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CLIMATE CHANGES AND RENEWABLE SOURCES OF ENERGY IN BOSNIA AND HERZEGOVINA

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Abstract: This paper outlines the basic information on climate characteristics, emissions of greenhouse gases (GHG) and the observed climate changes in Bosnia and Herzegovina (BiH). Special attention was paid to the possibilities of using renewable energy sources (RES) and their impact on the environment. In addition, the paper describes three GHG *emissions reduction* scenarios by 2025 in BiH and gives some information about RES legislation and feed-in tariffs in BiH. The paper points out that in order to establish the ecological balance and sustainable development of mankind, it is necessary to make greater use of renewable energy sources, as well as that renewable energy contributes to the reduction of the GHG emissions, reduction of the fossil fuels use, development of local industries and creation of new jobs.

Keywords: greenhouse gases, air and climate change in Bosnia and Herzegovina, renewable sources of energy.

1. INTRODUCTION

Mankind has lately been faced with climate changes and natural disasters of huge proportions. Although the climate in the world has been quite stable over the past 10 000 years and has represented a favorable environment for the development of human civilization, it is now becoming an increasing concern, and the changes that have been registered over the last decades are considered to have arisen as a result of human activities, not as a consequence of changes in the natural atmosphere. Humanity has, over the last century, caused huge disruptions in the climate system, with the biggest changes occurring in the atmosphere. The sudden increase in population, with multiple increase in global industrial and other human activities, have led to the increased use of energy resources, especially fossil fuels, and uncontrolled global air, water, and land pollution, climate change, rising sea levels, ozone layer depletion, degradation of biodiversity, etc.

The greenhouse effect is very important when we talk about climate change because it refers to gases which keep the Earth warm and allow the existence of life on it. The accumulation of *greenhouse gases* (GHG) in the atmosphere (carbon dioxide CO_2, methane CH_4, nitrogen oxides and other gases which are emitted in industrial processes) increases as a result of human activity. Research shows that GHG emissions generated by human activities significantly influence the increased warming of the Earth's atmosphere [1-6].

In the eighties, the scientific evidence of global climate change and its effects have caused an increased concern among scientists, politicians, and the public. In 1992 in Rio de Janeiro, the *UN Framework Convention on Climate Change* (UNFCCC) was adopted. In the framework of the Convention, a series of commitments for all countries, which are mainly related to the development and implementation of policies to reduce GHG emissions, was defined. Since the answer of the developed countries (which are the main emitters of greenhouse gases) proved to be very weak, in 1995 the *Berlin Mandate* was presented, establishing a negotiation process in order to strengthen the commitment to the UNFCCC for the period after 2000. This process finally led to the adoption of the *Kyoto Protocol* (KP) in 1997. The Kyoto Protocol entered into force on 16.02.2005 and so far it has been ratified by 144 countries. KP represents a very important step towards the limitation of six GHG emissions (CO_2,

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CH_4, N_2O, HFCs, PFCs and SF_6), since it was used for the first time to specify legally binding commitment. KP promotes and encourages research, development and an increased use of *renewable energy sources* (RES), promotes and supports technologies controlling emissions of greenhouse gases. Industrial countries have committed by the KP to decrease their GHG emissions in the period 2008 - 2012 by 5.2% on average, as compared to the reference value in 1990 [7–13].

Due to increase in the number of inhabitants on the Earth, there is an increase in the use of fossil energy sources, their reduced supplies, increased GHG emissions and the environment degradation. In order to restore the ecological balance and sustainable development of mankind, it is necessary to make greater use of RES. Today, a special attention is paid worldwide to the equipment and possibilities of the RES use and their impact on the environment. The use of renewable energy contributes to the reduction of GHG emissions, reduction of the fossil fuels use, development of local industry and creation of new jobs.

The Western Balkan countries belong to one of the regions of the world where significant changes in climate are expected in the near future, as well as the negative consequences of climate changes on human health, economic development and the availability of natural resources. Bosnia and Herzegovina (BiH) is a country in the southeastern Europe on the Balkan Peninsula consisting of two entities: the Federation of Bosnia and Herzegovina (FBiH) and the Republic of Srpska (RS), while Brcko District has a special status. BiH has ratified the KP on 16 April 2007, which entered into force on 15 July 2007 [7−15].

2. CLIMATE AND CLIMATE CHANGES IN BiH

There are several types of climate in BiH: temperate continental (northern and central parts), subalpine, alpine, Adriatic and modified Adriatic type. Temperate continental climate in BiH is mostly represented in the northern and central parts of the country, subalpine and mountain type of climate in areas over 1,000 m above sea level, the Adriatic (Mediterranean) and a modified Adriatic climate type in the coastal town of Neum, which also applies to lowland Herzegovina. For these reasons, the climate in BiH is changed from temperate continental climate in the northern Pannonia lowlands along the Sava River and in the foothill zone, to an alpine climate in the mountainous regions, the Mediterranean climate in the coastal area and in the region of low Herzegovina in the south and southeast. In the northern part of the country, an average air temperature varies from -1°C to -2°C in January and from 18°C do 20°C in July. On the Adriatic coast and in lowland Herzegovina, air temperature varies from 3°C to 9°C in January and from 22°C to 25°C in July (in the period 1961-1990). Lowland area of the northern BiH has a mean annual temperature between 10°C and 12°C, and in the areas above 500 m, the temperature is below 10°C. The mean annual air temperature in the coastal area ranges between 12°C and 17°C. In the period from 1981 to 2010, an increase in temperature was recorded on the entire territory of BiH. The largest increase is during summer and winter period by around 1°C. The mean annual temperatures for the period 1981-2010 were in the range of 1.6 ° C (Bjelasnica) to 15. 2°C (Mostar). In winter, temperature varies from -6.0° C to 6.2°C, and during summer from 9.8 °C to 24.7°C. In the entire area, annual temperature increase is obvious amounting to more than 1.5°C in the northwest part of the country (Banja Luka).

Annual precipitation varies from 800 mm in the north along the Sava River to 2000 mm in the central and southeastern mountainous areas (in the period 1961-1990). In the continental part of BiH, which belongs to the catchment area of the Danube River, a main part of the annual rainfall occurs in the warmer half of the year, reaching its maximum in June. Central and southern parts of the country with numerous mountains and narrow coastal areas are characterized by an altered Mediterranean pluviometric regime under the influence of the Adriatic Sea, so the monthly maximum amounts of precipitation occur in late autumn and early winter, mostly in November and December. In the period from 1981 to 2010, in most part of the low Herzegovina, there is a decline of rainfall annually, while the majority of the mountain weather stations recorded an increase in precipitation.

The average annual rainfall in BiH is about 1250 mm. Annual precipitation changes from 792 mm in the northeastern part (Semberija - Bijeljina) to 1707 mm (Herzegovina − Trebinje). During summer, there is an obvious decrease in rainfall. In the last two decades, the total sum per seasons and annual distribution of rainfall are very disturbed, which with the rise of temperature causes the occurrence of droughts and floods [17−20].

In the period from 1961 to 1990, it was noted that the duration of sunshine decreases from the sea towards the inland and at higher altitudes. The annual sum of the duration of sunshine hours in the central mountainous area is 1700-1900 hours, which

is the consequence of the above-average cloudiness (60−70%). Due to frequent fogs during the cold part of the year, solar radiation in the inland is lower than at the same altitudes in the coastal area. In the southern parts of the country, the number of sunshine hours per year is 1900-2300. In the northern BiH, number of sunshine hours per year is 1800−2000, more in the eastern than in the western part. Cloudiness decreases from west to east. The duration of the sunny period is increasing as follows: average insolation for the period 1961-2011 is 1806 hours in Sarajevo, 1821 hours in Banja Luka, and is the largest in Mostar, amounting to 2,337 hours per year. In extremely warm years, the value of insolation in Mostar was 2630 hours.

Extreme climate changes in BiH are increasingly frequent. Out of the last twelve years, six of them were very to extremely arid (2003, 2007, 2008, 2011, 2012, 2013). Also, very common are the years with large to catastrophic floods (2001, 2002, 2009, 2010, 2014). Extreme climate phenomena have been especially pronounced during the last five years (in 2009 and 2010, significant floodings were recorded, and in 2001, 2012 and 2013 there were large waves of drought and high/tropical temperatures at the beginning of 2012, a wave of very cold weather in early 2012, the occurrence of storms in mid 2012). In April and May 2014, record rainy series were recorded (> 420 mm) in the northern part of the country, which caused catastrophic flooding in the catchment area of the rivers Vrbas and Bosnia, in the area of Semberija [17,18].

2.1. Changes in air temperature for the period 1961−2010

Research related to the change in air temperature for the period 1961−2010 indicate the presence of an increase in temperature in all parts of the country. On the basis of a comparative analysis for the period 1981− 2010 as compared to the period 1961−1990, it was found that the largest average increase in temperature during the year was recorded in the southern part of the territory of Herzegovina (Mostar 1.2°C) and in the central regions (Sarajevo 0.8°C), while the largest increase in the spring and winter was recorded in the northern and central parts of the country (Banja Luka 0.7°C). The least temperature increase occurs during the fall and it ranges from 0.1 to 0.3°C. There is an obvious trend of increasing tropical days (days with maximum daily air temperature over 30°C) in almost the entire territory of BiH. Most of these days were recorded in the north of the country (Posavina), central regions and the Drina valley (Visegrad). In the area of low Herzegovina (representative is the city of Mostar), there is a slight trend of increasing tropical days, however the last 5 years (2007−2012) had an extremely high temperature up to over 40°C. So, although increase is not pronounced in the number of tropical days, increase was recorded in the frequency temperature over 40°C [17,18].

2.2. Changes in precipitation for the period 1961−2010

In the period from 1961 to 2010, most of BiH territory was characterized by a slight increase in the annual rainfall amount. The biggest positive change in annual precipitation is a characteristic of the central mountain areas (Bjelasnica, Sokolac) and Doboj area, while the largest deficit was recorded in the south of the country (Mostar, Bileca). The largest decrease in precipitation occurs during spring and summer, and is most pronounced in Herzegovina (up to 20%). In the autumn period, the largest increase in precipitation per seasons was observed, with the largest surplus in northern and central parts of BiH. Although there were no major changes in rainfall, pluviometric regime and annual distribution of precipitation were greatly disturbed, i.e. the annual rainfall distribution. The number of days with precipitation greater than 1 mm decreased in almost entire territory of the country, while the percentage of the annual rainfall due to the occurrence of rainfall, greater than 95 percentage percentile calculated for the period 1961-2010, was on the rise. In other words, although significant changes in precipitation were not recorded on an annual basis, reducing the number of days with precipitation exceeding 1.0 mm, and increasing the number of days with intense precipitation, a pluviometric regime was deeply disturbed. In addition, the pronounced change in the annual distribution of rainfall with increase in temperature is one of the key factors that influence the appearance of more frequent and more intense droughts and floods throughout the country. The highest daily precipitation in the period from 1961 to 2011 have the following values: 156 mm in Banja Luka, 127 mm in Mostar, and 118 mm in Sarajevo. Average maximum precipitation for the same period in Banja Luka is 54 mm, 79 mm in Mostar, and 50 mm in Sarajevo. Although it is unlikely that there will be an increase in the absolute maximum daily rainfall, increase in the number of days with precipitation over 10.0 mm indicates the seriousness of the problem [17−18].

3. GREENHOUSE GAS EMISSIONS IN BOSNIA AND HERZEGOVINA

The potential of "greenhouse" is a measure of any gas influence on the greenhouse effect as compared to CO_2 impact. In this case, the emission of GHG is expressed in Gg CO_2 eq (mass of equivalent CO_2). Graphics of CO_2 emissions originating from waste, industry, energy and agriculture in BiH in the period from 1990 to 2001 is shown in Figure 1 [17−18].

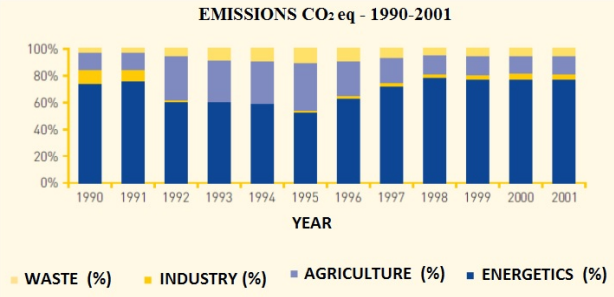

Figure 1. Graphics of CO_2 emissions originating from waste, industry, energy and agriculture in BiH in the period 1990-2001

Graphics of CH_4 emissions originating from solid fuels and their disposal, manure and intestinal fermentation in BiH in the period from 1990 to 2001 is given in Figure 2 [17−18].

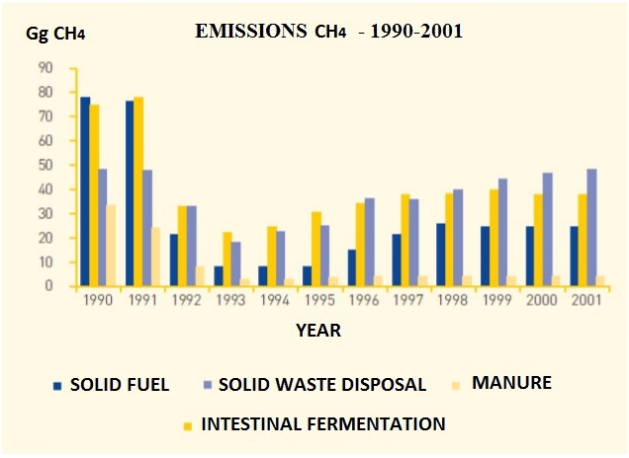

Figure 2. Graphics of CH_4 emissions originating from solid fuels and their disposal, manure and intestinal fermentation in BiH in the period 1990 - 2001

Figure 2 shows that in BiH, main sources of methane (CH_4) are: agriculture (cattle breeding), fugitive emissions from coalmines, and waste disposal.

Graphics of N_2O emission in BiH in the period from 1990 to 2001 is shown in Figure 3 [17,18].

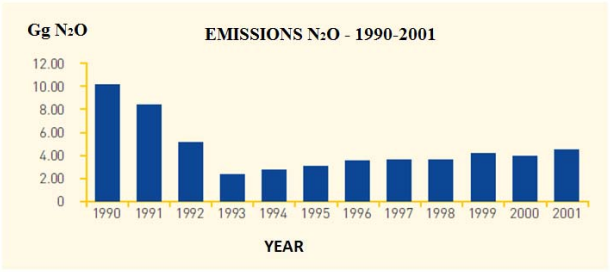

Figure 3. Graphics of N_2O emission in BiH in the period 1990−2001

The most important source of N_2O in BiH is agriculture. Many agricultural activities cause the deposition of nitrogen in the soil, thus increasing the available nitrogen for nitrification and denitrification, which has an impact on the amount of N_2O. There are three sources of N_2O emissions: direct emissions from the agricultural soils, emission due to the operation of the animals, and indirectly caused emission from agricultural activities. Among these, the largest emission comes directly from the agricultural soils through soil cultivation and crops. These include the use of mineral fertilizers, nitrogen fertilizers from the stable, growing legumes and soybeans (nitrogen fixation), nitrogen from agricultural crop residues and peat processing [17−18].

4. ASSESSMENT OF POTENTIAL TO MITIGATE THE IMPACT OF CLIMATE CHANGES

As a potential candidate for EU membership, BiH is taking steps in addressing climate change issues at the national and international level. In September 2011, BiH has formed an *Authorized body (DNA)* for the implementation of the project *Clean Development Mechanism* under the *Kyoto Protocol*. To date, this body has approved four projects aimed at reducing GHG emissions in BiH. Assessment of the potential for climate changes mitigation in the *Second national report of BiH* in 2012 focuses on sectors where the greatest potential for reducing GHG emissions was identified: electricity production, central heating, construction, transport, waste, agriculture and forestry. For each of these sectors, scenarios are made to reduce GHG emissions until 2025, and measures are proposed to mitigate climate changes, as follows: *Scenario S1* - basic, without changes; *Scenario S2* − with partial application of the stimulative measures and *Scenario S3* - advanced scenario, with the implementation of the entire set of stimulative measures. When considering the above mentioned scenarios, the initial data were taken for 2010, while emissions calculations are

made for 2015, 2020 and 2025, respectively [13−21].

4.1. Current state in the field of electric power

According to the resource base and the achieved technological development, the main sources of energy in BiH are coal and hydropower. Around 50% of electricity in BiH is generated by thermal power plants run on domestic coal with a relatively high specific CO_2 emission (1,3 tCO_2 /MWh). The rest of the electricity is produced by large hydro power plants and one part by small hydro power plants. A significant source of energy are fossil fuels, i.e. natural gas and oil. Total energy consumption in 2005 for BiH was as follows: 45.3% for coal and coke, 9.6% hydro, 21.1% liquid fuels, natural gas 5.6% and 20.5% wood. According to the used technology and fuel type, it can be concluded that BiH is largely dependent on imports, and that its energy sector is still characterized by a low energy efficiency. Particularly unfavorable ratio still exists in the field of natural gas consumption, which is the result of the inadequate structures and dynamics of its use. An additional disadvantage in the use of natural gas is that there is only one pipeline that is causing volatility in supply, especially during the winter season, when the consumption of this energy is greatest. For this reason, a large number of households in BiH uses electric stoves for the production of heat energy. However, regardless of these facts, today in BiH there is a number of district heating systems using natural gas as a primary energy source. An important source in BiH is the wood biomass as a primary source of heat, which is still used in smaller urban centers and rural areas. Energy efficiency in BiH, in terms of production, transformation and consumption of energy is low when compared to developed economies. Energy production in BiH is based on technologies developed some thirty years ago, when a number of blocks in thermal power plants were built. In case of new plants construction, and in major reconstructions of the existing ones, it is necessary to introduce new technologies, wherever possible [15−21].

4.2. Renewable sources of energy in BiH

BiH has considerable energy potential in RES, but it is not sufficiently used or not used at all when it comes to certain energy sources. Of all the RES, most used is hydropower (large and small hydropower plants) and wood for heating in the residential and other buildings. The potential for the development of small and large hydropower is considerable and largely untapped. Also, the significant potential of the wind energy, biomass and geothermal energy is very little used. Over the last few years, a more intensive use of solar energy has been noted. In the developed countries, today the transition to cost-effective and cleaner technologies is a major challenge. Despite many challenges, the goal of BiH is to increase the share of energy from renewable sources in energy, as its obligation arises from the membership in the Energy Community in South East Europe as a framework for the integration into the EU energy market [15−36].

Solar energy. Results of the research on the possibility of using solar energy for heat production − using solar collectors for 15 cities in BiH, as well as for the production of electricity, show that there is a significant potential for the application of solar energy in the area of BiH amounting to 70.5 mil. of GWh of the allocated energy for the total solar radiation per year. The technical potential is 685 PJ, and this is about three times more than the total primary energy needs in the energy balance of BiH. According to the calculation results of the possible degree of meeting the thermal needs for domestic hot water, for the average household, about 74% of heat needs for the preparation of hot water in the RS, that is, 78% in BiH, can be covered by solar collectors. In addition, the degree of meeting the needs for heating depends on the thermal insulation of the building, but on average, is around 30%. It is estimated that solar energy could meet about 5% of energy needs in BiH. In summer, it could provide about 80% of the demand for hot water, and in winter between 35 − 50%. It is estimated that in BiH, currently there are approximately 7.000 m^2 of collectors installed, and that the annual increase is about 28% [15−35].

Hydropower. The basis of the hydropower potential in BiH is made by its river network. The total length of the watercourse (which are individually longer than 10 km) is around 9,000 km, out of which the boundary streams account for about 930 km.The average density of the river network in BiH is about 220 m/km^2, whereby there is a pronounced unevenness in the continental and Mediterranean parts of the country. The average density of the river network in the continental part is about 300 m/km^2, while in the Mediterranean part of BiH it is less than 30 m/km^2. Significant amounts of water involved in fresh water balance are lakes in BiH. Rivers water supply in BiH is a direct function of the pluviometric regime. On the basis of previous studies results, it has been estimated that the total theoretical hydropower potential in BiH is about 99.256 GWh per year, technical hydropower potential (abo-

ut 360 large and small hydropower plants (HPP), which can be built) over 23,500 GWh per year. The economic hydropower potential of major watercourses in BiH is about 18,000 GWh per year, i.e. for small watercourses is approximately 3,500 GWh per year. The current level of use of this potential is approximately 40%, or approximately 7,182 GWh per year. Level of efficiency of small hydropower plants is still very low, at around 4.4% of the available power, or 5.7% of the available energy, though it can be concluded that the small hydropower plants are the source of renewable energy, which is seen as highly promising in BiH [3−13]. Possibilities of using the hydropower potential in BiH, however, is significantly limited due to the uncontrolled urbanization process, environmental problems and economic constraints. The research results contained in energy development studies indicate that, for the reasons stated, the usable portion of the total hydro potential is about 13,000 GWh per year, or about 56.5% [15–34].

Wind energy. Wind energy represents one of the more significant energy potential of BiH. Considering the territorial position of BiH, as well as the configuration of the land, the potential of wind energy in BiH is considered in two geographic macro-regions:

- Mediterranean region of BiH, where under the influence of cycle-genetic activities in conjunction with relief predispositions terrain, intensive regional circulation is formed;
- Mountainous-valley region of BiH, where orthographic factor positively affects the increased intensity of the regional and local circulation.

Both macro-regions provide favorable conditions for the production of electricity using wind power, although the Mediterranean macro-region has a somewhat more pronounced wind potential. One of the more suitable locations for wind energy utilization is a wider area of Podvelezje, which by its positional and relief predispositions is extremely suitable for the installation of wind turbines. For a serious analysis of wind potential at all potential locations, it is necessary to make detailed measurements of wind potential. In certain studies that have been conducted in this area, it was estimated that the economic potential of wind energy in BiH would be about 600 MW of electricity by 2020. These estimates are based on the introduction of the cutting edge technologies to harness the potential of wind with appropriate supporting incentives to produce electricity by the wind turbine. In the period from 1999 to 2004, a preliminary investigation and selection of the potential locations for the production of electricity from wind energy in BiH (*ADEG Project*) were carried out. On the basis of the project results, there were selected 16 locations suitable for the operation of wind turbines, with an estimated total installed capacity of 720 to 950 MW, i.e. with the estimated annual production from 1440 to 1950 GWh. Notwithstanding the above data in BiH, in addition to several locations, currently there are no wind power plants, which are connected to the existing network of high voltage. According to the available data, there is a number of small wind turbines for electricity generation for individual households, but their installed capacity is small and is not good enough parameter to assess the overall wind potential of BiH [15−34].

Geothermal energy (GE). According to the previous research, it was found that about 25% of the territory of BiH is considered to be a potential geothermal resource of threefold forms: hydrothermal systems geopressed zones and hot dry rocks. These areas cover mainly the central and northern part of BiH. Of the three forms of resources mentioned, hydrothermal systems draw the most attention because their exploitation is most developed and least expensive as compared to other two forms. By adding potentials of RS and FBiH, the total thermal power and geothermal energy sources in BiH are calculated. The total potential installed capacity of the geothermal wells at 42 locations is 9.25 MWt, if we consider only the possibility of space heating, i.e. 90.2 MWt if we consider geothermal energy for space heating and recreational and balneology needs. With the use of all sources and with a utilization factor of 0.5 it is possible in one year to produce 145.75 TJ of energy only for space heating, i.e. a total of 1421.75 TJ of energy if taken together space heating and bathing. Previous studies have shown that the area of Posavina, Semberija, Banja Luka Valley and Lijevce area are promising for the presence of geothermal waters. The energy potential is estimated at 1,260 TJ. There are practically no significant projects according to the level of the installed power. Still with a small share, but with the trend of modest expansion, heat pump systems in small and medium-sized objects are applied [3−13]. The greatest potential for the use of this energy source lies in aquaculture, agroculture and for settlements heating. It was also found that about 25% of the territory of BiH is a potential geothermal resource. There are practically no significant projects according to the level of the installed power. Still with a small share, but with the trend of modest expansion, heat pump systems in small and medium-sized objects are applied. A step forward was made because concession policies began to be realized. Concession realization occurs extensively in the

territory of Banja Luka, Sarajevo, Bijeljina and Doboj, and plans are being prepared for the realization of making deep wells in order to heat cities [15–34].

Biogas. BiH has excellent natural conditions for breeding livestock and an excellent economic basis for the use of manure to produce biogas. The ability to use solid and liquid manure, originated from the registered livestock from farms in BiH, for the production of biogas, is a way that allows the mitigation of climate changes. Energy agricultural potential of the available biomass (20,100,000 m^3) in BiH for the production of biogas from manure on livestock farms is 0,508 PJ. On the basis of data on livestock in 2010 and 2011, a potential production of biogas in BiH was calculated at 800,000 to 850,000 m^3/day. In BiH, only one biogas plant has been installed (designed and built). The installed electric power of the said plant is 35 kW and heat power is 70 kW and annually is expected to produce 290,000 kW of electricity and 560,000 kW of thermal energy [15-35].

5. SCENARIOS REGARDING USE OF RES IN BiH

The following is a description of scenarios relating to the potential and possibilities of using renewable energy in BiH, based on the available literature [17,18].

5.1. Scenarios regarding use of solar energy

Scenario S1 does not imply the introduction of significant changes related to the current trend of using solar energy, or condition by which solar energy will not be used to a greater extent.

Scenarios S2 and S3. BiH has started an initiative for the use and production of equipment related to solar energy. Prices are based on the basis of those imports from the Western countries and the Far East. If we consider a standard solar system of 4 m^2, the price of the complete system with the installation is estimated at about 3,500 to 4,000 euros. It is expected that the installed surface of solar collectors by 2020 increases to 50,000 m^2, which would be about 12.5 m^2 per 1,000 inhabitants. If one starts to apply the co-financing rate, by 2025 one can expect coverage of approximately 200,000 m^2, ie. approximately 42,000 households, which accounts for about 11% of the total number of households. The application of this technology, looking at its profitability, is most desirable for the use of domestic hot water. If we are talking about public facilities, these are primarily hospitals, nursing homes, sports facilities, etc. In private buildings, these are single family houses which have a minimum of five members of the household. In apartment buildings, the application of this technology is cost-effective only in the case of the centralized domestic hot water production. If there is a single preparation, additional works and installations in each apartment greatly increases the price of this installation, which leads to its unprofitability [17,18].

5.2. Scenarios regarding use of hydropower

Basis of scenarios preparation, relating to the use of hydropower in BiH, is based on the established facts about the changes in the annual thermal and pluviometric regime, which means that climate change will affect all water management systems. Unfavorable fact, related to the integrated assessment of the impact of climate change on the existing systems of hydro potential, refers to the lack of a comprehensive strategy that applies to all parameters of water balance and its optimum utilization. The mentioned fact has a negative impact both on the system of collecting and processing hydrological data and their interpretation, and in terms of management and planning in the entire hydropower and water management authorities, at the entity level.

Scenario S1 is based on the established changes in trends of the annual thermal and pluviometric regime, according to which in future there will be a reduction in the interannual amount of precipitation. This trend would certainly have a negative impact on the existing annual water balance, that is, there would be an additional decline of the existing accumulated amount of water in rivers and existing hydro reservoirs. Given the fact that in this scenario there are no planned appropriate measures to be taken, in the future this would certainly lead to a reduction of the total amount of electricity produced. Quantitative determination of the reduction of the total hydropower potential depends directly on the applied climate scenario, but the negative energy effect would certainly be expressed,which would result in the intensification of production from non-renewable energy sources, with a significant increase in the share of fossil fuels.

Scenario S2 is based on the application of the specific measures contained in the various state and entity strategies on water supply, that should be taken in the next few years. Surely, all strategies will define the trend of reducing the total intraannual rainfall and their spatial distribution, according to different geographical regions. This primarily relates to the sustainable management of water resources at

catchment areas at the entity level, which includes a series of measures for balanced working of hydropower plants by characteristic hydrological seasons. This approach would result in a slight increase in the current level of hydropower production. According to this scenario, a level of energy exploitation of reduced water resources is growing based on the increased energy efficiency by reconstructing the existing hydropower plants and by applying new technologies for the production of electricity. By this scenario, the planned increase in hydropower production MHE is at about 2,205 GWh, which would result in reduction of GHG emissions from the energy sector by about 2,425 $GgCO_2$ eq.

Scenario S3 is based on the inclusion of B&H into the European Union during the second part of the scenario period, by fully implementing all the guidelines contained in the Directive on Water. The result of applying the guidelines would surely reflect in a significant improvement of all aspects of water management, particularly at the level of the balanced use of water resources in the existing and planned hydro reservoir, for hydropower generation and water supply. This is particularly obvious in terms of recent climate change, and in this regard, increasingly frequent extreme hydrological events, so that the need for the organization of safe water supply and hydropower potential is increasingly growing. Under this scenario, integrated water management would be reflected positively on the total hydropower potential and on the increased production of electricity from hydropower plants. The result of this approach would be increased hydropower production at the level of MHE to around 3,600 GWh, i.e. a total emission reduction of about 3,960 $GgCO_2$ eq [17,18].

5.3. Scenarios regarding use of wind energy

Scenario S1 is based on the current trend of wind energy potential in BiH utilization, which means that recent production of electricity from this energy source does not exist. Since the S1 scenario does not envisage any use of incentive measures, i.e. the effects of climate change mitigation, using wind energy in BiH is equal to zero.

Scenario S2 involves the application of certain stimulative measures that would initiate the process of exploitation of wind energy in BiH. Those measures, first of all, should include the implementation of projects to research wind potential in certain locations which, according to their geographical characteristics, previously were assessed as potentially exploitable. These measures also should stimulate the purchase and construction of modern wind turbines, which can operate at minimum wind speeds. With the implementation of the mentioned measures, it can be expected the electricity production from wind power plants of about 1,600 GWh per year, which would result in reduced use of non-renewable, especially fossil fuels, and the reduced GHG emissions of about 1,760 $GgCO_2$ eq.

Scenario S3 involves the application of EU standards on the level of utilization of renewable energy sources. In this regard, a number of funds which support financially the establishment of technical capacity and this form of energy production would be available to BiH. According to the study of the energy sector of BiH, by the end of the scenario period production, capacity of wind energy could grow to 2,400 GWh per year, which would result in additional potential for climate change mitigation in the energy sector of about 2,600 $GgCO_2$ eq. [17,18].

5.4. Scenarios regarding use of geothermal energy

Scenarios relating to the use of geothermal energy are mainly based on the estimated reserves and technological possibilities for its exploitation.

Scenario S1 is based on current trends of the potential use of geothermal energy without specific additional research on resources and without changing the existing approach to this energy source. The largest increase in the consumption of geothermal energy is assumed in scenario *S1*, in the period 2015-2020, and amounts to about 2.5%.

S2 and *S3 scenarios* are based on the introduction of support model, where the main activities are focused on the implementation of the hydrothermal system in the whole BiH. Both scenarios provide indicators of the final energy consumption, with an average annual rate of increase or decrease in the five-year period, and the share of energy forms in the final consumption. In the structure of energy sources for the electricity production, *S2* and *S3* scenarios do not envisage geothermal energy as an energy-participant, although there are conditions for it, that is, on some locations concessionaires are offered.

Scenario S3 with measures applied, is very important, given the planned program joining the EU between 2015 and 2020, or assuming a commitment to reduce GHG emissions. According to the *S2* and *S3* scenarios a significant representation of the use of geothermal resources is assumed, using heat pumps in the residential sector [17,18].

5.5. Scenarios regarding use of biogas

Scenario S1 implies that it is not expected to increase the use of modern forms of energy from biomass, such as biogas, as the price of energy from these sources is still uncompetitive compared to technologies that use the conventional energy sources. This scenario does not involve the introduction of any change in the existing trends in rates of increase in the number of animals as well as the input of nitrogen fertilizers on arable land. A significant feature of this scenario is the relatively low level of interest and activity of state and entity institutions in the energy sub-sector.

Scenario S2 with respect to a very small proportion of the existing biogas, is based on activities that are focused on implementing a system for the collection and combustion of biomass in the farms in BiH. The most important characteristics of this scenario are: a gradual introduction of new technologies (orientation and higher use of renewable energy and biogas), production planning and energy consumption on farms to meet the needs for space heating, drying of hay, grain, vegetables, etc. biogas production in simple plants and biogas use to cover a significant part of the energy needs of households, even in a small number of livestock (using the mini plants).

Scenario S3 is based on a high degree of activities to mitigate climate changes which are being implemented at different levels of government - from the state to the entity. More intensive use of biogas to produce heat and electricity is expected, which would prove to be very profitable, thanks to the improvement of the equipment used for this purpose. Biogas from agriculture (animal husbandry) is an important source of energy in the scenario with measures in scenarios *S2* and *S3*. There are cogeneration plants that are assumed to have efficient locating (production of electricity and the use of heat). All electricity production is supplied to the power distribution network. Heat from agricultural plants is supplied to the regional heating in rural areas. Total installed capacity of cogeneration plants on biogas from agriculture (animal husbandry) in RS are defined with as twice bigger powers according to five-year periods. By analogy plans for FBiH are defined [17,18].

6. CONCLUSION

BiH is a country on the Balkan Peninsula consisting of two entities: the Federation of Bosnia and Herzegovina and the Republic of Srpska (Brcko District has a special status). There are several types of climate represented in BiH: temperate continental (northern and central parts), subalpine, alpine, Adriatic and modified Adriatic type. Extreme climate changes in BiH are increasingly frequent. There were recorded severe floodings in 2009 and 2010, severe droughts in 2001, 2012 and 2013, a streak of very cold weather in early 2012, and the occurrence of storms in mid-2012. Research related to the change in air temperature for the period 1961-2010 indicate the presence of an increase in temperature in all parts of the country; while at the same time most of the territory is characterized by a slight increase in the amount of rainfall annually.

The main sources of energy in BiH are coal, natural gas, oil and hydropower. Around 50% of electricity in BiH is generated by thermal power plants, and the rest is produced in large hydro power plants. In terms of production, transformation and consumption of energy, energy efficiency in BiH is low compared to developed economies. Energy production in BiH is based on technologies developed some thirty years ago. In the last few years, BiH started using intensively renewable energy sources. In 2013, both entities of BiH passed the laws on renewable energy sources and cogeneration (in FBiH the *Law on use of renewable energy sources and efficient cogeneration,* and in the RS the *Law on renewable energy sources and efficient cogeneration*).

According to the solar potential, BiH is one of the more favorable locations in Europe. The technical potential is 685 PJ, and that is about three times more than the total primary energy needs in the energy balance of BiH. However, solar radiation is still underutilized for heat and electricity.

BiH is one of the richest areas in hydropower potential. The current level of use of this potential is approximately 40%, or approximately 7,182 GWh per year. Efficiency of small hydro power plants is still very low (about 4.4% of the available power). The research results contained in energy development studies indicate that part of the total exploitable hydropower potential is approximately 56.5%.

Wind potential in BiH is significant. However, the wind is still not used for energy purposes. According to the available data, there is a number of smaller wind turbines that produce electricity for individual households, but their installed capacity is small and not good enough parameter to assess the overall wind potential of BiH.

According to the geothermal potential, BiH is one of the richer countries. About 25% of the territory of BiH is considered to be a potential geot-

hermal resource of the threefold forms: hydrothermal systems, geo-pressured zones, and hot dry rocks. These areas cover mainly the central and northern part of BiH. The use of geothermal energy for heating and other energy purposes is still in an early stage and very modest, as compared to the potential of geothermal resources.

The energy potential of biogas in BiH is significant, however, it has so far installed only one biogas plant.

To reduce GHG emissions in electricity production, central heating, construction industry, transport, waste, agriculture and forestry there were created three *Scenarios for reducing GHG emissions up to 202 in BiH* (baseline scenario - S1, scenario with partial application of the incentive measures - S2, and an advanced scenario with the implementation of the entire set of the incentive measures - S3).

In BiH, authorities at all levels (state, entity, cantonal and local authorities) have certain obligations in terms of the legal obligations in the field of energy management, energy efficiency and the use of renewable energy. Unlike the FBiH, the pace of adoption of secondary legislation in the field of energy efficiency and renewable energy sources, in the Republic of Srpska is satisfactory.

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КЛИМАТСКЕ ПРОМЕНЕ И ОБНОВЉИВИ ИЗВОРИ ЕНЕРГИЈЕ У БОСНИ И ХЕРЦЕГОВИНИ

Сажетак: У раду су дате основне информације о карактеристикама климе, емисији гасова стаклене баште и климатским променама у Босни и Херцеговини (БиХ). Посебна пажња посвећена је могућностима коришћења обновљивих извора енергије (ОИЕ) и њиховом утицају на животну средину. Поред тога, у раду су дата

три сценарија за смањење емисије гасова стаклене баште до 2025. године у БиХ и законска регулатива о ОИЕ и *feed-in* тарифама у БиХ. У раду се истиче да је за успостављање еколошке равнотеже и одрживог развоја човечанства неопходно више користити обновљиве изворе енергије, као и да обновљива енергија доприноси смањењу емисије гасова стаклене баште, мањем коришћењу фосилних горива, развоју локалне индустрије и отварању нових радних места.

Кључне речи: гасови стаклене баште, климатске промене у Босни и Херцеговини, обновљиви извори енергије.