the power plant is often drawn from rivers, lakes or hydrological collectors. The amount of water the power plant uses depends on the cooling technology it uses. Once-through cooling systems take significant amount of water, but most of it returns to the source. Recirculation cooling systems take much less water but can consume more than twice compared to once-through cooling systems, because a large portion of the water evaporates. [9]

According to the Union of Concerned Scientists [10], different types of power plants have different contribution to water withdrawal and water use, depending on the cooling system. The amount of withdrawn water per 1 MWh of electricity generated is the highest in case of the plants are powered by once-through cooling systems, but the amounts still differ. The withdrawal is the highest in case of nuclear power plants, followed by coal-fired power plants, biomass-fired power plants, and natural gas-fired power plants. However, the water consumption of these plants is much lower than in the case of power plants using recirculation cooling systems. Most of the water in this type of cooling per 1 MWh is used in solar thermal power plants, followed by coal-fired power plants, nuclear power plants, and biomass-fired plants. Hydroelectric technology does not require cooling, and therefore does not use water for electricity production, and usually the water flow through the hydroelectric power plant does not count as water withdrawal. [11]

However, the amounts of water withdrawn and used in the acquisition of fuel for these power plants or their construction are not included in the above mentioned calculations. These amounts have been calculated by Fthenakis and Kim [12], on the example of power plants in the United States. Water withdrawal and water consumption were measured in five stages of electricity generation: fuel extraction, fuel preparation, power plant construction, power generation and fuel disposal. Their results show that biomass-burning power plants in the south-west of the USA (Arizona, Colorado, Idaho, California, Nevada, New Mexico, Oregon, Utah, Texas and Wyoming) [13] withdraw the highest amount of water per unit of electricity generated as in this dry area, agricultural production requires irrigation. Next, there are power plants with a once-through cooling system, namely nuclear, coal and oil and gas-fired power plants. With the exception of biomass, renewable energy sources have relatively low amounts of withdrawn water. Most water is withdrawn by solar power plants, followed by wind power plants and hydroelectric power plants.

The energy mix of Spain and its planned future direction have been evaluated in the paper by Carrillo and Frei [14] on the basis of water use. They conclude that the current plans for higher biomass share in Spain's energy mix will lead to a high increase in water withdrawal. The authors therefore recommend reviewing current plans and increasing the share of wind power in the energy mix in the future as it requires much less water than biomass.

Recent studies, however, also begin to address the issue of water use in the operation of hydroelectric power plants. Although the electricity production itself does not use water, large water reservoirs cause increased evaporation of water. Hydroelectric power plants are rated based on the amount of evaporated water use per unit of energy produced. However, this approach presents several methodological problems described by Bakken, Killingtveit and Alfredsen. [15] The basic indicator, the amount of evaporated water, has two versions, gross and net. The gross indicator reports the real evaporated volume. The net volume represents the real evaporated volume minus the volume, which would evaporate if the reservoir was not built, that is, the evaporated volume before construction. The reporting is not unified, which of these indicators should be reported. Large differences are also caused by different climatic conditions. The highest use as a result of evaporation is reported in China, the lowest in Russia. The authors therefore propose to incorporate these variables into the reporting as well as the fact that some water reservoirs serve multiple purposes. [16]

3. POWER PLANTS IMPACT IN SLOVAKIA

In this part of the paper we evaluate the data on environmental impact of power plants in Slovakia and the recent development in this area. We evaluate the environmental impact of power plants in Slovakia based on indicators that are reported in accordance with the European Union standards. The majority of data we use is from the Ministry of Environment of the Slovak Republic. We also use data from international organizations, namely International Energy Agency (IEA) and Organization for Economic Cooperation and Development (OECD). The rest of the data were obtained from the private companies operating in Slovak energy sector.

Based on OECD data, the total electricity generation in Slovak Republic is 26.4 TWh. Electricity generation in Slovak Republic is heavily dependent on nuclear power plants that generate 57.4% of energy produced in the country. Second most important electricity source is hydropower with 17% share. Coal power plants have been an important source of electricity before the nuclear power and now they account for 11.4% of electricity generation. Other sources of electricity are biofuels and waste (5.8%), natural gas (4.3%), solar energy (2.5%), oil (1.6%) and wind power (0.02%). [17]

Slovak energy market is dominated by one company, Slovenské elektrárne a.s., which produces 81% of electricity in the country. The company owns two nuclear power plants, majority of hydropower sources and thermal power plants. Other 34 companies are usually small companies operating small hydropower plants or producing electricity from renewable sources. [18] Slovak electricity generating capacities are not operating on full installed capacity. While nuclear power plants achieve a capacity factor of 87%, gas-fired power plants have capacity factor of 20% and hydropower is achieving capacity factor of only 17%. [19]

Energy sector in Slovakia generates more than 50% of total CO_2 emissions in the country. The main fuels contributing to this are coal, natural gas and oil. However, the situation in energy sector is improving. The amount of CO_2 emissions is declining compared to previous year, and also compared to the year 2000. Since 1990, the emissions of CO_2 from energy sector in Slovakia declined by 58.8%. This is the result of growing energy effectiveness of Slovak industries, growing share of gas in energy mix and legally binding legislature for environmental protection. [20]

Less positive results are observable in case of other pollutants emitted by companies operating in energy sector. While the emissions of some potentially harmful substances are declining, the others are still growing. The emissions of polychlorinated dibenzo-p-dioxins (PCDD) and almost all heavy metals are declining, together with particulate matter emissions (both PM_{10} and $PM_{2.5}$). On the other hand, emissions of one heavy metal, cadmium, are increasing. Other substances whose emissions are on the rise in energy sector are polychlorinated biphenyls (PCB), polycyclic aromatic hydrocarbon (PAH) and non-methane volatile organic compounds (NMVOC). [21]

The indicator of waste water from energy sector in Slovakia clearly shows the difference between two main types of cooling in electricity generation systems. Since 2006 when the monitoring started, the amount of waste water (water used that changed quality, e.g. composition or temperature after use) was declining until 2011. In 2012 thermal power plant Vojany changed the cooling system from recirculation to once-through cooling system. This brought the change of waste water production from 17498.79 thousand m^3 in 2011 to 91408.25 thousand m^3 in 2012. After the cooling system changed back in 2014, the amount of waste water from energy sector dropped to 17643.778 thousand m^3 and continues to decline since. [22]

Fluctuation can be seen also in terms of waste production in energy sector and in nuclear waste production. Waste produced by energy sector is almost exclusively non-hazardous waste, with hazardous waste accounting for only 1.1%. Although the waste production declined compared to the amount in 2000, the comparison with last year shows slight increase in waste production from energy sector. [23] The same development can be seen in case of radioactive waste from two nuclear power plants. [24]

4. CONCLUSION

In this paper we evaluate the current state of environmental impact of power plants on environmental indicators and their development in general and in the Slovak Republic.

The electricity production causes several environmental problems, most importantly emissions of CO_2 and other substances, water use and water withdrawal and waste production. As we document in the first part of the paper, different power plant types have vastly different impact on these indicators.

The current energy mix of Slovakia follows the trend of decreasing CO_2 emissions and other indicators are also significantly improving. However, there are still indicators that are changing in unfavorable directions and not in accordance with world trends towards cleaner energy. These indicators pose a challenge for future decisions in Slovak republic energy sector.

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