UDC 504.054 52–56. https://doi.org/10.23947/2541-9129-2021-4-58-63

Comparative analysis of the impact of objects of traditional and alternative energy on the environment

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Introduction. Active withdrawal of energy raw materials from the subsoil, as well as technogenic impact from energy sources based on traditional fuel, lead to irreversible environmental consequences. To minimize this impact, it is necessary to start from two main conditions: the search for alternative energy sources and the improvement of the existing ones.
Problem Statement. The objective of this study is a comparative analysis of energy facilities in order to identify the plant that has the greatest negative impact on the environment.
Theoretical part. The comparative analysis of various energy production systems reflects the ecological and economic components of each. For example, a thermal power plant (TPP), a nuclear power plant (NPP) and a wind power plant (WPP) are considered. The negative impact on the environment is mainly exerted on the atmospheric air, in connection with which the data on the amount of pollutants are considered. Also, a modified Leopold matrix was constructed for an expert assessment of the mentioned stations.
Conclusions. The results of the analysis show that among the considered power plants, the wind power plant is the most environmentally friendly and favorable for the health of the population.

Keywords: wind energy, environment, air pollution, alternative energy source, traditional energy, comparison of energy systems, green energy.

For citation: Yu. S. Borisova, N. S. Samarskaya. Comparative analysis of the impact of objects of traditional and alternative energy on the environment. Safety of Technogenic and Natural Systems. 2021; 4: 58−63. https://doi.org/10.23947/2541-9129-2021-4-58-63

Introduction. Energy plays an important role in the development of the country's economy. This is due to the fact that no production process can be realized without the use of energy. Currently, there are two main problems in the energy sector: resource depletion and man-made impact on the environment. The exhaustion or non-renewability of natural resources is complicated by the unevenness of their location on the planet. Resource consumption leads to enormous changes in the biosphere. The removal of natural resources from the earth's crust disrupts the circulation of substances in nature. This entails a number of consequences, such as landscape changes, groundwater distribution, soil degradation, removal of areas of natural ecosystems both in the process of extraction and in the process of energy realization [1]. The problem of depletion of natural resources can be solved in two ways: the use of other (alternative) energy sources and energy conservation, i.e. improving the energy efficiency of the existing power plants and their rational use. The problem associated with the impact of energy enterprises on the environment increases with the growth of energy production rates. So, to date, man-made emissions into the atmosphere in the form of greenhouse gases from the energy industry account for more than 50%.

Most of the world's generated energy comes from thermal power plants. When fuel is burned at a thermal power plant, pollutants are released into the atmospheric air. Getting into the environment, they cause irreversible harm to human health. Penetrating in large quantities into the human body, they can cause acute poisoning, have an irritating effect on the mucous membranes of the respiratory and visual organs. Aluminum and silicon oxides can destroy lung tissue, leading to a disease such as silicatosis. In the places, where thermal power plants are located, the amount of oxygen in the atmosphere decreases, this is due to the fact that a significant proportion of it is spent on fuel combustion.

R. B. Goldman, A. S. Noskov, A. A. Peregonenko, D. A. Krylov and many others were engaged in research in the field of the influence of thermal power plants on the environment. D. A. Krylov presented specific indicators of the content of toxic elements in fly ash at Russian thermal power plants, these data allowed to assert that thermal power plants are sources of environmental pollution [2]. The research of the Institute of Fundamental Problems of Biology of the Russian Academy of Sciences assessed the pollution of Chelyabinsk and its environs with heavy metals (Cu, Co, Ni, Zn, Pb, Cd, Cr, Mo, Hg), the source of which are emissions from thermal power plants and boilers burning coal [3]. V. V. Yadutov, T. I. Petrov, Yu. N. Zatsarinnaya classified the forms of TPP influence on the environment:

— physical, related to acoustic, electromagnetic, radiation, thermal effects;

— direct, related to the introduction or removal of various components from the natural environment;

— indirect, including gravitational deposition of aerosols and solid particles [4].

Yu. A. Gradoboeva, I. V. Kondratieva, A. O. Margarint, A. S. Puzankov, M. R. Gafarov assessed the impact of nuclear power plants on the environment in their works. In 1988, the International Atomic Energy Agency developed a seven-level scale of nuclear events for the uniformity of the assessment of emergencies associated with accidental radiation emissions into the environment at nuclear power plants. According to it, the accident at the Three Mile Island nuclear power plant in the USA and the accident at Windscale (Great Britain) were assigned to the fifth level, and the accident at the Chernobyl nuclear power plant — to the seventh level of danger (global). When comparing the operating indicators of thermal power plants and nuclear power plants of the same capacity, it is obvious that the degree of negative impact of thermal power plants on the environment is much higher.

A. I. Zaporozhets, E. I. Sosnina, B. V. Ermolenko, M. A. Ryzhenkov, V. E. Vavilov, E. V. Andreeva, G. V. Pachurin, V. N. Beznosov considered the impact of wind power plants on the environment during their construction and operation. According to the research of Yu. A. Rolil, the direct physical impact of wind turbines is mainly associated with the laying of foundations, access roads and cables [5]. A.V. Gornostay and A.V. Bulekov estimated that during the life cycle of a wind power plant consisting of 12 installations, 2079 GW of electricity will be produced, which will reduce the emission of 2,491,200 tons of CO_2 into the atmosphere [6].

As the analysis shows, none of the presented works contains a comparative analysis of the environmental impact of all three power systems (thermal power plants, nuclear power plants and wind power plants).

Problem Statement. A significant reduction in the negative impact on the atmosphere can be achieved by switching to alternative energy. The prospects for the development of a complex of renewable energy sources are gaining momentum, in particular, this concerns wind power, which is a relatively young industry in our country. The relevance of the WPP lies in the fact that the raw material for generating electricity is wind, an inexhaustible source, which enormously reduces the consumption of the planet's resources [7]. The purpose of this study is a comparative analysis of energy sources with the choice of the object that has the greatest negative impact on the environment.

Theoretical Part. To compare wind power plants with traditional energy sources (thermal power plants and nuclear power plants), an analysis was carried out and factors that negatively affect the environment were identified.

TPP: influence on atmospheric air. Emissions from thermal power plants generated during fuel combustion contain pollutants: dust particles, carbon dioxide, nitrogen oxide, sulfur oxide, fly ash, sulfuric and sulfurous anhydride, fluoride pollution, gaseous products of incomplete combustion. To reduce the concentration of pollutants in the surface layer of air, thermal power plant boilers are usually equipped with chimneys 100-200 m high. Due to this, the scattering area increases by tens, and in windy weather — by hundreds of kilometers [8, 9].

Influence of TPP on soil. During the combustion of coal, a large amount of ash and slag waste is formed, for the storage of which the territories are needed, as a result of which lands are alienated for these needs. In addition, there is a radiation background in ash and slag dumps.

Influence of TPP on water bodies. The operation of a thermal power plant involves the use of a large volume of water that comes from the nearest water body, goes through a cycle and returns. At the same time, water is a source of

thermal pollution, leading to the death of aquatic flora and fauna, changes in hydrological indicators, evaporation, erosion, transformation of the microclimate.

NPP: influence on atmospheric air. The impact of nuclear power plants on the environment begins from the moment of construction and continues to exist even after its operation. Thus, aerosol and gas emissions enter the atmosphere from nuclear power plants. Radionuclides, as a rule, are long-living, and every year, accumulating in the biosphere, they increase the dosimetric cost. The most dangerous is the isotope of hydrogen, whose half-life is 12.3 years, it is formed by irradiation of water, partially passing into steam and entering the air. Radiation destroys the tissues of plants and animals, leads to mutations, infertility, and with high radiation exposure — to the death of humans and animals [10].

Influence of NPP on water bodies. Only 40 % of the used water is returned to the cycle, moreover with waste. Radioactive substances trapped in rivers, seas, oceans are absorbed by aquatic plants and animals, which return to the human body through the food chain.

Influence of NPP on soil. From the soil surface, radioactive substances enter the roots of plants, and then into the body of animals, including agricultural ones [11].

WPP: influence on atmospheric air. The nature and sources of atmospheric pollution during the construction of wind power plants are similar to standard capital construction projects. Vehicles and construction devices, welding and painting works, the use of bulk construction materials are the main sources of environmental pollution. At this stage, the following pollutants enter the environment: carbon monoxide, sulfur dioxide, nitrogen oxide and dioxide, iron and manganese oxides, gasoline, kerosene, soot, inorganic dust, fluoride compounds, etc. During the operation of the wind power plant, there is a significant reduction in heat losses. For example, one generator with a capacity of 1 MW leads to a reduction in CO_2 emissions by 1,800 tons per year, which is about 900 million tons per year on the scale of the existing wind power plants. Pollution at the operational stage is so small that it is customary not to take them into account. Pollutants are released only during the production of wind turbine components. These include carbon monoxide, nitrogen oxide and dioxide, sulfur dioxide, gasoline, kerosene, soot, inorganic dust, iron and manganese oxides, fluoride compounds and other substances [12, 13].

Influence of WWP on water bodies. There is practically no impact on the hydrosphere. The water consumed during construction is usually used irrevocably in cement mortars. Possible pollutants may be stormwater wastewater containing suspended solids and petroleum products.

Influence of WWP on soil. At the construction stage, waste is generated in the form of concrete in lump form, bitumen, construction rubble, asphalt, scrap of non-ferrous and ferrous metals, remnants of welding electrodes, cables, and wires. At the stage of operation, there is no negative impact; moreover, the territories occupied for the construction of the wind power plant make up 1% of the entire station, which allows the territory to be used for agricultural needs

Influence of noise. The noise from a wind power plant consisting of 10 wind turbines at a distance of 350 m is 35-45 dBA, which is an acceptable indicator. For comparison: a car moving at a speed of 65 km/h at a distance of 100 m creates a noise of 55 dBA, and background noise in a rural area at night varies in the range of 20-40 dBA. The influence is quite subjective and depends more on individual factors of sound perception.

Influence of vibration. Vibration during the operation is associated with the movement of the blades. According to the calculated data, a wind power plant (wind turbine) of modern design does not transmit vibration waves to surrounding objects if the mass of its moving part is 16 or more times the weight of its moving part [14].

In order to compare the quantitative characteristics of emissions into the atmosphere from energy facilities, Table 1 is compiled.

Table 1

Annual release of pollutants into the environment from energy facilities with a capacity of 1000 MW

Pollutatnt		TPP	NPP	WPP
NOx, t		20 900	74	-
CO, t		210	49	-
CO_2, t		6 mil	6700	-
Solid particles, t		4500	-	-
Fuel oil ash/soot , t		73 000	3	-
Radionuclides, TBq	IRG	-	375	-
	Iodine	-	0.018	-
	CO^{60}	-	0.074	-
	Cs^{134}	-	0.0009	-
	Cs^{137}	-	0.002	-

Based on the expert assessment method, the authors have constructed a modified Leopold matrix for energy facilities (Table 2). The impact of thermal power plants, nuclear power plants and wind power plants on the objects are evaluated on a three-point scale, where 0 points — no impact, 1 point — minimal negative impact, 2 points — average negative impact, 3 points — maximum negative impact.

Table 2

Modified Leopold matrix for energy facilities with a capacity of 1000 MW

impact / Object of impact	TPP	NPP	WPP
Atmospheric air emissions (quality)	3	1	0
Climate change (micro)	2	0	1
Soil (pollution)	2	2	0
Wastewater discharges	3	3	0
Waste generation	1	3	1
Noise	1	1	2
Vibration	0	0	2
Thermal effects	3	2	0
Occupied area	1	1	3
Flora	1	2	1
Fauna	1	0	1
Aesthetic need (landscape)	1	2	1
Consequences of accidents	1	3	0
Public health	2	2	0
Workers' health	3	2	0
Public safety	1	3	0
Safety of workers	2	3	0
Total intensity of exposure	28	30	12

The significance of all impacts is determined by the formula

$$\gamma = \frac{100}{n}, \quad (1)$$

where n — the number of cells in which the intensity of the impact is not zero.

Total intensity of exposure:

$$I = \gamma \cdot \sum_{i-1}^{n} \omega_i. \quad (2)$$

The results of the calculation showed that the lowest total intensity of the environmental impact is exerted by the wind power plant.

Table 3 shows comparative indicators: advantages and disadvantages of thermal power plants, nuclear power plants and wind power plants. The main advantage of wind energy is environmental cleanliness, and the disadvantage is its inconstancy [15].

Table 3

Advantages and disadvantages of energy facilities

	TPP	NPP	WPP
Advantages	– cheap raw materials – small investments in construction – construction is possible in any region – occupy a small area	– high output power – operation is cheaper than that of thermal power plants – do not require constant and large fuel supplies – no greenhouse gas emissions	– an inexhaustible type of energy used – wind – emissions into the environment are significantly reduced – quick assembly of the structure – occupied territories can be used for agricultural needs
Disadvantages	– non-renewable energy resources are used – a number of pollutants are released into the atmosphere – violation of the thermal balance of water bodies – consume atmospheric oxygen	– large capital investments – radioactive waste – the probability of an accident leading to irreversible consequences – a long period of dismantling work	– occupy significant territories – are located only in certain places – noise pollution – an obstacle to the spread of radioactive vibrations – threat of the death of wildlife – specific quality of metal per structure, which is characterized by contamination in the production of parts

Conclusion. It is obvious that any anthropogenic activity has a negative effect on the environment, and it is impossible to achieve an absolutely environmentally friendly way of obtaining and selling energy, therefore it is necessary to constantly be in search of solutions to minimize this impact.

Based on all the facts and arguments presented in the article, it can be concluded that with a detailed analysis, taking into account and minimizing possible factors of negative impact on the environment, in particular humans, the wind power plant is the safest power generation station. Atmospheric pollution during the operation of the wind power plant is insignificant, compared with traditional energy. Even taking into account the CO_2 emissions during the production of materials and equipment for wind power plants, their safety is many times greater than thermal power plants. Reducing emissions into the atmosphere from the operation of wind power plants improves the quality of life of the population. And speaking on a global scale, such energy saves the resources of our planet

References

1. Leskina A. N., Goshtynar A. S., Bizhanov S. A. Zhiznennyy tsikl ob'ektov stroitel'stva i upravleniya nedvizhimost'yu. Simvol nauki. 2016;1:132–137 (In Russ.)

2. Krylov D. A. «Toxicity» of coal-fired heat and power generation. Mining Industry. 2016;129(5). Available from: https://cyberleninka.ru/article/n/toksichnost-ugolnoy-teplo-elektrogeneratsii (accessed: 29.06.2021). (In Russ.)

3. Galiulin R. V., Galiulina R. A. Heavy Metal Pollution in the Territory of Chelyabinsk upon Coal Combustion. Solid Fuel Chemistry. 2013;2:62—64. (In Russ.)

4. Yadutov V. V., Petrov T. I., Zatsarinnaya Yu. N. Vozdeystvie TES na okruzhayushchuyu sredu. Vestnik Kazanskogo tekhnologicheskogo universiteta. 2013;19(16):78–79. (In Russ.)

5. Rolik Yu. A. Upravlenie innovatsionnymi vetroenergeticheskimi proektami. Author's thesis. Riga: Transport and Telecommunication Institute, 2008. 186 p. (In Russ.)

6. Gornostay A. V., Rolik Yu. A., Bulekov A. V. Ekologicheskie aspekty vozdeystviya vetroenergeticheskikh ustanovok na okruzhayushchuyu sredu. Nauka — obrazovaniyu, proizvodstvu, ekonomike: materialy 14-i Mezhdunar. nauchno-tekhnicheskoi konferentsii. Minsk, 2016;1:63. (In Russ.)

7. Shavlis A. K. Vliyanie vozobnovlyaemykh istochnikov energii na okruzhayushchuyu sredu. Aktual'nye problemy energetiki: materialy studencheskoi nauchno-tekhnicheskoi konferentsii. Minsk, 2018. p. 540–541. Available from: https://rep.bntu.by/handle/data/51583 (accessed: 15.06.2021). (In Russ.)

8. Guzhavina T. A., Lastovkina D. A., Ozerova O. Yu. Life Quality in the Estimates of Region's Population. Problems of territory's development. 2016;2(82):98–111. (In Russ.)

9. Krylov D. A. Otsenki udel'nykh vybrosov SO2 i NOX v atmosferu dlya sushchestvuyushchikh elektrostantsiy Rossii, szhigayushchikh kuznetskiy i kansko-achinskiy ugli, s uchetom vsey energeticheskoy tsepochki: ot dobychi etikh ugley do potrebleniya ikh na TES. Preprint Mezhdun. tsentra po ekologicheskoy bezopasnosti Minatoma Rossii. Moscow, 2001. p. 40. (In Russ.)

10. Abalkina I. L., Demin V. F., Novikov S. M. et al. Ekonomicheskie parametry otsenki riska dlya rascheta ushcherba, obuslovlennogo vozdeystviem na zdorov'e naseleniya raznykh faktorov. Issues of risk analysis. 2005;2(2):132–138. (In Russ.)

11. Krylov D. A., Sidorova G. P. Radioactivity of Coal and Ash-Slag TPP Wastes. Atomic Energy. 2013;114(1):43–47. (In Russ.)

12. Bubenchikov A. A., Demidova N. G., Malkov N. G. Ekologicheskaya ekspertiza vetroenergeticheskoy ustanovki. Molodoy uchenyy. 2016;28–2(132):31–35. (In Russ.)

13. Beznosov V. N., Suzdaleva A. L., El-Shair Kh. I. A. Otsenka ekologicheskoy bezopasnosti ob'ektov vetroenergetiki. Enegy fresh. 2011;3–4:37–43. (In Russ.)

14. Ryzhenkov M. A. Ekologicheskaya otsenka vozdeystviya VES na okruzhayushchuyu sredu v protsesse ekspluatatsii. Advances in Chemistry and Chemical Technology. 2011;25(10):28–32. (In Russ.)

15. Kotelenko S. V., Ryabov A. S. Preimushchestva i nedostatki netraditsionnoy energetiki. News of the Tula state university. Technical sciences. 2018;12:84–88. (In Russ.)

Received 24.09.2021
Revised 11.10.2021
Accepted 11.10.2021

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Contribution of the authors:

Y. S. Borisova — construction of research goals and objectives, search for literary sources, analysis, text preparation, conclusions; N. S. Samarskaya —formulation of the concept of the article, the choice of topics, scientific supervision, analysis of the results, revision of the text.