STUDY REGARDING HEAT PRODUCTION IN GEOTHERMAL SOLAR HYBRID SYSTEM

FELEA. I., BLAGA A. C., MOLDOVAN V.
University of Oradea, Universității no.1, Oradea,
ifelea@uoradea.ro, cblaga@uoradea.ro, moldovan@uoradea.ro

Abstract - The paper is structured in five parts. The first part studies the global and national framework of development of renewable energy sources. Part two contains the map of renewable energy potential on four components (solar, wind, geothermal and biomass) and the resulting map. The third part is intended to describe the technical solution of a solar geothermal solar hybrid system proposed by the authors to supply with heat the consumers in areas that have the two primary sources of energy. Part Four presents the results of the technical-economic analysis conducted with regard to the version of application of the geothermal solar hybrid system and the last part presents the conclusions of the analysis.

Keywords: hybrid solar-geothermal, solar heating, efficiency.

1. INTRODUCTION

At the beginning of the third millennium, two billion people, a third of the world's population, have no access to modern sources of energy. The world's population expects more from the third millennium. The key to a high standard of living is given by the accessibility to clean energy sources, at an affordable price. Energy affects all aspects of modern life. There is a close correlation between the energy used per capita and life expectancy.

The World Energy Council [2] presented several scenarios that meet future energy demands and emphasize economic development, technological progress, environmental protection and international ethics. Between 1990 and 2050, primary energy consumption is forecast to grow by 50%, in agreement with most real solutions for environmental protection and by 27.5% in agreement with the highest economic growth rate. In the scenarios take into account environmental protection, carbon emissions are projected to decline slightly from 1990 levels, compared with high economic growth rate scenarios which lead to doubling of carbon emissions. Lack of energy sources forecast in 1970 has not come true until now. Economic development in the new century will not be influenced by geological resources.

In all scenarios, the peak period of fossil fuels is almost over. Gasoline and gas are forecast to continue to be important sources of energy, a significant increase is expected in the field of renewable resources (30 ÷ 80% in 2100)[3]. Hydro power and biomass are already important factors in energy production, contributing 28% of the total energy required, where renewable energy resources constitute only 2% of primary energy used in the world. Solar energy is the only renewable energy resource with a large potential which is not yet competitively marketed as a conventional source of energy. Biomass, wind energy and geothermal energy are marketed competitively and have relatively rapid progress.

It is obvious that a single energy source will not help us overcome the pollution produced by fossil fuels in the new century. The integration of local energy resources in each country or region in the national / regional system and better use of local energy are important in finding solutions to local and global energy issues.

Sustainable development refers to that kind of economic development which ensures the needs of the present generation without compromising the possibility of future generations to meet their own requirements. Sustainable development of renewable energy sources highlights, with regard to the energy industry, the following objectives: [4][5][6] the reorientation of energy production technologies and controlling their risks; preservation and enhancement of the resource base; reduction of CO emission; development of renewable resources; unification of the decision-making processes on energy, economy in general and environmental protection in particular.

Energy technologies based on renewable resources generates relatively little waste or pollutants that contribute to acid rain, urban smog, or cause health problems and do not impose additional costs for environmental remediation or waste disposal. Owners of energy systems based on renewable resources should not be worried about potential global climate change generated by excessive CO_2 and other polluting gases. Solar, wind and geothermal energy systems do not generate CO_2 in the atmosphere, but the biomass absorbs CO_2 when it regenerates and thus the whole process of biomass generation, utilization and regeneration leads to global CO_2 emissions close to zero.

2. MAP OF RENEWABLE ENERGIES IN ROMANIA

Renewable energy refers to energy forms produced by energy transfer of energy resulting from renewable natural processes. Thus, solar, wind, flowing water, biological processes and geothermal heat energy can be captured by people using different methods.[3][7].

All these forms of energy are exploited to serve the generation of electricity, heat, hot water, etc.. Under a European Union directive, [5] member states must progressively hybridize traditional fuel used in transport with bio-fuel, so that by 2010, biodiesel represents 5.75% of diesel on the market, following that in 2020 the share rises to 20%.

The main resources of renewable energy of Romania are [12]solar energy (fig.1), wind (fig.2), geothermal energy (fig.3) and biomass (fig.4). At present, Romania produces the largest part of the renewable energy from hydropower resources. One of the solutions which could be developed in Romania to promote renewable energy use would be to correlate the tourism investment using European funds with the use of renewable energy installations (solar, wind, etc.). The resulting map of renewable energies in Romania is represented in fig.5.

Implementation of an energy strategy for the capitalization of the renewable energy sources (RES) potential observes the coordinates of medium and long term energy development of Romania and provides the appropriate framework for taking decisions on energy alternatives and the inclusion in the community acquis in the field.

ISES White Paper [14] predicts the percentages of each type of renewable energy source in energy production in the world (situation given for 2003) as follows:

- Bio-energy: almost 11% of energy currently used worldwide is produced from bio-energy; an average of 450EJ is estimated for bio-energy potential in 2050 (which is much more than current total energy demand in the world).
- Geothermal energy: geothermal energy can be a major renewable energy source for a large number of countries (at least 58 countries: 39 can be 100% geothermally powered, four more than 50%, 5 more than 20% and 8 with more than 10%).
- Wind energy: Global wind power capacity will reach over 32000MW and the percentage increase is 32% per year. The 12% target of global demand for electricity produced from wind energy by 2020 seems to have already been reached.
- Solar energy: solar energy had a growth rate of approx. 38% from 1971 to 2010.

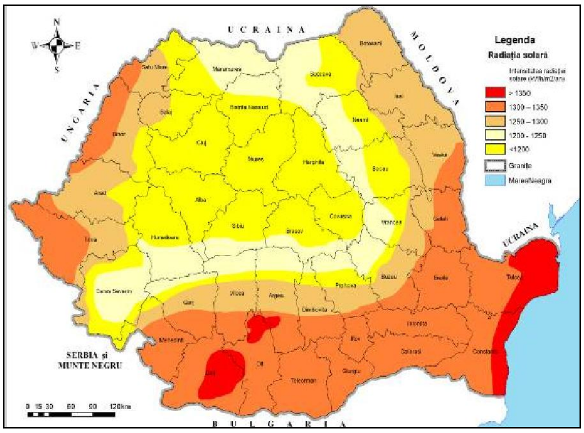


Fig.1. Solar radiation map
Source: M.E.C.M.A (Ministry of Economy, Commerce and Business Environment)

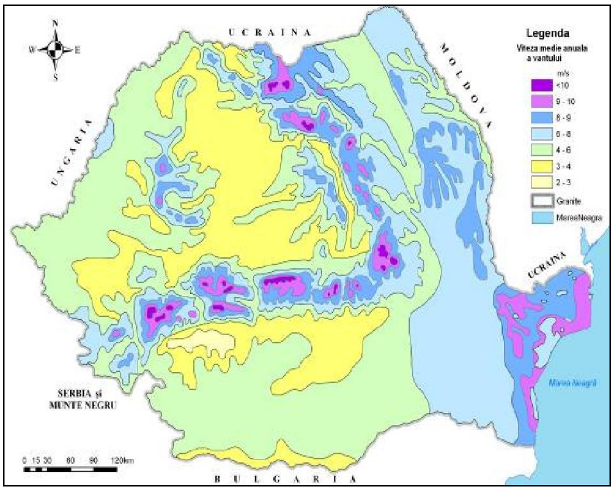


Fig.2. Wind potential
Source: M.E.C.M.A (Ministry of Economy, Commerce and Business Environment)

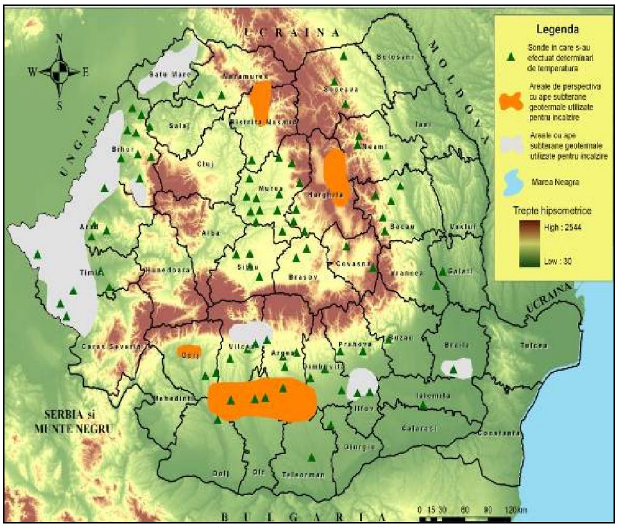


Fig.3. Geothermal potential
Source: M.E.C.M.A (Ministry of Economy, Commerce and Business Environment)

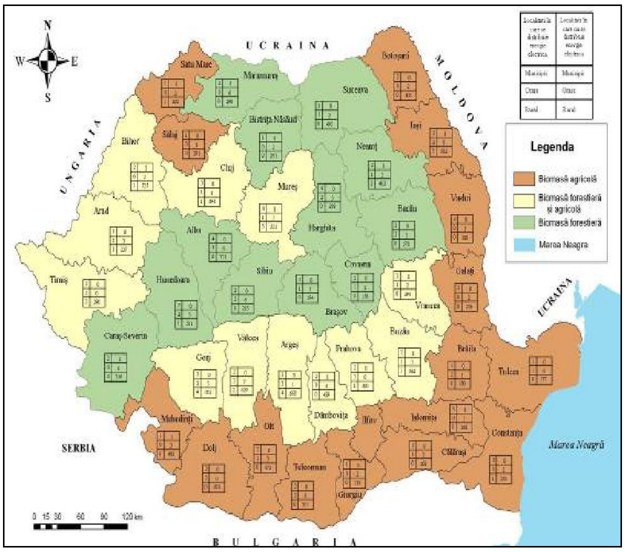


Fig.4. Distribution of biomass resources
Source: M.E.C.M.A (Ministry of Economy, Commerce and Business Environment)

ISSN 2067-5534 © 2011 JSE

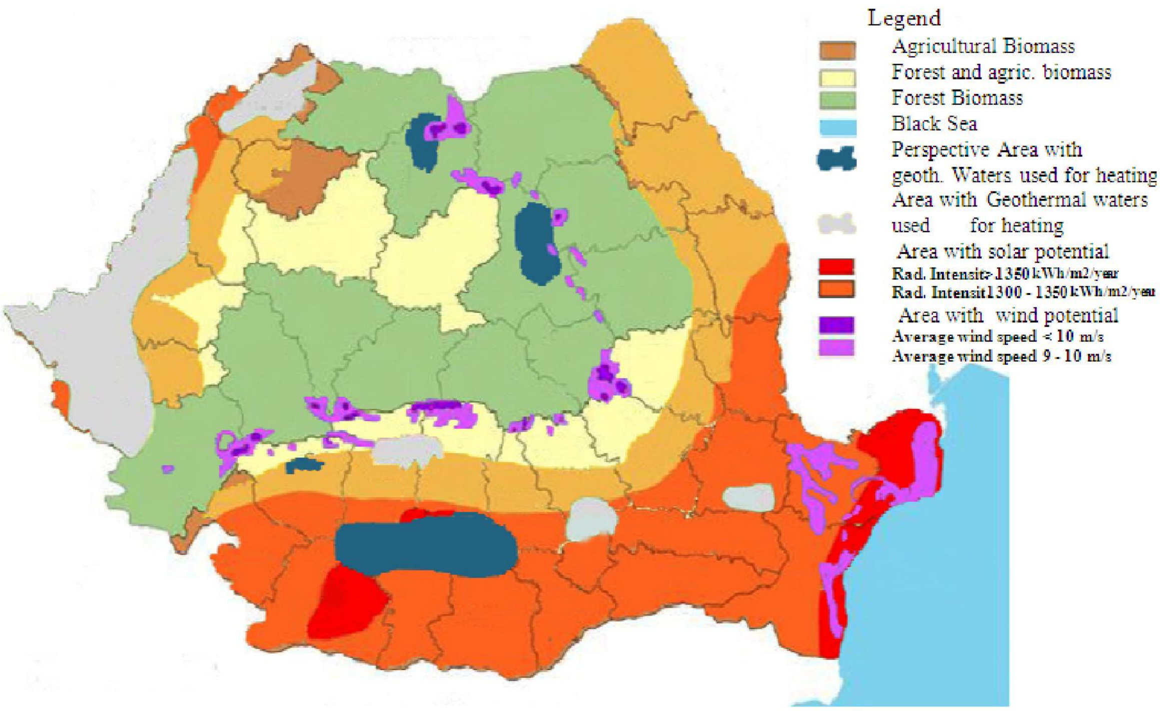


Fig.5. Resulting map of renewable energies in Romania

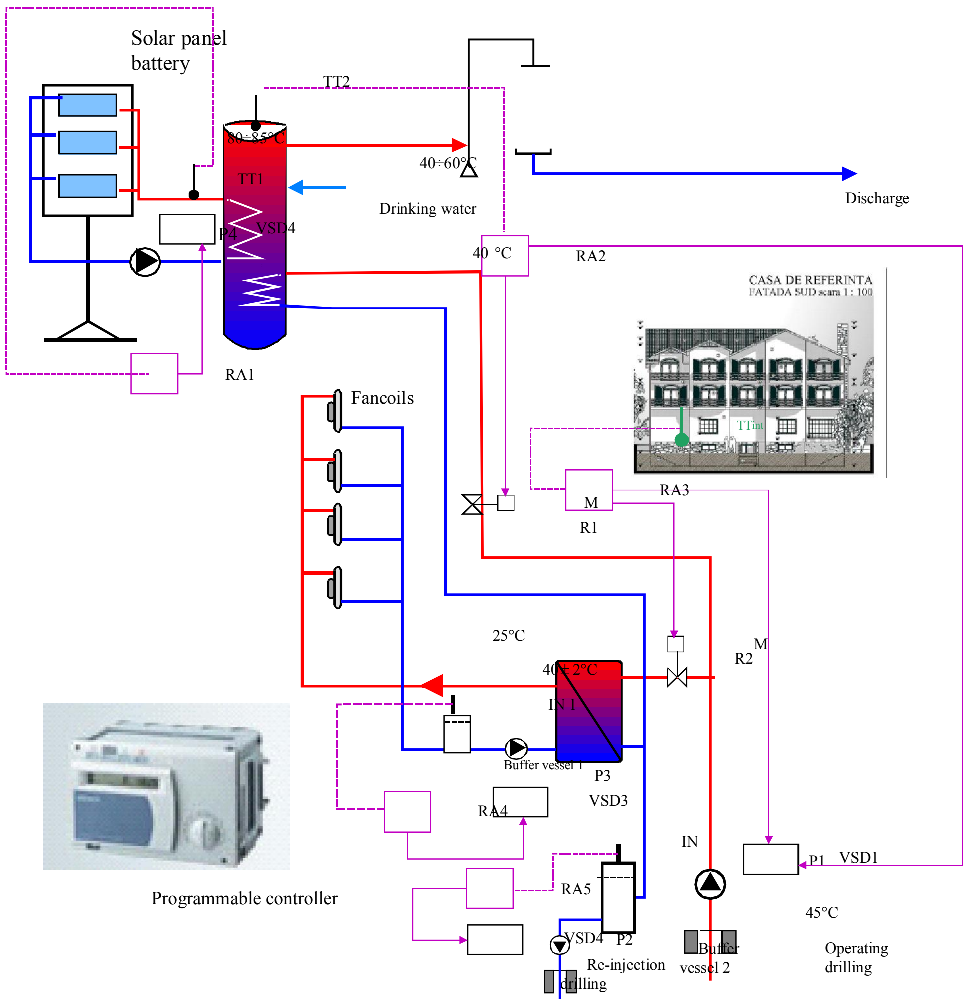


Fig.6. Thermo-solar – geothermal hybrid system for heating and domestic hot water production indicating automation loops

3. HIBRIDIZATION OF HEAT PRODUCTION SYSTEM

The hybrid system considered in this study (fig.6) consists of a thermo-solar system for domestic hot water and a geothermal system for room heating and domestic hot water.

RA1, RA2, RA3, RA4, RA5 automatic controllers are "fictitious" automatic controllers, included in the PLC software which is mandatory equipment for such a system. The PLC controls the function of the system according to the desired temperature, the desired time interval for its operation (time slot, weekdays, etc.).

The automation loops (fig. 7÷11) are:

a) Protection of the thermo-solar system by adjusting made by the automatic controller RA1of the speed of the circulation pump P4, according to t1 temperature measured by TT1.

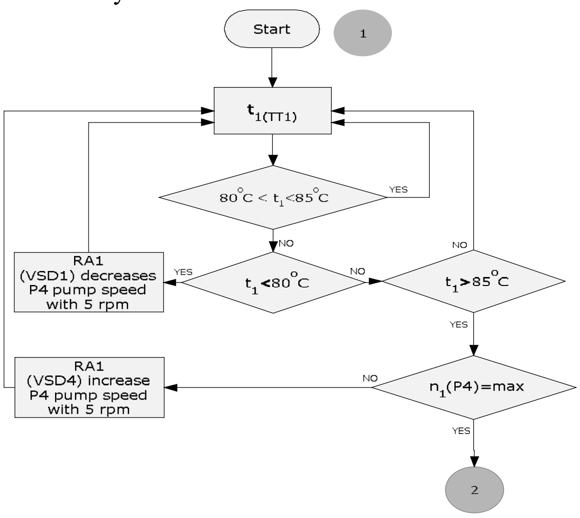


Fig.7. Automation scheme for thermosolar system protection

b) Maintaining domestic hot water temperature t2, measured with the temperature transducer TT2, between 40<t2<60°C, performed through RA2 automatic controller which controls, through VSD1 speed dimmer, P1 circulation pump.

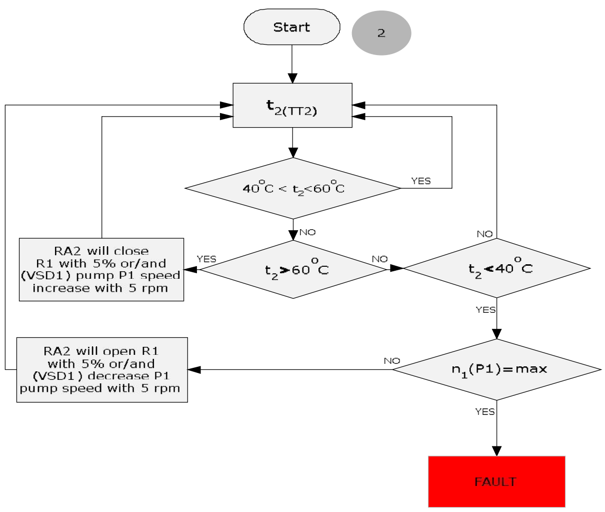


Fig.8. Automation scheme to maintain domestic hot water temperature

c) Maintaining temperature inside the house tint, measured with the TTint temperature transducer at 20 ÷ 24 ° C, performed by RA3 automatic controller which controls, through VSD1 speed dimmer, activating P1 circulation pump.

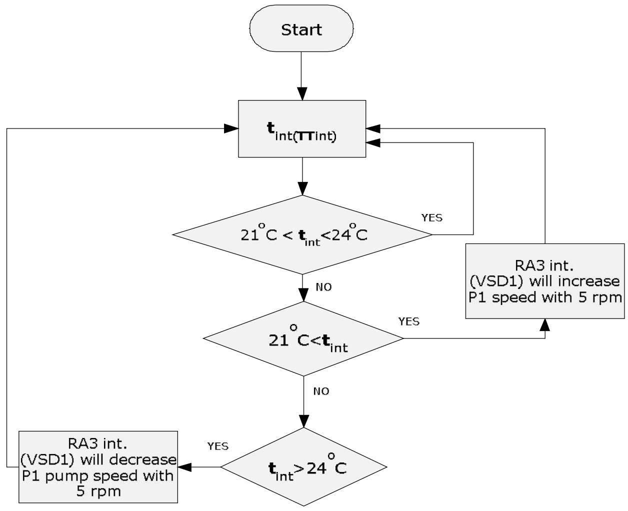


Fig.9. Automation scheme for maintaining the temperature inside the house

d) Activating P3 circulation pump depending on the h1 level in the buffer vessel, measured by the IN1 gauge controller, performed by RA4 automatic controller, through VSD3 speed dimmer of the P3 circulation pump.

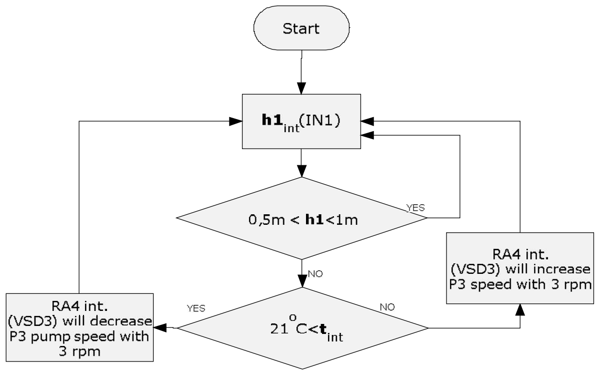


Fig.10. Automation scheme to maintain level in buffer vessel 1

e) Operating P2 re-injection pump according to h2 level in buffer vessel 2, through the VSD4 speed dimmer, by the RA5 automatic controller.

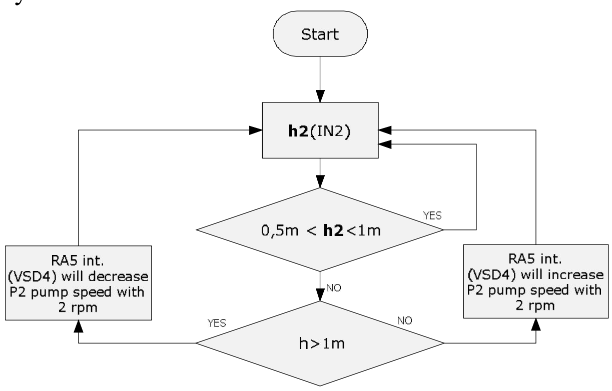


Fig.11 Automation scheme to maintain level in buffer vessel 2

ISSN 2067-5534 © 2011 JSE

4. TECHNICAL-ECONOMIC MODELING FOR GEOTHERMAL SOLAR HYBRID SYSTEM

Techno-economic modeling will be made for a standard consumer with a surface of 1000 square meters and with a high level of thermal insulation.

Calculations will be made with the help of RETSCREEN INTERNATIONAL Program [13].

RETScreen International Clean Energy Decision Support Centre aims to improve policy makers and industry to implement energy efficiency projects and clean energy. The objective is achieved by: developing decision-making tools that reduce SF costs; popularization of knowledge, training staff to better analyze the technical and financial viability of possible projects.

The software is freely available and can be used to evaluate energy production and savings, life cycle costs, emission reductions, financial data and risks of different energy efficiency technologies and renewable energy. The software includes products, prices and climate data and a detailed manual for use. RETScreen International is managed under the direction and financial support of Natural Resources Canada's (NRCan), Canmet- ENERGY.

The software can be used to evaluate different types of projects for heating, cooling and heating, combined projects & cooling projects. The software can be used to assess projects incorporating a variety of heating and / or cooling equipments, all working in different operating conditions (base load, intermediate and / or peak load) for one or a combination of following applications: single buildings or multiple buildings, industrial processes, community, district heating and cooling, crop drying, etc. Furthermore, it allows the analysis of a wide range of conventional and renewable sources (fossil) fuels (which can be used in parallel), including landfill gas;

- biomass;
- biodiesel,
- biogas;
- hydrogen;
- natural gases;
- oil / diesel;
- coal;
- municipal waste, etc.

In the applied analysis performed by the authors for technical-economic calculations using RETScreen program, two components of the hybridization solution (thermosolar and geothermal) were compared each with one reference system, namely domestic hot water heating and production systems, based exclusively on electric heating. Therefore two modellings were made by which the systems were compared as specified in table 1.

Table 1 – Analyzed and compared cases

Purpose, case / System	Home heating and DHW production	DHW production
	Component 1	Component 2
Reference System	Electric	Electric
Proposed System	Geothermal	Thermosolar

The results obtained from technical-economic calculations with reference to the two components and selected reference systems, respectively how to work with RETScreen are shown in figures 12 - 23 and table 2.

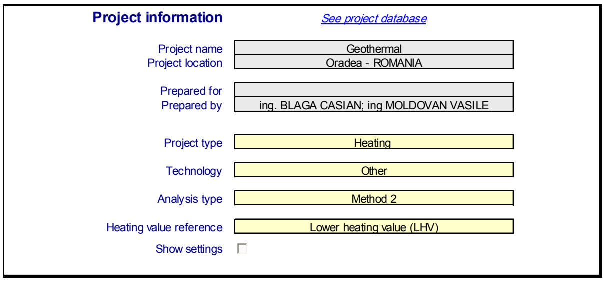


Fig.12. Initial Data. Component

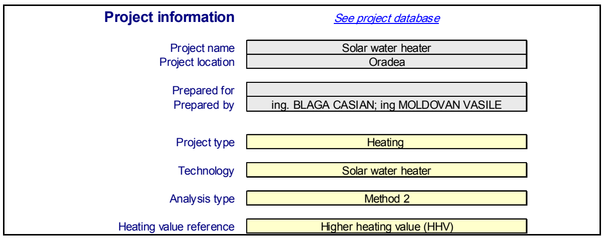
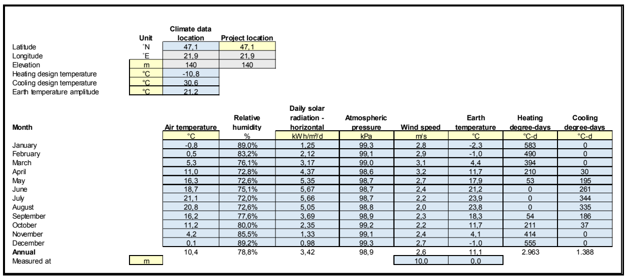


Fig.13. Initial Data. Component 2.



	Unit	Climate data location	Project location
Latitude	˚N	47,1	47,1
Longitude	˚E	21,9	21,9
Elevation	m	140	140
Heating design temperature	°C	-10,8	
Cooling design temperature	°C	30,6	
Earth temperature amplitude	°C	21,2	

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	-0,8	89,0%	1,25	99,3	2,8	-2,3	583	0
February	0,5	83,2%	2,12	99,1	2,9	-1,0	490	0
March	5,3	76,1%	3,17	99,0	3,1	4,4	394	0
April	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
June	18,7	75,1%	5,67	98,7	2,4	21,2	0	261
July	21,1	72,0%	5,66	98,7	2,2	23,9	0	344
August	20,8	72,6%	5,05	98,8	2,0	23,8	0	335
September	16,2	77,6%	3,69	98,9	2,3	18,3	54	186
October	11,2	80,0%	2,35	99,2	2,2	11,7	211	37
November	4,2	85,5%	1,33	99,1	2,4	4,1	414	0
December	0,1	89,2%	0,98	99,3	2,7	-1,0	555	0
Annual	10,4	78,8%	3,42	98,9	2,6	11,1	2.963	1.388
Measured at (m)					10,0	0,0		

Fig.14. On location projects. Weather and climate data.

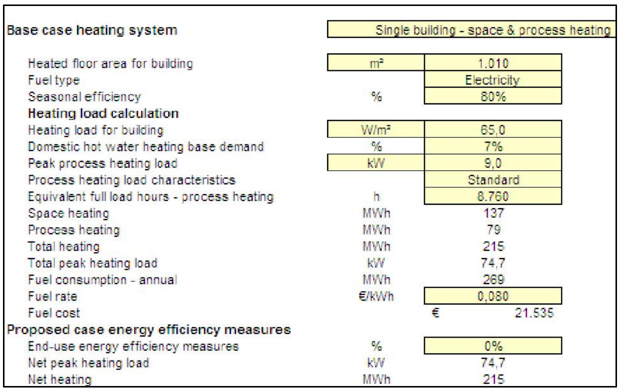


Fig.15. Thermal load of standard consumer.

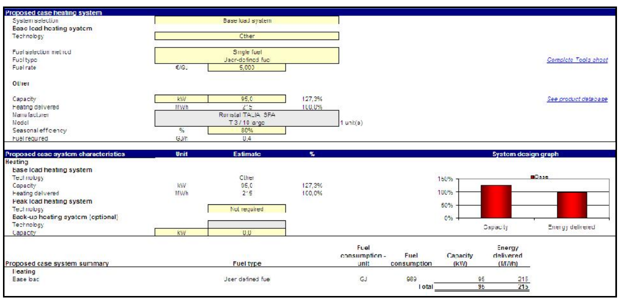


Fig.16. Energy model associated with component 1.

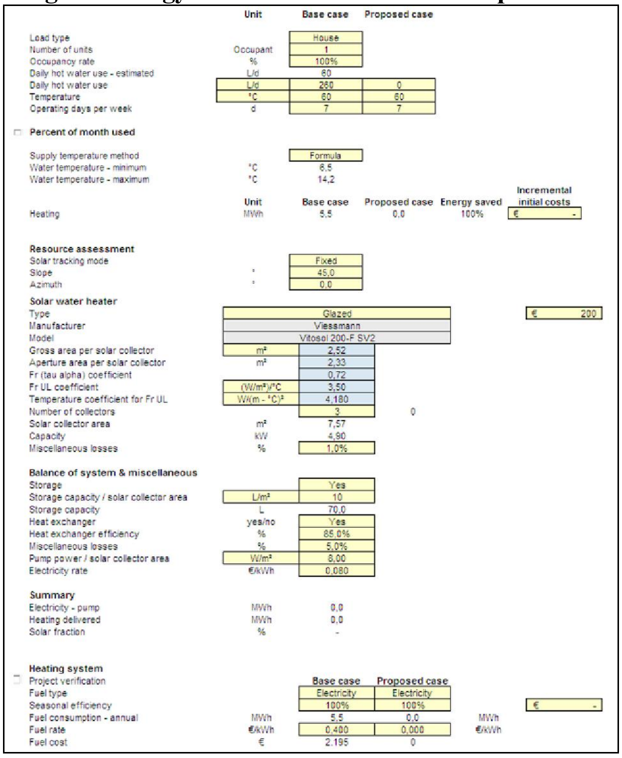


Fig.17. Energy model associated with component 2

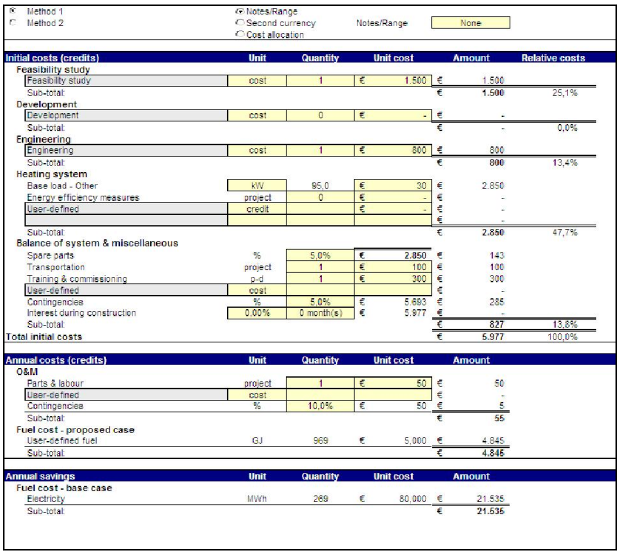


Fig.18. Cost analysis for component 1

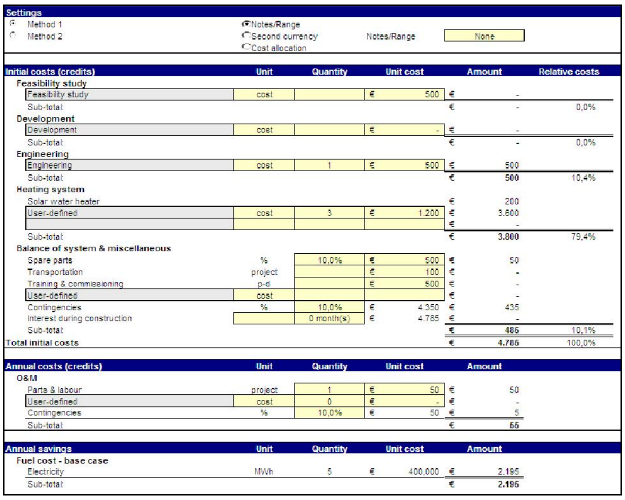


Fig.19. Cost analysis for component 2.

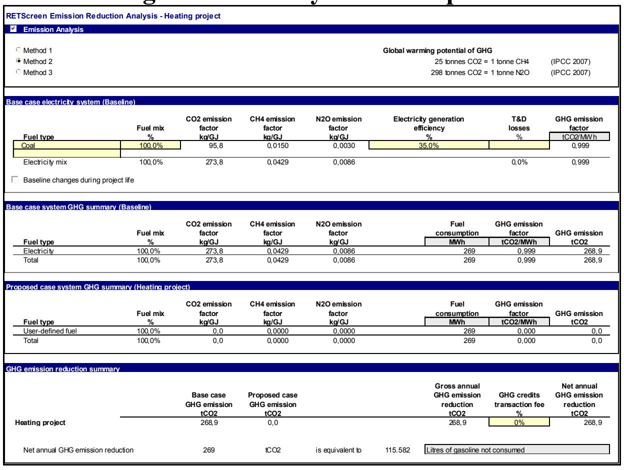


Fig.20. Pollutant emission analysis for component 1.

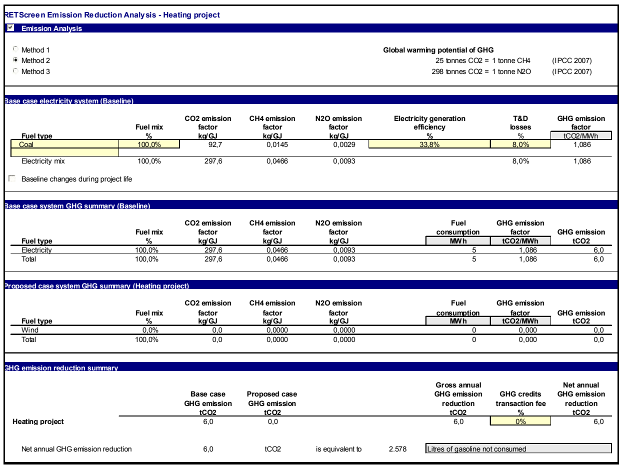


Fig.21. Pollutant emission analysis for component 2.

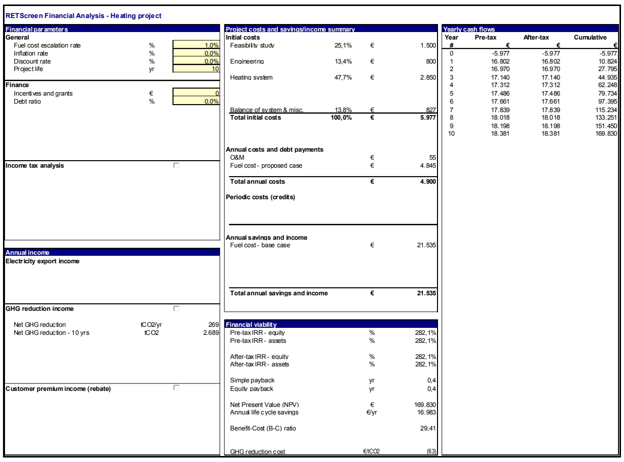


Fig.22. Financial analysis for component 1.

Table 2 – On investment included in I.R.R. calculation (internal rate of return)

System	Geothermal Model	Thermosolar
Investment necessary for system implementation (Euro)	5977	4785
Own Investment Reference model (Euro)	-	-
Debt Financing (Euro)	0	0
I.R.R. (%)	282,1	43,5

ISSN 2067-5534 © 2011 JSE

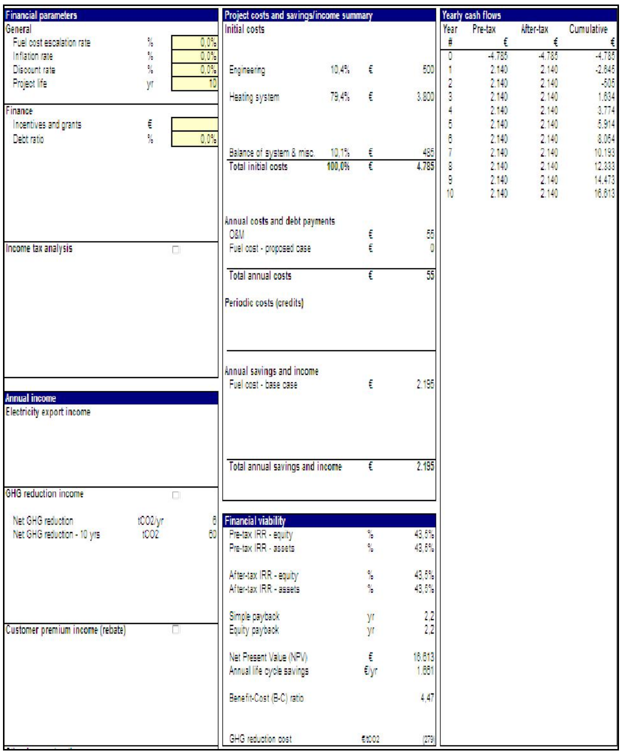


Fig.23. Financial analysis for component 2.

Similarly, in the case of a comparative analysis of component 2 with the reference system, the synthesis of results after financial analysis is presented in table 3.

Table 3 – On operating costs and the reducing the level of GHG emissions

System		Standard Model - geothermal	Thermosolar
A. DHW Supply			
System related expenses	Total (Euro)	4900	55
	Fuel (Euro)	4845	0
Expenses considered in R.I.R calculation (Euro)		16802	2140
Expenses resulting for reference model (Euro)		21535	2195
GHG emission reduction (to CO2)		269	6,0

5. CONCLUSIONS

Using geothermal and solar energy as a hybrid system has several advantages:

- Reduction of pollutant emissions is significant, the level of emissions being practically zero. After analysis, for the chosen reference case, we obtained a reduction of annual emissions (equivalent to 115.58 liters of non-used gasoline), of nearly 269 tons of CO2
- Both hybridized systems use only renewable resources;
- None of the systems uses fossil fuel resources, only the system uses a small quantity of electricity;
- Great flexibility regarding coupling with other types of systems.

In the last two decades we have witnessed an exponential increase in the degree of exploitation of renewable energy, the prediction for the next 50 years being in the same direction.

Romania has an important potential for renewable energy sources, currently also uses biomass in significant weight, has significant projects for using wind, solar and geothermal energy.

Hybrid subsystems are great prospects through the combined and alternative use of energy carriers which allows the optimization of their structure.

Table 4 - On investment included in I.R.R. calculation (INTERNAL RATE OF RETURN)

System	Investment necessary for system implementation (Euro)	Investment considered in graphic (Euro)	Own Investment Reference model (Euro)	Debt Financing (Euro)	I.R.R. (%)
Thermosolar	4 785	4 785	--	0	43,5
Geothermal Model	5 977	5 977	--	0	282,1

Table 5 - On operating expenses and the level of GHG emissions reduction

System	System related expenses		Expenses considered in I.R.R. calculation (Euro)	Expenses resulted for reference model (Euro)	GHG emission reduction (to CO2)
	total (Euro)	fuel (Euro)			
A. DHW Supply					
Thermosolar	55	0	2 140	2 195	6,0
Geothermal Standard Model	4 900	4 845	16 802	21 702	269

Using geothermal and solar energy as a hybrid system has several advantages:

- Both hybridized systems use only renewable resources;
- None of the systems uses fossil fuel resources, only the system uses a small quantity of electricity;

• Great flexibility regarding coupling with other types of systems.

REFERENCES

[1]. Fridleifsson, I.B. (2000). *Energy requirements for the next millenium.* Conference proceedings "On the Threshold: The United Nations and Global Governance în the New Millennium". United Nations University, Tokyo, January 2000.

[2]. Ingvar B. F., *Capacity building in renewable energy technologies in developing countries*, World Energy Congress, Montreal 2010.

[3]. Cutler J. C, Robert U. A., *Encyclopedia of Energy*, Elsevier Academic Press, 2004

[4]. Sanja K. P-V, I. Felea, *Contribution to modeling and simulation of thermal processes specific for Greenhouses heated with geothermal energy*, IEEE The international Conference on Computer as a tool EUROCON, pp. 2349-2355,2007\

[5]. *** Directiva 2009/28/CE a parlamentului european si a consiliului, 23 V. 2009, privind promovarea utilizarii energiei din surse regenerabile.

[6]. Nitu V., Felea I., *Energetica de tranzitie. Concepte si Modele*, Editura Mirton, Timisoara, 1997, 192 pg.ISBN 973-578-364-9

[7]. Felea I, Ingineria sistemelor de energie, Suport de curs pentru masterat, 2010, http://www.energetica-oradea.ro/cursuri/index.php

[8]. Rosca M., Karytsas K., *Posibilities of low enthalpy geothermal power generation in Romania*, 10th Regional Energy Forum – FOREN, 2010, Neptun-Olimp

[9]. Roşca, M., Karytsas, K., Mendrinos, D.: Low Enthalpy Geothermal Power Generation in Romania, Proceedings, WGC 2010, Bali, Indonesia (2010).

[10]. Roman M. Mirel I. *Tratarea şi utilizarea apelor geotermale Editura* Matrix Rom Bucureşti 2009

[11]. Antics, M., Roşca, M.: *Geothermal Development in Romania*, Geothermics, Vol. 32/4-6, Pergamon Press, Oxford, U.K, 2003, pp 361-370

[12]. *** http://cnr-cme.ro/

[13]. *** http://www.retscreen.net

[14]. ***http://www.minind.ro

ISSN 2067-5534 © 2011 JSE