MONOAGENT HEATING SYSTEM FOR SOLITARY CONSUMERS, USING HEAT FROM BIOMASS BURNING

BLAGA C. A. *, PANEA C.* GLIGOR E*
*University of Oradea, Universității no.1, Oradea,
cblaga@uoradea.ro

Abstract - This paper presents an optimal solution to generate thermal energy for individual consumers by using biomass as renewable resource. Currently, biomass provides about 10% of the world energy needs which is the equivalent of 8.5 million tons of oil barrels per day. Biomass is the main energy source in rural areas of developing countries where about half of world population is living. The fuels commonly used are wood, charcoal, phytomass obtained from short-term regeneration cycles, and biogas.[10] The technical and economic parameters of a single-agent heating system for a Residential House, located in Oradea metropolitan area, are settled by using energy derived from burning of biomass - wood (white oak); for this facility one uses the RETScreen software.

Keywords: biomass, thermal energy, heating system, renewable, individual consumers

1. INTRODUCTION

In an increasingly globalized economy, a state's energy strategy is made within the framework of developments and changes taking place worldwide. Total energy demand in 2030 will be of roughly 50% higher than in 2003 while the oil demand will be around 46% higher. The current known and certain oil reserves could sustain current levels of consumption only by 2040, and the natural gas ones until 2070, while world coal reserves ensures the supply for over 200 years even at an increase pace of energy consumption. Forecasts show economic growth which involves increased energy consumption.[3][6]

In terms of primary energy consumption's structure at global level, the evolution and prognosis of reference made by the International Energy Agency (IEA) for the next decade show a faster increase of renewable sources but of natural gas too.

Biomass is the biodegradable fraction of products, waste and residues from agriculture, including vegetal and animal substances, forestry and related industries, as well as the biodegradable fraction of industrial and urban waste.[10]

Biomass is the most abundant renewable resource on the planet. It includes the entire organic matter produced by metabolic processes of living organisms. Biomass is the first form of energy used by humans, with the discovery of fire.

The energy embedded in biomass is released through various methods, but which ultimately, is the chemical process of combustion.[10]

Renewable energy technologies generates relatively little waste or pollutants that contribute to acid rain, urban smog or cause health problems and they do not impose additional costs for environment greening or waste disposal. Owners of renewable based energy systems should not be concerned about potential global climate change caused by excessive CO_2 and other polluting gases. Solar, wind and geothermal based energy systems do not generate CO_2 emissions in the atmosphere, but when it is regenerated, the biomass absorbs CO_2 and therefore the whole biomass use and generation process leads to CO_2 global emissions to closing to zero level.[2]

2. CASE STUDY

One considers as thermal energy consumer a "Residential house" of Oradea metropolitan area consisting of: basement, ground floor, first floor, and attic.[7]

The main characteristics of residential house are as follows:

- *Useful area / floor – 1,010 sq.m.;*
- *Exterior brick walls of autoclaved concrete bricks type 35cm, 10 cm polystyrene insulation;*
- *Interior walls of autoclaved concrete bricks type of 15cm;*
- *Roof of ceramic tiles;*
- *Roof insulation of 20mm thick mineral wool;*
- *Thermal resistance of thermal transmittance ROS - 5m^{2}K / W;*
- *Total specific heat transfer k-0, 2W/m^{2}K;*
- *Required domestic hot water W 250 l / day (60 ° C).*

Home heating installation and preparation of domestic hot water using energy produced by biomass burning (see Figure 1) are based on the recovery of thermal energy obtained from wood burning (i.e. white oak).[7]

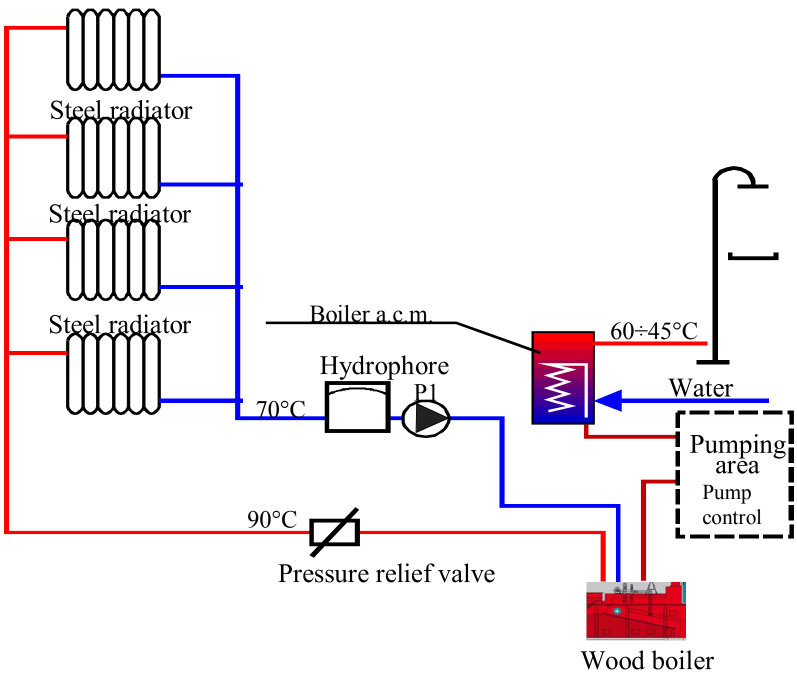


***Fig. 1.* Functional scheme of *Home heating installation* and preparation of domestic hot water using energy produced by biomass burning**

The main element of the home heating system and hot domestic water preparing using energy produced by burning biomass - wood (white oak) is the boiler that generates required heat, using the principle of biomass burning (White Oak) is manufactured by Lambion-model Custom Designed. In addition to the boiler plant also includes the main elements:

- ➢Boost pressure valve;
- ➢House water supply plant area – control pumps;
- ➢House water supply plant;
- ➢P_1 circulation pump;
- ➢Domestic hot water boiler;
- ➢Steel radiators.

Oradea metropolitan area's climatic characteristics are shown in Figure 2. Available data show for Oradea area show that outdoor standard temperature is -15 ° C. This value is taken over from RES 1907 Standard.

Country - region	Romania		
Province / State	n/a		
Climate data location	Oradea		
Latitude	°N	47,1	
Longitude	°E	21,9	Source
Elevation	m	140	Ground
Heating design temperature	°C	-10,8	Ground
Cooling design temperature	°C	30,6	Ground
Earth temperature amplitude	°C	21,2	NASA

	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
Jan	-0,8	89,0%	1,25	99,3	2,8	-2,3	583	0
Feb	0,5	83,2%	2,12	99,1	2,9	-1,0	490	0
Mar	5,3	76,1%	3,17	99,0	3,1	4,4	394	0
Apr	11,0	72,8%	4,37	98,6	3,2	11,7	210	30
May	16,3	72,6%	5,35	98,7	2,7	17,9	53	195
Jun	18,7	75,1%	5,67	98,7	2,4	21,2	0	261
Jul	21,1	72,0%	5,66	98,7	2,2	23,9	0	344
Aug	20,8	72,6%	5,05	98,8	2,0	23,8	0	335
Sep	16,2	77,6%	3,69	98,9	2,3	18,3	54	186
Oct	11,2	80,0%	2,35	99,2	2,2	11,7	211	37
Nov	4,2	85,5%	1,33	99,1	2,4	4,1	414	0
Dec	0,1	89,2%	0,98	99,3	2,7	-1,0	555	0
Annual	10,4	78,8%	3,42	99,0	2,6	11,1	2.963	1.388
Source	Ground	Ground	NASA	NASA	Ground	NASA	Ground	Ground
			Measured at	m	10	0		

***Fig. 2.* Annual average temperature of Oradea Metropolitan area**
Source Reetscren

3. COMPUTATION METHOD

For the calculation will use the features of RETScreen International.

The **RETScreen Clean Energy Project Analysis Software** is a unique decision support tool developed with the contribution of numerous experts from government, industry, and academia. The software, provided free-of-charge, can be used worldwide to evaluate the energy production and savings, costs, emission reductions, financial viability and risk for various types of Renewable-energy and Energy-efficient Technologies (RETs). The software (available in multiple languages) also includes product, project, hydrology and climate databases, a detailed user manual, and a case study based college/university-level training course, including an engineering e-textbook. [7]

RETScreen Load & Network Design - Heating project

Heating project	Unit	
Base case heating system	Single building - space & process heating	
Heated floor area for building	m²	1.010
Fuel type		Electricity
Seasonal efficiency	%	80%
Heating load calculation		
Heating load for building	W/m²	65,0
Domestic hot water heating base demand	%	7%
Peak process heating load	kW	9,0
Process heating load characteristics		Standard
Equivalent full load hours - process heating	h	8.760
Space heating	MWh	137
Process heating	MWh	79
Total heating	MWh	215
Total peak heating load	kW	74,7
Fuel consumption - annual	MWh	269
Fuel rate	€/kWh	0,080
Fuel cost		€ 21.535
Proposed case energy efficiency measures		
End-use energy efficiency measures	%	0%
Net peak heating load	kW	74,7
Net heating	MWh	215

Fig. 3 Entering data about load and network[7]

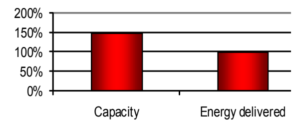
Significant result is underlined: Seasonal Efficiency - 80%

RETScreen Energy Model - Heating project ☐ Show alternative

Proposed case heating system				
System selection	Base load system			
Base load heating system				
Technology	Biomass system			
Fuel selection method	Single fuel			
Fuel type	Oak (white)			
Fuel rate	€/t	30,000		
Biomass system				
Capacity	kW	110,0	147,4%	See proc
Heating delivered	MWh	215	100,0%	
Manufacturer	Lambion			
Model	Custom designed		1 unit(s)	
Seasonal efficiency	%	80%		
Boiler type		Hot water		
Fuel required	GJ/h	0,5		

Proposed case system characteristics	Unit	Estimate	%
Heating			
Base load heating system			
Technology		Biomass system	
Capacity	kW	110,0	147,4%
Heating delivered	MWh	215	100,0%
Peak load heating system			
Technology		Not required	
Back-up heating system (optional)			
Technology			
Capacity	kW	0,0	

System design graph



Proposed case system summary	Fuel type	Fuel consumption - unit	Fuel consumption	Capacity (kW)	Energy delivered (MWh)
Heating					
Base load	Oak (white)	t	49	110	215
			Total	110	215

Fig. 4 System characteristics, choice of fuel

Significant results: Fuel - Wood (White Oak); Seasonal efficiency - 80%

RETScreen Cost Analysis - Heating project

Settings			
◉ Method 1	◉ Notes/Range		
○ Method 2	○ Second currency	Notes/Range	None
	○ Cost allocation		

Initial costs (credits)	Unit	Quantity	Unit cost	Amount	Relative costs
Feasibility study					
Feasibility study	cost	1	€ 500	€ 500	
Sub-total:				**€ 500**	1,8%
Development					
Development	cost	1	€ -	€ -	
Sub-total:				**€ -**	0,0%
Engineering					
Engineering	cost	1	€ 800	€ 800	
Sub-total:				**€ 800**	2,8%
Heating system					
Base load - Biomass system	kW	110,0	€ 190	€ 20.900	
Energy efficiency measures	project	1		€ -	
User-defined	credit			€ -	
				€ -	
Sub-total:				**€ 20.900**	73,7%
Balance of system & miscellaneous					
Spare parts	%	10,0%	€ **20.900**	€ 2.090	
Transportation	project	2	€ 500	€ 1.000	
Training & commissioning	p-d	1	€ 500	€ 500	
User-defined	cost			€ -	
Contingencies	%	10,0%	€ 25.790	€ 2.579	
Interest during construction	0,00%	0 month(s)	€ 28.369	€ -	
Sub-total:				**€ 6.169**	21,7%
Total initial costs				**€ 28.369**	100,0%

Annual costs (credits)	Unit	Quantity	Unit cost	Amount
O&M				
Parts & labour	project	8	€ 200	€ 1.600
User-defined	cost			€ -
Contingencies	%	5,0%	€ 1.600	€ 80
Sub-total:				**€ 1.680**
Fuel cost - proposed case				
Oak (white)	t	49	€ 30,000	€ 1.479
Sub-total:				**€ 1.479**

Annual savings	Unit	Quantity	Unit cost	Amount
Fuel cost - base case				
Electricity	MWh	269	€ 80,000	€ 21.535
Sub-total:				**€ 21.535**

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

Go to Emission Analysis sheet

Fig. 5 Cost analysis

Significant results are underlined: the initial cost (investment) -28.369 €, maintenance costs - 1.680 € per year, fuel cost - 1.479 €

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
Electricity	100,0%	273,8	0,0429	0,0086	269	0,999	268,9
Total	100,0%	273,8	0,0429	0,0086	269	0,999	268,9

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
Oak (white)	100,0%	0,0	0,0320	0,0040	269	0,007	1,9
Total	100,0%	0,0	0,0320	0,0040	269	0,007	1,9

GHG emission reduction summary

	Base case GHG emission tCO2	Proposed case GHG emission tCO2	Gross annual GHG emission reduction tCO2	GHG credits transaction fee %	Net annual GHG emission reduction tCO2
Heating project	268,9	1,9	266,9	19%	216,2

Net annual GHG emission reduction 216 tCO2 is equivalent to 92.809 Litres of gasoline not consumed

Complete Financial Analysis sheet

Fig. 6 Emissions analysis

Significant results are underlined: GHG emissions - 1.9 tonnes of CO2 equivalent GHG emissions annual reduction - 216.2 tonnes of CO2 equivalent.[7]

RETScreen Financial Analysis - Heating project

Financial parameters

General		
Fuel cost escalation rate	%	3,0%
Inflation rate	%	0,0%
Discount rate	%	0,0%
Project life	yr	10
Finance		
Incentives and grants	€	0
Debt ratio	%	0,0%
Income tax analysis		

Annual income

Electricity export income		
GHG reduction income		
Net GHG reduction	tCO2/yr	216
Net GHG reduction - 10 yrs	tCO2	2.162
Customer premium income (rebate)		
Other income (cost)		
Clean Energy (CE) production income		

Project costs and savings/income summary

Initial costs			
Feasibility study	1,8%	€	500
Engineering	2,8%	€	800
Heating system	73,7%	€	20.900
Balance of system & misc.	21,7%	€	6.169
Total initial costs	**100,0%**	**€**	**28.369**
Annual costs and debt payments			
O&M		€	1.680
Fuel cost - proposed case		€	1.479
Total annual costs		**€**	**3.159**
Periodic costs (credits)			
Annual savings and income			
Fuel cost - base case		€	21.535
Total annual savings and income		**€**	**21.535**

Financial viability

Pre-tax IRR - equity	%	69,7%
Pre-tax IRR - assets	%	69,7%
After-tax IRR - equity	%	69,7%
After-tax IRR - assets	%	69,7%
Simple payback	yr	1,5
Equity payback	yr	1,5
Net Present Value (NPV)	€	191.650
Annual life cycle savings	€/yr	19.165
Benefit-Cost (B-C) ratio		7,76
GHG reduction cost	€/tCO2	(89)

Yearly cash flows

Year	Pre-tax	After-tax	Cumulative
#	€	€	€
0	-28.369	-28.369	-28.369
1	18.978	18.978	-9.391
2	19.598	19.598	10.206
3	20.236	20.236	30.442
4	20.893	20.893	51.336
5	21.571	21.571	72.906
6	22.268	22.268	95.174
7	22.987	22.987	118.161
8	23.727	23.727	141.887
9	24.489	24.489	166.376
10	25.274	25.274	191.650

Cumulative cash flows graph

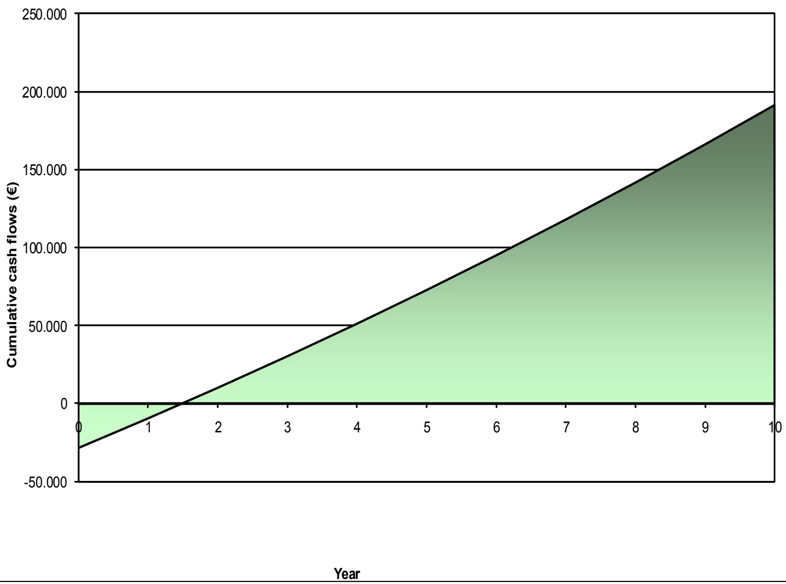
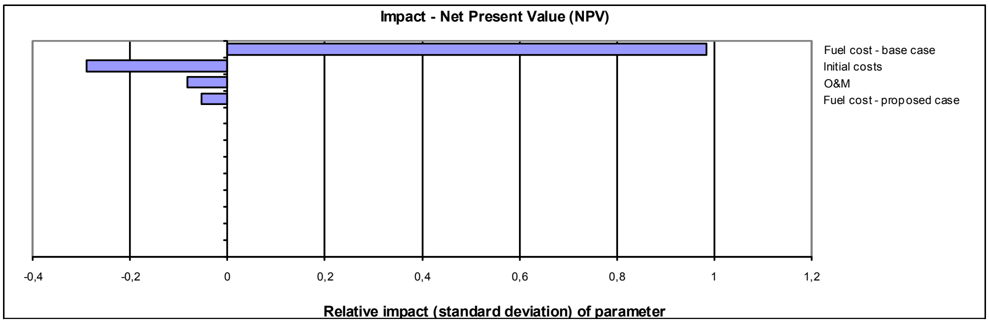


Fig. 7 Financial Analysis

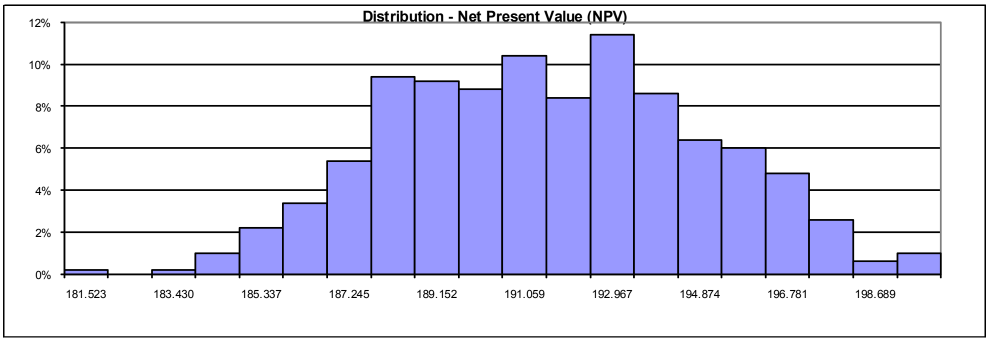
Significant results are underlined: Savings and annual revenues - 21.535 €, the net present value NPV - 191.660 €.

Perform analysis on: Net Present Value (NPV)

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	€	28.369	10%	25.532	31.206
O&M	€	1.680	5%	1.596	1.764
Fuel cost - proposed case	€	1.479	3%	1.435	1.523
Fuel cost - base case	€	21.535	4%	20.674	22.397
Debt term	yr	0	0%	0	0

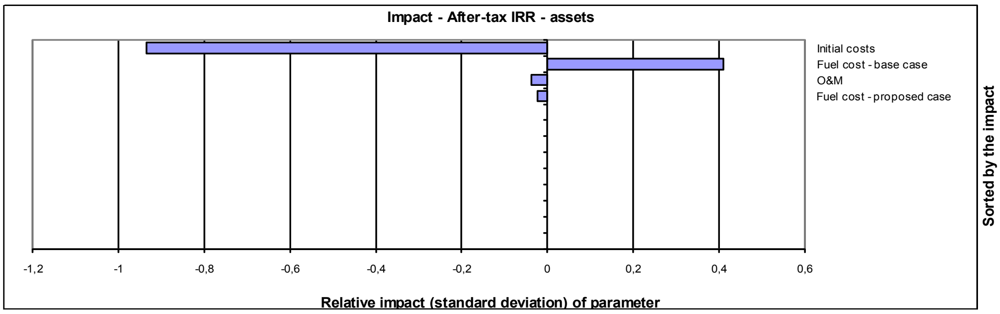


Median	€	191.472
Level of risk	%	5,0%
Minimum within level of confidence	€	185.492
Maximum within level of confidence	€	197.788



Perform analysis on: After-tax IRR - assets

Parameter	Unit	Value	Range (+/-)	Minimum	Maximum
Initial costs	€	28.369	10%	25.532	31.206
O&M	€	1.680	5%	1.596	1.764
Fuel cost - proposed case	€	1.479	3%	1.435	1.523
Fuel cost - base case	€	21.535	4%	20.674	22.397
Debt term	yr	0	0%	0	0



Median	%	69,6%
Level of risk	%	5,0%
Minimum within level of confidence	%	65,3%
Maximum within level of confidence	%	75,0%

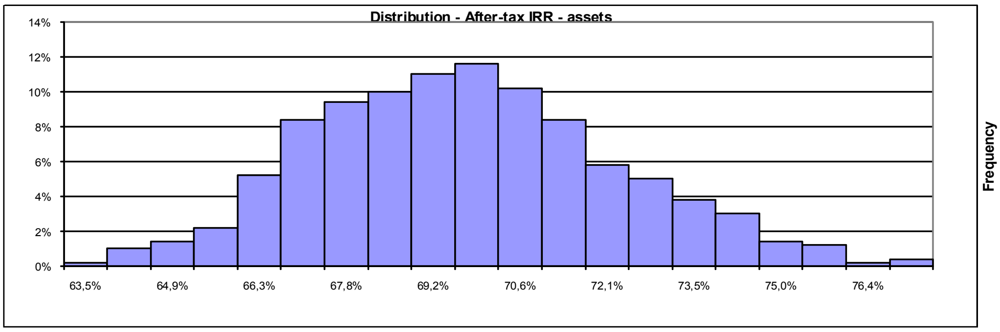


Fig. 8. Risk analysis

4. CONCLUSION

It clearly requires more legislative and organizational measures to diminish pollution, emission of greenhouse gases and dependence on more expensive and uncertain oil imports as oil is on its way to its exhaustion. One solution would be to use biomass resources to produce solid biofuels (firewood, pellets and chips), liquid (ethanol, biodiesel and vegetable oil) and gas (biogas). Biomass will be the EU's main source of renewable energy.

Wood is usually the best bio-fuel for combustion, due to its low ash and nitrogen content. Wood is suitable for household and larger plants heating.

As for wood combustion, a recent assessment indicates that the life cycle impact of a burning furnace on the environment is provided by 38.6% NO_x, 36.5% suspensions in air suspended and only 2% CO2, the remaining 22.9% being due to other pollutants. The assessment of wood life cycle assessment shows that environmental impact of wood is larger than natural gas one as regards the greenhouse effect. Therefore improvements to wood burning facilities are required.

After conducting the case study the following results were obtained:

- Heat generating - Biomass system;
- Fuel - Biomass - wood (white oak);
- Fuel Price - 3000 € / t;
- Type of heat production plant - Wooden boiler;
- Model manufacturer - Custom Designed, Lambion;
- Capacity - 110 kW;
- Delivered heat agent - 215 MWh;
- Seasonal Efficiency - 80%;
- Fuel required - 0.5 GJ / h;
- Initial costs (investment) - € 28,369;
- Maintenance Costs - € 1,680 per year;
- Fuel Cost - € 1,479 per year;
- Annual costs - € 3,159;
- Savings and annual revenues - € 21,535;
- Return on investment (ROI)- 69.7%;
- Net present value NPV € -191,660;
- Return period - 1 year and 4 months;
- GHG emissions – 1.900 tonnes of CO2 equivalent
- Annual reduction of GHG emissions – 216.2 tonnes of CO2 equivalent. This reduction is to as against heating produced by electric power, an energy produced from burning fossil fuel.

Profitability is not the strong point of this system, but it is part of the European trends of reducing environmental impact.

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