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Advantages and Disadvantages of Renewable Energy Sources Utilization

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ABSTRACT

Renewable energy sources are still not the predominant energy resource in the energy sector, although in certain developed countries they participate in a significant share in electricity generation. It is estimated that world energy consumption from renewable energy sources exceeds 20% at the present and continues to grow. Renewable energy sources appear as an additional source of energy in the conventional electro-industry. The main reason for the increasing investment and exploitation of renewables is certainly environment preservation and environmental aspect of sustainability. This study seeks to expand the existing literature and contribute to a comprehensive understanding of the characteristics of renewable energy sources as a whole. Therefore, the purpose of this paper is to determine the advantages and disadvantages of renewable energy sources utilization in general, without considering the individual type of renewables, such as wind or solar energy. Thereby, the paper presents numerous advantages of using renewable energy in the electricity generation, such as environment preservation in terms of reduced greenhouse gas emissions or improvement of innovations and technical/technological development. There are also presented certain disadvantages of renewables in the production of electricity, such as dependence on weather conditions or low energy efficiency and low ability to produce electricity.

Keywords: Renewable Energy Sources, Boosting the Economy, Environment Preservation, Renewables Limitations

JEL Classifications: Q42, Q56

1. INTRODUCTION

Alternative or renewable forms of energy appear as a supplement to conventional forms of energy, and, although in certain developed countries they participate in a significant share in energy production, they are still not the predominant energy resource in the energy sector. It should be noted that, in addition to the production of electricity, alternative forms of energy provide a significant role in the production of thermal energy. Renewable sources in electricity / heat generation do not pollute the environment with greenhouse gas emissions and enable the use of limited fossil resources in the future. This is the main reason for the increasing investment and exploitation of renewable energy sources.

The increase in use of alternative forms of energy is a consequence of growing economic development of individual national

economies (the classification of the International Monetary Fund, the World Bank or the United Nations Development Program can serve as a criterion for economic development). On the other hand, the production and use of alternative energy plants encourages the development of new technologies in energy, the development of entrepreneurship and, ultimately, the entire economy, confirming the mutual impact on each other.

In analysing renewable energy sources, the existing literature presents a number of advantages and disadvantages of their overall utilization. Thus, Mohtasham (2015) pointed out that application of any renewable energy requires a sustainability analysis, which has dependency on three main components, which are environmental effects, externalities costs, and economics and financing. Ellabban et al. (2014) indicated global benefits of renewable energies production where they categorized it to environmental, economic,

technological, social and political aspects. In addition, they proposed renewable energy market development process and depicted barriers to renewable energy technology deployment. Moreover, Peidong et al. (2009) presented disadvantages of renewable energy development policy in China, which could be lack of coordination and consistence in policy, weakness and incompleteness in encouragement system, lack of innovation in regional policy, incomplete financing system for renewable energy projects or inadequate investment in the technical research and development for renewable energy. On the other hand, Liu (2017) explored the influence of renewable energy policy in China and strategy for its development. Maradin et al. (2017) analysed positive and negative economic effects of renewable energy technologies. They have shown that renewable energy technologies have a multiplier effect in stimulating the economy and the development of not only the energy sector but also all the supporting activities related to such industry. In addition, the advancement of technology enables the costs of renewable energy technologies to decrease (Akinci, 2019). Decreasing investment costs also stimulate competition in the renewable energy sector (Tokic et al., 2020). Furthermore, competitive activity in the renewable energy sector has again an impact on cost reduction and efficient operation of energy companies.

It is necessary to emphasize that the majority of studies analyse an individual renewable energy source as a separate category, without considering them as a whole. To the best of authors' knowledge, afore-mentioned represents a notable lack of researches in the field of renewable energy sources, their advantages and disadvantages. Therefore, this study seeks to expand the existing literature and contribute to a comprehensive understanding of the characteristics of renewable energy sources.

Given the mentioned above, the purpose of this paper is to determine the advantages and disadvantages of renewable energy sources utilization in general, without considering the individual type of renewables, such as wind or solar energy. Thereby, the paper presents numerous advantages of using renewable energy in the electricity generation, such as environment preservation in terms of reduced greenhouse gas emissions or improvement of innovations and technical/technological development. There are also presented certain disadvantages of renewables in the production of electricity, such as dependence on weather conditions or low energy efficiency and low ability to produce electricity.

In analysing alternative forms of energy, this paper first defines the concept of alternative, namely renewable forms of energy, after which numerous advantages and disadvantages of using renewable energy sources in electricity generation are explained. Finally, the conclusions of the research are presented.

2. DEFINING RENEWABLE ENERGY SOURCES

At the current stage of technical-technological development, fossil fuels supply most of the world's energy requirements. Although

there are questions about the availability of energy resources, environmental pollution and related limitations in their use, fossil fuels are expected to be an important resource in providing energy in the coming decades, especially electricity (Dresselhaus and Thomas, 2001). However, in order to meet the growing global energy needs while preserving the environment, and to leave the possibility of using fossil fuels in the future, alternative "clean" energy sources are being developed that do not depend on fossil resources and have an acceptable impact on the environment.

Precise definition of alternative energy sources is "challenging," primarily due to the existence of diverse energy resources and choices, as well as various goals that promote their operation. However, in less words, alternative energy sources are all those energy sources that are an alternative to fossil resources. Although certain authors (Michaelides, 2012; Kowalski, 2011) state nuclear energy as one of the sources of alternative forms of energy and there are conflicting views in this regard, this paper does not analyse the justification or challenge of such inclusion nor does nuclear energy be viewed in the context of alternative forms of energy.

The expression alternative forms of energy are commonly used for renewable energy sources. Renewable energy sources are defined as any energy resource that can be naturally renewable at a rate comparable to or faster than the energy consumption rate of that resource or as a durable resource that is abundantly available in nature (van Vliet, 2012). Renewable energy sources are inexhaustible sources, namely even though energy conversion processes consume them, their quantities are only temporarily depleted and they can always be compensated or renewed (Labudović and Barbir, 2002). Strielkowski et al. (2013) stated that the renewable energy sources are able to endorse independence, employment and inherently improve environment, as it will be presented in this study. Apart from the fact it leaves the option of using fossil fuels in the future, the use of renewable energy sources has an impact on the preservation of the environment as well as it contributes to the ecological aspect of sustainability as the direct use of renewable sources, in principle, does not pollute the environment (Denona et al., 2012). This is one of the main advantages in encouraging the production of electricity from renewable sources.

More specifically, Nezhnikova et al. (2018) argued that the use of renewable energy sources has increased significantly in recent years due to a number of advantages: (i) First, from the point of view of energy security, renewable energy sources can provide opportunities for diversification of fuel mixtures; (ii) secondly, the widespread use of renewable sources reduce the impact on the environment (reduce CO₂ emissions and air pollution); (iii) thirdly, renewable energy sources are actively used in packages of measures to restore the economy in response to the global economic downturn; (iv) fourth, renewable energy sources can be one of the most effective tools for solving the problem of access to energy.

Renewable energy sources can be divided into wind energy, solar energy, hydropower, energy obtained from biomass (plant

matter), geothermal energy (Earth's heat) and ocean energy, which can include wave energy, tidal energy and sea current energy (Armstrong and Hamrin, 2000). It is estimated that world energy consumption from renewable energy sources has increased by about 4 times in the last decade, and at present exceeds 20% and continues to grow (Chubraeva and Sergey, 2018).

In this regard, the next part of the paper analyses the ecological dimension of renewable energy sources, and namely the resulting greenhouse gas emissions of individual renewable sources during the overall life cycle of a renewable plant, and other benefits achieved through the use of renewable energy sources.

3. ADVANTAGES OF RENEWABLE ENERGY SOURCES UTILIZATION

Alongside with the growing interest in the availability and availability of fossil energy resources and the exponential growth of energy demand over the last decades, renewable energy sources are becoming an important additional energy resource in meeting the needs, especially for electricity. Utilization of natural, unlimited energy resources from the environment with the aim of converting them into electricity, while ensuring the environmental aspect, gives renewable energy sources numerous advantages in their use, primarily the protection of environment. This is especially evident by the fact that renewable energy sources account for zero or almost zero percent of greenhouse gas emissions and other air pollution (United Nations Development Programme, 2000).

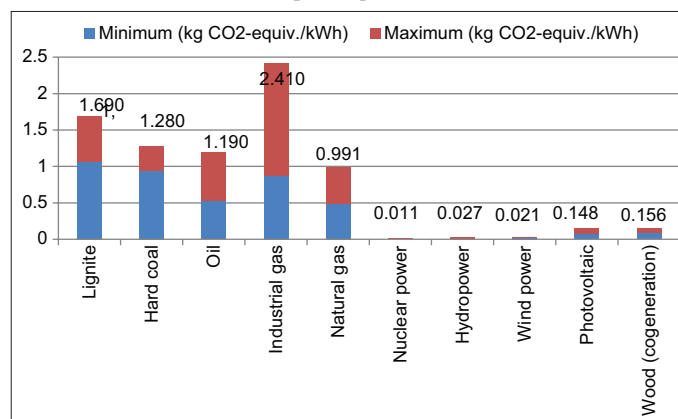
A comprehensive indicator of environmental pollution caused by a certain type of power plant in the activity of electricity production can be determined by the overall lifetime of an individual power plant. The assessment of the overall life cycle of different types of power plants understandably shows the highest level of greenhouse gas emissions in thermal power plants that use fossil fuels in electricity production. Greenhouse gases, as a by-product of electricity generation, do not occur in the application of nuclear energy. Since this is unlike fossil resources, this is also one of the reasons for observing nuclear energy in the context of "renewable sources". However, in this case, the radioactive nuclear waste, which has a high impact on the environment and human health, is being forgotten.

If the overall life cycle of a plant using a renewable energy source is observed, the emission of greenhouse gases expressed in carbon dioxide (CO₂) equivalent is still extremely small or negligible. The following Graph 1 shows the range of greenhouse gas emissions (expressed in kilograms of carbon dioxide [CO₂] equivalent per kilowatt-hour [kWh]) over the life cycle of different types of power plants.

In their overall life cycle, power plants using conventional renewable energy sources, such as wind or hydropower, have insignificant amounts of greenhouse gas emissions, which confirms their environmental acceptability.

It is precisely the negative externalities caused by pollution from the combustion of conventional, fossil fuels that are one of

Graph 1: Greenhouse gas emissions during the entire life cycle of a power plant



Source: Dones et al., 2004

the main arguments for promoting the production of electricity from renewable energy sources. As environmentally friendly energy resources, renewable energy sources appear primarily in the electricity system as additional support to already existing conventional energy plants in providing additional amounts of electricity. This directly affects the reduction of fossil fuel energy that would otherwise be consumed in a conventional power plant to produce an equal amount of electricity. Also, renewable energy sources reduce dependence on imports, primarily electricity, but also the import of the necessary fossil energy resources – fuels that produce electricity.

Another advantage in the use of renewable energy sources is manifested in the encouragement of economic development, namely the development of the energy sector and all related activities related to this industry. Renewable sources have a significant multiplier effect on those countries whose industry is capable and able to produce energy machinery and equipment based on technological innovations, especially in their exports (Granić, 2010).

The innovation that promotes technical/technological changes in new market structures has been identified as the most important benefit of renewable energy sources utilization (Fankhauser et al., 2008). In fact, innovations are related to new technological processes in the renewable energy sector that lead to the improvement of business processes and economic growth. Also, technological changes and innovation, as well as the gradual development of renewable energy technologies, increase demand for qualified workforce, thus directly boosting employment. In addition to the above, policy measures that contribute to environmental preservation and sustainable development are highlighted. One such measure is the so-called energy-based economic development, which integrates economic development and energy policy and planning into a new field of managing national economies. Energy-based economic development is defined as the process in which decision makers in economic and energy planning and development, government officials and other public authorities, energy regulators, industry representatives, and other market participants tend to increase energy efficiency and/or diversification of energy resources in a way that creates new jobs,

maintains employment, and encourages the prosperity of the region (Carley et al., 2011). The essence of the concept of energy-based economic development lies in fulfilling economic and energy development needs. Thus, the fundamental objectives relate to the increase of energy efficiency, diversification of resources and self-sufficiency, improvement of industry and economic growth and development, development of entrepreneurship, encouragement of technological innovation, increase in the level of employment and specialization, and so on. The pioneers in the development of clean “green” technologies have an opportunity to become regional or even global leaders in the industry. The example of Germany must be pointed out here, as this country is the leader in the export of renewable energy technologies (Fankhauser et al., 2008; Simas and Pacca, 2013).

Renewable energy sources are generally considered to have a strong effect on increasing employment, especially on the employment of the local population where a particular renewable source is located. Research has shown that this is not entirely correct, but differs significantly depending on the degree of activity of the life cycle of the plant that exploits the renewable energy source. Although each segment of renewable energy has specific characteristics, they all have a common life cycle that includes five phases (Llera-Sastresa et al., 2010):

1. Research and design
2. Development and manufacture
3. Construction and installation
4. Operation and maintenance or service
5. Updating and/or dismantling.

In order to adequately present the impact of a power plant life cycle on the quantity and quality of employment, the place and duration of employment, and the indirect development of the “green” economy, the abovementioned five phases are modified into three main phases: (1) technological development, (2) installation/uninstallation of a power plant and (3) operation or managing and maintenance of technological plants.

The first two phases (i.e., research and design, and development and manufacture) are commonly seen as a separate whole, due to their complementary work areas and identical generated employment. This creates a new starting phase of a life cycle, called technological development. Despite the third and the fifth phase being distant in time (i.e., construction and installation, and updating or dismantling), they create a single phase of installation/uninstallation, since there is no difference in terms of the types of activities and characteristics of engaged employment. Activities related to the maintenance of power plant operations comprise the third and the last phase of the life cycle. For example, some of these activities include management and maintenance of a wind power plant; the collection, supply and logistics of work of

a biomass power plant; and other activities related to the normal functioning of renewable energy power plants (Maradin et al., 2017). The impact of the three aforementioned life cycle phases of renewable energy technology on the previously mentioned elements of employment is shown in Table 1.

This division of power plants’ life cycle into phases could be useful for determining the need for a strategy that generates employment opportunities in one of the three phases, such as encouraging technological innovation (which increases the impact on local employment in the first phase) or professional specialization (which reduces the need for foreign engineers and technology installers). The amount of employment is particularly high in the installation/uninstallation phase, due to the workforce needed in the process of construction and installation, modernization and/or dismantling of the power plant. The adverse economic effect in this phase is temporary employment, because once the plant is built or dismantled, there is no more need for such specialized workforce. On the other hand, the management and maintenance of renewable energy power plants does not require much workforce, particularly in the case of the wind power industry (Maradin et al., 2017). Studies show that 20 MW of installed wind farm capacity requires only one or two full-time workers to operate and maintain a wind farm during its 20 to 30-year life expectancy (e.g. Maradin, 2015). The level of expertise and specialization in the maintenance and repair of faulty components does not need to be particularly high, since the case is of mid-level complexity, so this job permanently employs mainly local workforce, which is certainly an advantage in exploiting renewable resources. Every national economy aspires to achieve the phase of technological development, which ensures the greatest economic effects of renewable energy sources. Although the quantity of employment in this phase is of mid-level complexity, the quality of employment is very high, because many technical and technological achievements and improvements are applied; research and development influence the innovation. The substantial benefit of this phase is permanent employment (Maradin et al., 2017).

In addition to the many benefits of using renewable energy sources in terms of environmental benefits, reducing fossil fuel consumption and import dependence, stimulating economic development and the impact on increasing employment, the presence of renewable energy sources in rural areas, especially those underdeveloped, can contribute their economic development and in general the civilizational need for electricity. This environment is particularly suitable for investments in renewable energy sources, mostly due to the lack of alternative development projects in that area. In this way, renewable energy sources provide much-needed electricity in areas where the electrical grid is underdeveloped or does not exist, such as remote villages or islands (Sreeraj et al., 2010). The extension of the power grid

Table 1: Phases of the life cycle of the exploitation of renewable energy sources and influence on employment

Phase	Volume of employment	Location of employment	Duration of employment	Level of specialisation
Technological development	Medium	From foreign to local	Stable	Very high
Installation/uninstallation	High	From local to foreign	Temporary	High
Operation and maintenance	Low	Local	Stable	Medium

Source: Llera-Sastresa et al., 2010

in rural areas is not economically viable due to the high costs of electricity distribution. Therefore, electricity off the grid which is produced in the hybrid system of renewable energy resources enables the process of rural electrification and brings benefits for the community (Borhanazad et al., 2013).

However, it should be noted that renewable energy sources are not always the best solution in providing additional quantities of electricity and in their delivery to the electricity network there are certain shortcomings and difficulties that are presented in the following part of the paper.

4. DISADVANTAGES OF RENEWABLE ENERGY SOURCES UTILIZATION

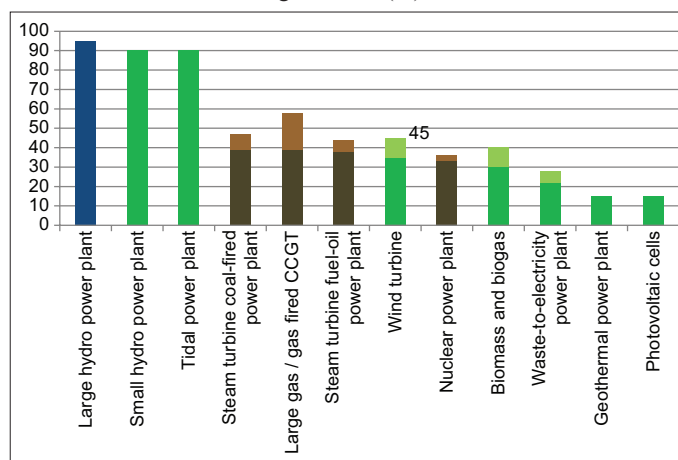
In addition to the multiple advantages of using renewable energy sources, there are certain disadvantages and limitations in their daily use. It is primarily due to their natural features that renewable sources depend entirely on geographical location and weather conditions, namely the volatility and unpredictability of the renewable source is a significant limitation and difficulty in electricity generation. This limitation can be alleviated by quality planning and careful site selection for a particular renewable energy source, as well as by conducting measurements and making environmental studies. Also, due to the large daily oscillations in the availability of a renewable source on the basis of which electricity is generated, it is necessary to consider the possibilities of accepting renewable electricity into the electricity system. There must always be a sufficient reserve in the electricity system network in the form of available installed power of the power plant that can eliminate the deficiency that occurs when a particular renewable energy source is not available. Furthermore, the electricity network at a certain location can receive only a certain amount of electricity without the risk of overloading and / or disturbing the stability of the power system. It is pointed out that the biggest difficulties in accepting electricity into the grid are posed by wind companies, primarily due to the relatively high installed capacity of wind farms, and therefore their power must be limited in each power system to ensure stable and safe operation of the entire electricity sector (<http://www.hep.hr/oie/oie/nestalnostIzvara.aspx>).

When comparing renewable energy sources with traditional fossil energy resources; renewable sources have a lack of capacity (capacity) to produce electricity, they are not able to produce as large amounts of electricity as power plants with fossil fuels. In order to try to reduce this shortcoming, it is necessary to further invest in the development of renewable energy technologies, but also simply to build more renewable energy plants (Agboola, 2014). In addition to this, renewable energy sources also have a lower ratio of installed plant power (in MW) or electricity production (in GWh) to the area of the location (in m²) occupied by the power plant, compared to fossil fuel power plants. This means that renewable energy plants should have a much larger area than thermal power plants in the production of the same amount of electricity. In addition to the required surface area, renewable energy sources also achieve relatively lower energy efficiency,

with the exception of water resources and wind farms. Efficiency in electricity generation can be defined as the ratio between the usable electricity output generated in a generating entity in a given unit of time and the energy value of energy resources delivered to the generating entity at the same time (Honorio et al., 2003). The efficiency of different technologies, i.e. certain types of energy resources in power plants is shown in the following Graph 2.

The presented values of energy efficiency of different production technologies represent the minimum and maximum level of efficiency of a certain power plant. Renewable energy sources, such as “clean” energy, are shown in green; large hydropower plants, as plants that significantly affect the ecosystem, are pointed out in blue; while thermal and nuclear power plants are shown in brown. It is stated that the energy efficiency of oil-fired thermal power plants can be from 38 to 44%, coal-fired power plants from 39 to 47%, gas thermal power plants up to 39%, but if we consider gas thermal power plants in a combined process (consisting of gas-turbine and steam-turbine part), then increases the efficiency of the energy process itself, which reaches up to 58%, because almost simultaneously produces thermal energy and electricity. It is also pointed out that the nuclear power plant has a relatively low energy efficiency of 33 to 36%. Renewable energy sources achieve relatively lower energy efficiency, apart from the already mentioned hydro power plants. In addition, biomass and biogas power plants have an efficiency of 30 to 40%, waste power plants from 22 to 28%, while photovoltaic and geothermal power plants have the lowest energy efficiency of 15% (Honorio et al., 2003). On the other hand, large hydropower plants have the highest energy efficiency of 95%, which, although they contain renewable water resources, are not classified as renewable energy sources. Thus, large hydropower plants have the most efficient technology for electricity production. Likewise, extremely high efficiency of as much as 90% are possessed by renewable power plants “on water resources,” namely small hydro power plants and tidal power plants. Although it is stated that the average wind power plant has an energy efficiency of about 35%, in the most modern wind turbines it can reach 45%. Moreover, theoretically the highest possible level of wind energy utilization in a wind turbine is defined by the so-called Betz law or Betz limit and it

Graph 2: Efficiency of different technologies in electricity generation (%)



Source: Honorio et al., 2003

is 59.3%. No currently available sophisticated wind turbine can have an energy efficiency higher than the stated 59.3% (<http://www.vjetrolektrane.com/moderni-vjetroatregati-i-pretvorba-energije?showall=1>). This means that, in reality, less than half of the kinetic energy of wind can be used as useful electricity in wind power plants.

Similarly, due to their natural characteristics and availability of energy, renewable sources generally operate for a shorter time period in hours in 1 year at full power (at maximum utilized capacity) compared to fossil power plants. For example, noting that one calendar year contains 8760 h, coal-fired or gas-fired power plants and nuclear power plants can operate on average up to 7500 h/year at installed (full) power, while renewable energy sources (wind or solar energy) on average operate at only about 2000 h/year at maximum power (Blesl et al., 2008). It is stated that onshore wind power plants typically operate from 2000 to 2500 h/year, while offshore wind power plants operate as much as 4000 h/year at maximum capacity, primarily due to less wind turbulence and higher wind speed. This indicates the operation of the power plant only at the installed (full) power during 1 year. It is normal to expect the operation of the power plant for a larger number of hours per year, but not with the maximum utilized production capacity. Similar to this indicator, it is necessary to point out the capacity factor indicator which represents the ratio of the actual amount of energy delivered to the electricity network during the year and the potential amount of energy that could be produced if the power plant operates at maximum installed capacity during all 8760 h/year. Equivalent to the number of hours of operation of a power plant at full power during 1 year, renewable energy sources have a significantly lower capacity factor than fossil fuel power plants. Thus, e.g. wind power plants have a capacity factor of only about 20 to 35% depending on the natural characteristics, namely wind characteristics and geographical location and technical capabilities of wind turbines, compared to about 60% of the capacity factor of other forms of power plants in electricity generation.

A significant disadvantage of even greater use of renewable energy sources is certainly their relatively high cost of electricity production. The literature suggests a higher cost of building a renewable energy plant compared to fossil power plants. This is especially true for power plants that use marine energy, whose technology is extremely expensive, and due to the specificity of the location, this energy source participates in a negligible share in electricity production. The construction of photovoltaic systems is also a high cost, also due to the high cost of technology and the complexity of making solar panels (<http://www.hep.hr/oie/oie/visokaCijena.aspx>). Depending on the factors involved in the formation of the price of electricity production by comparing renewable and non-renewable sources, different projections appear. This is illustrated by the following example. Assessing the economic competitiveness of power plants using different types of fuel, a study was conducted in Finland (Tarjanne and Kivistö, 2008) which analyses and compares the cost of electricity production from nuclear power plants, gas-fired combined heat and power plants, coal-fired power plants, biomass power plants (peat and wood), and a wind power plant. This seeks to explore an economic alternative for additional electricity generation in

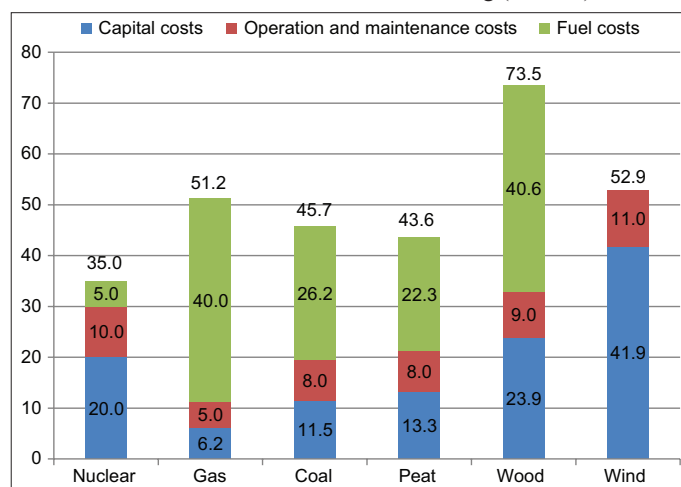
non-performing (basic) power plants. Looking at the price level (for example, the price of building a power plant, fuel prices, etc.) from the beginning of 2008, the calculations are shown in the following Graph 3.

Observing three types of costs; capital costs, management and maintenance costs of the power plant and fuel costs, the higher costs of electricity production of the plant (expressed in €/MWh) on renewable energy sources are evident, with the exception of biomass plants that use fuel peat, relative to fossil fuel plants. This is due to high capital costs, especially in the construction of wind farms, which capital costs (41.9%) are by far the highest in the structure of the observed entities, and almost the same fuel costs in the form of timber in biomass plants (40.6%). Out of the observed power plants, wind power plants, which use (basically) unlimited wind energy resources, are the only ones that do not have fuel costs. In the observed period, gas plants also have a significant amount of fuel costs (as well as wood biomass plants), but with a very low level of other costs.

If the costs of electricity generation of electricity plants include the costs of trading carbon dioxide (CO₂) emissions, renewable energy sources become competitive with fossil, conventional energy plants. This is shown in the following Graph 4.

Taking into account the ecological component of electricity production, due to exhaust gases into the atmosphere, namely harmful emissions that occur as a by-product of electricity production and which should be limited, gas, coal and peat plants (the earliest form of coal generation) have an additional cost of electricity production. energy. Limiting greenhouse gas emissions is carried out through the cost of emission rights; the market price of certificates of emissions into the environment, which at the time of publication of the results of the survey (2008) by Graph 4 amounted to about 23 €/t CO₂. It should be noted that today's price (14 December 2020) of the environmental certificate (emissions trading) is higher and amounts 30.92 €/t CO₂ (<https://www.eex.com/en/market-data/environmental-markets/auction-market>).

Graph 3: Electricity generation costs of different power plants and their structure, without emission trading (€/MWh)

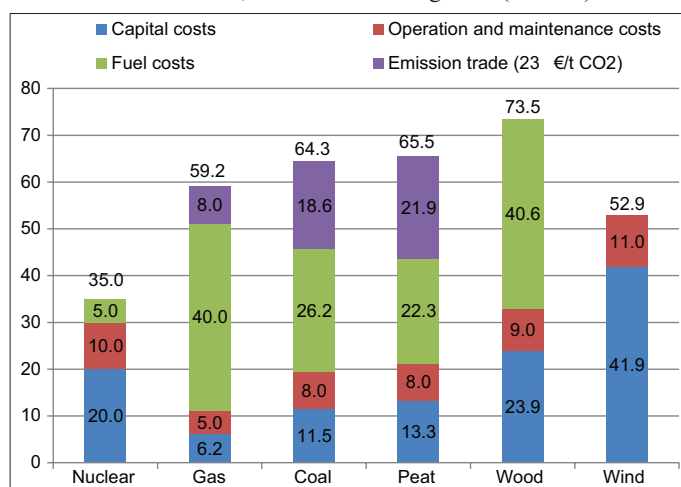


Source: Tarjanne and Kivistö, 2008

Table 2: Advantages and disadvantages of using renewable energy sources

Advantages	Disadvantages
Environmental protection (reduced greenhouse gas emissions)	Weather conditions dependence
Reduced fossil fuel consumption	Non-continuity and unpredictability
Reduced energy imports dependence	Acceptance of renewable electricity in the power system
Stimulating the development of innovation and the economy	Low ability to produce electricity
Increasing employment	Low energy efficiency
Rural development	Low maximum capacity utilization/low capacity factor
Reduction of energy scarcity (expansion of rural electrification capacities)	Relatively high cost of electricity production

Source: Author

Graph 4: Electricity generation costs of different power plants and their structure, with carbon trading costs (€/MWh)

Source: Tarjanne and Kivistö, 2008

With the aim of reducing greenhouse gas emissions, trade in environmental emission certificates for EU Member States began on 1 January 2005. The purchase of the certificate was conceived as an alternative to the failed project of introducing a single tax on emissions into the environment. The certification system covers greenhouse gas emissions into the atmosphere and other gases that have a detrimental effect on the ozone layer. All gases are denominated in carbon dioxide equivalents (Mance and Škalamera-Alilović, 2013). Including the trading of environmental emission certificates, thus the newly incurred cost of producing electricity from fossil fuels is higher than the cost of producing a wind farm. This suggests that in the process of electricity production it is necessary to consider and include the overall operating costs of the power plant, in order to qualitatively and adequately assess the efficiency of operations.

5. CONCLUSION

From all the above, it can be stated that renewable energy sources have numerous advantages and disadvantages in providing additional quantities of electricity, and their application should be seen primarily in the context of improving the electricity sector and the development of the national economy. In order to highlight the advantages and disadvantages of using renewable energy sources, which are presented in this paper, the following Table 2 is given.

Renewable energy sources, as environmentally friendly energy resources, will become even more important in the future, because

they are unlimited and provide additional energy forms along with the existing conventional power plants (Cеровić et al., 2014). Despite of some disadvantages of using renewables, and taking into consideration this literature overview, it can be perceived that the advantages outweigh the disadvantages of renewable energy sources utilization for the overall society.

This study could be further widened in order to analyse the use of specific, individual renewable energy source in a particular national economy. Starting from the assumption that each country has its own specifics, it could be useful to consider which renewable energy source can be utilized to the greatest extent in fostering the sustainability and progress of the economy.

6. ACKNOWLEDGMENT

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REFERENCES

- Agboola, A. (2014), Public sensitization on the adoption of renewable energy in Nigeria: Communicating the way forward. *IOSR Journal of Humanities and Social Science*, 19(5), 74-81.
- Akinci, T.C. (2019), Intelligent systems in renewable energy sources. In: Bostancı, S.H., Yıldırım, D.Ç., Nişancı, E., editor. *İktisadi Teknik ve Strateji Boyutları ile Türkiye’de Enerji Sorunsalı*. Turkish: Ekin Pub. p229-262.
- Armstrong, A.J., Hamrin, J. (2000), *The Renewable Energy Policy Manual*. Washington, USA: United States Export Council for Renewable Energy.
- Available from: <http://www.hep.hr/oie/oie/nestalnostIzvora.aspx>. [Last accessed on 2015 Feb 23].
- Available from: <http://www.hep.hr/oie/oie/visokaCijena.aspx>. [Last accessed on 2015 Feb 25].
- Available from: <http://www.vjetroelektrane.com/moderni-vjetroagregati-i-pretvorba-energije?showall=1>. [Last accessed on 2015 Mar 09].
- Available from: <https://www.eex.com/en/market-data/environmental-markets/auction-market>. [Last accessed on 2020 Dec 28].
- Blesl, M., Wissel, S., Mayer-Spohn, O. (2008), Private costs of electricity and heat generation. *Cost Assessment of Sustainable Energy Systems*, 1, 1-47.
- Borhanazad, H., Mekhilef, S., Saidur, R., Boroumandjazi, G. (2013), Potential application of renewable energy for rural electrification in Malaysia. *Renewable Energy*, 59, 210-219.
- Carley, S., Lawrence, S., Brown, A., Nourafshan, A., Benami, E. (2011), Energy-based economic development. *Renewable and Sustainable*

- Energy Reviews, 15(1), 282-295.
- Cerović, L.J., Maradin, D., Čegar, S. (2014), From the restructuring of the power sector to diversification of renewable energy sources: Preconditions for efficient and sustainable electricity market. *International Journal of Energy Economics and Policy*, 4(4), 599-609.
- Chubraeva, L., Sergey, T. (2018), Project of Autonomous Power Plant with High-Temperature Superconductive Devices. In: 2018 International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), Institute of Electrical and Electronics Engineers. p1-5.
- Denona, B.N., Cerović, L.J., Maradin, D. (2012), The security of electricity supply as the determinant of sustainable development. *Marketing and Management of Innovations*, 3(2), 254-265.
- Dones, R., Heck, T., Hirschberg, S. (2004), Greenhouse gas emissions from energy systems, comparison and overview. In: *Encyclopaedia of Energy*. Vol. 3. San Diego, USA: Academic Press/Elsevier. p77-95.
- Dresselhaus, M., Thomas, I. (2001), Alternative energy technologies. *Nature*, 414, 332-337.
- Ellabban, O., Abu-Rub, H., Blaabjerg, F. (2014), Renewable energy resources: Current status, future prospects and their enabling technology. *Renewable and Sustainable Energy Reviews*, 39, 748-764.
- Fankhauser, S., Schelleier, F., Stern, N. (2008), Climate change, innovation and jobs. *Climate Policy*, 8(4), 421-429.
- Granić, G. (2010), Kako Promišljati Energetsku Budućnost? [How to Rethink Energy Future?]. Zagreb, Croatia: Poslovna biblioteka, Energy Institute Hrvoje Požar.
- Honorio, L., Bartaire, J.G., Bauerschmidt, R., Ohman, T., Tihanyi, Z., Zeinhofer, H., Scowcroft, J.F., de Janeiro, V., Kruger, H., Meier, H.J., Offermann, D., Langnickel, U. (2003), Efficiency in Electricity Generation. Brussels, Belgium: Eurelectric Union of the Electricity Industry.
- Kowalski, K.M. (2011), *Alternative Energy Sources*. New York, USA: Marshall Cavendish Benchmark.
- Labudović, B., Barbir, F. (2002), *Obnovljivi Izvori Energije*. [Renewable Energy Sources]. Zagreb, Croatia: Energetika Marketing.
- Liu, Z. (2017), China's strategy for the development of renewable energies. *Energy Sources, Part B: Economics, Planning, and Policy*, 12(11), 971-975.
- Llera-Sastresa, E., Aranda-Usón, A., Bribián, I.Z., Scarpellini, S. (2010), Local impact of renewables on employment: Assessment methodology and case study. *Renewable and Sustainable Energy Reviews*, 14(2), 679-690.
- Mance, D., Škalamera-Alilović, D. (2013), Certifikati emisija u okoliš priznavanje u financijskim izvještajima [European Union Emission Allowances and their Recognition in Financial Reports]. *TIM4PIN MAGAZIN Specijalizirani časopis centra za razvoj javnog i neprofitnog sektora*. *TIM4PIN MAGAZINE Specialized Journal of the Center for Public and Nonprofit Sector Development*, 11, 27-35.
- Maradin, D. (2015), The Efficiency of Wind Power Companies in Electricity Generation. Doctoral Dissertation. Rijeka, Croatia: University of Rijeka Faculty of Economics and Business.
- Maradin, D., Cerović, L.J., Mjeda, T. (2017), Economic effects of renewable energy technologies. *Naše gospodarstvo/Our economy*, 63(2), 49-59.
- Michaelides, E.E.S. (2012), Alternative energy sources. In: *Part of the Green Energy and Technology Book Series (GREEN)*. Berlin, Heidelberg, Germany: Springer-Verlag.
- Mohtasham, J. (2015), Review article-renewable energies. *Energy Procedia*, 74, 1289-1297.
- Nezhnikova, E.V., Okhremenko, I.V., Papelniuk, O.V. (2018), Investigation of the features of investment in the development of renewable energy sources: Main consumers, legal regulation, equipment, rates and delivery. *International Journal of Energy Economics and Policy*, 8(4), 178-186.
- Peidong, Z., Yanli, Y., Yonghong, Z., Lisheng, W., Xinrong, L. (2009), Opportunities and challenges for renewable energy policy in China. *Renewable and Sustainable Energy Reviews*, 13(2), 439-449.
- Simas, M., Pacca, S. (2013), Socio-economic benefits of wind power in Brazil. *Journal of Sustainable Development of Energy, Water and Environment Systems*, 1, 27-40.
- Sreeraj, E.S., Chatterjee, K., Bandyopadhyay, S. (2010), Design of isolated renewable hybrid power systems. *Solar Energy*, 84(7), 1124-1136.
- Strielkowski, W., Krška, Š., Lisin, E. (2013), Energy economics and policy of renewable energy sources in the European Union. *International Journal of Energy Economics and Policy*, 3(4), 333-340.
- Tarjanne, R., Kivistö, A. (2008), Comparison of Electricity Generation Costs. Lappeenranta University of Technology, Faculty of Technology, Department of Energy and Environmental Technology, Research Report EN A-56.
- Tokić, A., Akinci, T.C., Zengin, A.T. (2020), Bosnia and Herzegovina's Renewable Energy Policy and Perspective. *International Journal of Energy Economics and Policy*, 10(5), 524-530.
- United Nations Development Programme. (2000), *World Energy Assessment: Energy and the Challenge of Sustainability*. United Nations: United Nations Development Programme.
- van Vliet, B. (2012), Renewable resources. In: Southerton, D., editors. *Encyclopedia of Consumer Culture*. Thousand Oaks, California, USA: SAGE Publications, Inc., p1212-1214.