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ENVIRONMENTAL ASPECTS OF USING NUCLEAR ENERGY

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Abstract

Nuclear technological production of electricity is characterized as a low-carbon technology, which on the one hand, has key importance in terms of reducing greenhouse gas emissions, while on the other hand there are numerous controversies, defensive approach and anxiety due to the danger of nuclear accidents and solving the problem of radioactive waste. Starting from the actuality and importance of the issue of the use of nuclear energy in the context of solving environmental changes, the paper carried out a thorough review of literature. On this occasion, the paper carried out an insight into the existing relevant scientific knowledge in this field and a secondary analysis of the contents of documents of relevant international institutions, which within their competence publish data on the energy state and current emissions of greenhouse gases on a global level. The majority of papers emphasize the advantage of the use of nuclear energy in comparison with the generation of energy in the process of combustion of fossil fuels. It is primarily stated that small amounts of radioactive gases, which are regularly discharged under controlled conditions in the operation of nuclear power plants, cannot produce effects such as acid rain, smog, ozone depletion and do not contribute to an increase in temperature of the troposphere. However, the possibility of producing nuclear accidents and the severity of the consequences if radioactive isotopes leave the reactor uncontrollably, and the generation of radioactive waste results in a dilemma in the scientific and social community and creates a division in the acceptance of nuclear energy as an alternative to the use of fossil fuels.

***Keywords**: environment, nuclear energy, climate change, sustainable development.*

1. INTRODUCTION

Problematization of issues related to different aspects of energy and environmental protection is of interest and is one of the key factors of long-term strategies for the sustainable development of modern countries (Filipović, *et al*). Some authors give to nuclear energy a key role in global power, meeting global energy needs and reducing environmental pollution (Fiore, 2006). Others believe that nuclear energy is important for the development of long-term environmental and energy strategies (Hong, *et al*., 2014; Verbruggen, *et al*., 2014). Nuclear energy is recognized as "great potential" for reducing the use of fossil fuels in global energetics (Kim & Edmonds, 2007). In addition, one of the crucial conditions for the planning, construction and commissioning of nuclear power plants is the preliminary consideration of the realized and expected environmental impact. The greatest impact relates to radioactive isotopes and the fact that their release can have significant repercussions on human health and the environment (Cvetković, 2013; Cvetković&Popović, 2011; Cvetković & Mlađović, 2015).

Nuclear energy has significant environmental benefits compared to fossil fuels. Under normal conditions, the nuclear plant almost does not produce harmful gases. Small amounts of radioactive gases are dischargedregularly under controlled conditions and pose no danger to workers and the surrounding population. Gaseous emissions from fossil fuel power plants pose a significant risk to human health and the environment. The basic gases are carbon dioxide, nitrogen oxides and various heavy metals including mercury as the most important. Adamantiades and Kessides state that nuclear energy does not pose a threat to humans and the environment compared to fossil fuel power plants (Adamantiades&Kessides, 2009).

2.USE OF NUCLEAR ENERGY AND MITIGATION OF CLIMATE CHANGE

Climate change is considered to be the greatest sustainability problem because it causes practically irreversible transformations of the Earth's climate system. These transformations will likely affect all future generations by compromising food and water supplies, leading to acidification of the oceans by absorbing greenhouse gases, ablation, more intense heat waves and other extreme weather conditions. The Earth's climate system is heated due to an increase in the concentration of greenhouse gases, in particular due to emissions, resulting from the burning of fossil fuels in the energy sector. The stabilization of atmospheric concentrations of SO_2 in order to avoid major climate change requires a global approach.

From the surface of the Earth, huge amounts of natural and industrial gases are emitted to the atmosphere, which in the upper zones of the atmosphere initiate greenhouse effects. The greenhouse gases form an air cover that absorbs a part of the thermal radiation from the Earth's surface and partly prevents the loss of heat into the universe, contributing to the warming of the atmosphere. Due to the greenhouse gas phenomenon, over the past 100 years the global temperature on the Earth's surface has increased, on average, from 0.4 to 0.8C°. In addition, without the emission of gases, the temperature on the Earth would be lower by around 3°C in relation to the current average temperature (Ramanathan& Feng, 2009; Pruess et al, 2003). According to the Intergovernmental Panel on Climate Change report, each of the last three decades has been successively warmer than any previous since 1850. Period from 1983 to 2013 was probably the hottest thirty-year period in the last 1400 years at the Northern Hemisphere (IPCC, 2014:2). The greatest contribution to the phenomenon of greenhouse effect is given by carbon dioxide emissions (SO_2), then methane (SN_4), nitrogen oxide (N_2O), fluorocarbons (HFCs), perfluorocarbons (PFCs), sulfurhexafluoride (SF_6) (Gor, 2008:28). The greenhouse gases and global warming equivalents are shown in Table 1.

Table 1: Greenhouse gases and global warming equivalents. Source (Metz et al, 2005).

Greenhouse gases	Global warming equivalents
carbon dioxide (SO_2)	1
methane (SN_4)	21
nitrogen oxide (N_2O)	310
fluorocarbon (HFC)	6 500-9 200
perfluorocarbon (PFC)	140-11 700
sulfurhexafluoride (SF_6)	23 900

According to Table 1, the reduction of 1 ton (t) of SN_4 is equal to and can be expressed as a reduction of 21t SO_2e; reduction of 1t N_2O corresponds to a reduction of 310t SO_2e, while 1t SF_6 is equal to a reduction of 23900t SO_2e. According to the International Energy Agency, the world's largest greenhouse gas emitters are China and the United States (USA), followed by the big national companies (IEA, 2016a). According to Benson, a reduction in emission, that is, emitted amount of greenhouse gases into the atmosphere, can be achieved (Benson, 2005): through reduced use of fossil fuels; increased energy efficiency; use of renewable energy sources (Sun, wind, biomass, water, geothermal, etc.); collecting industrial gases that are discharged into the atmosphere and their storage in underground geological formations.

Carbon dioxide can be separated from flue gases at the site of stationary sources and deposited in the deeper layers of the Earth's crust in the long term. Storage processes, that is, the existence of the storage, is planned for a longer period of time, for a thousand (or more) years (Bach, 2000). According to UN projections, nuclear power and renewable energy sources have the potential to respond to increased demand for energy without additional carbon dioxide emissions. The urgency in the cope with climate change and environmental impact is outlined in the thirteenth goal of sustainable development on climate actions, as well as in the agreement signed in December 2015 in Paris (UN, 2015a).

Without nuclear energy, the current global CO2 emissions due to energy consumption would be about 7% higher, depending on the use of fossil fuels being replaced (Turkenburg, 2004). The use of nuclear energy emits small amounts of fine dust and gases such as SOx and NOx which can not cause effects such as acid rain and smog neither damage to the ozone layer. All processes generally produce negligible amounts of carbon components (NEA, 2000). The use of nuclear energy contributes not only to the reduction in greenhouse gases, but also to the reduction in emissions of other pollutants such as sulphur dioxide, nitroxide, suspended particles and volatile organic compounds. Consequently, nuclear energy and other low

carbon technologies have prevented the emission of significant amounts of greenhouse gases over the past decades. It is estimated that in the period between 1970 and 2012, combined electricity generation from nuclear power plants, hydroelectric power plants and other renewable sources avoided emission of over 157 gigatons (Mileti& Darlington) SO_2 compared to emissions if these amounts of electricity were obtained from coal, oil or natural gas. In the Fifth report of the Intergovernmental Panel on Climate Change (IPSS), the Working Group No. III confirmed the significant potential of nuclear energy in the global decarbonisation of the economy, and especially the energy sector. Scenarios in line with the goals of the Paris agreement, projected more than double increase in the capacity of generating nuclear power (from 383 GW in 2015 to 930 GW in 2050) (IAEA, 2016: 51).

3.NUCLEAR ACCIDENTS AND RADIOACTIVE WASTE

The mentioned environmental advantages of nuclear energy in comparison with fossil fuels remain out of focus in the moment when radioactive isotopes leave the nuclear reactor uncontrollably. Bearing in mind the nuclear reactor accidents: Three Mile Island, Pennsylvania, USA, 1979, then major accidents in Chernobyl in 1986, and the most recent horror of nuclear disaster at the Fukushima nuclear power plant in 2011, there has been a change in the policy related to the mode of energy production in many countries. This raised the questions of environmental, social and economic risks of energy strategies that rely on nuclear technology (Rehner & McCauley, 2016: 289). Taking into account possible accidents at nuclear power plants, one of the first countries that opted to make decision on their accelerated shutting down and abandoning nuclear energy by 2020 was Germany. Swiss citizens have also opted for an accelerated process of shutting down nuclear reactors that provide 40% of electricity in the country. However, at the end of 2016, within the framework of energy planning until 2050, the Swiss government decided to reject a proposal to accelerate the shutdown of nuclear power plants and to leave them in operation until it was considered safe (Greiser, 2016).

The management and disposal of nuclear waste is probably an issue where the gap between the advocates and the opponents of nuclear energy is the biggest. Many in the industry believe that technical solutions are available, but politically blocked, while others see this backlog as a reason for blocking the use of nuclear power (Turkenburg, 2004). Annually 8 to 10 billion tons of waste are generated worldwide (this excludes mining and waste from mineral extraction, which is usually not counted as waste). Of this, about 400 megatons is hazardous waste, and less than 0.5 megatons is radioactive waste. About 2 to 3% of this radioactive waste, called high-level waste, is a particular challenge because of its radiotoxicity and long half-life. The remaining 97 to 98% (representing only 8% of radioactivity) can be classified into low-level and medium-level radioactive waste (McCombie, 1997). Non-radioactive waste also comes from the production of nuclear energy, but is not limited to fields of nuclear power. In some cases, this waste is deposited in landfills, while in the case where waste contains toxic and dangerous elements, special management, treatment and disposal are required. If this waste is not managed properly, it can cause significant effects on the environment and human health and significantly increase the environmental footprint of a country that has a nuclear facility in its area. The environmental footprint measures the impact of people on their environment and takes into account data such as the amount of arable land and water needed for production, for disposal of waste resulting from this production (Wackernagel & Rees, 1998). Significant waste reduction and management are stated in the twelfth goal for sustainable development in 2015 within the new global agenda for sustainable development.

4.NUCLEAR ENERGY AS A BASE OF SUSTAINABLE DEVELOPMENT IN THE FUTURE

The concept of sustainable development was first formulated in the 1980s. In the World Commission on Environment and Development report, entitled Our Common Future, sustainable development is defined as a development that meets the needs of present generations, without depriving future generations of opportunities to meet their needs (WCED, 1997: 7). In order to achieve sustainable development, environmental protection must become an integral part of the development process. The Brundtland Commission confirms the need for further economic growth in order to achieve further economic progress of developing countries, but only on condition that development is sustainable. Half a decade after the Brundtland Commission at the UN Conference on Environment and Development in Rio de Janeiro in 1992, a declaration was adopted with twenty-seven principles of sustainable development. All Member States were recommended to establish national strategies for achieving sustainable development goals. The concept of

sustainable development began to be studied in almost all the sciences, interpreted and analyzed in thousands of articles and became an integral part of many historical developmental and theoretical disciplinary paradigms. In addition to the advocates, the concept has had its critics since its inception. Even those who accept and promote its content, refer to the uncertainty of this notion. Gidens highlights the inaccurate definition of the concept and the contradiction between the two basic terms "sustainability" and "development", stating that "sustainability" implies continuity and balance, while "development" means dynamics and change, and while ecologists are interested in the aspect of sustainability, governments and companies are interested in development, usually in terms of the growth of gross domestic product (Gidens, 2009: 79). Others who start from the classic theoretical postulates of liberal economic science, in interpreting and "imposing" a sustainably arranged world, see a kind of conspiracy against free and individual market development, similar to social engineering that was sought to be achieved by Communism and Marxism (Demonja, 2014).

In addition to numerous criticisms and the very fact that the concept of sustainable development does not imply legal commitment, thus each member state independently decides on the acceptance of the principles of sustainable development and implementation of national strategies for sustainable development, the concept has managed to survive. Based on the principles of the UN Conference on Environment and Development in Rio and the Millennium Development Goals, it was strengthened on 25 September 2015 at the Sustainable Development Summit. One of the documents adopted at the Rio de Janeiro Conference was the Sustainable Development Plan, the so-called *Agenda 21*, which states that the approach to solving environmental problems and sustainable development planning must be based on strategic planning. The United Nations Commission on Sustainable Development (CSD) has been established to monitor the implementation of Agenda 21, which is a comprehensive and well-elaborated strategy for global partnership and the implementation of the sustainable development concept throughout the world.

Although the idea of sustainability stemmed from an environmentally-oriented analysis of reality, it could not stay only an idea of the natural environment, resources and environment, without economic concretization and social changes that followed inevitably. Namely, the lives of people are based on their economic activities and the way of doing these activities. In order to find a common solution for many socio-ecological problems, the United Nations Member States have adopted the Sustainable Development Program by 2030. The program contains 17 Sustainable Development Goals (SDG), dealing with the most important challenges of today and therefore called the *Global Goals*. Sustainable Development Goals (SDGs) are an upgrade and expansion of the eight Millennium Development Goals agreed by the UN member states to try to achieve by 2015.

At the ninth session of the Commission on Sustainable Development (CSD), nuclear energy was part of a controversial debate. On this occasion, there were disagreements between the countries that accept nuclear energy as the basic component of national sustainable development strategies, and those that consider nuclear energy fundamentally incompatible with the concept of sustainable development. Nuclear energy is associated with numerous dangers in terms of nuclear safety, spent fuel, cross-border potential consequences, hazardous waste management, and the decommission of nuclear facilities. Through adopted document CSD-9, the states agreed that nuclear energy has no role in sustainable development, and the choice of nuclear energy has been left to the states (UN, 2001: 8). A few years later, at the Summit on Sustainable Development in Johannesburg in 2002, nuclear energy was recognized in the category of advanced energy technologies for improvement of energy efficiency of countries. Three aspects of sustainable development defined in the Johannesburg Declaration of Sustainable Development at the United Nations World Summit on Sustainable Development in 2002 are environmental, economical and social. When it comes to economic aspects of sustainable development, one considers the investments necessary for the construction of nuclear power plants, access to resources (uranium), methods of financing the construction and maintenance of an adequate level of safety, in relation to significant return investments on the other side. The ecological dimension is recognized through the global contribution to mitigating climate change, protection of natural resources (water and land), biodiversity, the entire ecosystem, and biogeochemical cycles. Social aspects are recognized through the impact on human health as well as on other social relationships including education, culture, perception and public participation in decision-making.

3. CONCLUSION

Bearing in mind the increase in global demand for energy, concerns occur in almost all countries in the world, and many opt publicly to stimulating the production of energy produced and used in a way that at the same time helps in developing and satisfying the vital needs of the population now and in the future. When making decisions at the national level, politicians in their long-term developmental energy strategies opt for different sources of energy, primarily oil, coal, natural gas, wood and coal, and then for the most varied renewable sources of energy, solar, wind, hydropower, biomass, nuclear, etc.

A detailed insight into relevant scientific papers published in prestigious scientific journals produced a conclusion that nuclear power compared to fossil fuels has significant ecological advantages, especially when it comes to decarbonisation of the economy. The majority of papers state that nuclear energy, under normal conditions, almost does not produce harmful gases, and that small amounts of radioactive gases, which are regularly released under controlled conditions, can not cause effects such as acid rain, smog and ozone depletion. Thus, nuclear energy can be considered as a good support to global action to mitigate climate change.

In addition to the possibility of nuclear energy to prevent climate change and air pollution, there is still disagreement over the danger of nuclear accidents and the solution of radioactive waste. The negative attitude of the public is influenced by the security risks of nuclear energy production and potential nuclear disasters, risks of environmental contamination by radioactive isotopes and the problems of adequate disposal of nuclear waste. Waste generation is a key issue of sustainability that relates to resource use and proper waste management to avoid long-term consequences for people and the environment.

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