Original scientific papers UDK 502.131.1:539.1.078(100)
DOI 10.7251/COMEN2102166K

TENDENCY OF GLOBAL CAPACITY DEVELOPMENT OF RENEWABLE ENERGY SOURCES IN THE WORLD IN THE LAST TEN YEARS

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Abstract: It is well-known that, in the past decades, the burning of fossil fuels was identified as the major cause of climate change. Climate change mitigation is becoming a central concern of global society. Limiting global warming to below 2 °C above the temperature of the pre-industrial period is the key to preserving global ecosystems and providing a secure basis for human activities, as well as reducing excessive environmental change. The ambitions increased at an accelerated pace with a dramatic expansion of net zero-emission targets. Increasing pressure from citizens and society has forced countries to intensify their climate plans, while the private sector has bought a record amount of renewable energy. An energy system based on fossil fuels must be replaced by renewable energy with low carbon emissions with improved energy efficiency. That applies to all consumers of fossil energy: cities, villages, building sectors, industry, transport, agriculture, and forestry. The paper explores and presents the strategy of energy development of renewable energy sources in the world. The application of new technologies that have led to developing renewable energy sources is presented in detail: wind energy, solar energy, small hydropower plants, biomass, and their increase in the total share of energy production, i.e., reduced fossil fuel use in energy production. Investments in new technologies used in renewable energy sources have led to increases in employment worldwide. Analysis of the trend of increased energy production from RES (Renewable Energy Sources) with investment plans, the employment rate for each energy source, and the development of renewable energy sources in the coming period are provided.

Keywords: renewable energy sources, solar energy, wind energy, biomass energy, hydropower.

1. INTRODUCTION

It is well-known that humankind used natural energy sources that are still used today, such as wood for heating, wind energy to run mills and ships, water energy to run mills, solar energy to heat buildings, and geothermal energy used for heating. In the age of mass industrialization, i.e., the first industrial revolution in the world, fossil fuels have been used, which have caused global climate change that humanity has been facing for the last few decades, causing significant environmental changes, increased production of carbon dioxide and other greenhouse gases. The effects of climate change are already noticeable, so we can see glaciers melting, polar ice melting, permafrost melting, sea levels rising, and world ecosystems changing. Ecological changes in the world are a consequence of the use of fossil fuels, which has forced entire humanity to take steps to stop and change it. To reverse this negative trend of environmental change, it is necessary for the governments of almost all countries to seriously consider and adopt development policies and strategies for replacing fossil fuels with renewable energy sources [1–6,11–13,30,35,40,41]. In recent decades, we have witnessed that nuclear energy is an insecure source of energy, and the reason is that we have had major nuclear accidents. We will mention two accidents: Japan's Fukushima (March 2011) and Chernobyl in the former Soviet Union. The nuclear disaster in Japan has caused an increase in the share of renewable energy sources in energy production, and more attention has been paid to energy efficiency worldwide. Global greenhouse gas emissions growth should fall by 40-70 % between 2010 and 2050 to create prospects for achieving the UN's goals in limiting global warming. The Intergovernmental Panel on Climate Change (IPCC), held in 2007, states

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in its report that the world is doing little to meet the agreed targets and limit warming to less than 2°C compared to the pre-industrial period. That means that most countries in the world will have to reconsider their strategies and focus on investing in carbon dioxide removal (CDR) technologies, from collecting and burying coal-fired power plant emissions to planting forests that use carbon dioxide for growth. Renewable energy sources are playing an increasing role in the world's energy system. Energy evolution is the most ambitious, as it introduces the production of energy from renewable energy sources and rigorous energy efficiency measures so that the largest share in energy production by 2050 will belong to renewable energy sources. We know that renewable energy sources themselves can be divided into two main categories: traditional renewable energy sources such as biomass and large hydropower plants, and the so-called "new modern renewable energy sources" which include: wind energy, solar photovoltaic energy, solar thermal energy, biomass (bio-fuel, biogas), small hydropower plants, geothermal energy, sea energy (tides, waves, and sea currents) [13,27,31,50,52-54]. All scenarios in the world consider new modern renewable energy sources as the energy for the future, i.e., clean energy, which will reduce and replace fossil fuels, and thus reduce their harmful impact on ecosystem change and climate change occurring in the world today.

2. PROJECTION OF ENERGY DEVELOPMENT OF RENEWABLE ENERGY SOURCES IN THE WORLD BY 2050

We are witnessing that, currently, the world covers its energy needs mainly from non-renewable energy sources such as fossil fuels – coal, oil, and natural gas for the most part. The share of fossil fuels in total final energy consumption is the same as ten years ago. In the period 2009 - 2019, the annual growth trend of renewable energy sources grew by 5%, and the share of fossil fuels remained at about 80 % in the same period. Due to the release of large amounts of carbon dioxide (CO2) and other greenhouse gases into the atmosphere, and owing to this type of power production, some major climate changes have taken place, as well as damage to the health of the human population. To solve these global problems, many scenarios have been developed to replace fossil fuels with renewable energy sources [1–3,10,13,14,28,44-49,55,56]. Of the many versions, we will present the one created by the energy consulting company "ECOFYS", which in its report describes in detail how we can meet almost 100 % of global energy needs from renewable energy sources by 2050 [3]. Approximately half of the objective is achieved through increased energy efficiency to reduce energy needs, while the other half is achievable by changing renewable energy sources to produce electricity, as shown in Figure 1.

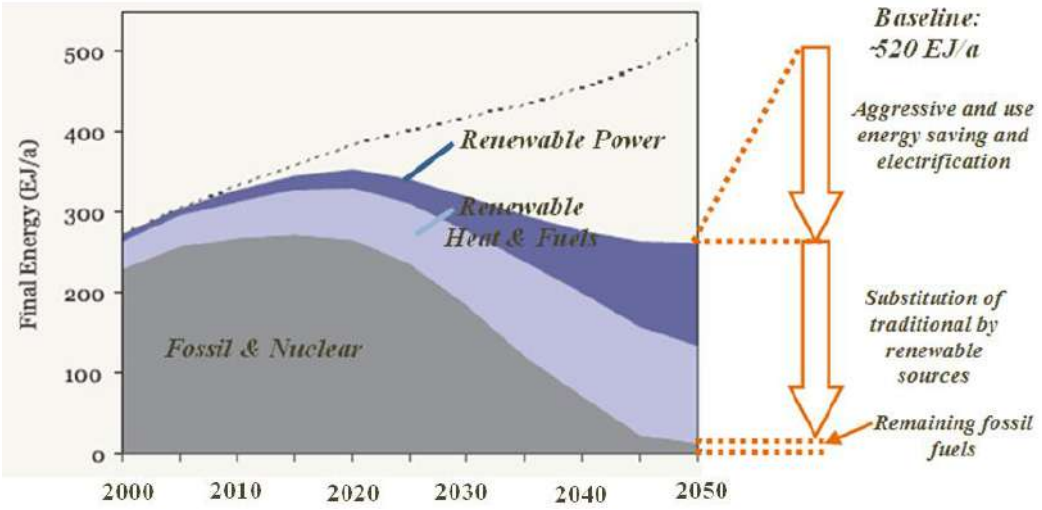

Figure 1. Global energy consumption for the period 2000-2050 (ECOFYS)[3]

ECOFYS projected global energy consumption between 2000 and 2050, and its report predicts that global energy demand will be 15 % lower by 2050 than in 2005, despite a growing population and steady economic development in countries such as India and China. Wind, solar energy, biomass, and hydropower are the sources of electricity, together with solar and geothermal sources and heat pumps, which provide a large share of heat for buildings and industry. Wind energy could

meet a quarter of the global electricity needs by 2050 if current growth rates continue and if they are set as a target. It also predicts that more than one-third of building heat will come from geothermal sources by 2050. According to ECOFYS research, as presented in Figure 2, the global use of renewable energy is gradually growing from now until 2050.

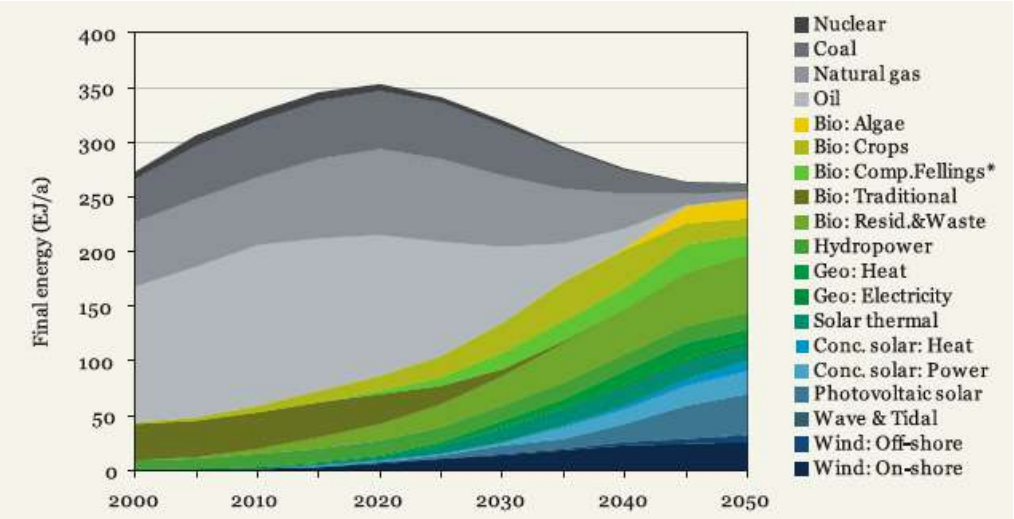

Figure 2. Energy consumption by sources in the period 2000-2050[3]

If we double the current growth rates of geothermal electricity production, it will meet 4% of our total electricity needs by that date. The power of the ocean, through waves and tides, will account for about 1% of global electricity needs by 2050. Hydropower, which currently supplies 15% of global electricity, will ultimately provide 12% under the ECOFYS scenario. ECOFYS also envisions using current technology and expertise to "create buildings that require almost no conventional energy for heating or cooling, through airtight construction, heat pumps, and sunlight." The ECOFYS scenario predicts all new buildings meeting these standards by 2030. 2-3% of the existing buildings will also need annual retrofit to improve energy efficiency. To accomplish this, ECOFYS believes we will need to redirect up to 3% of global gross domestic product (GDP) to investments in materials and energy efficiency, renewable energy sources, and the necessary infrastructure.

3. THE GROWING TREND OF THE SHARE OF RENEWABLE ENERGY SOURCES IN GLOBAL ENERGY PRODUCTION

We are aware that renewable energy sources have been playing an increasingly important role in the energy system in recent times. Energy evolution is the most ambitious because it introduces power production from renewable sources and rigorous energy efficiency measures. Hence, renewable energy sources will have the largest share in energy production by 2050. Renewable energy sources can be divided into two main categories: traditional renewable energy sources such as biomass and large hydropower plants, and the so-called new renewable energy sources like solar photovoltaic energy, solar thermal energy, wind energy, biomass (bio-fuel, biogas), small hydropower plants, sea energy (tides, waves, and sea currents) and geothermal energy [2,5,11,12,51,53,54]. Renewable energy sources are considered the energy for the future, i.e., clean energy, which will replace fossil fuels and their harmful impact on the environment. To depict how the trend of participation of renewable energy sources in energy production is increasing, we have shown the share of renewable energy sources in 2009 and ten years later in 2019, as shown in Figure 3 [14–26]. The percentage of renewable energy sources in total final energy consumption (TFEC- Total Final Energy Consumption) increases moderately due to the following facts:

– due to the growth of global energy demand,
– due to constant consumption and investment in new fossil fuels, and
– due to the decline of traditional biomass use and concern for sustainability, people prefer modern energy sources.

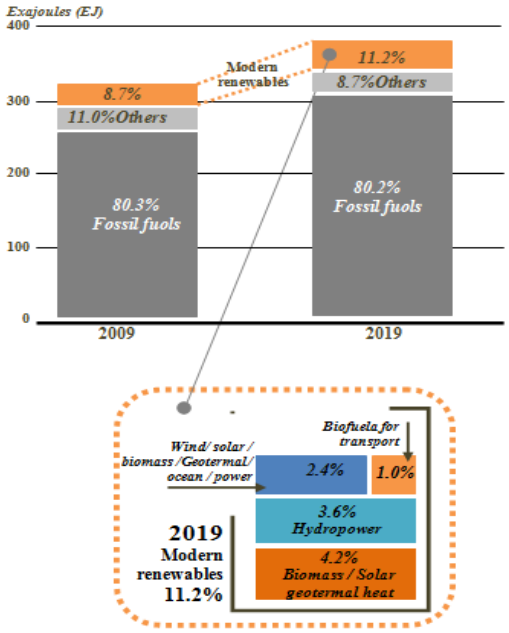

Figure 3. Estimation of the share of renewable energy sources in the total final energy consumption in 2009 and 2019[14,26]

Figure 3 shows the share of renewable energy sources, i.e., compares two years in a ten-year period. In 2009, the percentage of fossil fuels in the total final energy consumption was 80.3%, and the share of renewable energy sources was 18.7%, of which modern renewable energy sources were 8.7%. In ten years, i.e., in 2019, the percentage of fossil fuels in the total final energy consumption was 80.3%, and the share of renewable energy sources was 19.9%, of which modern renewable energy sources were 11.2%. We must state that the share of fossil fuels in the total energy consumption slightly reduced in ten years. In 2019, the percentage of modern renewable energy in the total final energy consumption was 11.2%, and the largest share had biomass/solar and geothermal heat with 4.2%, hydropower 3.6%, wind, solar, biomass, geothermal, ocean with 2.4% and biofuel for transport with 1.0%. To obtain a realistic representation of the participation of renewable energy sources in the total final energy consumption, we will analyze and show the trends of all renewable energy sources.

4. THE TREND OF GLOBAL CAPACITY OF RENEWABLE ENERGY SOURCE – SUN

The energy of the sun is inexhaustible. It spreads in space as light and heat, and only a small part reaches the Earth. At the annual level, the total solar energy absorbed in the atmosphere of the Earth, oceans, and landmasses is about 3,850.00 (EJ). The sun gives more energy in one hour than all of humanity consumes in one year. The amount of solar energy that reaches the surface of the Earth is so large that it is twice the total energy that people will ever obtain from all non-renewable sources of coal, oil, natural gas, and mined uranium combined [7,8,9,29]. Although solar energy is the cause of most energy sources, under optimal conditions, about 1 kW/m^2 can be obtained on the surface of the Earth, and the actual value depends on location, season, time of day, weather conditions, etc. The main problems in using this energy are small energy-flux density, wide fluctuations in radiation intensity, and high investment costs. Most individual countries in the world subsidize the installation of elements for converting solar energy into a usable form of energy. The basic principles of direct use of solar energy are solar collectors – preparing hot water and heating rooms, photovoltaic cells – direct conversion of solar energy into electricity, and focused solar energy – use in large power plants [32-34]. Figure 4 shows power production from solar energy.

Installing solar PV global capacity is increasing annually, as shown in Figure 4. The trend of installing solar PV global capacity in the last ten years has grown exponentially so that in 2020 it reached about 760 Gigawatts [14,36-39]. Demand for solar photovoltaic energy is growing and becoming the most competitive option for generating electricity in a growing number of locations, both residential and commercial, and utility projects. In 2020,

approximately 20 countries added at least 1 GW of new solar PV capacity, compared to 18 countries in 2019. All continents have contributed significantly to this global growth. By the end of 2020, at least 42 countries had a cumulative capacity of 1 GW or more. Figure 5 shows an analysis of renewable energy production – sun in the top ten countries in the world in 2020.

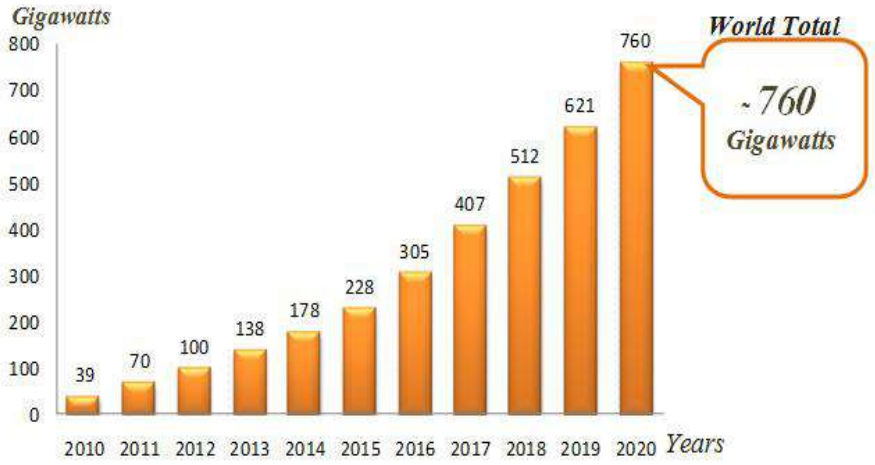

Figure 4. The trend of global solar photovoltaic (PV) capacity in the world on an annual basis in the period 2010-2020[14-26]

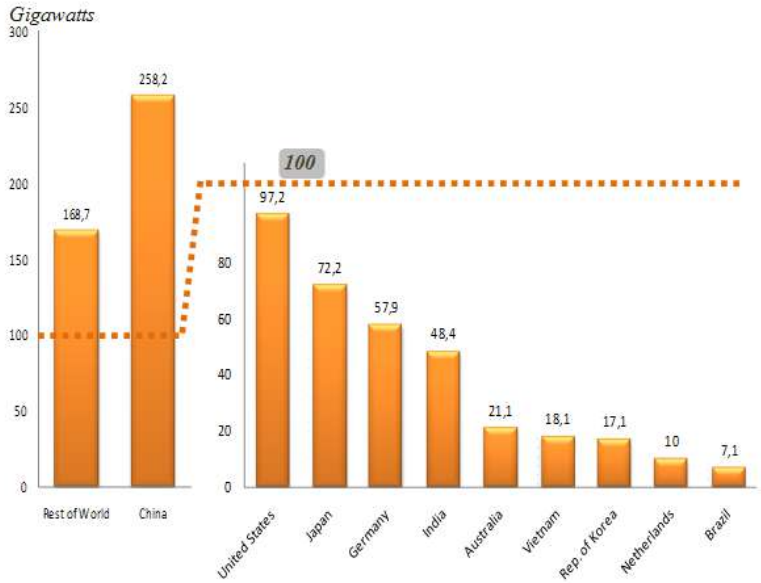

Figure 5. Global solar photovoltaic (PV) capacity in the top ten countries in the world in 2020[14]

Governments around the world are more and more focused on the integration of renewable energy sources. If we look at the solar photovoltaic capacity in 2020, we see that China is first, with 258.2 GW, whereas, in other countries, it is about 168.7 GW. The Chinese government has issued guidelines for providing renewable electricity so that governments at all levels support the local population and increasingly connect solar energy. Following China, the United States is second, with a solar photovoltaic capacity of about 97.2 GW, followed by Japan, with cca 72.2 GW. Of the European countries, Germany ranks first, with 579 GW, which places the country fourth in the world. After Germany, the rank of solar photovoltaic capacity by countries is as follows: India, Australia, Vietnam, Republic of Korea, Netherlands, and Brazil. Figure 6 shows the percentage analysis of the global solar photovoltaic capacity in the top ten countries and the rest of the world in 2020.

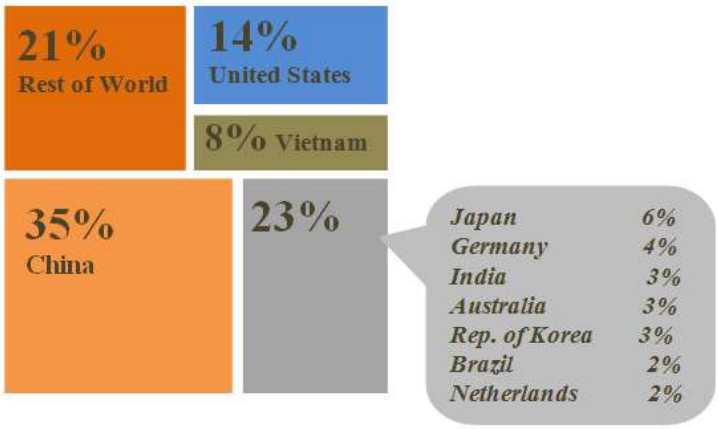

Figure 6. Percentage of solar photovoltaic (PV) global capacity in the top ten countries in the world in 2020 [14]

In 2020, China was first, with 35 % of solar photovoltaic global capacity, followed by the United States with 14 %, and Vietnam had 8% of global capacity. The next seven top countries (Japan 6 %, Germany 4 %, India 3 %, Australia 3 %, Republic of Korea 3 %, Brazil 2 %, and Netherlands 2 %) account for 23 % solar photovoltaic global capacity.

We must note that, in all countries, solar photovoltaic capacities are increasing the use of solar energy every year.

It is possible to store solar energy as heat, where thermal energy is used in various processes (for heating, industry, etc.), as shown in Figure 7.

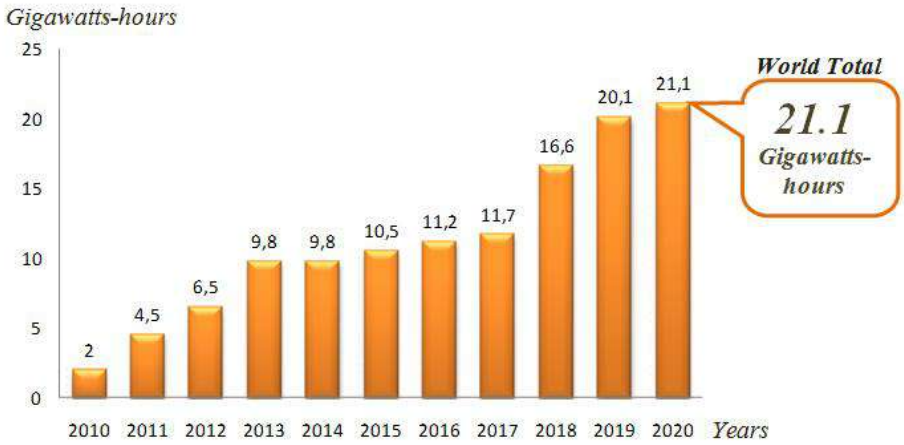

Figure 7. Global storage capacities of solar thermal energy (CSP) in the world in the period 2010-2020[14-26]

Based on Figure 7, we conclude that the global capacity for concentrating solar thermal energy increases every year so that in 2020 the stored thermal energy reached a value of about 21.1GWh (Gigawatts-hours). Solar energy is used for solar thermal heating in industry, households, construction, etc. Figure 8 shows the global capacity trend of solar water heating collectors in the last ten years.

Solar thermal energy has been growing annually for the last ten years worldwide. However, we must point out that in 2019 it dropped to 478 GWth, and the reason is caused and related to the pandemic of virusCOVID-19. The decrease is lower than expected due to various stabilization factors, and the reason is the continuous operation in the construction sector during the pandemic that helped maintain constant demand. The global capacity of solar water heating collectors in 2020 was 501 GWth, as shown in Figure 8[14].

To achieve such growth in the development of renewable solar energy sources, it is necessary to invest in technologies that accompany the development and implementation of solar energy. Figure 9 shows global new investments in renewable solar energy sources in the last ten years.

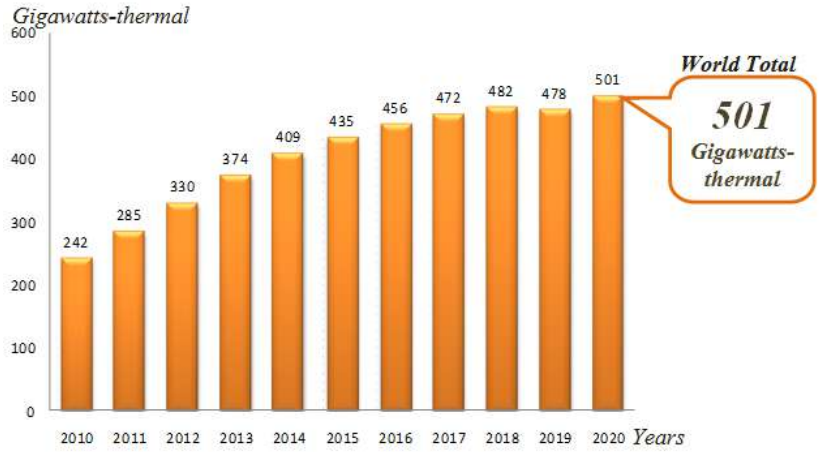

Figure 8. Global capacities of solar water heating collectors in the world in the period 2010-2020[14-26]

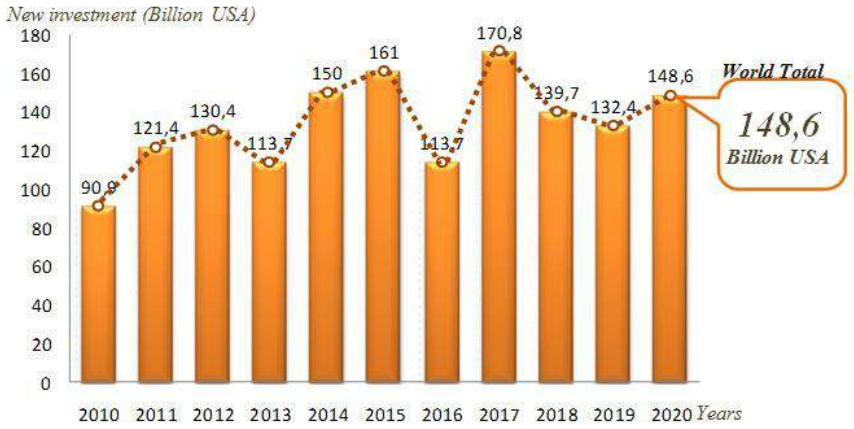

Figure 9. Global new investment in renewable solar energy through technology in the world in the period 2010-2020[14-26]

Based on the trend of global new investments in solar renewable energy through technology in the last ten years, we see that in 2010 the investment amounted to 90.9 billion USD, and in ten years increased to 148.6 billion USD. In the previous ten years, investment in solar energy in some periods has been declining, such as in 2013, 2016, and 2019. In 2019, the largest solar energy markets were limited due to the COVID-19 pandemic. That caused a delay in investment decisions by commercial companies, which caused the decline in investment in solar energy. It is expected that investments in solar energy will have a growing trend in the next period.

5. THE TREND OF GLOBAL CAPACITY OF RENEWABLE ENERGY SOURCE – WIND

Wind as a renewable energy source is the second in implementation in the world. Wind power plants had the fastest growth of all renewable energy sources at the beginning of the 21st century. We can conclude in Figure 10 that the capacity of renewable energy sources – wind in the world increased almost four times in 2000 - 2020. It is estimated that wind turbines will reach an increase of 21 % per year. In the long run, the technical potential of wind as a renewable energy source is increasing, but with that comes the solution of structural problems of wind turbines, because today they are produced up to 150 meters and 8 MW, and in the future, with the development of new technologies they will reach up to 300 meters and 20 MW. Wind power plants will be installed in large areas, at great altitudes, and in the oceans with high wind resources. The constructive solution of wind turbines is that they are mobile and can be moved to the area where the wind blows. A clear example is Denmark, where approximately one-fifth of electricity comes from wind turbines, which puts Denmark as the country with the largest share of wind turbines in power production [2,14–27,40,57].

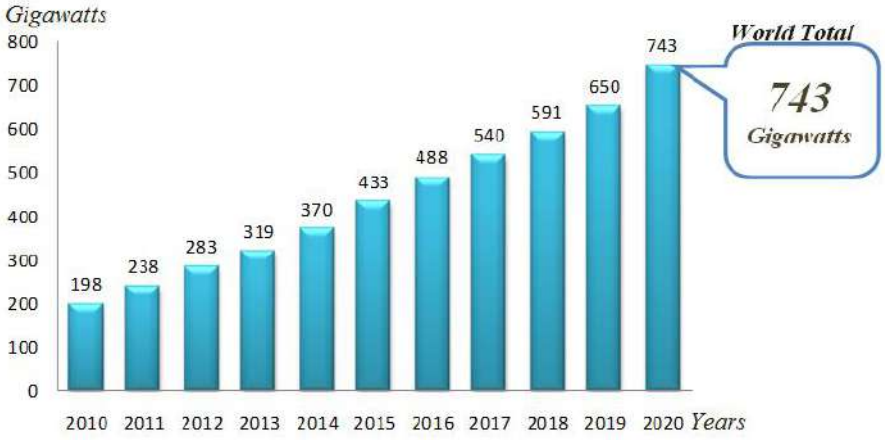

Figure 10. Global wind energy production capacity in the period 2010-2020[14-26]

In 2010, the global wind energy capacity in the world was 198 GW, and in ten years, in 2020, it reached a value of 741 GW. During this period, the global capacity of wind energy production was continuously increasing every year, so we can conclude that the trend is rising by a slight exponential function, regardless of the limitations in the world, such as the COVID-19 pandemic [14]. It is interesting to observe in which countries wind is most prevalent as a renewable energy source. We analyzed the global capacity of wind energy production in the top ten countries in 2020, as shown in Figure 11.

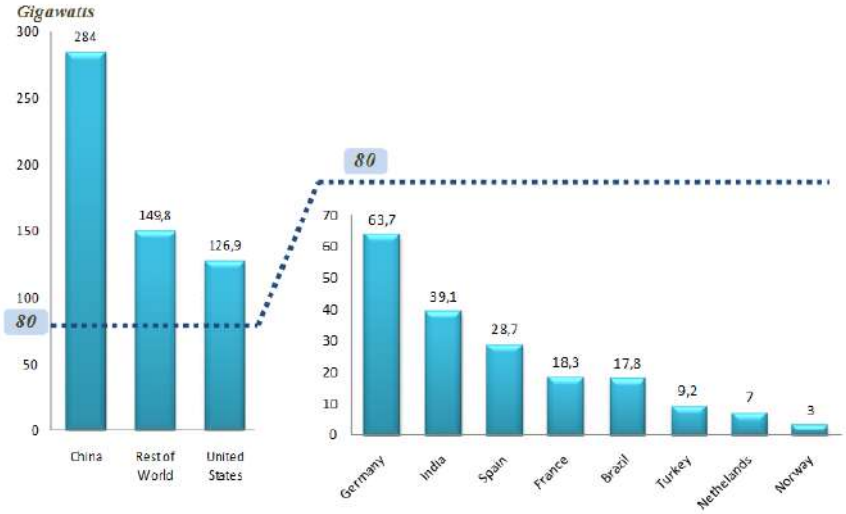

Figure 11. Global capacity of wind energy production in 2020 in ten top countries in the world[14]

The analysis of the diagram in Figure 11 has shown that China ranked first in the world in 2020 with 284 GW of global wind energy production capacity, followed by the United States with 126.9 GW, and all other countries with 149.8 GW global capacity. Germany is in third place with 63.7 GW, followed by India, Spain, France, Brazil, Turkey, Netherlands, and Norway. These are the ten countries with the largest capacity in wind energy production in 2020. We will also analyze the investment in wind energy production in the world. Figure 12 shows investments in technologies in this part of renewable wind energy in 2010-2020.

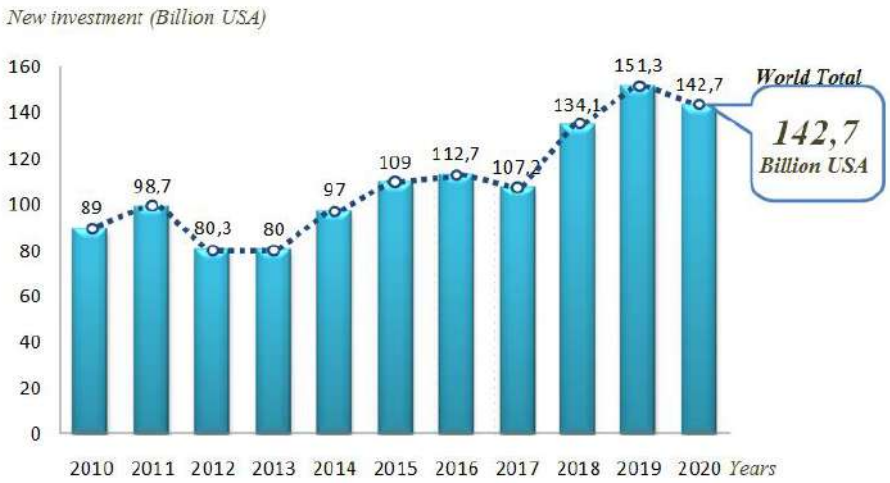

Figure 12. Global new investment in renewable wind energy through technology in the world in the period 2010-2020[14–26]

New investments in renewable wind energy are ongoing, and in the last ten years, they have increased by 62.3 %. In 2010 new investments in wind energy amounted to 89 billion dollars, and in 2020, they rose to 142.7 billion dollars. In some periods, investment in renewable wind energy was reduced, for example, in 2012, 2013, and 2017. During the virusCOVID-19 pandemic, investment was highest in 2019 and amounted to 151.3 billion dollars. It is expected that, in the future, investment in this type of renewable energy source will increase.

6. THE TREND OF GLOBAL CAPACITY OF RENEWABLE ENERGY SOURCE - BIOMASS

Biomass is a renewable source of energy; it can generally be divided into wood, non-wood, and animal waste, within which we can distinguish: wood biomass, agricultural residues and waste, animal waste and residues, and biomass obtained from waste. The definition of biomass, as cited in Directive 2009/28EK, is *"the biodegradable fraction of products, waste, and residues of biological origin from agriculture (both plant and animal origin), forestry and related sectors such as fisheries and aquaculture, as well as the biodegradable fraction of industrial and municipal waste"*. Using various transformation processes like combustion, gasification, and pyrolysis, biomass can be transformed into "bio-fuels" used for transport, "bio-thermal energy'' or "bio-electricity". Biomass is most often used directly in final energy consumption for heating, cooking, or water heating. However, it can also be used to produce electricity and heat, and increasingly, biofuels [2,10,28,39,45,49].

The total share of bioenergy in the total final energy consumption in 2019 was 11.6%, of which 6.5% referred to traditional biomass and 5.1% to modern biomass. Participation in modern biomass is distributed as follows: 1.2% for heating buildings, 1.0% for transport, 0.5% for electricity, and 2.5% for heating in industry.

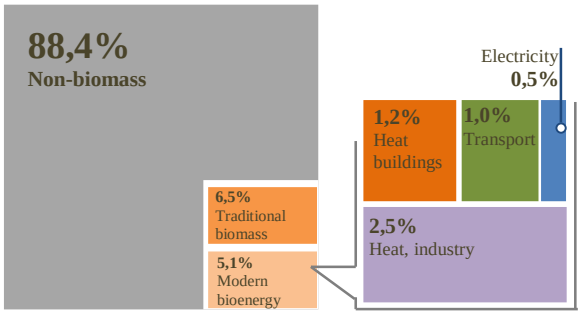

Figure 13. Estimated shares of bioenergy in total final energy consumption in 2019[15]

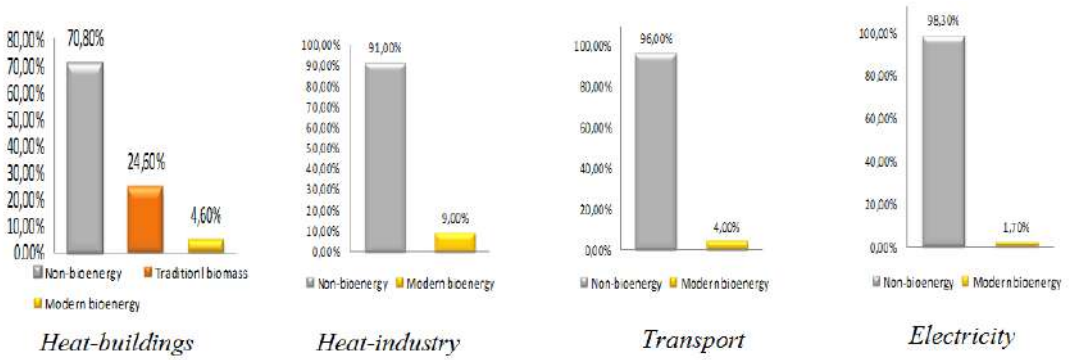

Figure 14. Percentages of bioenergy in the total final energy consumption for different purposes in 2019[15]

Based on Figure 14, we can see that the share of traditional biomass for heating buildings was 24.6%, and modern bioenergy was 4.5% in 2019, while for heating in the industry, the percentage of modern bioenergy is 9.0%. Biomass is also used in transporting bio-fuel with a share of up to 4.0% as modern bioenergy. The smallest share of bioenergy has power production, with 1.7%, as shown in Figure 14.e

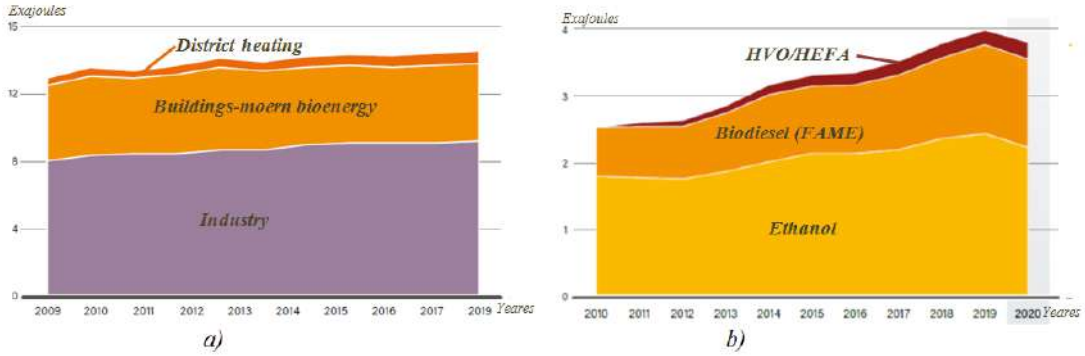

Figure 15. Use of bioenergy for heating in industry and buildings (a) and global production of ethanol, biodiesel and fuel HVO/HEFA(b) in the period 2019-2020[14-26]

Based on Figure 15.a), we can conclude that bioenergy for heating in industry and buildings in 2019 provided about 13 EJ, an increase of 11 % compared to 2009. In other words, we have had an 11 % increase in bioenergy in ten years. In addition, around 0.7 EJ of bioenergy was provided for district heating in 2019. Likewise, bioenergy is the main source of renewable heat in district heating systems, accounting for 95% of all heat delivered from renewable energy sources. Based on Figure 15.b) we conclude that global production of liquid biofuels fell by 5%, from 4.0 EJ (161 billion liters) in 2019 to 3.8 EJ (152 billion liters) in 2020, because overall demand for transport fuels fell as a result of the COVID-19 pandemic [14]. Also, the amount of ethanol and biodiesel production and their constant use decreased sharply in 2020. Lower transport demand for diesel fuel was offset by higher blending requirements and other factors, which significantly increased the production and use of hydro-treated vegetable oil (HVO). In total, in 2020, ethanol accounted for about 61% of biofuel production (in terms of energy), methyl fatty acid ester (FAME) biodiesel for 33%, and HVO for 6%. Other biofuels include biomethane and many other advanced biofuels, but their production remained low, estimated at less than 1% of total biofuel production[14].

The production of ethanol has decreased due to lower demand, negative operating margins, and limited storage capacity. To create a realistic picture of the implementation of bioenergy, we will show the trend of production and use of wood pellets used in the production of heating energy. The tendency of wood pellet production in the world in 2008-2018 is shown in Figure 16.

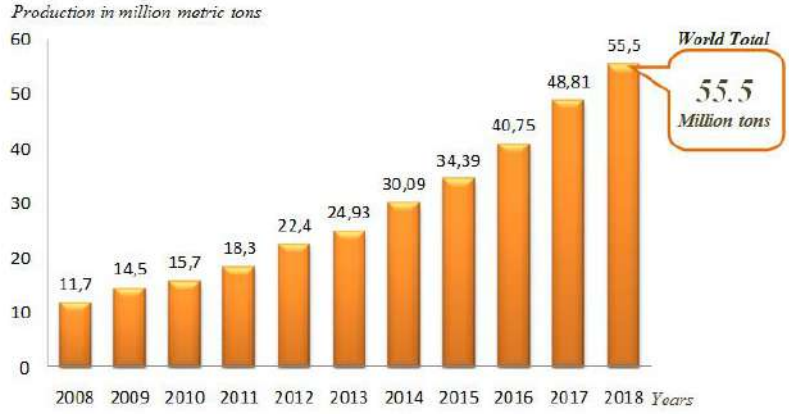

Figure 16. The trend of wood pellet production in the world in the period 2008 to 2018[2,14-26]

The analysis of the diagram shown in Figure 16 provided us with the conclusion that the production of wood pellets in the world increases every year. The increasing trend is exponential, which is expected in the coming period since the positive tendency of wood pellet production in the world will continue. Another parameter for a better understanding of the extent to which bioenergy will be a form of renewable energy is the investment in this area on an annual basis worldwide.

Investments in renewable bioenergy are continuous, and for the last ten years, the investments have decreased. In 2009, investments amounted to USD 22 billion, and in 2020, they were USD 10.6 billion. In other words, the investment trend has decreased by about 100% in ten years. One of the reasons is that the focus of the investment is on completely clean renewable energy sources, the sun and wind. Investments in solar energy in 2020 amounted to about USD 148.6 billion, wind energy about USD 142.7 billion, and bioenergy about USD 10.6 billion. The investment amounts tell us that solar and wind energy investments are a priority in the world.

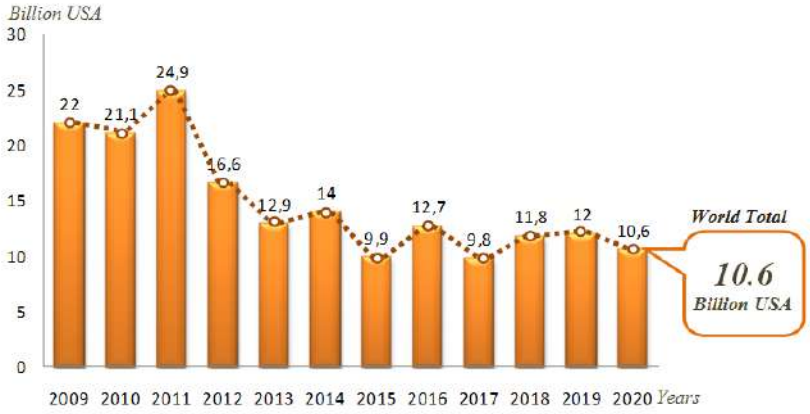

Figure 17. Global new investment in renewable bioenergy through technology in the world for the period 2009–2020[2,14–26]

7. THE TREND OF GLOBAL HYDROPOWER CAPACITY OF SMALL HYDROPOWER PLANTS

The construction of large hydropower plants brings about considerable ecosystem changes, affects soil, flooding, freshwater wildlife, produces increased methane emissions, and the existence of harmful emissions throughout the life cycle of hydropower plants. On the other hand, small hydropower plants do not have such an impact on the environment. The name of a small hydropower plant can be viewed from different points of view and varies from country to country, depending on its standard, hydrological, meteorological, topographic, and morphological characteristics of the location, and the degree of technological development and the standard of living in the

country. A small hydropower plant in Europe means the power of up to 10 MW, while in other countries, it is up to 25 MW, e.g., in China [2,19,14,38,44,55]. More than half of the global known hydro potential is in Asia, and about one-third is in Europe and America. Figure 18 shows the global capacity of energy production using small hydropower plants for 2010 – 2020.

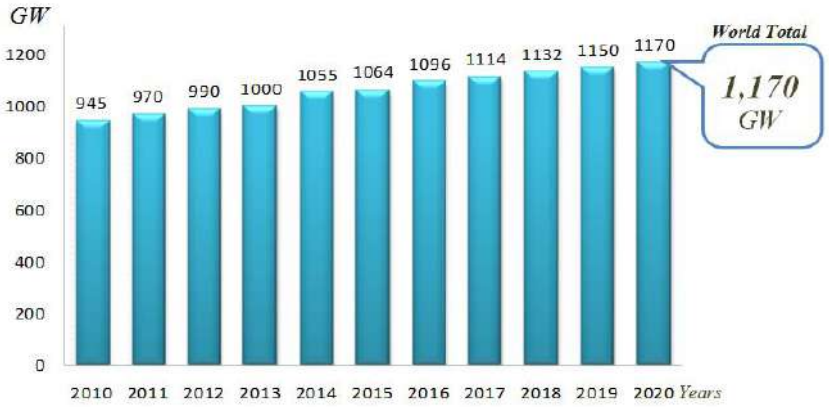

Figure 18. Global hydropower capacity of small hydropower plants in the world in the period 2010-2020[2,14-26]

The trend of global hydropower capacity of small hydropower plants in the world in 2010-2020 was continuously increasing. In 2010, the global capacity was 945 GW, while in 2020, it was about 1,179 GW, which is an increase of cca 13.2% in ten years. We can conclude that the trend of global hydropower capacity of small hydropower plants is based on the linear function, as shown in Figure 18. The percentage of global hydropower capacity of small hydropower plants in the world for the top ten countries in 2020 is shown in Figure 19.

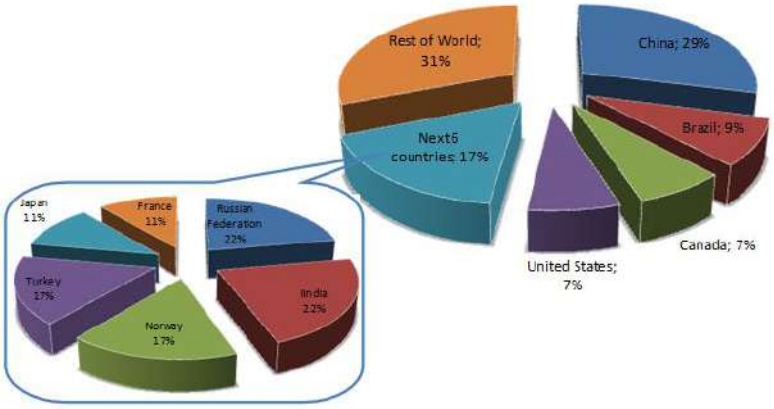

Figure 19. Percentage of global hydropower capacity of small hydropower plants in the ten top countries in 2020[14]

Based on Figure 19, we can determine that in terms of hydropower production of small hydropower plants, China ranks first in the world with 29%, followed by Brazil with 9%, Canada 7%, United States 7%, and the rest of the world 31 %, including Russian Federation 4%, Norway 3%, Turkey 3%, Japan 2%, France 2%, and Brazil 2%. The values of the global hydropower capacity of small hydropower plants in the top ten countries are shown in Figure 20.

A global hydropower capacity of small hydropower plants in China in 2020 was 332.6 GW, which places China the first in the world, followed by Brazil with 110.2 GW and Canada with 77.3 GW. The remaining top seven countries in global capacity are the Russian Federation, India, Norway, Turkey, Indonesia, Angola, and Guinea, with a capacity of less than 80 GW. Investments in hydropower of small hydropower plants in 2020 amounted to about 0.6 billion dollars. Investments in this energy are small compared to renewable sources of wind, solar, and bioenergy, therefore we did not analyze them.

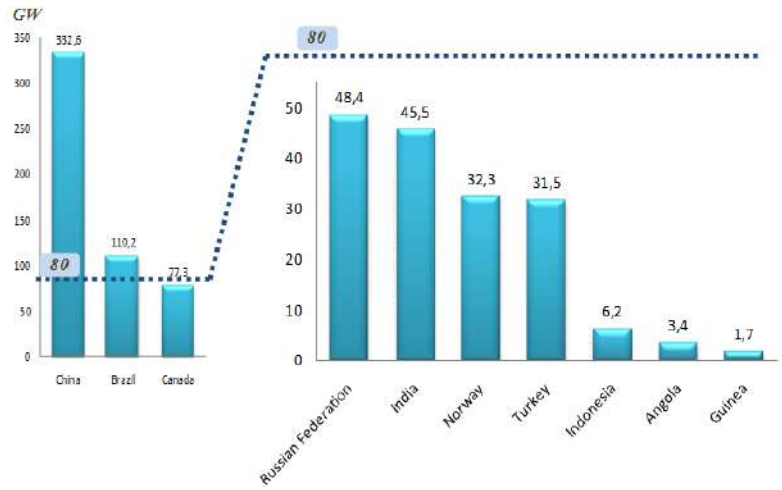

Figure 20. Global hydropower capacity of small hydropower plants expressed in GW in the world in the top ten countries in 2020[14]

8. THE TREND OF GLOBAL THERMAL ENERGY CAPACITY

Geothermal sources are used to obtain energy applications through two primary sources, either through electricity generation or through various thermal applications for the so-called direct use (without converting to electricity), such as space heating and industrial heat inputs. Geothermal energy is renewable if the tank is properly used. Energy utilization must be in accordance with the natural change in tank temperature. The temperature of the Earth's interior rises with depth. At a depth of 80 to 100 km, the rock temperature is between 600 and 1.200 °C. The heat is constantly flowing from the source inside the Earth to the surface. Kilometers of deep wells can be drilled into underground reservoirs to utilize steam and hot water that can be brought to the surface for power generation, direct use, and heating and cooling (Figure 21).

Figure 21. Utilization of geothermal energy in the world [58,59]

The largest share of geothermal energy or heat use (almost half) goes to bathing and swimming applications, with smaller amounts for heating (primarily district heating), industrial purposes, aquaculture pond heating, agricultural drying, snowmelt, etc. At least 78 countries use direct geothermal heating. The United States, China, Sweden, Germany, and Japan have the largest share of geothermal heating capacity. Geothermal electricity production was about 97 TWh in 2020, while direct usable heat output was about 128 TWh (462 PJ) [14,58].

In some cases, geothermal plants produce both electricity and heat for thermal applications (cogeneration), but this option depends on the location of the heat demand that matches the geothermal resource. The global capacity of geothermal energy in the top ten countries in the world in 2020 is shown in Figure 22. As can be seen in Figure 22, the first place in terms of global capacity of geothermal energy is held by the United States,

followed by Indonesia, the Philippines, Turkey, New Zealand, Mexico, Kenya, Iceland, and Japan, while the rest of the world has a global capacity of about 1.000 MW. Additional 0.1 GW of geothermal energy production capacities appeared in 2020, bringing the global total closer to 14.1 GW [14,58,59]. A distinctive feature of 2020 was the disproportionately low increase in capacity compared to recent years (attributable in part to pandemic-related disturbances), with almost all new facilities located in the country of Turkey.

Worldwide, geothermal direct use capacities – direct geothermal energy extraction for thermal applications have increased by an estimated 2.4 gigawatts-thermal (GWth) (about 8 %) in 2020 [14,58,59]. The use of geothermal energy for thermal applications has increased by approximately 11.3 TWh during the year to an estimated 128 TWh (462 PJ). Geothermal heat has different applications. Swimming and bathing are still the largest categories, with about 44 % of total use in 2019 (the last available consolidated data), and it is growing at an average of about 9 % per year [14,58,59].

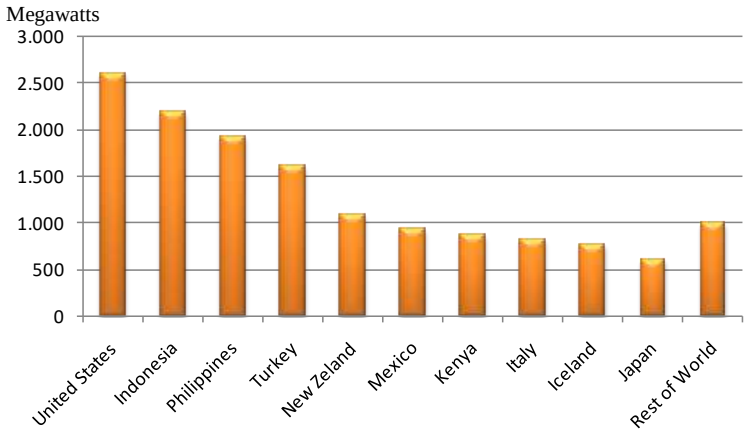

Figure 22. Global geothermal energy capacity in the top ten countries in the world in 2020 [14]

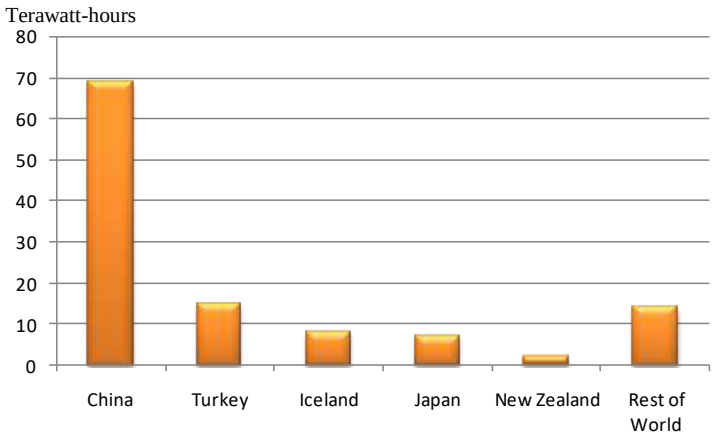

Figure 23. Top five countries in the world where geothermal energy is used directly, and the rest of the world in 2020 [14]

In second place is the fastest-growing space heating (about 39% of direct use), which increases by an average of about 13 % per year. The remaining 17% of direct use was allocated to greenhouse heating (8.5%), industrial applications (3.9%), aquaculture (3.2%), agriculture drying (0.8%), and snowmelt (0.6%) and other uses (0.5%) [14,58,59]. The most popular countries for direct geothermal use (in descending order) in 2020 were China, Turkey, Iceland, and Japan, which combined accounted for approximately 75% of global use Figure 23. Investments in geothermal energy and small hydropower plants are low compared to renewable sources of wind, solar, and bioenergy, and therefore, we did not analyze them.

9. CONCLUSION

The global climate changes that humanity has faced in the last few decades are caused by using fossil fuels in energy production. Climate change is

such that there has been an increase in carbon dioxide and other greenhouse gases in the atmosphere. The effects of climate change are already noticeable in the world, so we can perceive that, for example, glaciers are melting, polar ice is melting, permafrost is melting, sea level is rising, and ecosystems are changing. To stop this, humanity, i.e., the governments of virtually all countries have been forced to consider these changes and consequences seriously and adopt policies for the development of renewable energy sources and the replacement of fossil fuels with renewable energy sources. Several strategy scenarios are globally proposed, and one of the scenarios is shown in Figure 2. As can be seen, the share of renewable energy sources in world energy production at the expense of fossil fuels is increasing every year. In 2050, fossil fuels will have a small share in energy production, and almost 95% of the global energy production will come from renewable energy sources, as shown in Figure 1. The estimated share of renewable energy sources in total final energy consumption in 2019 is about 11.2%, fossil fuels 80.2%, and other energy sources 8.6%, as shown in Figure 3. The share of renewable solar energy has a growing annual trend, as shown in Figure 4. The trend of installing solar PV global capacity has a growing exponential curve in the past ten years, and in 2020 it reached a value of about 760 GW. Governments around the world are more and more focused on the integration of renewable energy sources. If we look at the solar photovoltaic capacity in 2020, we see that China is in first place with 258.2 GW, while in other countries, the solar photovoltaic capacity is about 168.7 GW. After China, the United States is in second place with a solar photovoltaic capacity of about 97.2 GW, and Japan with a solar photovoltaic capacity of about 72.2 GW. Based on Figure 7, we can conclude that the global capacity for concentrating solar thermal energy increases every year so that in 2020 the stored thermal energy reached a value of about 21.1 GWh (Gigawatts-hours) worldwide. The global capacity of solar water heating collectors in 2020 was 501 GWth, as shown in diagram 8. Based on the trend of global new investment in solar renewable energy through technology in the last ten years, we see that in 2010 the investment was 90, 9 billion USD, and, in ten years, it increased to 148.6 billion USD. When it comes to the use of renewable wind energy, based on Figure 3, we can conclude that the annual production of wind power energy is increasing worldwide. In 2013, it reached the production of 743 Gigawatts, as shown in the diagram in Figure 10. The analysis of the diagram shown in Figure 11 has proved that in 2020 China ranked first in the world with 284 GW of global wind energy production capacity, followed by the United States with 126.9 GW, and all other countries with a capacity of 149.8 GW. New investments in renewable wind energy are ongoing, and for the last ten years, investments have increased by 62.3%. In 2010 new investments in wind energy amounted to 89 billion USD, and in 2020 they increased to USD 142.7 billion. The total share of bioenergy in the total final energy consumption in 2019 was 11.6 %, of which 6.5% referred to traditional biomass and 5.1% to modern biomass. Participation in modern biomass was as follows: 1.2 % for heating buildings, 1.0 % for transport, 0.5% for electricity, and 2.5 % for heating in industry. In 2019, the share of traditional biomass in heating buildings was 24.6%, and modern bioenergy was 4.5%, while the share of modern bioenergy for heating in the industry was 9.0%. Biomass is used as a bio-fuel in transport with a share of up to 4.0% as modern bioenergy. The lowest share of bioenergy is in electricity production with 1.7%, as shown in Figure 14. The trend of global hydropower capacity of small hydropower plants in the world in 2010-2020 is continuously increasing. In 2010, the global capacity was 945 GW, while in 2020, it was about 1,179 GW, which is an increase of about 13.2% in ten years. A global hydropower capacity of small hydropower plants in China in 2020 was 332.6 GW, which places China the first in the world, followed by Brazil with 110.2 GW and Canada with 77.3 GW. The other seven top countries in terms of global capacity are the Russian Federation, India, Norway, Turkey, Indonesia, Angola, and Guinea with a capacity of less than 80 GW. The global capacity of geothermal energy in the top ten countries in the world in 2020 is shown in Figure 21. As can be seen, the first place in terms of global capacity of geothermal energy is held by the United States, followed by nine top countries: Indonesia, the Philippines, Turkey, New Zealand, Mexico, Kenya, Iceland, Japan, while the rest of the world has a global capacity of about 1,000 MW. The most popular countries for direct geothermal use (in descending order) in 2020 were China, Turkey, Iceland, and Japan, which combined accounted for approximately 75% of global use. Finally, we can conclude that the share of renewable energy sources in the last ten years (2010-2020) has increased. This trend will continue in the coming period, as shown by all scenarios. New investments in renewable energy technologies are also increasing on annual basis, leaders in the renewable energy sources being wind and sun. To stop climate change, it is the task of all countries in the world to invest and increase the share of renewable energy sources in total energy consumption in the world.

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TENDENCIJA RAZVOJA GLOBALNOG KAPACITETA OBNOVLJIVIH IZVORA ENERGIJE U SVIJETU U POSLJEDNJIH DESET GODINA

Sažetak: Poznato je da je u proteklim decenijama sagorijevanje fosilnih goriva identifikovano kao glavni uzrok klimatskih promjena. Ublažavanje klimatskih promjena postaje centralna briga globalnog društva. Ograničenje globalnog zagrijavanje na ispod 2 °C iznad temperature predindustrijskog društva ključno je za očuvanje eko-sustava u svijetu i

pruža sigurnu osnovu za ljudske aktivnosti, kao i smanjuje prekomjernu promjenu okoliša. Ambicija se povećala na ubrzani tempo sa dramatičnim širenjem ciljeva neto nulte emisije. Sve veći pritisak građana i društva navelo je zemlje da pojačaju vlastite klimatske planove, dok je privatni sektor kupio rekord količine obnovljive energije.

Energetski sustav zasnovan na fosilnim gorivima mora se zamijeniti obnovljivom energijom sa niskim emisijama ugljika uz poboljšanu energetsku efikasnost. Ovo vrijedi za sve korisnike fosilne energije: gradove, selo, sektore zgrada, industrije, transporta, poljoprivrede i šumarstva. U radu je obrađena i prikazana strategija energetskog razvoja obnovljivih izvora energije kao u svijetu. Detaljno je prikazana primjena novih tehnologija koje su dovele do razvoja obnovljivih izvora energije: vjetroenergije, sunčeve energije, malih hidroelektrana, biomase, te njihovog povećanja u ukupnom učešću proizvodnje energije, odnosno smanjenje fosilnih goriva u proizvodnji energije. Investiranje u nove tehnologije koje se koriste u obnovljivim izvorima energije dovele su do povećanja zaposlenosti u svijetu. Napravljena je analiza trenda povećanja proizvodnje energije iz OIE (obnovljivi izvori energije) sa investiranjem u svaku od nabrojanih, kao i zaposlenost za svaki izvor energije, te razvoj obnovljivih izvora energije u narednom periodu.

Ključne riječi: obnovljivi izvori energije, solarna energija, energija vjetra, energija biomase, hidroenergija.

Paper received: 25 October 2021
Paper accepted: 22 November 2021