THE POTENTIAL OF RENEWABLE ENERGY SOURCES FOR GREENHOUSE GASES EMISSIONS REDUCTION IN MACEDONIA

by

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As European Union candidate country, Macedonia is in the process of adoption of the EU strategic energy policies, harmonization of the national legislation with the EU legislation and defining the respective national goals. In this regard, the Government has recently adopted the National Strategy for Utilization of Renewable Energy Sources (RES), prepared by the Research Center for Energy, Informatics and Materials at the Macedonian Academy of Sciences and Arts. The main goal of this paper is to assess the potential for greenhouse gases emissions reduction by implementation of 21%-RES-scenarios from the Strategy. The corresponding emissions reduction is calculated against the baseline (reference) scenario developed within the Second National Communication on Climate Change. Furthermore, all potential RES technologies are analyzed from economic aspect and combined in a form of emissions reduction cost curve, displaying the total marginal cost of the greenhouse gases emissions reduction by RES. Finally, on the bases of the environmental and economic effectiveness of the considered RES technologies, as well as taking into account the country specific barriers, the priority actions for greenhouse gases emissions reduction are identified.

Key words: *climate change mitigation, environmental effectiveness, economic effectiveness, marginal cost curve*

Introduction

Greenhouse gases (GHG) emission is the biggest problem in this modern world. Intergovernmental Panel on Climate Change in [1] predicts that the global surface temperature is likely to rise a further 1.1 to 6.4 °C by the year 2100. As this global problem or global warming becomes a key issue, many national governments have developed strategies for reducing GHG emissions (*i. e.* [2-5]). Most countries which are developed have reduced GHG emissions in the period from 2008-2010 due to global financial crisis, but countries which are still developing actually emitted more in that period than before [6].

There are many ways how to reduce GHG emissions. Renewable energy sources (RES) are one of the most promising solutions for alleviation of energy import and diversification of the energy resources, which at the same time reduces the GHG emissions

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[7]. According to the Directive 2009/28/EC [8] EU Member-States are to ensure the share of energy from RES in the final energy consumption in the EU so as to achieve a share of at least 20% by 2020 and at the same time sets forth the national targets for all EU Member States. Also, by 2020 Member-States are to achieve at least 10% share of energy from RES (primary biofuels) in transport. Macedonia as a country that has aspirations to become member state of the EU is planning to increase the share of renewable energy sources to 21% by 2020 [9].

Following up on the work done in [10], in this paper the potential for GHG emissions reduction by implementation of 21%-RES-scenarios from the National Strategy for Utilisation of RES by 2020 [9] is presented. All potential RES technologies are also analyzed from economic aspect and combined in a form of emissions reduction cost curve (abetment cost curve), displaying the total marginal cost of the GHG emissions reduction by RES. On the basis of the environmental and economic evaluations, priority actions for RES impleme-ntation are recommended.

The examined renewable energy sources technologies

The country-specific RES technologies are identified by type and size in line with the projections from [9] (tab.1).

Table 1. Selected country-specific RES technologies

RES technology	Base unit	RES technology	Base unit
Small hydro power plants	1 MW	Photovoltaics (PVs) connected to grid	1 MW
Wind turbines	1 MW	Efficient biomass stoves *vs.* Electricity for heating	1 unit
Geothermal district heating	1 unit	Efficient biomass stoves *vs.* Inefficient biomass stoves	1 unit
Biogas from agro-industrial sewage water	1 digester	Wood pellets stoves *vs.* Electricity for heating	1 unit
Solar water heating	1 unit	Wood pellets stoves *vs.* Inefficient biomass stoves	1 unit

Methodology for evaluation

The software tool that is used in this analysis is GACMO-GHG emission reduction strategy evaluation model developed by the United Nations Environment Programme (UNEP) [11]. GACMO (GHG costing model) can be used to rank the cost effectiveness of various GHG reduction strategies in a transparent and simple way, even when there is no detailed data available. GACMO adopted the principle of calculating the reduction costs when individual reduction strategies replace high emission technologies under the same comparative basis (same power generation capacity/power generation, single plants/residence, passenger-kilometre), aggregate and rank the average cost of each emission reduction option, and then draw the reduction cost curve.

Economic and environmental evaluation of the selected renewable energy sources technologies

The basis for this analysis is a baseline or reference scenario for GHG emissions from the base year to the target year, which is 2020. The baseline comprises knowledge of the energy services supplied within different energy consuming sectors *i. e.* the number of energy consuming units and the annual energy consumption by each unit. The Macedonian baseline scenario is described in the GHG abatement analyses within the Second national commu-nication under the United Nations Framework Convention on Climate Change (UNFCCC) [5], according to which the total GHG emissions in 2020 amount to 21 Mt CO_2-eq.

In this section the GACMO spreadsheets for the ten RES technologies from the tab.1 are presented. The reference option in each case depends on the technology that is subject of consideration, but in most of the cases, it is use of electricity from the grid. The emissions related to electricity (grid factor) are calculated as to reflect the fuel mix for the existing and projected electricity generation in the country – lignite thermal power plants (Bitola, Oslomej), heavy fuel oil fired thermal power plant (Negotino), gas combined heat and power plants (TE-TO Skopje), hydro power plants, and candidate plants that will be built until 2020 as planned in the National strategy for energy development [12].

Table 2. Input data for reference option of the technologies: small hydro power plants, wind power plant, geothermal district heating, biogas from agro-industrial sewage water, and grid-connected solar PV

General inputs	
Discount rate [%]	6
Fraction of time using low tariff [%]	50
Fraction of time using high tariff [%]	50
Average electricity price [US$·kWh]	0.081
CO_2-eq. emission coefficient [$ton_{CO2-eq}.MWh^{-1}$]	0.960

Small hydro power plants

In the National Strategy for Utilisation of Renewable Energy Sources by 2020 [9] is planned to build small hydro power plants (SHPP) that will reach installed capacity in the range of 80 to 120 MW. For analysis in this paper, 116 MW is taken.

Because all SHPP have various capacities, for simplifying the analyses in this paper the activity unit is set to 1 MW and the capacity factor is set to 2,650 hours/year for each of the SHPP (tab. 3). The results for the technology SHPP are presented in tab. 4.

Table 3. Input data for reduction option of the technology "Small hydro power plants"

Reduction option: Small hydro power plants	
O&M [%]	1.0
Activity [MW]	1
Investment in hydro power [US$·kW^{-1}]	2,847
Capacity factor [hours]	2,650
Electricity production [MWh]	2,650

Table 4. Results for the technology "Small hydro power plants"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	2,847,222		
Project life	30		
Lev. investment	206,848		206,848
Annual O&M	28,472		28,472
Corrected lev. investment	206,848		
Corrected annual O&M	28,472		
Annual fuel cost		215,794	–215,794
Total annual cost	235,320	215,794	19,526
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission		2,544	2,544
Other			
Total CO_2-eq. emission	0	2,544	2,544
US$/ton CO_2-eq.			7.68

Wind turbines

According to the National Strategy for Utilisation of Renewable Energy Sources by 2020 [9] it is planned to build wind power plants (WPP) in Macedonia that will reach

Table 5. Input data for reduction option of the technology "Wind turbines"

Reduction option: Wind turbines	
O&M [%]	1.5
Activity [MW]	1
Investment in wind turbines [US$·kW^{-1}]	2,182
Capacity factor [hours]	2,000
Electricity production [MWh]	2,000
Power purchase price [US$·kWh^{-1}]	0.13809

installed capacity of 150 MW. For analysis in this paper, two WPP with installed capacity of up to 50 MW and several small WPP with total installed capacity of up to 35 MW are taken. Wind turbines of 1 MW with a capacity factor of 2,000 hours/year is considered as unit of technology (tab. 5). The results for the technology "Wind turbines" are presented in tab. 6.

Table 6. Results for the technology "Wind turbines"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	2,182,396		
Project life	30		
Lev. investment	158,549		158,549
Annual O&M	32,736		32,736
Annual fuel cost		162,863	–162,863
Total annual cost	191,285	162,863	28,421
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission		1,920	1,920
Other			
Total CO_2-eq. emission	0	1,920	1,920
US$/ton CO_2-eq.			14.80

Geothermal district heating

One MW_t for district heating and possible plant operation of 2,000 hours is considered for geothermal power plant. As a reference option, fuel oil heating plant is taken (tab 7). The results for the technology "Geothermal district heating" are presented in tab. 8.

Table 7. Input data for reduction option of the technology "Geothermal district heating"

Reduction option: Geothermal plant		Reference option: Fuel oil heating plant	
O&M [%]	6.0	O&M [%]	2.0
Activity [MWth]	1	Energy efficiency [–]	0.85
Heat from geothermal [MWh]	3,000	Annual fuel used [GJ]	12,706
Investment in geothermal plant [M. US$]	0.6795	Price of fuel oil [US$·GJ^{-1}]	15.7
Possible plant operation [hours]	3,000	CO_2-eq. emission coefficient [$kg_{CO2\text{-}eq}GJ^{-1}$]	77.6
Annual heat production [GJ]	10,800		

Table 8. Results for the technology "Geothermal district heating"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	679,500		
Project life	20		
Lev. investment	59,242		59,242
Annual O&M	40,770		40,770
Annual fuel cost		198,938	–198,938
Total annual cost	100,012	198,938	–98,927
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	0	986	986
Other			
Total CO_2-eq. emission	0	986	986
US$/ton CO_2-eq.			–100.31

Biogas from agro-industrial sewage water

In this case, the construction of biogas plant at agricultural industries is analyzed. The input into the biogas plant is the sewage water from the industry plus the manure from the animals at the site (tab. 9). The results for the technology "Biogas from agro-industrial sewage water" are presented in tab. 10.

Table 9. Input data for reduction option of the technology "Biogas from agro-industrial sewage water"

Reduction option: Efficient biomass pellets stoves			
O&M [%]	4	CH_4 production factor [$kg_{CH4}m^{-3}{}_{wastewater}$]	0.8
Activity, biogas plant	1	Annual CH_4 production [$m^3{}_{CH4}$]	892,800
Investment in digester [US$·kW^{-1}]	700	CH_4 density [kgm^{-3}]	0.671
Investment in power plant [US$·kW^{-1}]	500	CH_4 calorific value [MJm^{-3}]	39
Food production [tons·year^{-1}]	1,200	Annual gas production [GJ]	34,819
Waste water production [$m^3{}_{wastewater}ton^{-1}{}_{product}$]	62	Generator elec. efficiency [–]	0.30
COD production [$kg_{COD}/m^3{}_{wastewater}$]	3	Electricity produced [MWh]	2,902
CH_4 production [$kg_{CH4}kg^{-1}{}_{COD}$]	0.25	Capacity factor [–]	1.00
Waste water production [m^3year^{-1}]	74,400	Size of generator [kW]	331.2
Biogas production factor [$m^3{}_{biogas}m^{-3}{}_{sewage}$]	20	CO_2-eq emission factor [$kgGJ^{-1}$]	101.66
CH_4 content in the biogas [%]	60%		

Table 10. Results for the technology "Biogas from agro-industrial sewage water"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	397,479		
Project life	20		
Lev. investment	34,654		34,654
Annual O&M	15,899		15,899
Annual fuel cost			
Total annual cost	50,553		50,553
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	23.1		–23.1
CH_4 from sewage + manure		1,171.8	1,171.8
Total CO_2-eq. emission	23.1	1,171.8	1,148.7
US$/ton CO_2-eq.			44.01

In the National Strategy for Utilisation of Renewable Energy Sources by 2020 [9] it is planned to build biogas power plants in Macedonia with installed capacity in the range of 20 to 30 MW. The considered biogas power plant has installed capacity of 2.9 MW, and is assumed that seven biogas power plants will be built.

Solar water heating

In this case, hot water for a household is produced by a solar system with 2.2 m^2 solar collector with a 130 litre storage tank. As a reference option, an electric boiler is considered, for which it is assumed that the electricity usage will be 75% in periods with low tariff and 25% in periods with high tariff [13] (tab. 11). The results for the technology "Solar water heating" are presented in tab. 12.

In the National Strategy for Utilisation of Renewable Energy Sources [9] it is anticipated that 55,000-80,000 households will have such installation by 2020, which accounts for total use of solar energy (together with the commercial and service sector and the industry) in the range of 60-90 GWh annually. In this paper, it is assumed that 90,000 units will have this technology, which means 80,000 households and 10% of commercial and service sector.

Table 11. Input data for reference and reduction option of the technology "Solar water heating"

General inputs		Reference option: electrical water heater	
Discount rate [%]	6	Electricity used [GJday^{-1}]	0.019
Activity [location]	1	Annually electricity used [kWh]	1,931.5
Water usage [litres·day^{-1}]	130	Reduction option: Solar water heater & electrical backup	
Water supply temp [ºC]	15	Investment [US$]	997
Thermostat setting [ºC]	50	O&M [%]	1
Specific heat of water [Jkg^{-1}K^{-1}]	4,187	Size of Solar Heater [m^2]	2.2
Fraction of time using low tariff [%]	75	Solar Heater Annual Energy Output [kWhm^{-2}]	450
Fraction of time using high tariff [%]	25	Input from Solar Heater [kWh]	990
Average electricity price [US$·kWh^{-1}]	0.068	Annual electricity used [kWh]	941.5
CO_2-eq. emission coefficient [ton$_{CO2\text{-eq.}}$MWh^{-1}]	0.960		

Table 12. Results for the technology "Solar water heating"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	997		
Project life	15		
Lev. investment	103		103
Annual O&M	10.0		10
Annual electricity cost	64	131	–67
Total annual cost	176	131	45
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	0.90	1.85	0.95
Other			
Total CO_2-eq. emission	0.90	1.85	0.95
US$/ton CO_2-eq.			47.81

Grid-connected PV

In this case PV system of 1 MW with capacity factor of 1400 hours/year is analysed. Reference option is use of electricity (tab. 13).

In [9] it is planned to build photovoltaic power plants in Macedonia that will reach installed capacity in the range of 10 to 30 MW. For analysis in this paper 10 MW is taken (tabs. 14 and 15)

Table 13. Input data for reduction option of the technology "Grid-connected solar PV"

Reduction option: Solar PV	
O&M [%]	1.0
Activity [kW]	1,000
Investment in Activity[US$·kW^{-1}]	5,694.44
Capacity factor [Hours]	1,400
Electricity production [kWh]	1,400,000

Table 14. Results for the technology "Grid-connected solar PVs"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	5,694,444		
Project life	20		
Lev. investment	496,468		496,468
Annual O&M	56,944		56,944
Annual fuel cost		114,004	–114,004
Total annual cost	553,412	114,004	439,408
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission		1,344.0	1,344
Other			
Total CO_2-eq. emission	0.0	1,344.0	1,344
US$/ton CO_2-eq.			326.94

Table 15. Input data for reference and reduction option of the technology "Efficient biomass stoves *vs.* Electricity for heating"

General inputs		Reduction option: Efficient biomass stoves (continuation)	
Discount rate [%]	6	Investment in stoves [US$]	700
Reference option 1: Electricity for heating		Possible stove operation [Hours]	1,440
Fraction of time using low tariff [%]	75	Annual heat production [GJ]	20.7
Fraction of time using high tariff [%]	25	Energy efficiency [–]	0.70
Average electricity price [US$·kWh^{-1}]	0.068	Calorific value [GJm^{-3}]	9.90
CO_2-eq. emission coefficient [ton$_{CO2\text{-}eq}$MWh^{-1}]	0.960	Annual fuel used [GJ]	30
Reduction option: Efficient biomass stoves		Annual fuel used [m^3]	3
O&M [%]	5.0	Price of wood [US$·m^{-3}]	60
Activity [kW]	4	CO_2-eq. emission coefficient [kg$_{CO2\text{-}eq}$.GJ^{-1}]	109.60
Heat from stoves [kWh]	5,760		

Efficient biomass stoves vs. Electricity for heating

Considering that the price of the electricity will grow in the next period, it is assumed that people in Macedonia will change their electric thermal storage systems with effective biomass stoves. People usually charge their electric thermal storage systems in the periods with low tariff (75%), but sometimes in the period with high tariff (25%) [13]. The CO_2 emission is analysed in a scenario in which the electric thermal storage systems are replaced with effective biomass stoves of 4 kW, with possible operation set to 1,440 hours/year and energy efficiency of 70% (tab. 16).

Table 16. Results for the technology "Efficient biomass stoves *vs.* Electricity for heating"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	700		
Project life	20		
Lev. investment	61		61
Annual O&M	35		35
Annual fuel cost	180	391	–211
Total annual cost	276	391	–115
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	3.2	5.5	2.3
Other			
Total CO_2-eq. emission	3.2	5.5	2.3
US$/ton CO_2-eq.			–50.38

Efficient biomass stoves vs. Inefficient biomass stoves

This case is similar with the previous one (tab.15), and the only difference is that the energy efficiency of the biomass stoves is set to 90% (tabs. 17, 18, and 19).

Table 17. Input data for reference option of the technology "Efficient biomass stoves *vs.* Inefficient biomass stoves"

Reference option 2: Biomass stoves			
O&M [%]	5.0%	Calorific value [GJm^{-3}]	9.90
Activity [kW]	4	Annual fuel used [GJ]	52
Heat from stoves [kWh]	5,760	Annual fuel used [m^3]	5
Possible stove operation [hours]	1,440	Price of wood [US$·m^{-3}]	60
Annual heat production [GJ]	20.7	CO_2-eq. emission coefficient [kg$_{CO2\text{-}eq}$.GJ^{-1}]	109.60
Energy efficiency [–]	0.40		

Table 18. Results for the technology "Efficient biomass stoves *vs.* Inefficient biomass stoves"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	700		
Project life	20		
Lev. investment	61		61
Annual O&M	35	35	0
Annual fuel cost	180	314	–135
Total annual cost	276	349	–74
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	3.2	5.7	2.4
Other			
Total CO_2-eq. emission	3.2	5.7	2.4
US$/ton CO_2-eq.			–30.23

Table 19. Input data for reference and reduction option of the technology "Wood pellets stoves *vs.* Electricity for heating"

General inputs			
Discount rate [%]			6
Reference option 1: Electricity for heating			
Fraction of time using low tariff [%]	75	Average electricity price [US$·kWh^{-1}]	0.068
Fraction of time using high tariff [%]	25	CO_2-eq. emission coefficient [$ton_{CO2\text{-}eq}$.MWh^{-1}]	0.960
Reduction option: Efficient biomass pellets stoves			
O&M [%]	3.0	Energy efficiency [–]	0.90
Activity [kW]	6	Calorific value [GJkg^{-1}]	0.0180
Heat from stoves [kWh]	5,760	Annual fuel used [GJ]	23
Investment in stoves [US$]	1,100	Annual fuel used [kg]	1,280
Possible stove operation [hours]	960	Price of wood [US$·kg^{-1}]	0.301
Annual heat production [GJ]	20.7	CO_2-eq. emission coefficient [$kg_{CO_2\text{-}eq}$.GJ^{-1}]	10.28

Wood pellets stoves vs. Electricity for heating

In the last two or three years the interest for wood pallets stoves is growing and because the price of the electrical energy will grow it is assumed that people will change their electric thermal storage systems with efficient wood pellet stoves. Pallets stove of 6 kW, possible stove operation of 960 hours/year and energy efficiency of 90% is considered (tab. 20).

Table 20. Results for the technology "Wood pellets stoves *vs.* Electricity for heating"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	1100		
Project life	20		
Lev. investment	96		96
Annual O&M	33		33
Annual fuel cost	385	391	-5
Total annual cost	514	391	124
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	0.2	5.5	5.3
Other			
Total CO_2-eq. emission	0.2	5.5	5.3
US$/ton CO_2-eq.			23.34

Wood pellets stoves vs. Inefficient biomass stoves

It is expected that the sense of the people for energy efficiency will grow until 2020 and most of the families in Macedonia will change their old biomass stoves with new wood pellets stoves. The reference option is: a biomass stove of 4 kW, energy efficiency of 40% (tab. 21).

Table 21. Input data for reference and reduction option of the technology "Wood pellets stoves *vs.* Inefficient biomass stoves"

Reference option: Biomass stoves			
O&M [%]	5.0	Calorific value [GJm^{-3}]	9.90
Activity [kW]	4	Annual fuel used [GJ]	52
Heat from stoves [kWh]	5,760	Annual fuel used [m^3]	5
Possible stove operation [Hours]	1,440	Price of wood [US$·m^{-3}]	60
Annual heat production [GJ]	20.7	CO_2-eq. emission coefficient [kg$_{CO2-eq}$.GJ^{-1}]	109.60
Energy efficiency [–]	0.40	Calorific value [GJm^{-3}]	9.90

Table 22. Results for the technology "Wood pellets stoves *vs.* Inefficient biomass stoves"

Costs in US$	Reduction option	Reference option	Increase (Red.-Ref.)
Total investment	1100		
Project life	20		
Lev. investment	96		96
Annual O&M	33	35	-2
Annual fuel cost	385	314	71
Total annual cost	514	349	165
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	0.2	5.7	5.4
Other			
Total CO_2-eq. emission	0.2	5.7	5.4
US$/ton CO_2-eq.			30.29

There are 564,292 households in Macedonia [14]. 76% of them (around 430,000) use biomass for heating purposes and the rest use electrical energy for heating [9]. In this paper it is assumed that 4.5% (around 6,000) of the households that use electrical energy for heating will change their electricity stoves with efficient biomass stoves and 9% (around 12,000) of the households will change their electricity stoves with wood pellets stoves. On the other hand, it is assumed that around 25% (around 105,000) of the households that use biomass for heating will change their inefficient biomass stoves with efficient biomass stoves and around 16% (around 70,000) of the households will change their inefficient biomass stoves with wood pellets stoves. The results for the technology "Wood pellets stoves *vs.* Inefficient biomass stoves" are presented in tab. 21.

Abatement cost curve

In tab. 23, the results including specific costs of ton CO_2-equivalent, emission reduction, but also unit penetration in 2020 for each technology are presented.

The results obtained for specific costs of ton CO_2-equivalent and reduction of the CO_2 emissions, for each of the technologies is plotted as a curve, which is called abatement cost curve. This curve is shown in fig.1. On the vertical axis specific costs (costs for reduction of a ton CO_2-equivalent) are presented, while on the horizontal axis reduction of the CO_2 emissions is presented. The technologies are introduced according to their cost-effectiveness (the option with smallest specific costs is introduced first on the left side of the curve).

In 2020 the reduction cost varies in the range from 100.31 $/ton CO_2-eq to 326.94 $/ton CO_2-eq. The total achievable reduction (if all considered options are implemented with the assumed breakthrough rate) in 2020 is estimated to be 1.44 Mt CO_2-eq, which is 6.69% of the baseline emissions (21 Mt CO_2-eq [5]).

Four technologies have the greatest contribution in CO_2 emission reduction: wood pellets stoves *vs.* inefficient biomass stoves with annual reduction of 0.38 Mt CO_2-eq, small hydro power plant with annual reduction of 0.29 Mt CO_2-eq, wind turbine with annual reduction of 0.26 Mt CO_2-eq and the efficient biomass stoves *vs.* inefficient biomass stoves with annual reduction of 0.256 Mt CO_2-eq. The most cost effective option of the four technologies is efficient biomass stoves *vs.* inefficient biomass stoves which is win-win implementation. Wood pellets stoves *vs.* inefficient biomass stoves technology is in the category medium specific cost and the rest two technologies are in small specific cost category.

Table 23. Results obtained for specific costs of ton CO_2-equivalent and reduction of the CO_2 emissions, for each of the technologies

RES technology	Specific costs [US$/t$CO_2$-eq]	Unit type	Emission reduction [tCO_2-eq]	Units penetrating in 2020	Emission reduction in 2020		
					Per option [Mt/year]	Cumulative	
						[Mt/year]	Percentage of baseline emission in 2020
Geothermal district heating	–100.31	1 unit	986.18	63	0.0621	0.0621	0.29%
Efficient bio-mass stoves *vs.* Electricity for heating	–50.38	1 unit	2.28	6,000	0.0137	0.0758	0.35%
Efficient bio-mass stoves *vs.* Inefficient biomass stoves	–30.23	1 unit	2.43	105,000	0.2557	0.3315	1.54%
Small hydro power plant	7.68	1 MW	2,544.00	116	0.2951	0.6266	2.91%
Wind turbines	14.80	1 MW	1,920.00	135	0.2592	0.8858	4.12%
Wood pellets stoves *vs.* Electricity for heating	23.34	1 unit	5.29	12,000	0.0635	0.9493	4.42%
Wood pellets stoves *vs.* Inefficient biomass stoves	30.29	1 unit	5.44	70,000	0.3811	1.3305	6.19%
Biogas from agro-indstry sewage water	44.01	1 dig.	1,148.67	7	0.0080	1.3385	6.23%
Solar water heating	47.81	1 unit	0.95	90,000	0.0855	1.4240	6.62%
PV connection to electric grid	326.94	MW	1,344.00	10	0.0134	1.4375	6.69%

As to the economic aspect, the most cost effective option appears to be the application of geothermal district heating, which is followed by efficient biomass stoves *vs.* electricity for heating and efficient biomass stoves *vs.* inefficient biomass stoves. On the other hand, the most expensive RES technology is PV connected to electrical grid. The reason for that is the high initial investment.

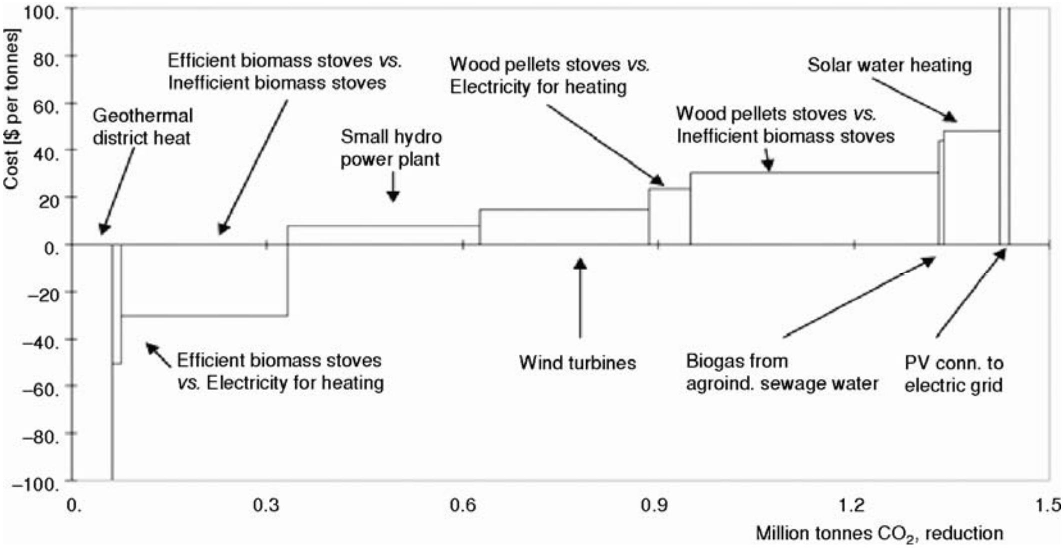

Figure 1. Marginal cost abatement curve of the RES technologies for the year 2020

Concluding recommendations

In this section, suggestions and conclusions for almost each of the RES presented in this paper are given. It has been shown that the total achievable reduction (if all considered option are implemented with the assumed breakthrough rate) in 2020 is estimated to be 1.44 Mt CO_2-eq, which is 6.69% of the baseline emissions (21 Mt CO_2-eq). In order to create enabling environment for better utilization of RES technologies variety of measures and actions should be undertaken.

Hence, pivotal in terms of support for SHPP is the simplification of procedures on water concessions, which are to include a requirement for previously settled issue of land use. The procedure should guarantee the right to primacy to owners of the private land in question as concerns the concession awarding for SHPP construction.

Macedonia does not dispose with sufficient quality data on the wind potential, the State lacks sufficient expert, but also administrative experience in regard to developing projects of this type. In order to solve these problems in [12] it is recommended to construct WPP as a "pilot" project that would also serve the purpose of identifying all possible legal and administrative barriers.

Solar water heating like a technology and change of biomass stoves with more efficient biomass stoves is great opportunity to include all household in reduction of the CO_2 emission. Based on this, it is recommended to introduce a mechanism on regular subsidies and proper taxation credits aimed to facilitate mass purchase and installation of these systems.

On the other hand, it is recommended to increase sense among people for the energy efficiency. Encouraging the use of geothermal energy should be aimed at stimulation of development and use of heating pumps as part of the Energy efficiency program. Promotion activities for biomass for combustion are mainly targeted at Incentive programs for small and medium industries to manufacture high-efficiency devices for biomass combustion, as well as subsidies to replace old and purchase new high-efficiency combustion devices, especially targeting vulnerable population groups.

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