RENEWABLE ENERGY SOURCES AND THEIR POTENTIAL ROLE IN MITIGATION OF CLIMATE CHANGES AND AS A SUSTAINABLE DEVELOPMENT DRIVER IN BOSNIA AND HERZEGOVINA

by

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Bosnia and Herzegovina have significant physical potential regarding to renewable energy sources. Hydro, biomass, geothermal, wind, and solar potential can play important role in the whole state economy. Bosnia and Herzegovina is Non-Annex I country according to UNFCCC and according to that it is obligated to participate in the global efforts in order to reduce green house gases emission. This paper gives some analysis of the physical, technological, economic, and market potential of renewable energy sources in Bosnia and Herzegovina and their potential role in mitigation of climate changes. Paper also gives the analysis of the potential connections between renewable energy sources and sustainable development of the economy, taking in to consideration specific political structure of the state. Bosnia and Herzegovina is consisting from two entities: Republic of Srpska and Federation of Bosnia and Herzegovina, and Brcko District; energy sector and climate changes mitigation measures are under their jurisdiction. According to that some of this paper results can be useful for the improvement of entity and state strategies with the final aim to place renewable energy sources on the right position, as some of the major economy drivers, not only in Bosnia and Herzegovina, but in whole region.

Key words: *climate changes, renewable energy, mitigation potential waste management*

Renewable energy sources technical potential

In order to illustrate present renewable energy sources (RES) role in Bosnia and Herzegovina (B&H), tab. 1, show total primary energy supply (TPES) by energy sources in B&H. This table is prepared by the authors and it is based on energy balance of entities in B&H – Federation of B&H (FB&H) and Republic of Srpska (RS) – because there is no energy balance at state level. For the first time, Agency for Statistics of B&H has made the energy balance for

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2008, but only for electricity and heat and there is no biomass at all in energy balance of FB&H. Because of that, some calculations for biomass have been made by the authors, emphasizing potential uncertainties for biomass (deviation can be 10%, because there are no data related to private forests cutting and assumption of illegal cutting).

Table 1. Total primary energy supply by energy source in Bosnia and Herzegovina

Energy source	2006	2007	2008
Wind energy	0 PJ	0 PJ	0 PJ
Hydro power	12.41 PJ	15.03 PJ	17.57 PJ
Biomass	16.668 PJ	14.630 PJ	16.317 PJ
– Heat	16.668 PJ	14.630 PJ	16.317 PJ
– Electricity	0 PJ	0 PJ	0 PJ
– Transport	~ 0 PJ	~ 0 PJ	~ 0 PJ
Solar thermal	0.012 PJ	0.012 PJ	0.012 PJ
Solar photovoltaic	~ 0 PJ	~ 0 PJ	~ 0 PJ
Geothermal	0 PJ	0 PJ	0 PJ
Other RES	0 PJ	0 PJ	0 PJ
Total RES	**38.450 PJ**	**29.672 PJ**	**33.899 PJ**
Oil	44.785 PJ	48.378 PJ	53.47 PJ
Coal	126.161 PJ	127.058 PJ	138.420 PJ
Natural gas	12.372 PJ	10.805 PJ	10.672 PJ
Nuclear power	0 PJ	0 PJ	0 PJ
Net imports of electricity	– 8.606 PJ	– 2.764 PJ	– 5.94 PJ
Other	0 PJ	0 PJ	0 PJ
Total **Total**	**213.522 PJ** **5.1 Mtoe**	**213.149 PJ** **5.1 Mtoe**	**230.521 PJ** **5.5 Mtoe**

Small hydro power plants

B&H has a high participation of RES in electricity production (about 34%) which is one of the biggest shares in the Europe.

In addition to hydro energy potentials of the major water streams, B&H has available hydro energy potential of small water streams. Economic hydro energy potential of major water streams in B&H according to the study "Current Understanding of Hydro Energy Potential in SR B&H", prepared in 1986 by the Institute for Electrical Power Industry Sarajevo is around 18,000 GWh per year [1]. Utilization level of that potential is around 40% or 7,182 GWh per year. Some another sources says that theoretically water power of B&H amounts 99,256 GWh per year, technical water power potential of 356 small and big hydro power plants (HPP) (which may be built) amounts to 23,395 GWh per year, out of which 2,599 GWh per year is in small HPP [2]. From that amount around 77% is in RS and 23% is in FB&H. Utilization degree of small HPP is 4.4% of the power at disposal, or 5.7% of the energy at disposal, and these degrees of the water power potential are at very low level comparing it with other European countries.

According to the Law on concessions in FB&H, cantons are in charge of giving concessions for the electricity plants up to 5 MW. Therefore, concessions for the small hydro plants up to 5 MW are to be obtained by cantonal authorities, and for those with capacity higher than 5 MW Federation is in charged. Republic of Srpska is in charged for giving concessions for all electricity plants.

Biomass

The tradition of biomass use in B&H has been exist for a long time, but that use is characterized with a very low rate of utilization, mainly in rural and sub-urban areas as primary source for heating and cooking purposes in households and buildings. Today, biomass in B&H participates with ca. 9% in total primary energy supply. Apart from the traditional use of firewood and the recycling of wood waste in the wood-processing industry, there is no reliable data on the exploitation of different biomass sources in B&H, especially of wood waste. There are no reliable data how much of the wood waste is used or dumped into open field. The most significant source of biomass for energy production is wood mass from forestry (firewood, forestry residues) and wood waste from wood processing industry. Annual production of different types of wood (logs, firewood, wood residues) per region of B&H is shown in tab. 2.

Table 2. Annual production of wood assortment per regions of Bosnia and Herzegovina [m^3] [3]

Forestry central	Logs	Firewood	Wood residues	Total
Federation B&H	2,795,227	947,732	576,887	4,319,846
Republic of Srpska	1,791,417	516,974	279,186	2,587,577
Total B&H	4,586,644	1,464,706	856,073	6,907,423

As is common in many countries, in B&H, when felling a tree, only the straight cylindrical log is taken out of the forest and all other parts such as branches and roots are left behind. In general, no commercial value is given to it leading to waste estimated at around 15% of the total tree; about 600,000 m^3 [3].

Sawmill waste production is generally high due to a low process efficiency of sawmills: the net end product (lumber) represents an estimated 40-45% of the log (a well managed mill in Europe runs at up to 50% efficiency). The waste produced consists of wet sawdust, slabs, and the trimmings from cutting to length and width. Based on this ratio, waste from the primary and secondary wood processing industries would amount to approximately $1.14 \cdot 10^6$ m^3 [3].

Panel boards industry is not operational but some of this waste is used for production of steam for drying chambers, for internal heating, and for the production of briquettes and pellets. In addition to these global aims of environmental protection further, locally important advantages of biomass resources utilization become effective in developing countries such as B&H.

B&H energy potential in biogas from the livestock. Potential production of biogas and reduction of methane emission will be considered from the climate changes point of view. It is important to emphasize that B&H has excellent natural conditions to develop livestock farming. Here are some important remarks.

Sheep are most commonly bred in the south, while cattle and poultry farming prevails in the northwestern part. In RS and FB&H cattle is bred in about the same proportion, except that in the FB&H there was a small drop 2004 through 2007, accompanied by the increase in RS during the same period. Sheep farming is about 70% lower in RS, although the production experienced an increase in both entities 2004 through 2007. Pig farming is 95% lower in FB&H than it RS. Poultry farming is equally prevalent and is considerably on the rise in both entities. Cattle production resources represent the main source of manure production, making 60% of the total manure production.

Based on the current livestock estimate for the period 2004 to 2007, tab. 3 shows estimation of physical potential of biogas production.

Table 3. Calculated values of the physical potential of annual biogas production for B&H according to livestock data and amount of manure produced in the analysed area (in m^3 per day).

Type of animal	Estimate per year			
	2004	2005	2006	2007
1. Cattle (bovine)	447,395	454,188	466,640	460,360
2. Sheep	890,941	902,481	1,005,963	1,030,746
3. Pigs	587,171	625,473	686,430	506,759
4. Horses	27,346	26,690	25,614	25,158
5. Poultry	8,975,735	9,804,886	12,563,840	1,4302,229
Total biogass produced	791,462.2	816,214.2	873,605.9	853,175.8

Wind

Insufficient data and adequate measurements make it impossible to estimate the real potential for wind energy in B&H. A preliminary study carried out by the GTZ have indicated that there is an economic potential for developing approximately 600 MW of wind-based electricity by 2010, assuming that an appropriate incentive system to build wind power installations is introduced. In period from 1999 to 2001, some preliminary selection of potential locations for installing wind power plants in B&H is performed. Temporary, 16 macro-locations (with 33 micro-locations) are marked as good-potential. Total estimated installed capacity for these locations is 720-950 MW, implying annual production of 1440-1950 GWh. The infrastructure offers adequate conditions for connecting possible locations to the grid, as the high- and medium-voltage network is well developed.

Solar

During the one year, daily-emitted solar energy at the horizontal surface in B&H amounts 3.4-4.4 kWh/m^2. With solar irradiation figures of 1.240 kWh/m^2 per year in the north of the country and up to 1.600 kWh/m^2 per year, in the south, conditions for using solar energy are very favorable in B&H. Theoretical potential of the solar energy in B&H amounts 74.65 PWh. Technical potential amounts 685 PJ, that is 6.2 times more than quantity of energy out of totally balance needs for the primary energy in FB&H during 2000. Despite this, the use of solar energy is insignificant and the exploitation of solar energy with flat-plate collectors is also limited. At this moment only very small-scale consumers in B&H use it for water heating need (4000-6000 m^2 solar collectors). The main reasons for that are: the capital costs are still too high (450-550 €/m^2, depending on the type of the system and collectors), and there is no legislation that promotes and subsidizes the use of renewable energy systems.One of the first PV installations is being fitted on the roof of an orphanage in Trebinje with assistance from the GTZ. In view of the relatively high cost involved, the introduction of photovoltaic on the market beyond very small-scale consumers far from the utility grid is dependent on promotional programs and the international projects.

Geothermal

It is difficult to estimate total B&H's technical geothermal potential. According to fig. 1 it is obviously that certain energy potential exists, but it is not explored in details on whole potential sites. All estimates are mainly based on some experimental drills and theoretical investigation. According to that temperatures at the known locations in Bosanski Samac (85 °C), Kakanj (54 °C), Sarajevo (58 °C), and Gračanica (37-39 °C) is too low for electricity generation, which is why the reserves are currently only under consideration for thermal exploitation (there are no sites have a temperature around 100 °C).

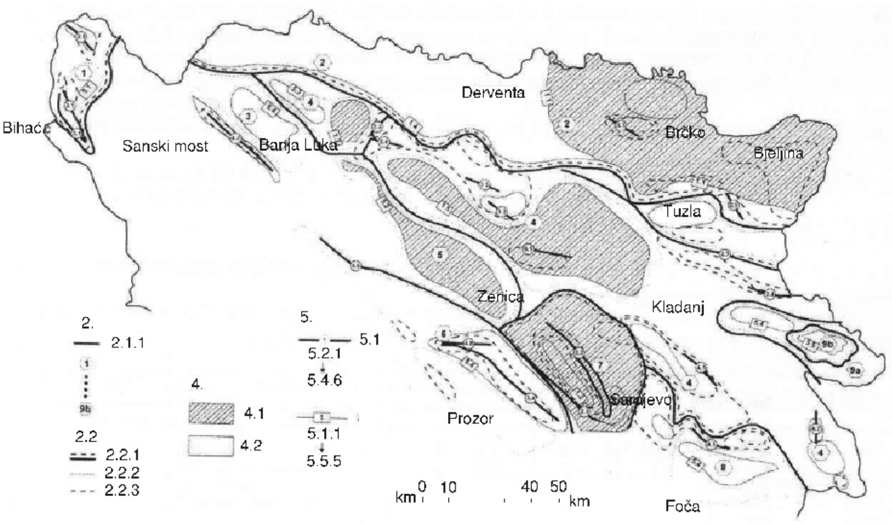

Figure 1. Zones of hydrothermal potentials [4]

Current activities relating to geothermal energy continue to be limited to exploitation for thermal use. For example, activities which will result to district heating system of Bijeljina are already undergoing, a group of buildings in Illidza (a suburb of Sarajevo) is to be heated with geothermal energy. In a case that higher temperatures will be discovered in the course of the exploratory drilling, there are also some plans for partial conversion to electrical energy on the sustainable way. Also, there are some plans to trying to find an investor for one pilot geothermal borehole near Banja Luka. Current activities related to geothermal energy are mainly related to heating purposes, there are a few examples related to geothermal water is use for heating purposes as Laktasi Spa and the Dvorovi Spa. In 2005, a spa owned by Slovenian company Terme Catez, has started to work in Ilidža near Sarajevo where geothermal energy is used for heating of swimming pools. According to existing studies and analysis made for some certain places tab. 4 gives some estimates for the potential installation for heat energy exploitation.

Table 4. Some estimates for thermal energy production from geothermal heat sources [4]

	Number of sites	Water temperature [°C]	Thermal power [MW_t]	Geo-fluid flow rate [kg/s]
FB&H	29 sites	20.5-75	57.08 (up to 20 °C) 7.15 (up to 50 °C)	From 1 to 1000, depending on site
RS	16 sites	20-75	33.12 (up to 20 °C) 2.09 (up to 50 °C)	

Waste

The impact of solid waste management on the global warming equivalence of European greenhouse gas emissions comes mostly from CH_4 released from biodegradable wastes decay under the anaerobic conditions in landfills. About a third of anthropogenic emissions of CH_4 in the EU can be attributed to this source. In contrast, only 1% of N_2O emissions and less than 0.5% of CO_2 emissions are associated with solid waste disposal [5].

Solid Waste Management Strategy (SWMS) gives review on the solid waste management conditions in B&H and defines policy and strategy in this sector. Although SWMS does not directly mention reduction of GHG emissions, defined strategy suggesting construction of the regional sanitary landfills according to EU standards (Landfill Directive 99/31/EC) and outlining possibilities of waste incineration with energy recovery and recycling, directly involve measures for reduction of GHG emissions. Implementation of SWMS commenced with WB/IDA credit for Project "Solid Waste Management Project" (ex. Environmental Infrastructure Protection Project) in 2002. The analysis of the current situation in this sector has shown that the objectives concerning the construction of regional sanitary landfills defined in the SWSM are unrealistic. The plan is to have 16 regional landfills by December 2009, but until now, only 2 landfills have been constructed. Therefore, it is necessary to adopt, new waste management strategies, which would more clearly define the quantitative objectives in terms of recycling and reduction in biodegradable waste amounts disposed of at landfills, and define more realistically the dynamics of regional sanitary landfills construction. In order to calculate possible reduction of GHG emission, quantity and morphological structure of municipal solid waste (MSW) have been estimated. Table 4 shows estimated total MSW and household waste (HHW) amounts, in accordance with the methodology recommended in the SWMS [6], and population statistic [7, 8]. A linear annual rate of waste production growth is projected at 3%, according to the 1999 data, which includes the growth of population and amounts of produced waste per capita – growth rate of 1,8%, and which are only official data concerning growth of waste production by far. It was assumed that a total MSW amount generated in the RS in 1999 was 724,269 t (population of 1,448,537   0,5 t per year per capita), and a total HHW amount was 362,134 t (population of 1,448,537   0.25 t per year per capita), according to the estimated average values of waste production presented in the SWMS and the available statistics. By the analogy, the MSW amount in the FB&H in 1999 was 1,138,000 t (population of 2,276,000   0.5 t per year per capita), and a total HHW amount was 569.000 t (population of 1,448,537   0.25 t per year per capita). The amounts of waste generated in the B&H Brčko district were included through the data for the RS and the FB&H, regarding of the SWMS and the 1999 statistics (tab. 5).

Table 5. Estimated annual amounts of MSW and HHW at entity and country level

	MSW generated in 1999 [Gg MSW]	MSW generated in 2010 [Gg MSW]	MSW generated in 2020 [Gg MSW]	MSW generated in 2030 [Gg MSW]
MSW in RS	724,269	1,002,558	1,347,354	1,810,731
HHW in RS	362,134	501,278	673,676	905,364
MSW in FB&H	1,138,0	1,575,258	2,117,015	2,845,091
HHW in FB&H	569,0	787,629	1,058,508	1,422,546
Summary MSW	1862,269	2,577,812	3,469,369	4,655,822
Summary HHW	931,134	1,288,907	1,732,183	2,327,911

Mitigation potential of renewable energy sources

Renewable energy sources obviously has significant potential and can play important role in climate changes mitigation activities in B&H. Their role depends on very complex factors, and has to be defined by the corresponding sectors strategies on the state, entities level, as well as local level.

Taking into account the facts and considerations related to the RES potential, it is necessary to point out some generally measures that should be overtaken by the state and entity ministries responsible for energy sector. If these measures would be overtaken, it would be easier to make the assessment of mitigation potential in sector of RES. It is necessary:

– to create a legal framework for renewable and/or distributed sources of electricity that should process,
– to develop a functional system of promotion energy production from RES, there are a lot of mechanisms available, subsidies, for example, can be successful model of support (incentive measures) for construction of systems based on renewable energy sources, taking into account some fulfilled preconditions (functioning of environmental funds),
– to develop a strategy related to the building of energy facilities on RES in close co-operation with other competent institutions for water management, agriculture and forestry, in order to achieve sustainable systems from all aspects,

- to solve the problem of management of small electricity production facilities, as HPP and wind power plants – primarily connection to distribution network,
- to perform a systematic substitution of liquid fuels with renewable sources, especially in the public institution's facilities in order to promote and encourage installation of RES in construction of new buildings and renovation the old ones,
- to consider a possibility of development biomass-fueled remote heating system (eventually combined with solid municipal waste), in places with developed timber and wood processing industry, together with industrial power plants of industrial companies, by using different organizational and financial models as ESCO, for example,
- to remove all the identified general barriers as soon as possible in order to allow large scale application of RES, and
- apart from the above-mentioned general measures, it is needed to overtake some measures those are specific for some RES only.

Small hydro power plants

Most of the hydro potential could be realized if the measures mentioned would be taken. If we suppose, that hydro potential for small HPP would be realized by 80%, it means, it could be built ca. 800 small HPP with the potential installed capacity of 700 MW and possible annual energy production of 3600 GWh. Taking in to account necessity of connection of small HPP with other economy activities as agriculture or tourism, it is obviously that this kind of business can be very promising, and first of all sustainable.

Biomass

This kind of RES can play very significant role in B&H economy. It is obvious that with good organization of collecting and use of their own waste, wood processing industries can satisfy they own energy demands. It is easy to show that small municipalities in P&H (with 10000 to 20000 inhabitants) with centralized wood processing industry can satisfy their all energy needs from its own wood waste, from the other side introduction of the new technologies, as "flash" pyrolysis or other thermo chemical processes can activate new sustainable economy activities in the some specific local areas. Taking into account above presented data related to biogas production (which is 60 to 70% methane), any kind of methane transformation to CO_2 is acceptable from mitigation point of view.

In order to achieve a more significant application of biomass in B&H, it is necessary to carry out the following research:
- definition of target areas in B&H where detailed research of economically and ecologically sustainable use of biomass should be performed,
- quantification of physical, technical, and economical potential of non-used biomass in target areas,
- estimation of biomass and bioenergy costs as a fuel in the future and a comparative analysis with the costs of other fuels,
- identification of the possibilities for suitable, financially competitive solutions for biomass application in different sectors,
- identification of the most suitable technologies, investment methods, and incentive measures for selected solutions of biomass application,

- identification of obstacles in legislation and regulations that influence the selection of technologies for biomass application in the target areas in a most efficient way, and
- identification of institutional obstacles for accepting the most efficient solutions for the construction of a biomass-fuelled system for production of thermal and/or electrical energy.

Implementation of the above-mentioned steps would clearly show the real economical and ecological potential and solutions for the application of biomass-fuelled facilities in the target areas in B&H, and it would help the competent authorities to plan the construction of such facilities. The identified activities greatly depend on the agriculture and forestry development strategy and the ministries of energy should plan and implement them together with the competent ministries for these areas.

Some preliminary calculations showed that present methane emissions from cattle rising activities in B&H is about 32 Gg per year, which makes relatively large mitigation potential and makes this sector attractive for potentially CDM projects. Unfortunately typical livestock farms in B&H are relatively small (20 cows, 100 pigs or 5000 to 12000 poultry) and due to organic fertilizer and electricity market present situation, potential investments, for example in biogas plant with gas engine devices (6 kW_e) requires relatively long payback period, about 8 to 10 years for cow farms, 11 to 14 years for pig farms, and 7.5 to 9.5 years for poultry farms [9].

Solar

Apart from the application of thermal energy, obtained from solar collectors, for heating and preparation of sanitary water in building construction, this form of energy is also applicable for cooling, industrial process heat, pool heating application, *etc*. Each of the mentioned applications is certain in B&H in the period until 2020, and the intensity of that application is directly dependant on the Government incentive measures policy. It is realistic to expect that in the period until 2020 in B&H there will not be more significant application of solar energy for production of electrical energy, except of individual construction of low-power photovoltage systems (negligible for the energy balance of B&H), and the same trend is to be expected even until 2030. There are several limitations for this, and the main ones are: non-competitiveness of such facilities, and the required area (space) for their construction.

Wind

Challenges and limitations, when the issue of wind power plants construction in B&H is considered, can be viewed from the aspect of problems that appear, recommendations for overcoming those problems, as well as technical, market, and regulatory measures for the reduction of the risk of wind power plants construction. If would be realized measures mentioned most of technical (till now known potential) could be realized. It means, it would be build wind power plants with the total installed capacity of 900 MW and the annual energy production of 2300 GWh.

The basic problems for the integration of wind power plants into the electricity system are:

- increased losses in the transmission network due to overloads, circular flows, and power transmission to large distances,
- increased consumption of reactive energy due to energy transmission to large distances and an increased line load factor,
- wind power plants are sensitive even to very little and brief “drops” of voltage, and

– there is a considerable economic influence of wind power plants on conventional generation.

Geothermal

Assessment of geothermal energy use for B&H in the future is such that the technology of use of geothermal resources is possible in a few areas, such as:
– agriculture for production of ecologically valuable food (agro- and aquaculture),
– district heating systems in municipalities,
– health industry and human body care industry – balneotherapy, and
– tourism purposes, as well as for electricity generation by means of mini power plants.

Still, realistically taking into perspective the past research of this resource potential in B&H and present available technologies for the application of geothermal energy, in the period until 2020, the application of geothermal energy in B&H will be limited to past sectors of application (agriculture, healthcare), possibly for heating and tourism purposes, and the application of geothermal energy for electricity generation is not expected in this period. There are several reasons for this, and the fundamental ones are: insufficient level of exploration of locations and potentials of geothermal energy, in general, and especially for those purposes, followed by the price and availability of technologies for the application of geothermal energy for electricity generation. Namely, out of all technologies for the application of renewable energy sources, geothermal energy for production of electricity is the least competitive one. If in the period until 2020 the research shows a more significant availability of geothermal sources in B&H, and if the technologies for the application of geothermal energy in electricity generation become more competitive, from 2020 to 2030 this application will be worthy to consider in B&H as well.

Taking into account the investments in exploration drilling, which are considerable, and the level of insecurity that such explorations carry, it is not possible to expect more significant investments in this sector without a more significant support from the state and entities administrations or the international community.

Waste management

GHG emission reduction potential of different waste management option has been analyzed through two different scenarios, *i. e.* baseline scenario and mitigation scenario.

The *baseline scenario* anticipates waste management development and a projection of the situation according to the current documents and plans, based on the SWMS. The basis of such waste management is the disposal of waste remaining after the implementation of economically justifiable and environmentally acceptable measures aimed at avoiding the production, separate collection and recycling of waste, at regional sanitary landfills. The baseline scenario anticipates the continual growth of municipal waste amounts (tab. 4), which will gradually decrease over time due to the effects of the measures aimed at avoiding the production and recycling of waste. It is envisaged that all 16 regional sanitary landfills will be constructed by the end of 2020.

It is assumed that the envisaged measures aimed at separate collection and waste recycling rate will be implemented at a pace anticipated in the SWMS, *i. e.* the recycling rate of 10% of the total generated HHW by the end of 2020. It was anticipated that the HHW recycling rate would be 5% for 2010, while for 2030 the HHW recycling rate would be 20% in both B&H entities. Owing to the unclear defined quantitative objectives with respect to the reduction of biodegradable waste amounts on one hand, and the clearly defined EU requirements with respect to the reduction of biodegradable waste amounts disposed of at landfills on the other, it was assumed that 50% of recycled waste would be biodegradable waste which is going to be treat by means of composting and anaerobic digestion technology. It was also necessary to assume the rate of coverage by waste collection services as compared to the total population in order to get an estimate of the amounts of waste disposed of at official landfills, which the calculation of the GHG emission reduction potential relates to. Using the SWMS estimates, it was assumed that 80%, (95 + 60)/2, of the population would be covered by waste collection services in 2010, and the same percentage of generated MWS would be disposed of at landfills, and by analogy, this percentage for 2020 would be 84%, (98 + 70)/2. For 2030, it was assumed that the entire population would be covered by waste collection services. The remaining waste is assumed to be locally composted in rural areas and disposed of at illegal landfills. All aforementioned assumptions are used in both scenarios.

The current limits of financial and other resources pose a serious obstacle to introducing any other important waste management option, except for the construction of regional sanitary landfills, in the forthcoming period by 2020. Although the SWMS foresees measures for the thermal processing of waste (incineration), that is, the incineration of 20% of MSW with energy recovery by 2020, it is realistic to assume that this will not happen according to this baseline scenario. For that reason, a rescheduling compared to the deadlines set by the SWMS is anticipated, as is the case with the construction of regional sanitary landfills, and incineration of 20% of MSW with energy recovery is anticipated by 2030.

Table 6. Impact of waste recycling and incineration initiatives on the amount of municipal waste disposed of at landfills in RS [13]

	2010	2020	2030
MSW collected [Gg]	802,046	1,131,777	1,810,731
Waste recycled* [Gg]	25,064	67,368	181,073
Waste incinerated [Gg]	–	–	362,146
Net MSW disposed on landfill [Gg]	776,982	1,064,410	1,267,512

* It is assumed that 50% of recycled waste is biodegradable waste reduction

Table 7. Impact of waste recycling and incineration initiatives on the amount of municipal waste disposed of at sanitary landfills in FB&H [13]

	2010	2020	2030
MSW collected [Gg]	1,260,206	1,778,293	2,845,091
Waste recycled* [Gg]	39,381	105,851	284,509
Waste incinerated [Gg]	–	–	569,018
Net MSW disposed on landfill [Gg]	1,220,825	1,672,442	1,991,564

* It is assumed that 50% of recycled waste is biodegradable waste reduction

The *mitigation scenario* anticipates the introduction of measures for the combustion of methane by flame flare system, as well as measures aimed at using landfill gas (methane) to generate electricity, along with the already defined measures in the baseline scenario. Apart from directly reducing the amounts of released methane, analogously to combustion by flare, the measure for using methane to generate electricity also reduces the equivalent amount of CO_2, which would be released by the use of fossil fuels in the course of the generation of the given amount of electricity. Given the defined dynamics of the construction of sanitary landfills in RS and FB&H, a gradual increase is anticipated in the amount of methane combusted by flares and in the generation of electricity in suitable facilities, such as internal combustion engines and gas turbines (tabs. 8 and 9). It was anticipated that an average of 37 kg of methane is consumed for the generation of 55 kWh of electricity [10], and that a reduction of 0.7 t of CO_2 per 1 MWh of electricity is achieved owing to avoiding the use of fossil fuels.

Table 7. Reduction in methane emission according to the measure concerning methane combustion by flare and the measure of electricity generated from methane, in accordance with the mitigation scenario for the RS

	2010	2020	2030
Methane generation from Net MSW disposed of in landfills [Gg CH_4]	35.90	49.18	58.56
Percentage of methane combusted by flame flares system* [% CH_4]	9	27	27
Emission reduction by combustion by flame flares system [Gg CH_4]	3.23	13.28	15.81
Presentage of methane used for electricity generation [% CH_4]	0	27	27
Emission reduction utilising methane for electricity generation [Gg CH_4]		13.28	15.81
Avoided emission from fossil fuels due to electricity generation [Gg CO_2-eq]		13.82	16.45
Net reduction of emission [Gg CH_4]	3.23	26.56	31.62

* This assumes an EU-average landfill gas collection efficiency of 54% [5]

Applying the measure of methane combustion by flare results in an emission reduction of 67.83 [Gg CO_2-eq] in 2010, 88 [Gg CO_2-eq] in 2020 and 332 [Gg CO_2-eq] in 2030 in the RS. Applying the measure of using methane to generate electricity results in a total emission reduction of 292.77 [Gg CO_2-eq] in 2020 and 348.46 [Gg CO_2-eq] in 2030 in the RS, and while at the same time generating electricity amounting to 19.740 MWh in 2020 and 23.501 MWh in 2030.

Applying the measure of methane combustion by flare results in an emission reduction of 51.03 [Gg CO_2-eq] in 2010, 438.06 [Gg CO_2-eq] in 2020 and 521.64 [Gg CO_2-eq] in 2030 in FBiH. Applying the measure of using methane to generate electricity results in a total emission reduction of 67.22 [Gg CO_2-eq] in 2010, 459.78 [Gg CO_2-eq] in 2020 and 547.49 [Gg CO_2-eq] in 2030 in FB&H, while at the same time generating electricity amounting to 4534 MWh in 2010, 31.008 MWh in 2020, and 36.924 MWh in 2030.

Table 9. Introduction of measure concerning methane combustion by flare and measures concerning electricity generated from methane in accordance with the mitigation scenario for FB&H

	2010	2020	2030
Methane generation from Net MSW disposed of in landfills [Gg CH_4]	56.40	77.27	92.01
Percentage of methane combusted by flame flares system* [% CH_4]	4.32	27	27
Emission reduction by combustion by flame flares system [Gg CH_4]	2.43	20.86	24.84
Percentage of methane used for electricity generation [% CH_4]	5.4	27	27
Emission reduction utilizing methane for electricity generation [Gg CH_4]	3.05	20.86	24.84
Avoided emission from fossil fuels due to electricity generation [Gg CO_2-eq]	3.17	21.71	25.85
Net reduction of emission [Gg CH_4]	5.48	41.72	49.68

* This assumes an EU-average landfill gas collection efficiency of 54% [5]

Above presented projection of GHG emissions from this (waste) sector includes balancing emissions of methane due to decomposition of the MSW disposed of in solid waste disposal sites (SWDS). This balancing involves different waste management options and consequent net reduction of MSW disposed of in SWDS and therefore net reduction of the methane released from the landfills. Projections of methane emissions generated by waste management have been based on the default IPCC methodology method 1 [11].

According to EU15-average costs and total potential reduction of methane options in the waste sector, investment into landfill gas flaring measure is 5 €/tCO_2-eq, while investment into electricity generation measure is 31 €/tCO_2-eq [12]. In that regard, taking into account current economic situation in country as well, it is easy to conclude that country, and governments of booth entities, have to support and to expedite construction of regional sanitary landfills with gas flaring system as first and prominent measure for reducing the amount of CH_4 emitted from landfill.

Conclusions

According to the materials presented above it is obviously that renewable energy sources have significant climate changes mitigation potential. Bosnia and Herzegovina is Non-Annex I country according to UNFCCC and it is not directly obligated to reduce GHG emissions, but can participate to the global efforts for GHG emission reduction. From that point of view, one of the important aspects are CDM projects, B&H's is on a way to establish whole necessary mechanisms for realisation of such kind of projects. Renewable energy sources are directly related to the energy sector, but closely corresponding with some other sector (agriculture, tourism, forestry, *etc.*) as one of the most important drivers of sustainable development in whole economy. According to that promotion mechanisms for RES, and the other necessary measures are crucial to be implemented in order to position RES on an adequate place in B&H economy.

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