ENVIRONMENTAL INNOVATIVE TECHNOLOGY, CO_2, AND GREEN ENERGY

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There is a growing interest in the world for environmental protection, climate change mitigation, energy security, and sustainability of production and energy capacities of innovative renewable energy sources Increasing industrial activity has caused air pollution due to projected particles of pollutants. There are global concerns about the increased CO_2 emissions and risks to human health and sustainable development. The paper aims to apply technologies that reduce the use of fossil fuels and CO_2 emissions as much as possible. Green environmental technology is relevant worldwide because it contributes to the decarbonization and development of new technologies in the energy sector and enterprises. The purpose of the paper is to point out to decision-makers an innovative approach to the use of new technologies, which would indicate the future directions of green sustainable development. By applying different methods in the paper, it is concluded that all countries have to introduce modern technologies and innovative energy development, not only improve the quality of life of all citizens of Serbia but also of all inhabitants of the planet.

Keywords: CO_2, environmental technology, energy innovation, green development.

Introduction

The decarbonization of the energy sector has a key role to play in climate neutrality by 2050, as a significant percentage of fossil fuels are used in the energy system of countries around the world. For several decades, the global temperature of the planet Earth has been rising due to the greenhouse effect, which can have catastrophic consequences for the health and life of people around the world. All the governments of the world have to enable the temperature to rise to a maximum of 2 °C. By gradually reducing emissions and successfully decarbonizing, it is important to stop or reduce the combustion of fossil fuels, such as oil, natural gas, and coal. Acceptable solutions are: 1. technological eco-innovation and renewable energy sources that have effects on CO_2 reduction; 2. creating national energy and climate plans for each country; 3. introduction of eco-innovative sources for the production of electricity from renewable sources; 4. market design - internal energy market should be formed for new energy networks; 5. harmonization of national policy with global goals of climate neutrality and change; 6. harmonization of interregional policy, 7. providing individual national reports with current EU data, following the elements of the "European Green Deal" [1]. Ecological technological innovations are very important in the initial phase because it is estimated by IEA experts that about a 35% reduction in CO_2 emissions requires technology that is still in the "prototype" and "demonstrative" phases of development. About 40% of the technologies that have been innovated have not yet been introduced or commercially applied. Examples that are in commercial use and accepted by consumers are lithium-ion batteries and LEDs, which took about 10 to 30 years to go from the prototype phase to the phase of mass commercial use, i.e. to the market [2]. It is further suggested, given the uncertainty about deadlines and costs, that progress in eco-technological innovation should be accelerated in the initial phase, so that governments and companies can more efficiently and quickly pursue the global goal of "zero emissions" by 2050. The synergy of different technologies is necessary for a more favorable and cheaper way of introducing ecological innovations and technological progress, i.e. it is possible to introduce small modular technologies, such as solar panels [2].

Material and methods

The method used is based on a review of the literature related to ecological technological innovations. The method of measuring through the innovation index was used based on the obtained results of the index, development policies and the way for their implementation are defined. A comparative method, case study, and SWOT analysis were applied to use the results to define development projects for environmental technological innova-

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tion, and to create and implement a green policy, without the effects of greenhouse gases (GHG) or carbon dioxide (CO_2). The development of advanced technological green development and green policy requires monitoring and adjustment in certain segments. The paper combines theoretical, statistical, and comparative analysis regarding the relatively new economic and technological categories of eco-innovation, i.e. ecologically advanced technologies. The synergy and implementation of certain Danish strategies and policies create the conditions for the introduction of technological innovations in the energy sector, with the aim of decarbonizing and mitigating climate change. The results of the research provided quantitative and qualitative insight into the challenges that Serbia needs to face, to identify areas based on comparative indicators, and innovation index. The analysis highlighted the need for creative and innovative policies and resources that have identified strengths and weaknesses, opportunities and obstacles concerning Serbia's existing capacities. This means adopting a green strategy that contains the necessary measures for ecological technological innovation in the energy sector with a gradual reduction of fossil fuels and CO_2. The results showed existing national capacities and identified key areas that require government focus in formulating a new national strategy for environmental technology, innovation, energy efficiency, and green development. In this regard, it is pointed out that it is important to raise awareness among all decision-makers, at all levels, in all institutions, and among all citizens about advanced technological innovations in the energy sector. In this way, opportunities are created for green transformation, development of green industry, environmental sustainability, and sustainable ecologically innovative technological development.

Technology Readiness Level (TRL) method

Today, many countries use the Technology Readiness Level (TRL) method, which assesses the level of readiness for the market for a demonstrated eco-innovation technology project and is an integral part of the European “Horizon 2020” program. Based on a certain scale, technological priorities for program and project design are examined by researchers and technology developers around the world [3]. The TRL method contains six scales: 1) The “Concept” or theoretical scale of technology, has three levels: the first level of the scale represents the initial idea and defines the basic principles; the second level is the formulation of the initial idea and all variants of the concept and application; the third level is the legitimacy of the concept, i.e. with the variant of application of the prototype of the technological research project; 2) The “Small prototype scale” of the eco-innovation project, represents the first phase of the innovation/project prototype and is tested under certain conditions; 3) The “Large prototype” or pilot scale of technology, includes all components of a large prototype of a technological project that have been tested and proven under certain conditions; 4) The scale "Demonstration", or pilot phase of testing, means presentation of the technological innovations under certain conditions immediately before commercial use; 5) The "Early adoption" or a commercial scale of technology is a technological process in the relevant environment for commercial use, at the same time, there is a need for further integration of components of all sizes and a requirement for an evolutionary outcome and competitiveness test over a period of time; and 6) The “Mature”, or maturity phase in scale technology is a technological and commercial phase of readiness for the realization of a technological eco-innovation project and for predicting the achieved technological growth [3]. The mentioned project scales of technological readiness [3] in the number and design of various clean energy sectors are: Buildings (and infrastructure), Transport, Industry, Power technological generation, Fuels transformations, as shown in Figure 1:

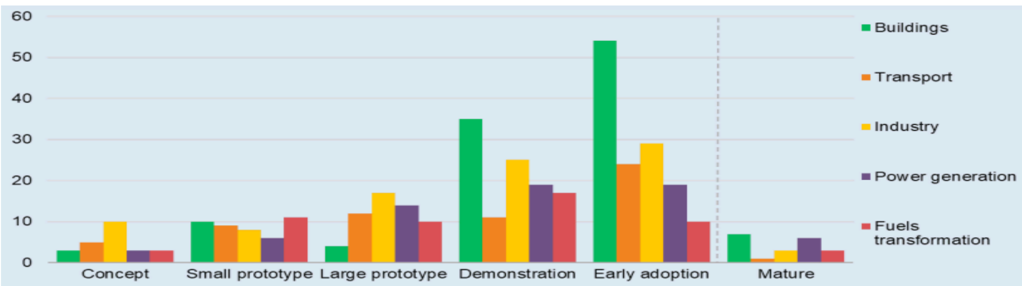

Figure 1. Scales and projected clean environment energy technologies.

To determine key data on the development of eco-innovation in technology, based on the active research for the periods 2020 to 2050 at intervals of ten years, [4], the following method was used to calculate: leveled energy costs - LCOE, leveled heat costs - LCOH, and the leveled cost of CO_2 DAC - LCOD, based on the calculation of the equation. All project readiness scales [3] were taken into account during the research. For the periods from 2020 to 2050, with intervals of ten years, they determined the key data of the development of eco-innovation in technology, based on active research. The equation and calculation were presented as follows: *capex* - capital costs; *crf* - annuity factor; *opex* - annual operational costs (expenditures); *Output* CO_2 - annual production of DAC plant; *FLh* - total load hours per year; *DACel.input* - electricity demand of DAC plant per ton of CO_2 produced;

DACheat.input - heat demand of *DAC* plant per tCO_2 produced; *fuel* - fuel costs; *η* - efficiency; *COP* - coefficient of performance of heat pumps; *N* - lifetime; *WACC* – the weighted average cost of capital, where *WACC* of 7% was used for calculation, *el* - electricity, *fix* - fixed, *th* - thermal, *var* – variable. Leveled electricity cost - *LCOE*, leveled heat costs - *LCOH,* leveled cost direct capture of CO_2 from the air - *LCOD*, and annuity factor - *crf*, are calculated as follows:

$$LCOE = \frac{Capex.\ crf + Opex_{fix}}{Flh} + Opex_{var} + \frac{fuel}{\eta} \qquad (1)$$

$$LCOH = \frac{Capex.\ crf + Opex_{fix}}{Flh} + Opex_{var} + \frac{fuel}{\eta} + \frac{LCOE}{COP} \qquad (2)$$

$$LCOD = \frac{Capex_{DAC}.\ crf + Opex_{fix}}{Output_{CO_2}} + Opex_{var} + DAC_{el.input}.\ LCOE + DAC_{th.input}.\ LCOH \qquad (3)$$

$$crf = \frac{WACC.(1 + WACC)^N)}{1 + WACC)^N - 1} \qquad (4)$$

According to calculations and future projections, it is assumed that by 2050 in the following sectors: a) electricity (waste-energy, power-gas, sewerage), b) transport (road, sea, air, rail), and c) industrial sector (chemical industry, cement, pulp and paper factories, etc.) the following changes will occur: 1. high rates of direct electrification based on renewable energy sources; 2. synthetic fuels and chemicals will replace the fossil fuels; 3. carbon will be removed from the energy system; 4. the main energy potential will be the remaining capacities of the direct air capture (DAC) [4]. In modern conditions, new ecological potentials and innovative technologies for decarbonization have appeared in the form of systems for capturing, storing, and using CO_2 (CCUS - Carbon Capture Utilization Storage), unlike five decades ago when CO_2 was used in various industries only for ammonia processing and natural gas [3]. Carbon capture and storage (CCS) contributes to mitigating CO_2 emissions that are captured directly from the air, or bioenergy, then transported and stored as raw material for other uses. Before compressing CO_2 to a critical pressure of 73.8 bar, carbon is purified from flue gas impurities and transported in the gaseous or liquid state. The most optimal variant is by pipelines with a transport capacity of 1-5 million tons and distances of more than 2400 km. Ships have an advantage in terms of pipelines because they have terminals and developed hubs. Also CO_2 is transported by tanks, trucks, ships, or rail, depending on the capacity, distance, and type of terrain.

The traditional way of storing (sequestration) CO_2 includes storing CO_2 in various physiological formations, but also abandoned mines and salt caves. Although the global storage capacity is large, some physiological formations have limited capacities: formations of deep saline solution of 1000-10000 Gigaton CO_2 (Gt CO_2); oil reserves of 675-900 Gt CO_2, while coal formations of 3-200 Gt CO_2. CCUS is a technological process of: a) capturing CO_2 directly from the atmosphere where it originated from industrial sources, such as coal-fired power plants, b) storage, and c) using it to prevent it from entering the atmosphere. In addition to the CSUS variant, to reduce the harmful effects of carbon, it is necessary to improve energy efficiency by using fuels with reduced CO_2 emissions: nuclear energy, renewable energy sources, and biological sinks. CCS and its application depend on the diffusion and transfer of technology during economic development, expansion of technology and its innovations, technological maturity, and capacity, regulatory framework, public perception, etc. which is specific to each country. The optimal level of CO_2 concentration in the greenhouse is not determined or defined by the UN Convention on Climate Change [5]. However, although the optimal stable CO_2 level is not defined by the 1992 United Nations Framework Convention on Climate Change (UNFCCC), which emphasizes the importance of stabilizing greenhouse gas emissions at a level that would prevent irreversible damage to the climate system, the optimal level of CO_2 can be determined as follows: 1. the level at which the rate of CO_2 is equal to the rate at which CO_2 emissions can be removed is the level of stabilization; or 2. the optimal level of CO_2 is when the level of anthropogenic emissions is in balance with the level of natural processes, atmospheric reactions in which CO_2 is removed to the biosphere or oceans. If the stabilization rate is lower and the baseline greenhouse gas emissions are higher, then a greater reduction in emissions below the baseline emissions is needed. The level of CO_2 emissions is directly dependent on these factors: 1. the size of the world's population (Population), 2. the level of global wealth (GDP/Population), 3. the energy intensity of the global economy (Energy/GDP), and 4. emissions that arose in the process of production using energy (Emissions/Energy), which can be shown by the equation [5]:

$$CO_2 = Population\ x\ \frac{GDP}{Population} + \frac{Energy}{GDP} + \frac{Emission}{Energy} \qquad (5)$$

It is concluded that there is a trend in the world to continuously increase energy consumption, and increase the population, while at the same time, declining slowly, the amount of energy required per unit of GDP, in many countries. To achieve a high level of CO_2 reduction, significant changes in the third and fourth factors in the equation, energy intensity, and emissions from energy technology are needed, assuming other factors, first, population and second, wealth (GDP), remain constant. This indicates that there are global demands for global policy to focus on intensive reduction of energy emissions of CO_2, i.e. greenhouses, and positive results of stabilizing CO_2 levels are possible depending on the level of use of eco-innovative advanced technology [5].

Environmentally innovative energy technologies

1. Photoreduction technology CO_2 includes photocatalytic CO_2 reduction systems, as follows: 1) the first photocatalyst is with 0D (zero dimension - quantum dot), 2. the second is with 1D, which is one-dimensional in the form of nano-tubes, nano-rods, 3. the third is with 2D, two-

dimensional, in the form of nano-plates, or atomic layers, and 4. the fourth is a 3D photocatalyst that represents three-dimensional, hollow nanostructures, microstructures. According to [Ulmer et al., [6], the advantages of using CO_2 photoreduction technology are: 1. high energy density of stored “synthetic” natural gas (SNG) which is a medium for storing excess renewable energy sources; 2. infrastructure for storage, distribution, and use of SNG is largely in use and easily accessible; 3. SNG has added a use-value, 4. SNG has a sufficient amount, and 5. CO_2 and H_2O are raw materials with relatively low prices. SNG is produced with energy-to-gas (PtG) conversion technology. Solar PtG is used in the process of electrolysis of water. Then, with the use of photovoltaic cells, a chemical reaction is started. “Sustainable production of “synthetic natural gas (SNG) is possible through the conversion of CO_2 and water (H_2O) into CH_4 and oxygen (O_2) using renewable energy such as sunlight. This reaction proceeds as follows” [6]:

$$CO_2 + 2H_2O \rightarrow CH_4 + 2O_2 \quad (6)$$

The conversion of CO_2 into solar methane, as a form of advanced eco-technology, is still being investigated and is not yet in commercial use [6].

2. E-fuels - synthetic liquid fuels are a product of the synthesis of carbon and hydrogen, which is why they are called synthetic fuels. The following sources are used for their production: electricity from the sun or wind, water where hydrogen is obtained after electrolysis, and CO_2 is obtained from the atmosphere. Industrial production of e-fuels based on hydrogen derivatives is suitable where areas are rich in solar energy and wind, which is an economically viable way of using energy. These sources are considered neutral sources because they do not emit CO_2 and are an innovative alternative to energy sources. They play a significant role in the demand for renewable energy sources in the field of global energy transition and innovation. Also, advanced technological fuels have transport, distribution, and infrastructure applications because they can be used to launch airplanes or ships, heating systems, or gas stations. EU electricity production from fossil fuels, especially coal and natural gas is projected to decline gradually with innovative generations of electricity, synthetic hydrogen and methane, and renewables, especially wind and solar, by 2050. The production of innovative renewable energy sources will be doubled by the application of advanced technology in the projected period [1].

3. Digital technology contributes to the increasingly transformed energy network into renewable energy sources. The use of renewable wind and solar sources is driving the growing need to introduce and spread digital technology. It is used in substation automation, automation distribution, network application monitoring, and database exchange, which integrates data from wind farms, solar farms, etc. Network operators match supply to demand via the Internet, e.g. for V2G network vehicles, which connect to EV batteries in which energy is stored and serves for smart charging of electric vehicles. This expands the need for new customer requirements in the market and new strategies for the decarbonization of electricity. Digitization in the industry applies smart manufacturing that uses 3D printing, robots, artificial intelligence, and automated technologies, which has effects on optimization of production, supply chain, and resource use [7]. Lafarge Holcim's Company as “tomorrow plant”, was launched in 2019. The plant uses virtual and predictive simulations in cement production to increase productivity and reduce operating costs and energy consumption. The operational efficiency of production capacities has a positive effect on environmental improvement, i.e. on the reduction of CO_2 emission intensity by 15 to 20 %. Digitization is a key determinant of eco-innovation technology for decarbonization, for the introduction of which there are certain obstacles due to numerous requirements. For the realization of digital potentials and for reducing the effects of the greenhouse, a broader integrative approach of all institutions and synergies of different sectors is necessary: financial, infrastructural, energy, environmental, information technology, and educational sectors of the national economy.

4. Carbon Capture Storage (CCS) technology in the energy sector is a technology for capturing and storing CO_2. This type of technology has positive effects on the resilience and reliability of low-carbon networks in power plants equipped with appropriate network stabilization, through control of voltage, frequency, inertia, and control. The introduction of CCS after the production of fossil fuels creates less favorable cost opportunities for countries that are predominantly dependent on fossil fuels, coal, which is the case with China, India, some countries in Southeast Asia, and Serbia.

5. Direct Air Capture and Carbon Sequestration (DACCS) is a technology that captures CO_2 directly from the atmosphere, which has the following advantages: industrial carbon capture plants are located near storage sites, where CO_2 can be injected into appropriate underground geological storage facilities, or they are located where they have access to renewable sources for electricity generation, which affects cost reduction. In this regard, the Alam-Fatwedt cycle for the production of natural synthetic gas "syngas" is known, which is used for the production of electricity with the help of inseparable, i.e. inherent CO_2 capture. The plant uses oxygen fuel that burns CO_2, while the built-in system of the plant pre-captures CO_2, then compresses, dehydrates, and eliminates unwanted gases NOx and SO, creating a "working" gas. The resulting syngas product is used to produce low-carbon electricity. Other forms of reduced CO_2 emissions, such as nuclear energy, renewable energy sources, biological sinks, etc., are used to mitigate greenhouse effects and energy efficiency.

6. Digital decarbonization in the energy sector is a process of energy system transformation. Decarbonization reduces the greenhouse effect and CO_2 emissions

and is implemented through special industrial software developed by a digital company, for example, GE Digital. The company's software serves to make electricity production smarter, more innovative, more efficient, more reliable, safer, and more resilient, to reduce waste and achieve climate change goals. The company's goal is to develop new digital technologies and transform the energy system, which will help companies move forward and ahead of time, with adequate service from the company. ADMS (Advanced Distribution Management System) is an advanced management solution within the digital transformation program "Digital Utilities", which includes two digital energy platforms: Digital Small World Electric Office and Geographic Information System (GIS). The system will provide companies with energy services to solve many problems, operational efficiency, and smart management. It will also create an energy platform that will be resilient to climate change. Opportunities will be created to improve energy efficiency and investment conditions [8].

7. Smart electrical grid

Electricity transmission system operators (TSOs) represent the secure transmission of energy from generation facilities to regional or local electricity distribution operators through the electricity grid. A smart electricity grid is a network that uses digital information and communication technologies related to the supply and consumption of electricity. The European Network of Transmission System Operators for Electricity (ENTSOE) has defined the following upcoming priority objectives in the publication "European Commission Roadmap 2050", for the period from 2017 to 2026, which relate to the transition tasks to a low-carbon electricity system: 1. modernization of the electricity system, 2. security and stability of the system, 3. the flexibility of the power system, 4. economy and efficiency of the power system, and 5. ICT and digitalization of the power system. The importance of investments in the research and development (R&D) sector was emphasized, as it was determined that the existing investments are insufficient for electricity system operators. Thanks to research and development activities, there is an opportunity to identify advanced technological needs for electricity networks, identify potential risks and means to mitigate them and improve efficiency in energy policies and investments in infrastructure. Investments in research and development bring huge benefits. The size of the investment required for effective TSO research and development is relatively small, but the potential long-term benefits of research and development are enormous. Through Pan-European research and development, transmission operators will be in a position to progressively identify new functional and technological needs for networks in a more coordinated way.

Moreover, research and development (R&D) provides the means to mitigate the potential risks of failure in energy policies and infrastructure investments. Besides, long-term and insufficient public funding for R&D has affected the importance of incentives for investment. The "Common Information Model" created serves to integrate renewable energy sources, through a unique and balanced electricity grid infrastructure into the energy system, which is achieved through a continuous exchange of information between companies [9]. The European Union has adopted, based on the Third Energy Package, numerous regulations, methodologies, laws, standards, and a set of network codes. In this way, opportunities are created for connecting through the operating network system and for connecting customers and producers in the electricity system and services, which would unite a single European energy platform.

Measuring ecological technological innovations (eco-innovation)

The European Regional Innovation Scoreboards (European RIS) include, in addition to EU countries, other non-member European countries, such as Serbia. Eco-innovative countries are the leaders of innovation to the greatest extent: Switzerland (1), Sweden (2), Finland (3), Denmark (4), and Belgium (5), and in contrast, the least innovative countries are beginner innovators, such as Croatia, Hungary, Serbia, Slovakia, Poland, Latvia, Bulgaria, and Romania. Unlike the European RIS, according to the Global Innovation Capabilities (GII), highly developed countries have the best performance in innovation capabilities [10]. As the GII Composite Index contains more than 80 indicators, the main pillars of the Composite Index are: 1. Institutions, 2. Human Capital Research, 3. Infrastructure, 4. Market sophistication, 5. Business sophistication, 6. Knowledge and technologies - Output, 7. Creative outputs. Out of a total of 132 observed countries, the best are ranked, in order: Switzerland, Sweden, USA, Great Britain, Norway, Finland, Singapore, Denmark, Germany, France, Japan, Hong Kong, and Israel. Countries that have continuously and "consistently" had the top performance in the last three years are Switzerland, Sweden, the United States, and the United Kingdom. Compared to 132 countries in the world, Serbia ranked 54th in terms of the Global Innovation Index, while compared to 39 European countries, it ranked 34th. Serbia has achieved above-average results in five pillars: 1. Infrastructure, 2. Market sophistication, 3. Knowledge and technology, 4. Human capital and 5. Research.

According to the Global Innovation Index, 2021, the key innovation forces of Serbia among 132 countries in the world in terms of performance and rank were: Scientific and Technical Articles, 7th, Environmental Sustainability, 7th, Gross Expenditure on Research and Development (R&D), 17th, Import of information and communication technologies (ICT), 12th, and Export of information and communication technologies (ICT), 23rd rank. The key weaknesses according to the Global Innovation Index that Serbia should pay attention to in its policy are: Insufficient funds allocated from GDP for energy use, where Serbia is 101st, Market sophistication (underdevelopment), where it is 58th; Small allocations and small expenditures of GDP for computer software, rank 104th; Cluster Development, rank 104th, High Technology Imports, rank 98th. According to Molnar et al., [11] the key internal strengths and weaknesses, opportunities, and threats to eco-innovation in Serbia are shown in the Table 1.

Table 1. SWOT analysis of ecological technological (eco) innovations in Serbia

STRENGTHS	WEAKNESSES
Quality of scientific research institutions; Quality of mathematical and scientific education; Share of renewable energy in gross final energy consumption concerning the EU average (23.4 versus 16.1); Legal documents related to energy and environmental protection are in line with EU recommendations and standards; Systemic government approach to accreditation and standardization policy; Openness to investments, the interest of potential investors;	Lack of awareness of the importance of eco-innovation; Very low spending on research and development (0.8% of GDP), while world leaders in innovation have far above 2.6% of environmental spending (as% of GDP) is almost 10 times lower than the EU average; 66% of microfinance providers do not have any special loans for green projects or finance green projects through their usual microcredit activities; Huge gap in technology (average age of means of production lags three decades behind developed countries);
OPPORTUNITIES	**THREATS**
Introduction of cleaner production principles in the energy sector; Intensified use of EU pre-accession funds in the energy sector; More efficient operations of public energy companies and other economic entities in the field of energy; Attracting foreign partners, banks, and investors in safe and long-term investment in the energy system of Serbia; Development of electricity and natural gas markets in the country and the region; The share of 65.2% of unused RES is high;	Outdated technology in the manufacturing sector; The trend of declining levels of mineral rent payments (% of GDP) in recent years; Financial potential is insufficient to reinvest in domestic companies; Risk of restructuring and privatization of certain state and public mining companies; Legislation related to eco-innovation is incomplete or inadequately implemented; Insufficient financial investments in expenditures related to the environment; The emergence of "brain drain" to a large extent.

Despite many weaknesses and threats, there are significant implications in the trend of the impact of innovation, as there is a positive correlation between income levels, GDP per capita, and innovation. Expectations are that Serbia has a chance to "catch up" with the successful countries of the European Union because it is moving upward according to the GII result. Serbia is above the EU GII average line. "Performance according to expectations for the level of development", which characterizes the GII of Serbia, shows that there are positive tendencies of Serbia in the gradual catching up of innovative world leaders. According to the official World Bank statement, number 2021/ECA/3, "Serbia is making great strides towards faster, greener, more resilient and inclusive economic growth, implementing a series of legal and regulatory reforms to create a more efficient and transparent public sector to increase its resilience to natural disasters and Climate Change" [12].

Denmark vs Serbia - a comparative method

According to WIPO [10], Serbia is ranked in the 3rd quartile (as a country with above-average higher average incomes), and in 54th place, the general rank of the Global Innovation Index (GII), which shows that Serbia is in 45th place after Denmark. In terms of certain components of the GII, Serbia has achieved the following positions: components of the Institution, achieved position 50, i.e. lower position by 42 places compared to Denmark, Human Capital and Research components, 62 and lower position by 57 places, Infrastructure components, 44, lower position by 39, Market Sophistication components 63, lower position by 52, Knowledge and Technology components (outputs) 43, lower position by 29, components Creative inputs, 76, lower position by 63, compared to Denmark. The best comparative results are from Knowledge and Technology, the difference is 29, and the most unfavorable from Creative Inputs, where the difference is 63. Denmark in 2021 had values that belong to the leaders in terms of innovation capacity, 9th rank, 4th quartile (group of 1 to 33rd place). The way Denmark is ranked, as a good example of ecological technological innovations, and Serbia in terms of components of the composite Global Innovation Index (GII), according to data for 2021, is shown in Table 2:

Table 2. Global Innovation Index, Comparative Components (GII) of Denmark and Serbia, 2021

Country	Total GII	Institutions	Human resources and research	Infrastructure	Business sophistication	The sophistication of the market	Knowledge and technology - outputs	Creative outputs
Denmark	**9**	8	5	5	7	11	14	13
Serbia	**54**	50	62	44	58	63	43	76

Denmark performed best on the following components of the GII index: Human Capital and Research 5, and Infrastructure 5, with unfavorable results on Components: Knowledge and Technology 14 and Key Inputs 13. However, Denmark achieved significant comparative advantages in terms of overall GII index about 121 countries, as follows: (a) concerning the leading countries, (4th quartile); (b) about countries with above-average positions (3rd quartile); (c) in respect of countries with below-average positions (2nd quartile); and (d) about low-performance countries (1st quartile). Although Serbia, as a more moderately developed country, and Denmark, as a highly developed country, are not formally comparable, Denmark, by its example of good practice, is paving the way for less successful countries, and Serbia, should follow Denmark's policies, strategies, and business models.

According to Rajaković [13], in Denmark, unlike Serbia, the energy system is decentralized to a significant extent. Local farmers, local cooperatives, landowners, and consumers belong to the ownership structure. In the Serbian energy system, the electricity company belongs to the public sector, which has a monopoly on the market. In contrast to the monopolistic one, it is necessary to apply a democratized and decentralized approach to the market. A good example of a democratic and decentralized approach refers to the construction of wind turbines in Denmark, where opportunities have been created for the population to directly participate in their construction with the investment of financial resources by the individual. It was pointed out that the financial market is developed in Denmark, while in Serbia only banks are a source of financing for individuals and legal entities. Regarding technological energy eco-innovation projects in Serbia, there is no sustainability of projects due to high risks. Future directions of the development of the financial market of Serbia should be focused on global international investors and private financial institutions so that the selected projects can be used for eco-innovation and sustainable development. The attention of the Serbian government should be focused on the storage of fossil fuels and the circular economy, which would have positive effects on decarbonization, climate change, and employment [13]. For Serbia to follow the lessons of Denmark in certain policy segments, the following recommendations need to be met: 1. the government's commitment and motivation towards long-term energy policy goals; 2. motivation for the introduction of renewable energy sources to decarbonize; 3. financial support from the government for research and development and advanced environmental energy technologies; 4. expansion of renewable energy infrastructure; 5. creation of financial plans, models and schemes, and 6. simplification of procedures for obtaining permits for the construction of renewable sources, such as wind turbines or solar panels, etc. Denmark has always applied the principle of openness and cooperation with all countries in its national policy, which refers to climate change mitigation and cost-effective climate action. Denmark continues to share its knowledge and experience in modeling green growth, regarding the Green REFORM model, with EU members, to share its experiences and share its lessons learned with other countries. Therefore, it seeks to develop future capacities for eco-innovation modeling.

Case study Denmark

The efficiency of environmental technology as defined by the Danish Government (2009) is reflected in the direct or indirect improvement of environmental quality with the help of all technologies that reduce emissions; in the production of environmentally friendly products and the more efficient management of production processes, resources, and technological systems. Denmark has proven to be a leader in efficient eco-technology, thanks to constant political "pressures", research and development processes, and the adoption of new environmental regulations that refer to the application of environmental technology as an integrative aspect of economic growth, and sustainable development. The Danish Government's first plan on technology, development, and innovation for the environment and resources - the "Government Action Plan for Promoting Eco-Technology Efficiency", has influenced Denmark to be a leader in the environment and business community [14]. The Ministry of Energy, Communal Services, and Climate is obliged to submit regular reports to the Assembly on energy policy.

According to the Law on Climate, every five years, the Minister is obliged to submit proposals to the Assembly for national climate goals, which should be in line with international guidelines and policies, with a deadline of 10 years and ambitious goals by 2050. The development of wave energy is based on partnership and floating power plants (FPP - Floating Power Plant) on a common platform that combines two renewable sources, wind and waves. The partnership is based on the development of joint floating power companies: one company is “DP Energy” in Ireland, and the other two, “Dyfed” and “Katanes Floating Energy Ltd.” are in South Wales and northern Scotland. The Public Funding Program (EUDP) stimulates Denmark's energy and environmental policy objectives in the areas of: 1. hydrogen technology, 2. biomass transport and energy technology, 3. integrated energy systems, 4. low-energy buildings, 5. more efficient and environmentally friendly production of all types of energy, 6. CO_2 storage, 7. more efficient transformation of oil and gas, and 8. areas of renewable wind and other energies, such as wave energy. Companies with successful program implementation receive 2.5 to 50 million DKK for development and demonstration, commercialization and partner network development, and successful technology and knowledge transfer. The annual budget is about 180 million DKK to co-finance new and efficient energy (eco) technology [15]. To obtain adequate solutions to the problem of harmful CO_2 emissions and climate change, for many years in Denmark, methodologies have been developed, knowledge has been innovated, and experience has been gained, especially in wind energy. Capacity has increased by more than 60%, due to the increasing proliferation of offshore wind turbines. Biomass is used for heating buildings, which is used in industrial plants with heating processes, and the heat is obtained from the use of straw and wood pellets for cogeneration. Biofuels have a perspective in technological innovation, in transport. Given that more than 90% of fossil fuels are used in transport, the transition to renewable energy sources in road transport is very important for achieving CO_2 reduction goals. The use of plug-in hybrid vehicles is also being introduced to limit carbon dioxide energy, which is a more cost-effective option than fossil fuels, petrol, and diesel. Thanks to the ambitious strategies of the 1970s, Denmark has become, after many years, one of the leaders in green transition and eco-innovation of renewable energy sources. Denmark is sharing its ambitious experiences with other countries, to follow the appropriate path of transition and decarbonization of the energy sector. The energy system is characterized by the combined production of heat and electricity. The plants supply heat (64%) to citizens through district heating and a large amount of electricity. The plant is supplied by the combined use of energy sources such as coal, natural gas, biomass, and municipal waste, which tends to reduce the use of coal and the increased use of biomass [16].

The share of various renewable energy sources in 2020 in Denmark is: other fuels 4%, gas 4%, coal 15%, solar energy 4%, bioenergy 18, and the largest share is wind energy, 56%. Solar energy includes both thermal and photovoltaic production, and bioenergy includes production from flammable renewable sources and waste, renewable and non-renewable. A floating power plant is a new eco-technology that, among other sources, solar energy, wind energy, bioenergy, etc., contributes to decarbonization and prevents climate change. The technology is commercialized for two short-term markets: 1. for a large network of floating farms and 2. for an application that is not connected to the Power-2- X network, which refers to islands, oil and gas installations, etc. The power plant is a patented technology of the future and is based on generating unlimited quantities of a combination of wind and ocean energy. Offshore wind plants require the need to build floating foundations, as they are moving further and further away from the coast and into greater depths of the sea. The plant that was tested for the first time as a combination of wind and waves is a floating platform (FPP) floating platform on which there is a wind turbine from 4 MW to 15 MW of wave power, depending on the wave resource.

The platform has the ability, although anchored, to rotate around one point to "meet" the waves, it has a wave absorption capacity of 60-80% of the inherent wave energy [17]. Floating renewable energy plants are being built in Denmark, which contributes to reducing greenhouse gas emissions and mitigating global climate change and the health of all mankind. In this way, the leveled energy costs are reduced, thanks to which Denmark has become a leader in the segment of water depth over 45 m. The hybrid water and wind power plant is the first generation of its kind, capital has been increased by 34 million euros, and the long-term goal is to increase capital by about 50 trillion euros by 2050. The well-known company "Vestas Wind Systems A/S" is one of the world's leading manufacturers of offshore wind turbines, which had a global share of 16% in 2010, and a value with a delivery of 5,842 MV. The Vestas company has installed 43,000 wind turbines, 6 MV class, economical for electricity production, in 66 countries on different continents. The first wind turbine plant, the so-called Vestas was installed in Sweden in 1990, employing 21,600 workers. There were 200 wind energy companies in Denmark. Exceptional Danish experts and engineers have been employed around the world. Since 2019, it has installed 66,000 wind turbines with a capacity of 100 GW in more than 80 countries around the world. The total number of employees in 2019 was 25,000, net income was 700 million euros, while total gross income was 12,147 trillion euros [18]. (Denmark's climate goal is to completely replace fossil fuels, with 100% renewable energy sources and about a 75% reduction in greenhouse gas emissions, by 2050, which is achievable because Denmark has managed to achieve the goals of decarbonization and mitigate climate change. It has achieved successful results, as it has continuously increased the use of renewable sources since 2010 by 1.7% every year. The average annual increase in the share of renewable sources in gross final energy consumption in the period from 1990 to 2010 was 22%, and in 2019 was 37%, based on which it became the EU leader in the same year [19]. It is concluded that the reasons for Denmark's success are [20]: Danish policy in the energy sector was predictable in the long run; all public and private stakeholders who supported innovative technology participated; various public policy schemes have been created; tender models were linked to the “Danish Investors Agency”; Thanks to the Danish Investor Agency, all agreements and contracts with investors were directly executed, thus avoiding complicated and lengthy administrative procedures. In addition, Denmark's success is reflected in major CO_2 capture and storage projects, as well as the projected "low-carbon" energy islands.

Denmark has been successful and a leader in eco-innovation, advanced technology, and the use of renewable resources in the European Union. Denmark achieved success thanks to the fact that: 1. she was motivated for innovative technologies; 2. implement the synergy of regional and international policy; 3. continuously achieve comparative market advantages; 4. is fully committed to energy policy with long-term future projections; 5. had a holistic approach to stakeholders, i.e. with high-level of respect, the state provided access to many public and private actors [20]. The essential recommendations according to [21], regarding the further development of advanced environmental technology, green energy policy, and further progress for decarbonization are: creating a specific strategy for research and development, environmental technology development projects, i.e. projects for eco-innovation technologies, stimulating public and private funding for energy research at the level of funding from 2010-2012, to increase energy technology exports, and the need for Danish government efforts to obtain additional funding from the EU [21].

Denmark needs to take further steps to implement plans, programs, and projects to mitigate climate change. It was proposed to the Danish government, by experts from the International Energy Community (IEA), for further progress: the creation of a specific strategy for research and development, further development of projects and eco-innovation technology, stimulating private and increasing public funding for energy research since 2010 to 2012, to increase the export of energy technologies, increased commitment of the Danish government to obtain additional funding from the EU [21]. To achieve the future goal of reducing the greenhouse effect, Denmark must electrify the energy consumption sector through conversion, i.e. switching from fossil fuels to non-green technology. Although Denmark is making progress on renewables, more optimal use is needed. Denmark is an example of good practice for other countries, as well as for Serbia, because Serbia could apply certain segments of Denmark's eco-innovation climate policy. Following the example of Denmark, Serbia would gradually catch up with successful countries such as Denmark, gradually striving towards the global goal of a safer and more sustainable climate future, with the application of advanced environmental technologies, without CO_2 emissions.

Ecological technological innovations in Serbia

In Serbia, various projects and programs are financed by the Ministry of Education, Science, and Technological Development for the preservation of the environment. According to the statement of the Assistant Minister for International Cooperation and European Integration in the Ministry of Education, Science, and Technological Development, [22], projects and programs are based on the cooperation of scientific research and economic activities, integral and interdisciplinary research. The research is focused on the study of land use, biodiversity, the assessment of exposure to pollutants, climate change, and their impact on human health and the environment. New methods and systems for monitoring the quality of water, air, and soil, radiation, UV radiation, the impact of mining waste on watercourses, technology for purification of natural watercourses and wastewater, and technology for eliminating air pollution from energy from thermal power plants [22].

Furthermore, the Innovation Fund financially supports projects in the field of environment, such as software applications for graphene acoustic cameras, for recording noise sources, or mushroom growing technology, which is carried out with the use of waste and minimizing costs of Energy. Eco-innovations and innovative projects that are significant and are promoted as proposed projects in Serbia are [23]: 1. "Institute of Chemistry, Technology, and Metallurgy" in Belgrade gave a project proposal entitled "Innovative renewable biomaterials and biopolymers" composites based on microbial exopolysaccharides and waste from the wood processing, paper, and agricultural industries". The project has effects on reducing CO_2 emissions and on environmental and economic benefits; 2. LIQUID3 is the name of the project created by the "Institute for Multidisciplinary Research" in Belgrade. The project is an innovative biotechnological solution for air purification and reduction of CO_2 emissions in cities at the source of emissions. The biomass that is produced is used in public parks for soil fertilization and biodiesel production; 3. "Challenge for innovative solutions - E-Mobility Cloud Center" is a project created by the "National Association of Electric Vehicles" where based on the innovative software "E-mobility Cloud Center", a public network for charging electric cars is established; 4. The “Solar Mobile Power” project offers innovation in terms of energy supply, through the combination of renewable energy sources. It was created by the company "Telefon inženjering Ltd.". The advantage of the project is that by combining energy, diesel generators are replaced and can be used on the go, outdoors, or in inaccessible places; 5. The eco-innovative project entitled “A new approach in the production of electricity and heat from wood biomass” was offered by the company "Bioenergy Point d.o.o./GreenEnergy Point d.o.o. "which uses innovative technology for the production of combined heat and power in the combustion of wood biomass. The produced thermal energy could be used for the production of pellets, with the simultaneous production of electricity. The produced energy will be delivered by the public company "EPS - Electricity of Serbia", at more favorable prices. Lower transport costs will be provided, as the plants will use mainly biomass in the immediate vicinity, while the other part will use wood waste from Djerdap. Projects are important not only for the application of eco-innovative technologies but also for raising public awareness of their importance [23].

One of the important regional projects for the countries of the Western Balkans, Serbia, Montenegro, Bosnia and Herzegovina, Macedonia, and Albania is the implementation of the project "Green Economy for Advanced Region" (GEAR). The project is funded by the European Union to increase the activities of civil society through networking of countries for the development and promotion of green economies. The project partners are "SMART collective" from Serbia, "EKO svest" from Macedonia, "Association Slap" from Croatia, and "Center for Support and Development" from Bosnia and Herzegovina [24]. Porter and Stern [25] identified important factors for assessing national innovation systems and developed an innovation index. The innovation factors were used in the development of quantitative modeling and regression analysis methods. Porter and Stern [25] pointed out that the relative contributions of national policy and innovation factors are decisive for the objectively determined performance of nations, which is determined based on the results of the innovation index. It is concluded that the success of a country's innovation system is positively correlated with key innovation factors. The "critical" factors of the innovation system are: 1. the size of the workforce engaged in (R&D) and other technical jobs related to innovation; 2. the degree to which national policy is engaged in financial investment in (R&D) and commercialization; 3. investments intended for research and development; 4. resources for the higher education sector, which as important factors are the drivers of national innovation capacity. Innovations in one country where companies are focused on research and development, "with new ideas" can benefit other countries. Applying the same model and methods of innovation to another country can improve national innovation, and thus productivity and higher economic growth. The Porter and Stern Innovation Index was presented with the aim of not highlighting winners or losers but using the Innovation Index to measure national performance and innovation capacity [25].

Denmark is a good example of innovation, as it has incorporated green technological innovation into its national development strategy. To achieve green growth, Denmark's strategy covers the forthcoming goals of structural change, the development of green innovative technology, and the green industry. According to Pakulska's [26] research, it was pointed out, based on the eco-innovation indicator (Eco-IS), that high-income countries with high GDP per capita are characterized by high innovation. However, countries with lower incomes, and lower GDP per capita, do not have the opportunities or financial resources to invest in innovation and development. In addition, it is uncertain whether the future innovative project is profitable and whether the invested capital will provide the expected profit. It was found that there is a certain correlation and connection between eco-innovation and the level of economic development.

However, due to the relatively new concept of eco-innovation, one can only assume that only GDP affects Eco-IS because so far it has been shown that innovation has a positive attitude towards economic development. Based on that, it is assumed that eco-innovation has such an impact on the economy. Based on Pakulska's [26] research, it is concluded that to achieve eco-innovative results, it is important for Serbia to continuously strive to increase national revenues, i.e. increase GDP because research has shown that GDP has positive tendencies over the past few years. For Serbia to follow the lessons of Denmark and succeed on the path of climate change mitigation and decarbonization in renewable sources, it is necessary for the government to respect certain recommendations, because Serbia does not sufficiently use the existing natural potentials of renewable sources. To use alternative forms of energy, instead of fossil fuels, it is necessary to use other innovative technologies, which are still not sufficiently researched or represented. For these reasons, expert analysis of various renewable sources is necessary, especially in the public sector, where a new system of renewable heating sources can be applied instead of fossil fuels, e.g. heat pumps or solar energy.

According to GAJP, [27], in Serbia, it is possible to achieve the goals of ecological, technological, and green development with the creation of appropriate climate programs, which is supported by the Serbian Chamber of Commerce, because it encourages innovative ideas and motivates professionals, experts, and researchers. Eco-technological innovation requires investments, dedicated green research programs, and evidence-based policies in synergy with all policies, at all levels, with relevant aspects for research and development [27]. The achievement of the goal of decarbonization and mitigation of climate change, i.e. for complete transition, 100%, to renewable sources, by 2050, requires investments. It has been estimated, according to Doljak et al., [28], that complete energetic decarbonization and technological transition investments of 91.837–206.153 billion dollars will be needed, for a period of 30 years, from 2020 to 2050. According to the proposed scenario, Doljak et al. [28], by 2050, renewables would 100% replace fossil fuels in Serbia. Currently, energy efficiency is at an unsatisfactory level, as the untapped potential of at least 30% of renewable sources. According to the scenario, it is necessary to build certain energy capacities: (a) 6077 wind turbines, of 12 GW, in areas where the average annual wind speed is higher than 5.5 m/s, with the application of appropriate environmental standards; (b) a heating plant of 11,300 MW using biomass from millet cultivation, panicum virgatum, per 95,000 ha and energy willow, salix viminalis, per 300,000 ha; (c) solar panels on the roofs of houses, 2.2 million, capacity 13.75 GW; (d) 7 biogas plants, 38 MW; (e) 2447 solar power plants, 16 GW.

Further, it is concluded that according to the projected scenario, Serbia does not need hydro-energy potentials. The results of the research showed that mass installation of solar photovoltaic energy systems and installation of wind energy would be sufficient and would enable 69,289 TWh of electricity, as well as greatly contribute to the energy independence of Serbia [28]. The Government of the Republic of Serbia has adopted the draft Strategy for Low Carbon Development of the RS with the Action Plan for 2018. Among other things, according to the research of Coalition 27 in Serbia, a "Shadow Report: Chapter 27 in Serbia" was prepared. According to the recommendations in the Report, it is necessary to adopt a more innovative strategy of low-carbon development of RS with the Action Plan, formation of the National Climate Change Council with members of the scientific and professional public, state bodies of public institutions, and civil society, with Rules of Procedure.

The recommendations for Serbia are: 1. development of a financial mechanism with redirection of funds for renewable sources, to decarbonize the fossil fuel industry and mitigate climate change; 2. Creating strategic local plans and strategies for climate change adaptation; 3. improvement of renewable energy sources and energy efficiency; 4. defining legal regulations; 5. establishing an institutional framework in line with the goals of climate change (decarbonization and environmental technological innovation), in synergy with the energy and environmental sectors [29].

Conclusion

Given that the Serbian economy is significantly dependent on fossil fuels, it is concluded that a low-carbon transition can be achieved in small and micro-enterprises. An appropriate document has not been officially adopted in Serbia, which defines the goal in terms of how to stop using coal, which is possible with a gradual transition to renewable energy sources and eco-innovation. It is necessary to create and adopt the Energy Development Strategy of the Republic of Serbia with plans and programs as soon as possible. It is necessary to adopt a national energy and climate plan within the prescribed period with the participation of interested citizens of civil society, as well as the adoption and implementation of legal instruments to establish a tax system with a mechanism of tax on CO_2 emissions. Serbia, as a signatory to the Paris Agreement, has committed itself under Article 4 to make efforts within its nationally determined contributions (NDCs) to reduce the greenhouse and CO_2 effects. To achieve ambitious climate and low-carbon goals in Serbia, it is important to achieve gradual adaptation to the ecosystem in a certain period and to establish ecological, technological, and sustainable energy development. In this regard, Serbia should be guided by the guidelines of the Paris Agreement, to eliminate the effects of the greenhouse through gas sinks and CO_2 storage, and to make long-term strategies for accelerating the green transition. Serbia is energy-dependent on fossil fuels, and it takes more time to apply modern scientific knowledge and climate-environmental technology because the rapid adoption of environmental technology would be economically unjustified and socially unacceptable. However, through gradual and continuous efforts to introduce ecological and technological innovations, Serbia would contribute to the achievement of global goals on climate change for the benefit of all citizens of Serbia and all humanity and the planet.

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Izvod

EKOLOŠKE INOVATIVNE TEHNOLOGIJE, CO_2 I ZELENA ENERGIJA

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U svetu raste interesovanje za zaštitu životne sredine, ublažavanje klimatskih promena, energetsku bezbednost i održivost proizvodnih i energetskih kapaciteta inovativnih obnovljivih izvora energije. Sve intenzivnija industrijska aktivnost izazvala je zagadjenje vazduha usled projektovanih čestica zagadjujućih materija. Nastala je globalna zabrinutost zbog povećane emisije CO_2 i rizika po ljudsko zdravlje i održivi razvoj. Cilj rada je da se primene tehnologije koje maksimalno smanjuju upotrebu fosilnih goriva i emisiju CO_2. Zelena ekološka tehnologija je relevantna širom sveta jer doprinosi dekarbonizaciji i razvoju novih tehnologija u energetskom sektoru i preduzećima. Svrha rada je da donosiocima odluka ukaže na inovativan pristup korišćenju novih tehnologija, koji bi ukazivao na buduće pravce zelenog održivog razvoja. Primenom različitih metoda u radu dolazi se do zaključka da sve zemlje moraju uvesti moderne tehnologije i inovativni razvoj energetike, ne samo za kvalitet života svih građana Srbije već i za sve stanovnika planete.

Ključne reči: eko-inovacije, fosilna goriva, CO_2, ekološka tehnologija, energetska održivost, zeleni razvoj.