MODELING AND SIMULATION OF A BIOENERGY SYSTEM FOR CAMPUS OF THE UNIVERSITY OF PETROSANI

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ABSTRACT: *Biomass energy systems have been and will be an important part of the production of electricity or heat. We modeled and simulated a biomass energy system, as well, the analysis of implementing issues for a biomass energy system. The simulation was performed for two student residences (3 and 4) in the campus of the University of Petrosani, located near the Parang Mountains. We wanted to evaluate the feasibility of installing a biomass system, combined with the present one of natural gas used for periods when it reaches the peak load.*
KEYWORD: *Biomass, bioenergy system, Petrosani, Parang, modeling, simulation, campus, Retscreen, university.*

1. INTRODUCTION

Human emissions of carbon dioxide in the atmosphere exceed natural fluctuations and these activities have altered seriously the global carbon cycle.[4] Changes in the amount of atmospheric CO_2 have significantly changes for the weather patterns and indirectly influence of the ocean chemistry.[2]

Biomass systems for energy production may increase economic development without contributing to the greenhouse effect, because biomass is a net emitter of CO_2 in the atmosphere when it is produced and used sustainably.[9] The use of biomass in larger commercial systems based on sustainable resources and waste can help the improve of the natural resource management.

2. BIOMASS

Energy from biomass can be a sustainable source, environmentally friendly and economical. Biomass means any organic material derived from vegetable and which is participating in the carbon cycle in the nature such as plants, trees and crops which are completed their life cycle. Using biomass as a primary source of electricity, means to interrupt the normal carbon cycle in nature by accelerating its development, extracting in a usable form, the energy that would otherwise be released into the environment by oxidation. This principle tells us that “burning” biomass to produce energy does not pollute the atmosphere because the carbon dioxide is absorbed by plants.

Biomass is the most important source to increase energy production based on renewable sources. Biomass energy is the conversion of biomass into useful forms of energy such as heat, electricity and liquid fuels. Biomass absorbs solar energy through photosynthesis. The main sources of biomass are: dedicated energy crops, crop residues generated in the processing of foods, industry, consumer waste, demolition debris and municipal waste.[6] Through conversion processes, biomass is converted into liquid, gaseous or solid biofuels.

Biomass is a renewable energy source, sustainable and relatively environmentally friendly, is not uncertainty of supply of imported fuels, it reduce consumption of fossil fuels and biomass fuels have a sulfur content not negligible contribute to sulfur dioxide emissions. Burning agricultural and forestry residues and municipal solid waste for energy production is an efficient use of waste which significantly reduces waste disposal problem, especially in municipal areas. Biomass provides a clean source of renewable energy that could improve the environment, economy and energy security.

3. MODELING AND SIMULATION OF A BIOMASS SYSTEM

RETScreen ® International[10] is a standardized software and integrated for analysis of renewable energy projects. It can be used to evaluate the energy production, life circuit costs and the reduce emissions of greenhouse gases for different renewable energy technologies.

The simulation was performed for two dormitories (3 and 4) on the campus of the University of Petrosani. Petrosani is situated near Parang Mountain. The climatic conditions of chosen location can be seen in Figure 1.

We wanted to evaluate the feasibility of installing a biomass system, combined with the current with natural gas used for periods when the load reaches a peak.

Climate data location	Petrosani		
	Unit	**Climate data location**	**Project location**
Latitude	°N	45,4	45,4
Longitude	°E	23,4	23,4
Elevation	m	599	599
Heating design temperature	°C	-11,3	
Cooling design temperature	°C	27,1	
Earth temperature amplitude	°C	21,0	

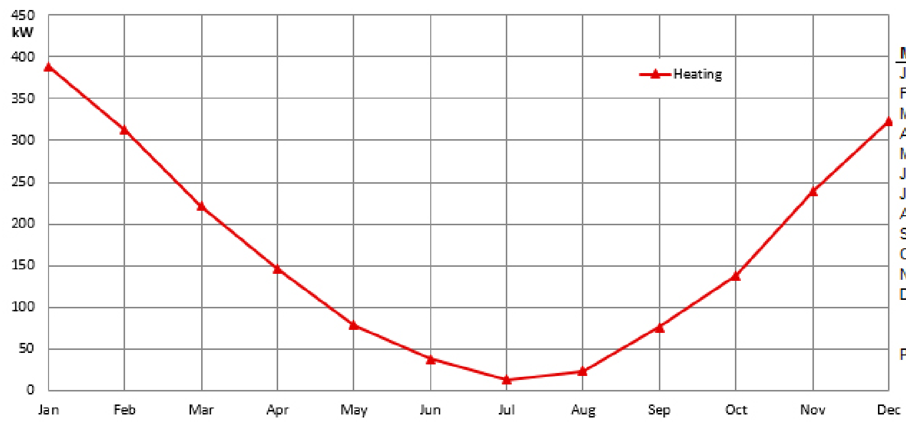
Month	Air temperature	Relative humidity	Daily solar radiation - horizontal	Atmospheric pressure	Wind speed	Earth temperature	Heating degree-days	Cooling degree-days
	°C	%	kWh/m²/d	kPa	m/s	°C	°C-d	°C-d
January	-1,8	87,7%	1,46	96,0	0,6	-3,8	614	0
February	-0,8	83,6%	2,27	95,8	0,9	-2,4	526	0
March	2,9	80,0%	3,32	95,7	1,3	3,3	468	0
April	8,1	81,2%	4,01	95,3	1,2	10,1	297	0
May	13,0	82,3%	4,94	95,5	1,2	16,0	155	93
June	16,0	83,3%	5,40	95,5	1,2	19,3	60	180
July	17,8	81,5%	5,55	95,6	1,1	21,9	6	242
August	17,2	81,6%	5,07	95,6	1,0	21,9	25	223
Septembe	13,1	83,6%	3,62	95,7	0,9	16,6	147	93
October	8,5	84,6%	2,48	96,0	1,0	10,1	295	0
November	2,6	85,9%	1,51	95,9	0,8	2,9	462	0
December	-0,9	90,4%	1,16	96,0	0,5	-2,6	586	0
Annual	8,0	83,8%	3,41	95,7	1,0	9,5	3.641	831
Measured at	m				10,0	0,0		

Fig. 1. Climatic conditions of the location

RETScreen Load & Network Design - Heating project

Heating project	**Unit**			
Base case heating system	Single building - multiple zones - space heating			
			Building zones	
			1	**2**
Heated floor area per building zone	m²	9.000	6.200	2.800
Fuel type			Natural gas - m³	Natural gas - m³
Seasonal efficiency	%	-	65%	65%
Heating load calculation				
Heating load for building zone	W/m²	-	75	50
Domestic hot water heating base demand	%	10%		
Total heating	MWh	1.512	1.162	350
Total peak heating load	kW	605	465	140
Fuel consumption - unit		-	m³	m³
Fuel consumption - annual		-	189.466	57.043
Fuel rate - unit		-	€/m³	€/m³
Fuel rate		-	0,350	0,350
Fuel cost		€ 86.278	€ 66.313	€ 19.965
Proposed case energy efficiency measures				
End-use energy efficiency measures	%	0%	0%	0%
Net peak heating load	kW	605	465	140
Net heating	MWh	1.512	1.162	350

Fig. 2. The reference case of heating project



Month	Heating average load kW
January	389
February	312
March	221
April	145
May	78
June	38
July	13
August	23
September	76
October	138
November	239
December	322
Peak load - annual	605

Fig. 3. Proposed case system load characteristics graph

One aspect of this simulation is the importance of improving energy efficiency in buildings and investing in sustainable technologies.

It also represents a starting point in the development of other projects with woody biomass heating in the area. Funds for the development of these projects can be obtained from the European Commission, the Ministry of Education or Ministry of Environment.

These two dormitories are part of the same building, so we split it into two parts. The building has 5 floors with a total area of approximately 9000 m^2 (Figure 2), providing accommodation for about 300 students. The maximum load that we took into account is 605 kW (Figure 3).

In the reference system, the heating is done using a plant operating on natural gas and in the proposed system, the heating will be using a wood biomass power plant.

RETScreen Energy Model - Heating project

Proposed case heating system			
System selection		Base load system	
Base load heating system			
Technology		Biomass system	
Fuel selection method		Single fuel	
Fuel type		Biomass	
Fuel rate	€/t	100,000	
Biomass system			
Capacity	kW	300,0	49,6%
Heating delivered	MWh	1.379	91,2%
Manufacturer		Dan Trim	
Model		Uzual	
Seasonal efficiency	%	70%	
Boiler type		Hot water	
Fuel required	GJ/h	1,5	

Fig. 4. The energy model of the proposed heating project

The biomass heating system is based on a boiler with an output of 300 kW (Figure 5a) to meet the basic needs of the heating of the two dormitories. The boiler is produced by DanTrim Ltd. and it can be supplied with different woody biomass, such as sawdust, pellets, wood chips.

A reserve system based on natural gas of 530 kW (Figure 5b) is used to cover periods when load peaks are recorded, or in case of failure of the main system. As shown in Figure 3, the main system can meet the heating load for most of the year, without the secondary. For the winter months and coldest days, but mostly to have energy security, we need the both systems.

The biomass that will supply the energy system will be stored in a silo built specifically for this task and will be supplied as needed. Being a mountain area, logging is one of the economic activities in the area. There are sawmills and factories dealing with wood and using only some parts of the wood collected from the forest. Waste wood can be obtained from them and used for this biomass heating system, even at a very low price.

The amount of wood available can be increased if takes into account the planting of energy crops with short rotation time. If the type of the waste is unknown, it is assumed average heating value and moisture content of about 40%.

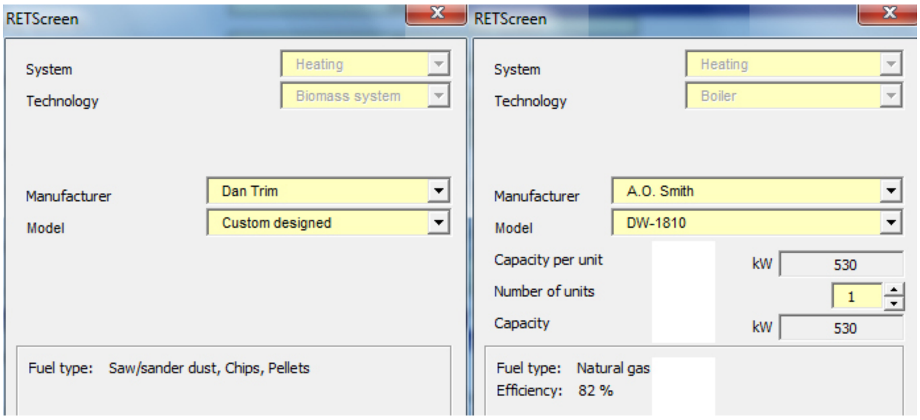


Fig. 5. a) Biomass heating system b) Natural gas heating boiler

Proposed case system characteristics	Unit	Estimate	%
Heating			
Base load heating system			
Technology		Biomass system	
Capacity	kW	300,0	49,6%
Heating delivered	MWh	1.379	91,2%
Peak load heating system			
Technology		Boiler	
Fuel type		Natural gas - m³	
Fuel rate	€/m³	0,340	
Suggested capacity	kW	305,0	
Capacity	kW	530	87,6%
Heating delivered	MWh	132,9	8,8%
Manufacturer		A.O. Smith	See PDB
Model		DW-1810	1 unit(s)
Seasonal efficiency	%	65%	
Back-up heating system (optional)			
Technology			
Capacity	kW	0,0	

Fig. 6. Proposed case system characteristics

Project costs and savings/income summary

Initial costs			
Feasibility study	3,9%	€	4.000
Development	3,9%	€	4.000
Engineering	6,9%	€	7.000
Heating system	71,1%	€	72.400
Balance of system & misc.	14,2%	€	14.460
Total initial costs	**100,0%**	**€**	**101.860**
Annual costs and debt payments			
O&M		€	3.960
Fuel cost - proposed case		€	45.829
Debt payments - 10 yrs		€	12.144
Total annual costs		**€**	**61.933**
Periodic costs (credits)			
User-defined - 7 yrs		€	3.000
Annual savings and income			
Fuel cost - base case		€	86.278
Total annual savings and income		**€**	**86.278**

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	€	€	€
0	-20.372	-20.372	-20.372
1	25.075	25.075	4.703
2	25.820	25.820	30.523
3	26.579	26.579	57.102
4	27.353	27.353	84.455
5	28.143	28.143	112.598
6	28.949	28.949	141.547
7	26.325	26.325	167.872
8	30.609	30.609	198.481
9	31.464	31.464	229.945
10	32.336	32.336	262.282
11	45.370	45.370	307.652
12	46.278	46.278	353.929
13	47.203	47.203	401.132
14	44.189	44.189	445.321
15	49.110	49.110	494.431
16	50.092	50.092	544.523
17	51.094	51.094	595.617
18	52.116	52.116	647.733
19	53.158	53.158	700.892
20	54.221	54.221	755.113
21	50.759	50.759	805.872
22	56.412	56.412	862.284
23	57.540	57.540	919.824
24	58.691	58.691	978.515
25	59.865	59.865	1.038.380

Fig. 7. Financial analysis

RETScreen Cost Analysis - Heating project

Initial costs (credits)	Unit	Quantity		Unit cost		Amount	Relative costs
Feasibility study							
Feasibility study	cost	1	€	4.000	€	4.000	
Subtotal:					€	**4.000**	3,9%
Development							
Development	cost	1	€	4.000	€	4.000	
Subtotal:					€	**4.000**	3,9%
Engineering							
Engineering	cost	1	€	7.000	€	7.000	
Subtotal:					€	**7.000**	6,9%
Heating system							
Base load - Biomass system	kW	300,0	€	200	€	60.000	
Peak load - Boiler	kW	530,0			€	-	
Energy efficiency measures	project				€	-	
Appliances & equipment - credit	credit	126	€	100	€	(12.600)	
Spare parts	cost	100	€	250	€	25.000	
Subtotal:					€	**72.400**	71,1%
Balance of system & miscellaneous							
Spare parts	%				€	-	
Transportation	project	1	€	1.000	€	1.000	
Training & commissioning	p-d	20	€	60	€	1.200	
User-defined	cost	50	€	60	€	3.000	
Contingencies	%	10,0%	€	92.600	€	9.260	
Interest during construction	0,00%	6 month(s)	€	101.860	€	-	
Subtotal:					€	**14.460**	14,2%
Total initial costs					€	**101.860**	100,0%

Annual costs (credits)	Unit	Quantity		Unit cost		Amount
O&M						
Parts & labour	project	100	€	20	€	2.000
User-defined	cost	1	€	1.600	€	1.600
Contingencies	%	10,0%	€	3.600	€	360
Subtotal:					€	**3.960**
Fuel cost - proposed case						
Natural gas	m³	21.668	€	0,340	€	7.367
Biomass	t	385	€	100,000	€	38.462
Subtotal:					€	**45.829**

Annual savings	Unit	Quantity		Unit cost		Amount
Fuel cost - base case						
Natural gas	m³	246.509	€	0,350	€	86.278
Subtotal:					€	**86.278**

Periodic costs (credits)	Unit	Year		Unit cost		Amount
User-defined	cost	7	€	3.000	€	3.000
					€	-
End of project life	cost				€	-

Fig. 8. Cost Analysis

For the financial analysis (Figure 7) and cost analysis (Figure 8), we used the typical financial figures provided by the database software: an inflation rate of 2%, debt ratio of 80%, debt rate 8%, discount rate of 9% and a debt within 10 years. The heating is presumed to last 25 years.

The cost of energy is expected to grow at the same rate as inflation. The price of wood biomass is estimated at 100 euros/tonne, but for large quantities and for a longer period, it can be negotiated. The cost of natural gas is calculated at 0.34 euro/m^3.

Another advantage of such a power system is the use of local labor, use of nearby resources, with benefits for the entire community.

Reduction of greenhouse gas emissions (Figure 9), is also a strong point of this type of heating systems, with positive effects for the whole community. On globally is trying to reduce emissions of greenhouse gases, so that energy projects should take very much into account the emissions analysis. Intensive use of fossil fuels has affected the Earth's atmosphere, and the effects are beginning to see growing sharper.

This analysis can be extended and applied to other dormitories in the university campus, and buildings where teaching activity takes place. Also, the local authorities can benefit from this simulation and can perform similar simulations for the city education units or other public institutions or private. By accessing European funds or national funds having as the starting point this type of simulation can be performed on biomass energy systems or other types of renewable energy, thus lead to substantial savings but also at durable and sustainable development of these projects, the resource management and an increase in revenue.

RETScreen Emission Reduction Analysis - Heating project

☑ Emission Analysis

○ Method 1
◉ Method 2
○ Method 3

Global warming potential of GHG
25 tonnes CO2 = 1 tonne CH4 (IPCC 2007)
298 tonnes CO2 = 1 tonne N2O (IPCC 2007)

Base case system GHG summary (Baseline)

Fuel type	Fuel mix %	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	100,0%	54,5	0,0040	0,0010	2.327	0,197	459,5

Proposed case system GHG summary (Heating project)

Fuel type	Fuel mix %	CO2 emission factor kg/GJ	CH4 emission factor kg/GJ	N2O emission factor kg/GJ	Fuel consumption MWh	GHG emission factor tCO2/MWh	GHG emission tCO2
Natural gas	9,4%	54,5	0,0040	0,0010	205	0,197	40,4
Biomass	90,6%	0,0	0,0320	0,0040	1.971	0,007	14,1
Total	100,0%	5,1	0,0294	0,0037	2.175	0,025	54,5

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	GHG emission reduction tCO2	GHG credits transaction fee %	GHG emission reduction tCO2
Heating project	459,5	54,5	405,0	0%	405,0

Net annual GHG emission reduction 405 tCO2 is equivalent to 74,2 Cars & light trucks not used

Fig. 9. The emission reduction analysis

4. CONCLUSIONS

In conventional electricity generation the losses associated with the transmission and distribution of electricity are due to the distance from the power plant. Cogeneration and trigeneration units, reduce these losses, because they are located close to the consumers, thereby, increasing the distribution efficiency. Considering the fact that cogeneration or trigeneration unit has a single fuel source and uses waste heat, occurs also a fuel efficiency. An important aspect is the reduction of greenhouse gas emissions, even when is using natural gas instead of coal.

Both in Romania as well as worldwide, it is necessary to develop full waste recovery technologies. Also, an effective analysis of land use and technologies for energy crops in order to not affect the adjacent ecosystems.

For the environmental impact assessment, studies and scenarios are required. Must be used the degraded lands where you can grow energy crops. Studies should include an assessment of the economic impact and the introduction of incentives for producers.

For efficient use of biomass should be considered the availability of the resources, in order to determine access and resources seasonality. Geographical factors such as weather conditions, indicates the temperature and water availability in each area and if this area may be covered by biomass. Also, the profitability of biomass as an energy source will depend upon the market prices at any time.

Development and exploitation of forest biomass generates an environmental impact through a series of social and economic effects.[7] The introduction of a species in one location can affect the surrounding flora and fauna. Also, we should not forget some of the main objectives of renewable energy, reduce global warming and CO_2 emissions to the atmosphere by burning fossil fuels. Effect on soil nutrients is an important aspect, which may question the sustainability of this type of exploitation.[8]

A well-fitting legal framework to improve forest management, promoting bio-energy system and state of sustainability criteria and durability.

Biomass in the form of solid and gaseous fuels continue to be the primary source for heat produced from renewable sources. In Europe, biomass is being used even more in district heating systems. Another increasing trend is the use of biomethane, which is obtained by purification of biogas, which can be injected directly into the gas grid and used to produce electricity, heat and fuel.

Biomass present challenges are the development of biomass conversion technologies and research into the effects of these processes and reduce of production costs and an increase in efficiency.

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