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The impact of renewable energy sources on the environment

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Abstract
The use of renewable energy sources is becoming a modern phenomenon that saves energy costs and protects the environment in the long term. The contribution is mapping selected energy and environmental aspects and evaluating renewable energy sources' impact on the environment. At present, energy supply is still mostly provided by sources coming from fossil or nuclear reserves. Although the concept of the "upper limit of exhaustibility" of these resources is increasingly used, there are still disagreements between experts in the field of the life expectancy of the reserves. Population growth means higher consumer demands, which also results in higher consumption of energy resources. Environmental degradation has become a global problem that requires the emphasis of recent studies. Non-renewable energy is a significant factor in environmental degradation. Therefore, policymakers have focused on supporting the production and consumption of energy from renewable sources in all economic activities to ensure a low-carbon economy.

Keywords
renewable energy sources; sustainable development; energy; environment

Introduction

All life on Earth is based on the intake and consumption of energy, which also applies to human civilization. In recent decades, environmentalists and stakeholders in the field of the environment have been increasingly overwhelmed by the impact of environmental degradation and ecological deformations of the Earth's geographical space (Ali et al. 2019, Alola 2019). Ongoing and somewhat unwanted climatic experiences, which in most cases lead to ecological disasters, are common signs that indicate these drastic "revolutions" in the Earth's climate systems (Kuriqi et al. 2017, 2019). Human sustainability is increasingly threatened by increasing human activities, which include direct and indirect activities on the atmospheric layers and the biosphere (Bekun et al., 2019). The impact of human engagement on the environment has been continuously measured for several decades by the response of the environment to economic growth, population dynamics, energy consumption and several other important factors (Usman et al. 2020). Such environmental impact is consistently attributed to carbon dioxide (CO_2) emissions. Specifically, CO_2 emissions are estimated to account for about 76% and 94% of total anthropogenic greenhouse gases (GHG) and anthropogenic CO_2 emissions, respectively (Bekun et al. 2019). The emissions of GHG, which cause climate change, are currently determined mainly by consumer habits in the developed world's cities (Campbell-Lendrum and Corvalán, 2007). Therefore, limiting or mitigating their emissions is necessary to preserve biodiversity. Carbon emissions contribute approximately 75% of global greenhouse gas emissions (Tolmac et al., 2014, 2016).

Since the beginning of the industrial revolution almost two centuries ago, there have been amazing technological advances and improvements in human well-being. Environmentalists believe that rapid economic growth in the world causes not only the depletion of natural resources but also the harmful emissions resulting from this growth, which pose a threat to the existing and future sustainability of the environment (Tolmac et al., 2016). GHG emissions into the atmosphere from energy production have increased exponentially in recent decades (Manish et al. 2006). Climate scientists are increasingly focusing their efforts on the root causes of environmental change. Environmental experts are very interested in climate change because CO_2 emissions are released and absorbed into the atmosphere globally in significant quantities (Tolmac et al., 2014). Lower fossil fuel reserves are attracting increasing interest in alternative energy sources such as wind energy, biomass, solar energy, geothermal energy, hydropower (Tolmac et al., 2016; Pavolová et al., 2015) and hydrogen energy for electricity generation to overcome the current environmental crisis (Sanitka et al., 2019; Ludin et al., 2018; Ang et al., 2022). The use of fossil resources has a significant impact on the degradation of the environment because they cause high CO_2 emissions (Kartal, 2022). On the other hand, the use of renewable resources is increasing. According to the recently published literature, renewable resources contribute to reducing CO2 emissions because they are naturally produced, and using such resources does not contribute to CO_2 emissions. In addition, some countries prefer nuclear energy as an option for obtaining energy (Kartal, 2022). For this reason, the use of nuclear energy is also increasing in some countries. In short, the share of fossil resources in total energy production is quite high, while the share of renewable resources is increasing daily (Iwata et al., 2010). Such a structure of energy production causes high CO_2 emissions, climate change and global warming problems, and social changes and effects (Zaporowski, 2016). For this reason, it is necessary to examine CO_2 emissions at the level of individual countries, including a group of countries, especially those that cause a high amount of CO_2, and to consider adverse effects on human health (Kartal, 2022). Conventional sources provided 66% of global energy demand in 2017. This dependence of the world on fossil fuel sources has resulted in several global challenges, the most serious of which is the issue of climate change. Consequently, these concerns have forced countries to shift their dependence from conventional energy sources to alternative or modern energy sources (Bekun et al. 2019). The contributions of each renewable and non-renewable source have changed rapidly in recent years due to the Intergovernmental Panel on Climate Change (IPCC) and the United Nations (UN) agreements. Their agreement regarding the increase in the use of renewable energy and the decrease in the use of non-renewable energy changed the share of both energies in the deterioration of the environment (Kartal 2022). Renewable energy sources (RES) are becoming more and more popular because they are cheaper and more efficient than conventional energy sources. New green energy technologies are mostly used in developing regions to ensure a sustainable and clean environment (Chang et al. 2022a). "Energy is said to be renewable when it is sourced from renewable resources such as the sun, wind, water, or biomass. Renewable energy does not use fossil fuels, coal, or gas, but rather natural resources that can be replenished within the human lifetime "(Garrett, 2023). RES play a key role in reducing carbon dioxide and other harmful gases (Solaun and Cerdá 2019). The world will have to increase the share of RES from 19% in 2017 to 65% in 2050 to reduce the temperature by 20°C (IRENA, 2019). Renewable energy, among other production factors, has a decisive role in the growth of economies; therefore, the need to use renewable energy has expanded dramatically as economies have reached a significant level of development.

Non-renewable energy consumption and economic growth increase the burning of carbon emissions, while renewable energy consumption reduces CO_2 emissions (Bekun et al., 2019). Panel causality analysis reveals a backward mechanism. The ever-increasing consumption of natural resources has adverse effects on the ecosystem, increasing multidimensional environmental degradation and causing negative climate change (Bilgili and Ulucak,

2020; Rudolph and Figge, 2017). As a result, the long-term goals of socio-economic development are threatened worldwide. Despite some concerted efforts worldwide, the problem continues to grow (Shahbaz et al., 2017). These globally accepted problems have attracted the attention of researchers for future policy-making for sustainable development as well as for environmental sustainability. Over the past five decades, we have witnessed a gradual, uninterrupted and significant increase in CO_2 by 172% (Cui et al., 2022).

Many papers have been published on renewable and non-renewable energy sources and their exploitation connected to GHG emissions. In this study, the legislation of the EU that was implemented to limit the emissions of substances negatively affecting the environment was used as a basis for the study of RES by comparing the usage of RES and fossil fuels for their impact on the environment on a global scale emphasizing the risks, challenges and disagreements related to global climate change.

Materials and Methods

Global energy demand has increased significantly in recent decades. If current trends continue, the International Energy Agency (IEA) predicts that global energy demand will increase by 1.2% by 2035. Although there has been a slight decline in conventional fossil fuels such as coal, oil and natural gas, they remain the world's main sources of energy. In 2016, oil, natural gas and coal accounted for almost 90% of the resources for electricity production (Chang et al., 2022b). The dominance of natural fuels in the electricity market inevitably leads to low efficiency and major environmental problems, especially greenhouse gases. Recently, due to environmental concerns caused by fossil fuel energy consumption, renewable energy has become a popular alternative to conventional fossil fuels. Growing evidence suggests that RES, including solar-, wind- and hydropower, volcanic energy, and biofuels, can be used to reduce CO_2 emissions, increase energy efficiency, alleviate energy shortages, and promote sustainable development (Chang et al., 2022b). In countries with lower levels of economic complexity, solar and wind increased their relative share of renewable energy generation while the total amount of renewable energy generation remained stable. Consequently, in the absence of scale effects associated with renewable energy consumption (as total renewable energy consumption remained constant over the period under review), such a shift benefitted the environment. Under these circumstances, the transition from older forms of renewable energy to newer forms, such as solar and wind, has reduced air pollution (Khezri et al., 2022). Energy demand is expected to increase by 56% by 2040. If the same policy of reliance on fossil fuels continues, increasing energy demand will increase greenhouse gas emissions. Consequently, climate change mitigation is necessary to avoid these consequences. RES plays a key role in achieving carbon neutrality, reducing global warming and climate change, and meeting the goal of the Paris Agreement. RES are considered affordable, sustainable and free of energy (Cui et al., 2022).

The share of RES in electricity production (Figure 1) and the share of renewable energy in electricity capacity (Figure 2) in most EU countries has been increasing during the last 10 years (IRENA, 2023ab). The largest contributor to electricity production is hydropower. Solar and wind energy together make up 50% of the total share of electricity. Geothermal, ocean, and biomass power plants account for slightly more than 6%.

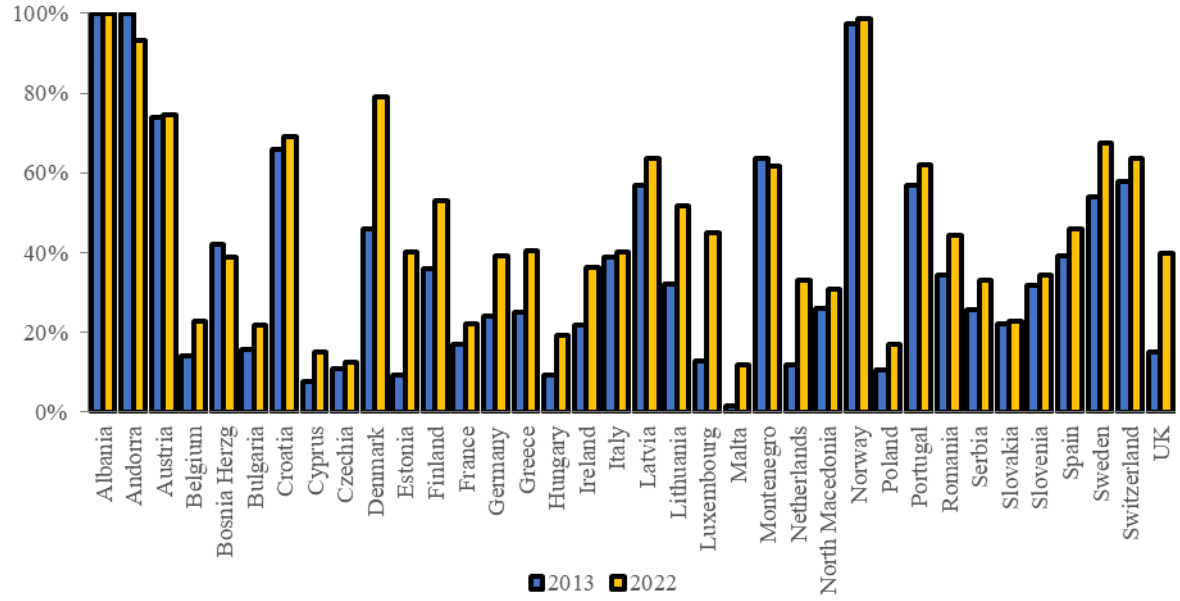

Fig. 1. Share of RES in electricity production in EU countries in 2013 and 2022 (IRENA, 2023a).

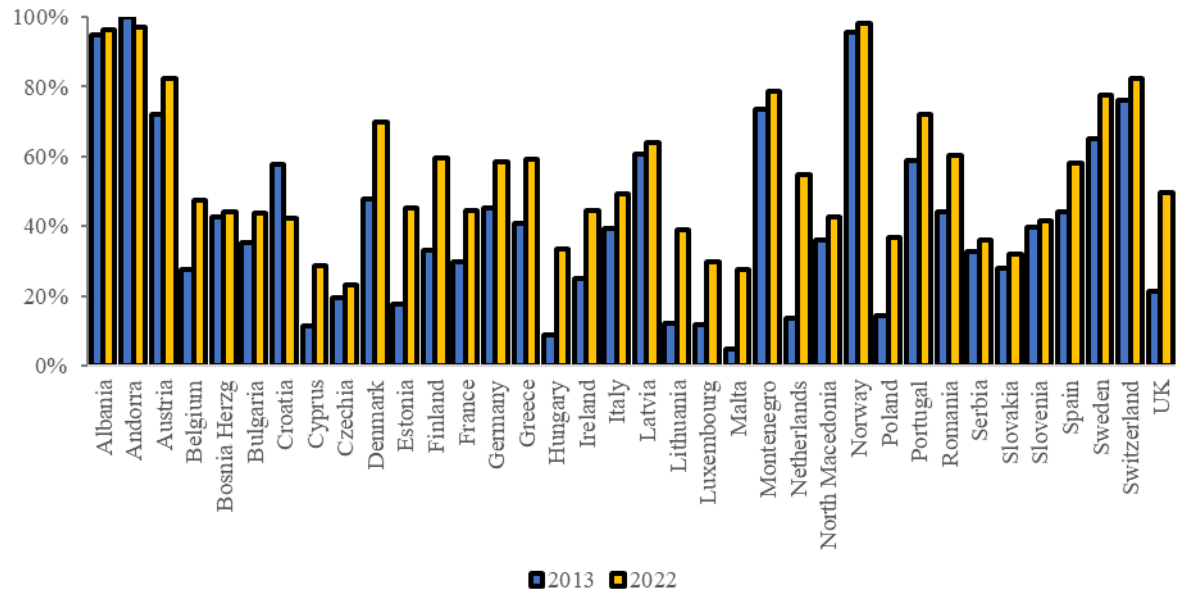

Fig. 2. Share of renewable energy in electricity capacity in the EU in 2013 and 2022 (IRENA, 2023b).

The use of renewable resources is key to decarbonizing the energy sector and combating climate change, but the availability of solar, hydro and wind power depends on weather conditions and future climate change. In addition, there has been less research on the environmental impacts of the use of RES (Osman et al., 2023). This review was therefore conducted to discuss (i) the most used RES, (ii) renewable energy needs and costs, (iii) climate change impacts on RES and their future prospects under climate change scenarios and (iv) the potential environmental impacts caused by RES that are the most environmentally friendly. For some time, it has been argued that the world's energy mix is too reliant on its natural resources, such as coal, oil, natural gas and others. Even though world economies greatly emphasize energy conservation and diversification, fossil fuels are still the most used fuel worldwide. The adverse effects of fossil fuels on environmental protection, green development and global warming are significant problems in the energy industry, which pressure economies to find solutions to reduce these effects without disrupting economic growth. One of the possible solutions in this direction is the transition to RES. This requires significant improvements in the energy sector in the transition from energy based on fossil fuels to using energy with zero carbon emissions by relying on natural energy sources (Li et al., 2023). Excessive use of natural reserves, such as coal, oil, and natural gas, seriously threatens the environment. The most pressing reason for concern in the energy sector is the use of fossil fuels and their adverse impact on the environment. The urgency is to minimize negative externalities on the well-being of the environment without disrupting the process of economic growth. A promising solution in this context is the need for an energy transition. The energy transition is crucial in reshaping energy consumption towards zero-carbon goals to maintain environmental sustainability and decarbonize the energy sector. In addition, the transition to renewable sources can promote sustainable growth, reduce pollution levels and reduce the overall environmental burden (Bashir et al., 2023). In recent decades, climate change has been recognized as the main environmental problem facing the world. It is a complex phenomenon arising from complex interactions between three different parameters: economy, energy, and environment. Energy is essential for economic production and, therefore, also for economic growth and development of society, but it is also the main source of GHG emissions. The need to reduce CO_2 emissions is stronger than ever. According to many studies, renewable energy has one of the most significant cost-effective potentials for reducing energy-related greenhouse gas emissions. Increasing the supply of renewable energy would make it possible to replace carbon-intensive energy sources and significantly reduce emissions of pollutants (Belaïd and Zrelli 2019). Currently, some of the most devastating effects of global warming are witnessed as a result of both economic and non-economic activities. Worst of all, the current wave of GHG emissions and their adverse effects are greater than in the pre-industrial revolution era. Traditionally, the main cause of growing GHG emissions are emissions of CO_2 and other pollutants produced during the production of goods and services, which are key engines of economic growth and development. Global climate change and severe weather conditions, including floods, droughts, heatwaves, and heavy rains, have become common over the past decade due to rising CO_2 levels; the increase in GHG emissions is simply a consequence of economic growth and development. Policymakers and governments are generally torn between pursuing greater growth, promoting sustainable policies to maintain a healthy living environment, and pursuing increased production (Liu et al., 2023).

The methods used in this study are based on analytical and evaluation methods of the current situation in the impact of renewable energy sources on the environment. The necessary data and information were collected from

the peer-reviewed literature, which provided an up-to-date analysis of the studied topic. To assess the development of RES with the premise of environmental protection, the study concentrates on the EU legislative framework that has been implemented to limit any emissions of harmful substances into the environment. The study of applications and types of RES compares the usage of RES and fossil fuels to the changes in the environment on a global scale. This study also emphasizes the risks, challenges and disagreements related to global climate change.

Results and Discussion

Development of RES with the premise of environmental protection. One of today's global challenges, which can be achieved through tasks at the level of national economies, is forming a low-carbon economy and increasing the use of RES. This is due to the need to stop or at least reduce the negative impacts of climate change. Several scenarios were performed to predict the future development of RES on a global scale (Dembicka-Niemiec et al., 2023). It was found that climate policies would limit the extent of RES development, and the size of RES would also be affected by technical changes in RES and the ability of RES to integrate with conventional energy systems (Maslin and Scott, 2011). The breakthrough event for entering a new stage of development of RES was the signing of the Kyoto Protocol at the end of 1997, which was followed by an international agreement on climate change and the fight against global warming (Gotowska and Jakubczak, 2011). Climate science has produced overwhelming evidence that human-caused greenhouse gas (GHG) emissions must fall if global warming is limited to below 1.5 °C. The Paris Agreement responded to this challenge by legally binding signatory countries to achieve a climate-neutral world by mid-century. The European Commission also agreed on the European Green Deal, the aim of which is to support a future with a decarbonized economy and zero net emissions by 2050 (Vieira et al., 2023). The main reason for the ongoing energy transformation process in the global economy is the need to protect the environment, especially the climate. Increased public awareness of the destruction of the Earth's ecosystem and technological development have resulted in an increased importance of RES, which is increasingly replacing classical sources. In addition to the environmental aspect, renewable energy also offers a chance for greater energy independence and the possibility of energy production for countries without conventional energy sources. These factors cause individual countries and their groups to adopt increasingly decisive measures for the development of renewable energy. In order to protect Earth from uncontrolled economic growth, which could have adverse consequences on the natural environment, the concept of reducing CO_2 emissions was adopted (Grodzicki and Jankiewicz, 2022). Considering that conventional energy sources could one day be used and produce a lot of environmental pollution, implementing the energy mix, especially renewable energy, is a fundamental step towards sustainable development. The use of renewable energy is essential to reduce greenhouse gas emissions and the dependence of many countries on fossil fuels and imported energy. Renewable energy can also refer to the concept of sustainable energy, sometimes called green energy. By definition, green energy has minimal or even zero impact on the environment (Ang et al., 2022).

A very strong climate and energy policy, which has been implemented in the EU for about a dozen years, aimed at limiting emissions of harmful substances into the environment, has led to a gradual shift away from conventional energy sources. The increase in demand for energy while reducing its extraction from conventional sources means that the dynamic development of renewable energy is necessary so that the economy will not be too dependent on energy imports (Tutak and Brodny, 2022). The EU is therefore taking very large-scale operational and strategic measures to use other sources for production, such as wind, solar, mechanical water energy, biomass and geothermal energy, as well as tidal waves, ocean heat, wave energy and ocean currents. Directive 2009/28/EC, in turn, imposed on the EU-27 member states the need to increase the share of energy obtained from RES in their total energy consumption, as well as in transport, heating and cooling and electricity production within the scope of indicative targets. At the pan-European level, the directive focused on increasing the share of energy consumption produced from RES to 20%, while in transport, this consumption was supposed to be at least 10% by the end of 2020. On the other hand, the 2018 Renewable Energy Directive set a target by 2030 for the share of renewable energy in the EU's energy mix to be at least 32% (Vieira et al., 2023; Pavolová et al., 2012). The constant increase in the global average temperature makes the environment more and more expensive and physically demanding to live in, which poses a significant risk to public health in all countries, developed or developing, rich or poor. Sources of excess carbon emissions are widespread, with the World Health Organization finding that worsening outdoor air pollution causes about 4.2 million premature deaths annually. In addition, global warming amplifies the negative impact of seawater acidification, leading to coral bleaching and the irreparable destruction of marine life (Magazzino et al., 2022). Despite the extensive focus of world economies on diversification and energy conservation, fossil fuels remain the primary fuel consumed worldwide. Thus, there is great concern in the energy sector about the adverse impact of fossils on environmental protection, green development and global warming, which encourages economies to find ways to minimize the negative consequences of energy use without disrupting the growth process. A potential solution in this direction lies in the transition of energy to renewable sources (Afshan et al., 2022).

Applications and types of RES. It should be noted that growth and energy are positively linked. Economic growth increases the level of energy use, especially the need for fossil fuels. Renewable sources are ecological and low-carbon sources of energy. Solar, wind, geothermal and hydropower do not produce GHG. Many countries have recently adopted renewable energy technologies to protect the environment. In addition, various factors such as the security of energy supply, energy dependence, climate change, energy price fluctuations, health problems, and environmental disasters have promoted the consumption of RES in developing economies (Akbar et al., 2021).

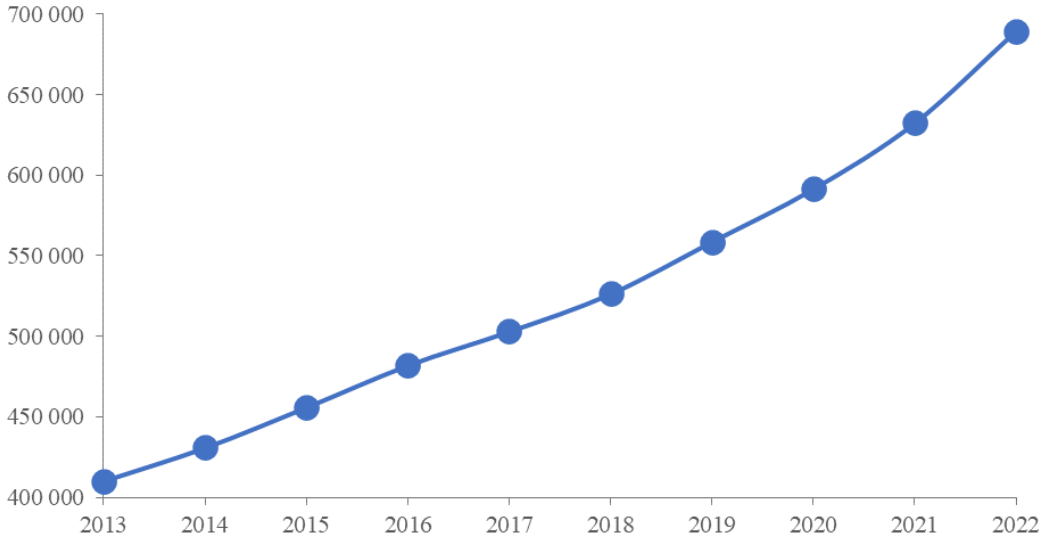

Fig. 3. Total renewable energy capacity in MW of EU countries in 2013-2022 (Khezri et al. 2022).

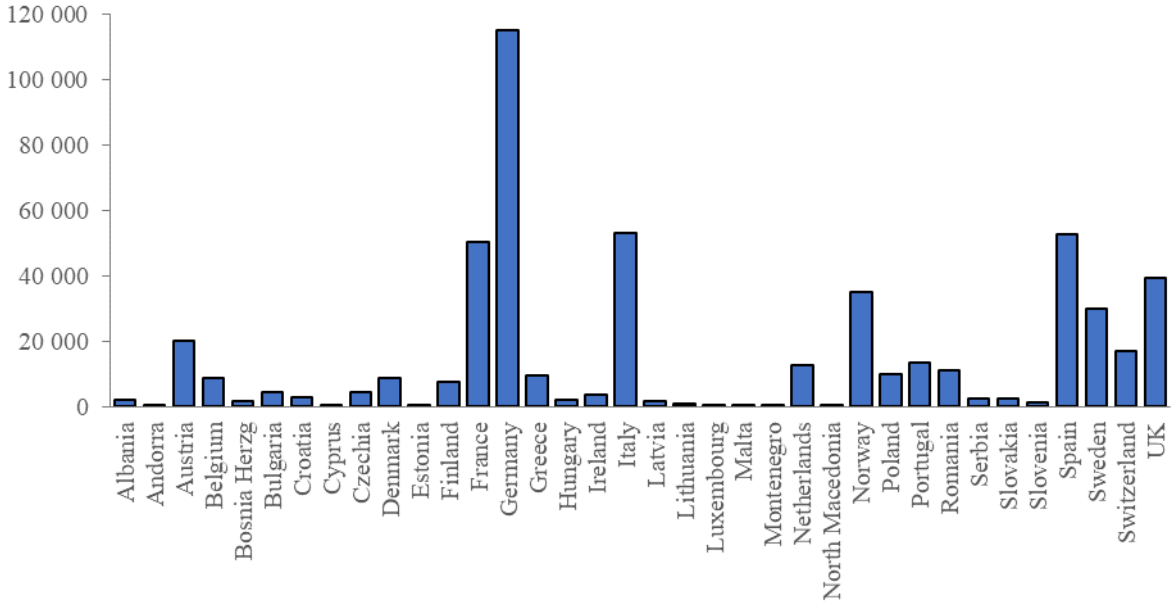

Fig. 4. Average total renewable energy capacity in MW by EU countries for 2013-2022 (Khezri et al. 2022).

Production and life processes based on fossil fuels cause fundamental environmental and social problems (Tschulkow et al., 2020). Earth is experiencing substantial changes in the ozone layer, air and water resources along with rising temperatures. Therefore, it is more urgent to use more sustainable resources to mitigate these destructive processes (Zhuang et al. 2020). RES such as wind (Bout et al., 2021), solar (Tina et al., 2021), biomass (Ribó-Pérez et al., 2021) and geothermal energy (Di Fraia et al., 2020), as well as other sources (Stančin et al., 2020), can provide an economic and ecological alternative to fossil fuels to satisfy growing global energy demand. Figure 3 shows the total renewable energy consumption for electricity production from 2010 to 2020 (Ang et al., 2022).

According to the IEA's Global Energy Outlook in 2021, total renewable energy consumption has shown a significant increase, from 4098 TWh in 2010 to 7627 TWh in 2020 (Bak et al., 2021). EU countries' total renewable energy capacity increased from about 0.4 TW in 2013 to about 0.7 TW in 2022 (Figure 3) (Khezri et al., 2022).

Hydropower contributes the largest share of renewable energy capacity for electricity production worldwide, although the growth rate of hydropower is the lowest compared to other RES. Meanwhile, decarbonization control also requires using new technologies and energy sources (Bak et al., 2021). Renewable energy applications have attracted international interest for various reasons, including the development of renewable energy technologies, the depletion of fossil fuels, sustainable development and energy security. In the 21st century, renewable energy has gained great importance because non-renewable energy sources were overused, together with their escalated emissions (Amjith and Bavanish, 2022). The average total renewable energy capacity (Figure 4) is different in the EU countries (Khezri et al., 2022).

Among the above systems, the implementation of solar thermal collectors is expected to grow rapidly (Lemence and Tamayao, 2021). Solar energy (SE) is radiant ionizing energy emitted by the Sun and one of the energies that is highly utilized worldwide (Alhamrouni et al., 2020). Two main types of SE systems are solar thermal energy and photovoltaic energy, which are commonly implemented in developing and developed countries. Researchers are also gradually improving these two SE systems to achieve better efficiency. Photovoltaic (PV) energy is one of the popular SE technologies as a prospective energy source in the future (Alhafadhi et al., 2020). Current photovoltaic energy provides approximately 2% of the worldwide electricity demand (Bughneda et al., 2021). According to the International Energy Agency, the gross area of solar systems reached 686 million m^2 in 2018, which is expected to grow by 191% by 2030 and by 745% by 2050 to reach 2000 million m^2 and 5800 million m^2, respectively (Lemence and Tamayao, 2021; Bednárová et al., 2023). Wind energy is usually considered a cost-effective and environmentally friendly source of energy. It is the second main preference of renewable energy for electricity generation after hydropower due to its relatively simple/light infrastructure, cost-effectiveness and technological maturity (Herbert et al., 2007). Wind energy is converted into electrical energy in power plants based on wind turbines. Wind turbines can convert kinetic energy into electrical energy without any combustion, reducing CO_2, SO_x and NO_x environmental pollution (Moldovan et al., 2021). Wind turbines play a key role for countries that are heavily dependent on fossil fuel imports. Biomass energy is also an attractive alternative to get rid of dependence on fossil fuels, thus mitigating the greenhouse effect. It is also an effective waste management strategy (Lovrak et al., 2020). Biomass energy is available in several forms, such as agricultural and energy crops, municipal waste, wood waste and their waste products, which are used for direct combustion and co-combustion with fossil fuels (Mancusi et al., 2021; Rajnoha and Kánová, 2022). Hydropower is the oldest and most common type of renewable electricity source available, and one of the main RES used worldwide, accounting for 70% of all renewable energy measures undertaken as of 2016. It comes from water flows from lakes and mountain ranges and is produced by converting kinetic energy into mechanical energy in hydropower plants (Bhattacharjee and Nayak, 2020; Kostikova et al., 2022). Hydropower is a proven and cost-effective renewable energy source, and electricity is produced from the collected energy of moving water from higher to lower altitudes. Compared to other sources of renewable energy, hydropower has the highest conversion efficiency for electricity production, which is approximately 90%. Hydropower accounts for 20% of electricity production worldwide. Hydropower can be adjusted to meet the load requirement with a maximum capacity factor (Ang et al., 2022). Therefore, there are different types of hydropower, such as pumped storage systems, small hydropower and cascade hydropower. Global hydropower capacity is expected to increase by 17% between 2021 and 2030. Although electricity generation is only one of the many purposes of reservoirs, storage hydropower provides the flexibility to integrate intermittent renewables into the power system (Dujardin et al., 2017). However, due to the uneven spatiotemporal distribution of water resources in the basin, possible risks of insufficient water supply are also being considered. For example, recent work has focused on joint distribution and conditional expectation models to analyze the association of water supply, hydropower, and environmental variables to assess multiple risks in water resource systems (Chen et al., 2020). For hydropower production frequencies higher than 90%, the expected values of water supply sufficiency and sustainability of water use drop significantly, which creates possible risks of insufficient water supply and damage to the environment above the dams. Most developing countries rely primarily on hydropower, which is cost-effective and highly efficient, while countries with abundant renewable resources are gradually moving towards sustainable measures. Geothermal energy is thermal energy from the radioactive decay of mineral raw materials and from the primitive structure of the planet Earth. In general, the geothermal gradient increases by 0.03 °C.m^{-1} with the depth of the Earth so that 99% per cent of the Earth's temperature is higher than 1000 °C (Ang et al., 2022). The geothermal energy inside the Earth is abundant and inexhaustible compared to other intermittent renewable sources such as solar energy, wind energy, and hydropower (Barbier, 2002). In addition, geothermal energy is naturally stable and has no CO_2 emissions (Li et al., 2015). Hydrogen energy is known as a non-toxic and clean energy carrier that contains high specific energy on a mass basis. For example, the energy content of 9.5 g of hydrogen equals 25 g of gasoline (Polat et al., 2012). Hydrogen energy can be stored to generate electricity. Through direct or electrolytic methods, hydrogen is stored for a certain time before being released to achieve a chemical reaction to produce electricity (Koohi-Fayegh and Rosen, 2020). Hydrogen energy is sustainable because it can be generated from renewable and non-renewable energy sources (Koohi-Fayegh and Rosen, 2020) and thus can be used in various sectors such as transportation, commercial, institutional and residential areas (Dincer and Rosen, 2004).

In addition to the positive sides of the RES, there are also some limitations that must be considered. Using a photovoltaic system may contaminate the watercourse with toxic chemicals used in the heat transfer system, negatively impacting the environment when toxic chemicals are disposed of in the system (Baechler and Lee, 1991; Bradley, 1998). Animals, especially birds, hit the support systems and propellers, and the production of noise and vibrations may occur with the use of wind energy (Suaad, 2013; Pimentel et al., 2002). The use of hydropower may affect the ecology of the watercourse connected to sediment transport, fish migration and flooding (Ang et al., 2022). Air pollution due to the release of pollutants, soil and vegetation degradation connected to erosion and overexploitation and also economic disadvantages in the form of an increase in food price and risk of food security may result from the use of biomass energy (Ang et al., 2022; Robertson et al., 2008; Headey and Fan, 2008). Air pollution is also a problem of geothermal energy due to the production of hydrogen sulfide, which is also connected to the release of toxic metals (Energy Information Administration, 1991).

Risks, challenges and disagreements related to global climate change. Currently, subsidies and support for RES implementations between industry, governmental and non-governmental organizations are constantly developing. Authorities are looking for environmental, energy and development programs at different, local, regional and global levels in order to expand policy, economy and production of RES in developed and developing countries (Bayer et al., 2013; Pavolová et al., 2012b). Politics is a significant driving force for the development of renewable energies. Many studies have summarized the policies and development status of different countries. Scientists applied empirical methods to analyze the effects of government policies on the development of RES. Boie (2016) classified government policies into production and investment incentives. In October 2014, the European Council (EC) adopted the Framework for EU climate and energy policy until 2030, which included, among other things, a binding goal of reducing EU greenhouse gas emissions by at least 40% below 1990 levels by 2030. The same goal The EU has collectively set its reduction target under the Paris Climate Agreement. Based on this framework, the entire EU climate and energy legislation was comprehensively revised in the following years. The document analyzes the options for the transition to a low-carbon economy, which would lead to the fulfilment of the ambitious goals of the EU in reducing greenhouse gas emissions or would lead to climate neutrality by the end of the first half of this century. In this context, eight scenarios were analyzed, of which the two most ambitious scenarios would achieve a 100% reduction in emissions (after considering negative emissions), which would mean reaching climate neutrality as early as 2050. These two scenarios are in line with "the 1.5 °C" ambitious goal of the Paris Agreement. At the EC in December 2019, all member states signed up to the goal of climate neutrality for the EU by 2050, while some member states (Sweden, Finland, Austria) chose even more ambitious goals at the national level. The agreement contains measures and a plan of key policies related to the whole range of issues – from ambitious reduction of emissions through investment in top research and innovation, transformation of the entire industry, economy and agriculture to the protection of the natural environment in Europe. According to this agreement, the above-mentioned 40% reduction target for the EU by 2030 should also be reviewed (the EC proposes a 50% to 55% reduction target). The European Green Deal is a package of political initiatives, the purpose of which is to direct the EU on the path of green transformation with the ultimate goal of achieving climate neutrality by 2050. It supports the transformation of the EU into a fair and prosperous society with a modern and competitive economy. It emphasizes the need for a holistic and cross-sectoral approach in which all relevant policy areas contribute to the ultimate climate goal. The package includes initiatives on climate, environment, energy, transport, industry, agriculture and sustainable finance, all of which are closely linked. The Commission presented the European Green Deal in December 2019, and the EC took note of it at its December meeting. The Green Agreement includes initiatives to align EU legislation with EU climate goals. The renewable energy sector should be a dynamic industry that actively supports the country's economic development and reduces differences from the EU. The more renewable resources are introduced into the system, the higher the costs will be in the form of subsidies. The most important topics on the use of renewable resources that have been reflected in environmental organizations are those related to the location of wind power plants and the construction of small hydropower plants in protected areas. Non-governmental organizations most often do not have problems directly with producers or investors but with authorities that need to implement legislation. According to the national action plan in the field of renewable energy, the financial mechanism resulting from the awarding of green certificates is based on the transfer of financial costs to the consumer (residents or economic entities) for whom the green energy component is reflected in the value of electricity bills. The EU energy industry will face significant challenges in the coming decades. New ways of achieving energy security and transition to carbon neutrality (Rabbi et al., 2022) were selected as typical cases in this document. Although some countries face many serious environmental challenges, there are real opportunities to make fundamental changes in their economies. The transition to an ecological and low-carbon economy brought several advantages in addressing food, energy, and water security and in achieving sustainable development. By the second half of this century, the energy sector will transform from fossil to zero-carbon (IRENA, 2019). Energy-related CO_2 emissions need to be reduced to limit climate change. The energy transition can create vast socio-economic opportunities by supporting the decarbonization of communities. The degree of environmental hazard reduction will ultimately depend on the policies adopted, the speed with which they are implemented, and the deployment of resources (Liu, 2022). The development of RES

is significantly limited by the internal costs of energy and the way in which it is implemented (da Silva, 2010). The key to the global implementation of green energy will have to be based on pragmatism and political and strategic wisdom, correlated with massive financing of research and development in the field of energy and technology. Of course, reasonable time planning will always include risks – directly referring to the danger posed by the widespread use of nuclear and even hydropower, which will also significantly damage the biodiversity of plants and animals in rivers and streams. If everything was quick, perfect and sure, it would be possible to find out that instead of saving the planet and human society, there would be a gigantic step towards economic and social self-destruction (Bakalár et al., 2021; Chenic et al., 2022; Al-mulali, 2014). RES are an alternative to traditional primary non-renewable energy sources such as fossil fuels. Obtaining energy from these sources is much less ecological than renewable sources. The use of renewable energy in the energy mix significantly reduces the harmful impact of the energy sector on the natural environment, mainly by reducing emissions of harmful substances, especially greenhouse gases (Rajchel and Walawender, 2018). Irregularity in the operation of RES systems causes a significant difference between the average and maximum output, which is not observed in the case of system power plants, e.g. coal, nuclear or gas. In order to cover the gap in energy production in case of wind or solar failure, the country must maintain sufficiently large operational energy reserves – both rotating and stationary (Miciuła, 2015). In addition to wind and solar energy, agricultural and forest biomass is a particularly important RES. The reason is the universality and availability of this raw material (Zaporowski, 2016; Raheem et al., 2016). In addition, biomass is a solid and more stable fuel and does not depend on the weather like solar or wind energy. Every year, there is a significant increase in the global use of RES in the energy system. EU member states face the need to build competitive internal energy markets and respond to global problems resulting from climate change (Miciuła 2015). Economic development is closely related to the level of total energy consumption, as well as emissions into the environment. Therefore, renewable energy systems with improved energy efficiency are gradually emerging and are designed to achieve sustainable economic and financial development (Ouramdane, 2021). The EU is one of the leaders in this transition and aims to achieve a sustainable economy, products and markets (Bluszcz and Manowska, 2020).

Conclusions

The existence of human society on Earth is based on the need and satisfaction of consumption and energy needs, and with development, these energy demands are constantly increasing. The supply of the decisive amount of energy is currently ensured by the so-called conventional energy sources – fossil or nuclear. Since the environment is significantly and irreversibly polluted and devastated by the processing and burning of these fuels, this method of energy production is not the most suitable for sustainability and literally the survival of the entire living world. Innovations and research are constantly continuing to improve and develop the current state of RES in terms of economic, technical and energy conversion efficiency. Environmental problems such as climate change, global warming and ozone depletion are more serious/catastrophic/destructive. To solve this problem, more developed industrial countries are cooperating to increase the use of renewable energy technologies. At the same time, it is necessary to carry out various research and innovations, and introducing newer methods and components is very welcome for a more efficient and affordable production of energy from renewable sources. The current task in the energy industry is to find ecologically clean, energy-efficient and safe solutions that will ensure sustainability and energy supply for ever-increasing consumption, economic efficiency and energy portability (networks and distribution systems), as well as stability of energy supplies and a clean environment at the same time and reducing burdens from the past as well as compatibility with other related human activities and accessibility for various developed regions.

The use of RES as a domestic energy source increases the security and diversification of energy supplies and simultaneously reduces the economy's dependence on unstable oil and natural gas prices. Their use is based on advanced and environmentally friendly technologies, and they significantly contribute to reducing greenhouse gas and pollution emissions. Increasing the share of RES represents an important element in the package of measures to achieve the goals of the Kyoto Protocol. RES contribute to strengthening and diversifying the structure of industry and agriculture. They support innovation and development of information technologies, open space for new directions, and are one of the pillars of building a knowledge-based economy. The rational management of domestic RES is in accordance with the principles of sustainable development. Increased use of RES has an impact on improving the health of the population.

Solar energy has the greatest overall potential. Considering the financial and technological possibilities, the assumption is that solar energy is mainly used to produce heat and domestic hot water. Current photovoltaic technology makes it possible, without major structural changes, to integrate photovoltaic generators into the energy distribution system, ensuring the share of several per cent of the annual electricity consumption. Compared to other technologies, the use of photovoltaic potential is currently more financially demanding.

Geothermal energy has the second-largest overall potential. The properties of geothermal water predetermine the use of this energy, mainly for heating and medical purposes. The technical potential is also significantly lower due to technological problems related to the chemical composition of geothermal waters.

Biomass has the greatest technical potential. Biomass has a great perspective in the production of heat, especially in central heating systems, less so in households, in the form of pellets, briquettes, wood chips and straw. A relatively quick solution to the increased use of biomass is co-combustion with fossil fuel in thermal power plants and in the combined production of electricity and heat. In the case of larger facilities, one of the important factors is the optimization of logistics costs. Hydropower is the most used renewable source for electricity production, and it covers over 98% of electricity production from RES. Hydropower, like most RES, is created because of solar activity, which helps evaporation from water surfaces, then the formation of water vapour clouds, and finally returning to the Earth's surface in the form of precipitation, which creates a closed water cycle. The energy that the water produces in this way can then be used to produce electricity in hydroelectric power plants. The use of hydropower potential is approximately 57%. The global use of wind energy is constantly increasing, and many countries are using this renewable source. Countries such as China, the United States of America, Germany, India and Spain are leaders in the field of wind capacity. These countries invest significantly in wind energy infrastructure, which leads to a significant reduction in carbon emissions and a transition to a more sustainable energy mix. Continuous advances in wind turbine technology have played a key role in the growth of wind energy. Turbines have become more efficient, more reliable and cheaper over the years. Technological innovations such as taller towers, larger rotor diameters, and improved rotor blade designs have greatly increased energy harvesting, making wind power more competitive than conventional energy sources. In addition, research and development efforts focus on integrating wind energy into energy storage systems, improving grid stability, and exploring the potential of offshore wind energy. Hydrogen energy represents about 2% of the EU's energy mix. Almost all hydrogen – up to 95% - is produced using fossil fuels, which releases 70 to 100 million tons of CO_2 annually. Based on the research, RES could supply a substantial part of Europe's energy in 2050, of which hydrogen could represent up to a fifth. It could cover 20-50% of energy demand in transport and 5-20% in industry. It is mostly used as a raw material in industrial processes but also as fuel for space rockets. Due to its properties, hydrogen can be a good fuel because:

- its use for energy purposes does not cause greenhouse gas emissions; the only by-product of the process is water,
- it can be used to produce other gases as well as liquid fuels,
- the existing infrastructure for gas transportation and storage can be adapted for hydrogen,
- it has a higher energy density than batteries, so it can be used to transport long distances and heavy goods.

Today, everyone is aware that energy is needed to live – whether in the form of heat, light, or other forms of energy. However, few people are willing to acknowledge that the current way of using fossil fuels is limited in time and that the life of creation on the planet is at the expense of nature. Few human activities affect the environment to such a serious degree as the current energy use. This manifests itself in the growing threat of global climate change, acid rain and smog in cities or, ultimately, nuclear power plant accidents. It is precisely classic energy sources, and the way industry and society use them that cause irreparable damage to nature and people's health. The use of RES is one of the ways of understanding nature protection as a whole and providing a perspective for the sustainable development of society.

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