COMPARATIVE ASSESSMENT OF PROSPECTIVE RENEWABLE ENERGY SOURCES IN MACEDONIAN CONDITIONS

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ABSTRACT:
The main goal of this paper is to present a comprehensive assessment of the prospects for implementation of new renewable energy sources in Macedonian conditions. The economic and environmental evaluation is performed for several renewable energy technologies (small hydro power; wind power; biogas from small agricultural industries; grid-connected photovoltaics; geothermal heating for greenhouses and hotels; solar heaters for individual houses; large solar heaters for public buildings and industry) using the software tool GACMO (greenhouse gases costing model), developed at the UNEP Risø Centre. To consider the environmental impacts, this model deals with the potential of the technology to reduce the greenhouse gases (GHG) emission - the most important pollutants associated with the energy production. The cost and benefits of each of the listed renewable energy technologies are evaluated in terms of GHG emissions reduction (tons of CO2-eq), as well as the average reduction costs expressed in US$ per ton of CO2-eq. Furthermore, all technologies are combined in a form of emission reduction cost curve, displaying the total marginal cost of the GHG emissions reduction. Finally, the limiting barriers to the promotion of renewables in local conditions are discussed.

1. INTRODUCTION

One of the most important problems of today is how to supply enough energy without unacceptable damage of health and the environment and without compro-

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mising the possibilities of the future generations to meet their own needs. Based on non-depletive resources and at the same time being environmentally sound, the renewable energy technologies are in favour of sustainable development and certainly can help to secure the quality of living and the well-being of future generations. In line with this guiding principle, the promotion of renewable energy sources (RES) should be a significant aspect of the national energy policy.

The energy sector in Macedonia is highly polluting and in critical need for modernization. According to the emissions of GHG which are the most important pollutants associated with the energy production, the contribution of the energy sector is about three-quarters of the total emissions, the rest being shared nearly equally by industrial processes, agriculture and waste [1]. Within the energy sector itself, the GHG emissions appear to be mostly due to electricity generation (73%), followed by heat generation (17%) and transport (10%). In order to identify the prospects for implementation of the new RES, economic and environmental evaluation is performed for several RES technologies in Macedonian conditions (listed in Table 1.1, with indication on the corresponding base units).

Table 1.1. Selected country-specific RES technologies

No.	**RES technology**	**Base unit**
1	Mini hydro power (4 plants of 1 MW)	4 MW plant
2	Wind power plants	1 MW
3	Geothermal heating for greenhouses and hotels	1 plant
4	Biogas from small agricultural industries	1 plant
5	Grid-connected solar PVs	1 kW
6	Solar heater for hot water in individual houses	1 unit
7	Large solar heaters for hot water in hotels, hospitals, public buildings	1 unit

For this purpose the software tool GACMO - GHG costing model [2], developed at the UNEP Risø Centre is used. Hence, costs and benefits of each of the seven RES technologies are evaluated through calculation of the GHG emissions reduction if the given technology is implemented, as well as average mitigation costs expressed in US$ per ton of CO_2-eq reduced.

The basis for this analysis is a baseline or reference scenario for GHG emissions from the base year to the target year, which is 2010, as a midyear of the first commitment period under the Kyoto Protocol. 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 First National Communication under the UNFCCC [3], according to which the total GHG emissions in 2010 amount to 18 Mt CO_2-eq.

Finally, all the seven RES technologies are combined in a form of emission reduction cost curve, displaying the marginal cost of the GHG emissions reduction associated to the prospective RES implementation.

2. THE EXAMINED RES TECHNOLOGIES

Recently, technology needs assessment in the energy sector has been conducted, analyzing sixteen country-specific mitigation options [4, 5, 6]. Within this section, the GACMO spreadsheets for the seven selected RES technologies, assumed to be operating in Macedonian conditions are presented. The items highlighted in yellow are input data which are identified from existing national studies or on the basis of the common knowledge related to the given RES technology. Also, in each case the reference option is indicated, according to which the comparative environmental and economic evaluation of the RES technology is performed.

2. 1. Mini hydro power plants: Construction of four small hydro plants of 1 MW, each with a small capacity factor of 2000 hours/year.

General inputs:		
Discount rate	6%	
Reduction option: Hydro power plants		
O&M	1.0%	
Activity	4	MW
Investment in hydro power	1,500	US$/kW
Capacity factor	2,000	hours
Electricity production	8,000	MWh
Reference option: Lignite fueled power plant		
O&M	2.0%	
Investment saved	1,200	US$/kW
Efficiency	0.33	
Annual fuel saved	87,273	GJ
Cost of fuel saved	24.00	US$/ton
Cost of fuel saved	3.20	US$/GJ
CO_2-eq. emission coefficient	0.142	tons CO_2-eq./GJ
Capacity factor	7,000	hours

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	6,000,000	4,800,000	
Project life	30	30	
Lev. investment	435,893	348,715	87,179
Annual O&M	60,000	96,000	-36,000
Corrected lev. investment	435,893	99,633	336,261
Corrected annual O&M	60,000	27,429	32,571
Annual fuel cost		279,273	-279,273
Total annual cost	495,893	406,334	89,559
Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0	12,424	**12,424**
US$/ton CO_2-eq.			**7.21**

2. 2. Wind power plant: Construction of wind plant of 1 MW with a capacity factor of 1,850 hours/year.

General inputs:		
Discount rate	6%	
Private discount rate	10%	
Reduction option: Wind Turbines		
O&M	1.5%	
Activity	1	MW
Investment in wind turbines	1,000	US$/kW
Capacity factor	1,850	hours
Electricity production	1,850	MWh
Power purchase price	0.01735	US$/kWh
Reference option: Fossil fueled power		
O&M	2.0%	
Capacity value of wind	10%	
Investment saved	1,200	US$/kW
Efficiency	0.33	
Annual lignite saved	20,182	GJ
Cost of fuel saved	24.00	US$/ton
Cost of fuel saved	3.20	US$/GJ
CO_2-eq. emission coefficient	0.142	ton CO_2-eq./GJ

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	1,000,000	120,000	
Project life	30	30	
Lev. investment	72,649	8,718	63,931
Annual O&M	15,000	2,400	12,600
Annual fuel cost		64,582	-64,582
Total annual cost	87,649	75,700	11,949
Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0	2,873	**2,873**
US$/ton CO_2-eq.			**4.16**

2. 3. Geothermal heating for greenhouses and hotels: Construction of plant of 1.03 MWth for greenhouses and hotels in Bansko.

General inputs:		
Discount rate	6%	
Reduction option: Geothermal plant		
O&M	6.0%	
Activity	1.03	MWth
Heat from geothermal	7210	MWh
Investment in geothermal plant	0.6795	Mill. US$
Possible plant operation	7000	hours
Annual heat production	25956	GJ
Reference option: Diesel oil heating plant		
O&M	2.0%	
Energy efficiency	0.85	
Annual fuel used	30536	GJ
Price of diesel oil	17.2	US$/GJ
CO_2-eq. emission coefficient	74.3	kgCO_2-eq./GJ

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		524,719	-524,719
Total annual cost	100,012	524,719	**-424,707**

Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0	2,269	**2,269**
US$/ton CO2-eq.			**-187.15**

2. 4. Biogas from sewage water and animal manure in small agricultural industries: Construction of biogas plant at agricultural industry producing milk and other diary products. The input into the biogas plant is the sewage water from the industry plus the manure from the cows at the site.

Reduction option: Biogas from waste water		
O&M	4%	
Activity	1	biogas plant
Investment in digester	700	US$/kW
Investment in power plant	500	US$/kW
Food production	12,000	tons/year
Waste water production	62	m^3 wastewater/ton product
COD production	3	kg COD/m3 wastewater
CH4 production	0.25	kg CH_4/kg COD
Waste water production	744,000	m^3/year
Biogas production factor	20	m^3 biogas/m^3-sewage
CH4 content in the biogas	60%	
CH4 production factor	0.8	kg CH_4/m^3 wastewater
Annual CH4 production	8,928,000	m^3 CH_4
CH4 density	0.671	kg/m^3
CH4 calorific value	39	MJ/m^3
Annual gas production	348,192	GJ
Generator elec. efficiency	0.30	
Electricity produced	29,016	MWh
Capacity factor	1.00	
Size of generator	3,312.3	kW

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	3,974,795		
Project life	20		
Lev. investment	346,541		346,541
Annual O&M	158,992		158,992
Annual fuel cost			0
Total annual cost	505,532	0	**505,532**

Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	18.1		-18.1
CH_4 from sewage + manure		11,718.0	
Total CO_2-eq. emission	18.1	11,718.0	**11,699.9**
US$/ton CO_2-eq.			**43.21**

2.5. Grid-connected solar PVs: Construction of small pilot projects of 1 kW solar roofs

General inputs:		
Discount rate	6%	
Fraction of time using low tarif	50%	
Fraction of time using high tarif	50%	
Average electricity price	0.044	US$/kWh
CO_2-eq. emission coefficient	1.000	ton CO_2-eq./MWh
Reduction option: Solar PVs		
O&M	1.0%	
Activity	1	kW
Investment in Activity	5,000	US$/kW
Capacity factor	1,100	hours
Electricity production	1,100	kWh
Reference option: No solar PVs		

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	5,000		
Project life	20		
Lev. investment	436		436
Annual O&M	50		50
Annual fuel cost		48	-48
Total annual cost	486	48	**438**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission		1.1	1.1
Other			
Total CO_2-eq. emission	0.0	1.1	**1.1**
US$/ton CO_2-eq.			**398.22**

2. 6. Solar heater replacing electricity consumption for hot water in individual houses: Hot water for the household is produced by a 2.2 m^2 solar collector with a 130 liter storage tank. The reference technology is an electric boiler for which we assume that the backup electricity usage will be 75% in periods with high tariff and 25% in periods with low tariff. The solar collector covers 68 % of the energy demand, the rest is covered by an electrical backup.

General inputs:		
Discount rate	6%	
Activity	1	location
Water usage	130	liters/day
Water supply temp	15	ºC
Thermostat setting	50	ºC
Specific heat of water	4,187	Joule/kg/ºC
Fraction of time using low tarif	75%	
Fraction of time using high tarif	25%	
Average electricity price	0.036	US$/kWh
CO2-eq. emission coefficient	1.000	ton CO_2-eq./MWh
Reduction option: Solar water heater and electrical backup		
Investment	650	US$
O&M	1%	
Size of Solar Heater	2.2	m^2
Solar Heater Annual Energy Output	600	kWh/m^2
Input from Solar Heater	1320	kWh
Annual electricity used	611.5	kWh
Reference option: electrical water heater		
Electricity used	0.019	GJ/day
Annually electricity used	1,931.5	kWh

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	650		
Project life	15		
Lev. investment	67		67
Annual O&M	6.5		7
Annual electricity cost	22	70	-48
Total annual cost	96	70	**26**
Annual emissions (tons)	Tons	Tons	Reduction
Total CO_2-eq. emission	0.61	1.93	**1.32**
US$/ton CO_2-eq.			**19.35**

2.7. Large Solar heaters replace electricity consumption for hot water in hotels, hospitals, public buildings and industry: The hot water for hotels, hospitals, public building and industry is produced by a 120 m^2 solar collector with a 9000 liter storage tank. The reference technology is an electric boiler. In this case, the solar collector covers 46 % of the energy demand, the rest is covered by an electrical backup.

General inputs:	Discount rate 6%	
Activity	1	location
Water usage	9000	litres/day
Water supply temp	15	ºC
Thermostat setting	50	ºC
Specific heat of water	4187	Joule/kg/ºC
Fraction of time using low tarif	75%	
Fraction of time using high tarif	25%	
Average electricity price	0.036	US$/kWh
CO2-eq. emission coefficient	1.000	ton CO_2-eq./MWh
Reduction option: Solar water heater & electrical backup		
Investment	220	US$/m^2
O&M	1%	
Size of Solar Heater	120	m^2
Solar Heater Annual Energy Output	518	kWh/m^2
Input from Solar Heater	62,160	kWh
Annual electricity used	71,555.9	kWh
Solar Fraction	46%	
Reference option: electrical water heater		
Electricity used	1.319	GJ/day
Annually electricity used	133,715.9	kWh

Costs in US$	Reduction Option	Reference Option	Increase (Red.-Ref.)
Total investment	26,400		
Project life	15		
Lev. investment	2,718		2,718
Annual O&M	264		264
Annual electricity cost	2,596	4,850	-2,255
Total annual cost	5,578	4,850	**728**
Annual emissions (tons)	Tons	Tons	Reduction
Fuel CO_2-eq. emission	71.6	133.7	62.2
Other			
Total CO_2-eq. emission	71.6	133.7	**62.2**
US$/ton CO_2-eq.			**11.70**

3. MARGINAL COST OF THE PROSPECTIVE RES IMPLEMENTATION

The results of the economic and environmental evaluation of all seven country-specific RES technologies) are presented in the Table 3.1. Besides the calculated specific costs and emission reduction, for each technology the assumed penetration rate in 2010 is indicated.

The most cost effective option appears to be the application of geothermal energy in greenhouses and hotels. However, the potential for GHG emissions reduction of this technology is relatively low. On the other hand, PVs connected to electric grid is by far the most expensive option due to the high initial investments.

The total achievable reduction (if all considered RES technologies are implemented) in 2010 is estimated to be 0.34 Mt CO_2-eq, which is 1.88% of the baseline emissions.

Table 3.1 Economic and environmental effectiveness of the RES technologies

RES technology	Specific costs US$/t CO_2-eq	Unit type	Emission reduction t CO_2-eq	Units penetrating in 2010	Emission reduction in 2010: Per option Mt/year	Emission reduction in 2010, Cumulative: Mt/year	Emission reduction in 2010, Cumulative: Percentage of baseline emissions in 2010
Geotherm. heat. for greenhouses, hotels	-187.15	1 unit	2,269.34	1	0.0023	0.0023	0.01%
Wind turbines	4.16	1 MW	2,872.98	50	0.1436	0.1459	0.81%
Mini hydro power	7.21	4 MW	12,423.71	1	0.0124	0.1583	0.88%
Large solar heater	11.70	1 unit	62.16	200	0.0124	0.1708	0.95%
Residential solar water heating	19.35	1 unit	1.32	100,000	0.1320	0.3028	1.68%
Biogas from agro-ind. sewage water	43.21	1 digester	11,699.89	3	0.0351	0.3379	1.88%
PVs connected to electric grid	398.22	1 kW	1.10	500	0.0006	0.3384	1.88%

The combined representation of reduction/cost indicators is a curve called marginal cost abatement curve (Figure 3.1), with the achievable reduction in 2010 (kt CO_2-eq) in the horizontal axis and the specific cost of the RES technologies (US$/t CO_2-eq) in the vertical axis. The technologies are introduced according to their cost-effectiveness (the options with smallest specific costs are introduced first in the left side of the curve). It must be emphasised that it is only an approximating curve but serves well as an illustrative tool for recognising priorities in national policy for RES promotion.

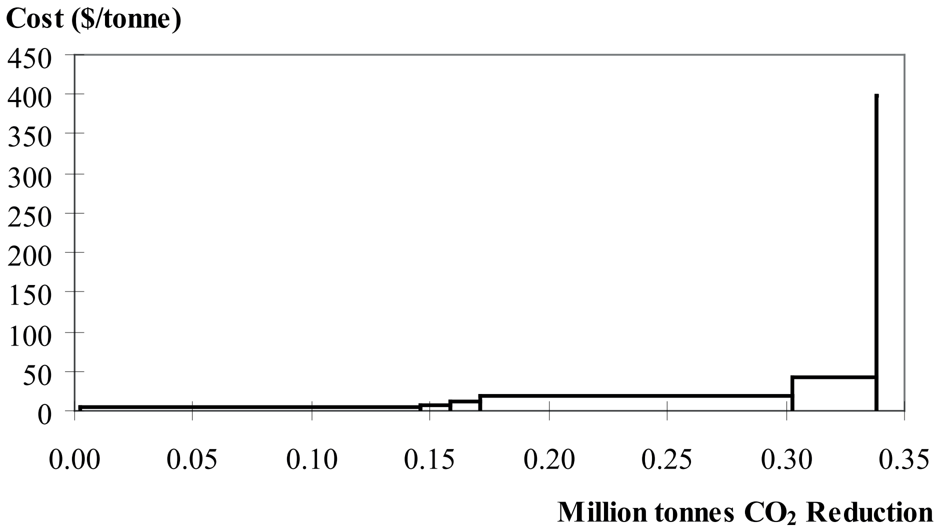

Figure 3.1 Marginal cost abatement curve of the RES technologies for the year 2010

4. LIMITING BARRIERS TO RES IMPLEMENTATION

4.1. Financing

The largest constrain to RES implementation in Macedonia, as a country with economy in transition facing significant economic and social problems, is the lack of financing. Even in the case of "no regret" technologies, it is very difficult to find national sources for the initial investment. In addition, the potential for attracting foreign investments is quite low, as a result of the high degree of uncertain political circumstances, bad economic situation and unfavourable business climate in the country.

Particularly important for the financial aspect RES technologies is the rationalization of energy prices in the country. To encourage self-investing in these technologies, the energy prices must reflect the actual costs, providing thus, the consumers with economic motivation. Moreover, economic incentives, such as import duties and tax deduction, must be put forward, and that will make more general economic advantages for the country in terms of creation of new markets, as well as new services and production sectors.

The real barrier to the creation of the Financing Facility for Sustainable Energy appears to be the commitment of financial and staff resources from an already constrained national budget. However, there are possibilities to use funding (grants and favourable loans) from international financing institutions, such as World Bank, GEF, etc. and donations of the governments of some developed countries as revenues of Facility. Also, once the required national institutional setting is established and relevant capacity building programs are conducted, as a signer of the Kyoto Protocol, Macedonia will be able to develop project proposals to be financed under the Clean Development Mechanism (CDM).

4.2. Private and public decision-making

In addition to financial barriers, another major obstacle is the lack of actual awareness of the situation and of possibilities for environmentally and economically beneficial interventions in the energy sector, among which is the utilization of RES. In many cases the main constraints concern the inertness and reluctance to new technologies along with the low level of interest even for the application in resolving vital energy related problems.

In some cases, different interests of the stakeholders are serious constraints, since very large number of independent decision-makers are present and their objectives are very difficult to harmonise. A starting point then, could be the implementation of the new technologies to public buildings like hospitals, schools, universities, where the decision is made on a centralised level. The benefit of such action is doubled - from one side it is in favour of the transfer of technology in the country, and from another, it is a good example for replication not only in public, but also in the residential sector.

Still, the fact that in the countries with economy in transition, such as Macedonia, the economic criterion is the leading one in the decision-making, is the main rationale behind the low level of interest for investment in RES technologies. For this reason, uncertainties related to expected energy and economic savings in such circumstances obtain more influential role in the decision-making and become more pronounced barriers.

4.3. Required infrastructure

In general, the effectiveness of the transfer and diffusion of RES technologies in the energy sector strongly depends on the established infrastructure - institutional arrangements, legislative and administrative tools, and engagement of stakeholders, whose list by function ideally includes:

- Government departments with responsibility for:
  – relevant areas of policy – energy, environment and development

  - regulation of energy sector
  - promotion and development of industry and international trade
  - finance
- Industries and/or public sector bodies responsible for provision of energy services
- Companies, industry and financial institutions involved in the manufacture, import and sale of RES technologies
- Households, small businesses and farmers using the technologies in question
- NGOs involved with the promotion of environmental and social objectives
- Institutions that provide technical and scientific support to both government and industry (academic organizations, industry research and development centers, consultants, forums)
- Labour unions
- Consumer groups
- International organizations and donors

Macedonia lacks the required infrastructure in terms of institutions, legislative framework and economic incentives, as well as personnel capable to deliver the required technical, managerial and financial services. There are no specialized institutions for promotion and support of RES technology transfer in the country. In many cases the inter-ministerial communication is missing or insufficient, which holds true for almost all other stakeholders. Moreover, the national legislation fails to address necessary commitments, having the situation further impaired by the complex and inefficient administration. The available human capacity is not enough and needs further empowerment in terms of skills, knowledge and awareness.

The transfer and diffusion of RES technologies in the country could not be realised without all stakeholders' support, including substantial "buy in" from the private sector. Therefore, development of specialized national private companies that would assume the financing and execution of RES technologies' breakthrough is strongly recommendable and deserves serious consideration.

5. CONCLUSION

The total achievable reduction (if all considered RES technologies are implemented) in 2010 is estimated to be 0.34 Mt CO_2-eq, which is 1.88% of the baseline emissions. Compared to the other abatement technologies in the energy sector, that are energy efficiency technologies, the RES technologies appear to be less attractive from both, environmental as well as economical aspect.

Nevertheless, contributing to sustainable energy development, the RES technologies should be a part of the national energy policy. In that sense, the removal of the limiting barriers to RES implementation, discussed in section 4, should be a great challenge to all stakeholders: government, industry, households and small businesses, academic sector, NGOs, international organizations and donors.

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