MAPPING REGIONAL VARIATION OF COST OF HOT WATER PRODUCED BY CONVENTIONAL SOLAR COLLECTORS IN ALBANIA

Daniela Halili[1], Pellumb Berberi[2], Valbona Lame-Muda[3], Driada Mitrushi[4], Irma Berdufi[5], Margarita Kuqali[6], Urim Buzra[7]

[1]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, topciudaniela@yahoo.com

[2]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, pellumb.berberi@gmail.com

[3]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, v_muda@hotmail.com

[4]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, driadamitrushi@yahoo.com

[5]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, irmaberdufi@gmail.com

[6]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, mkuqali@yahoo.com

[7]Department of Engineering Physics, Faculty of Engineering Mathematic and Engineering Physics, Polytechnic University of Tirana, Tirana, Albania, rimibuzra@yahoo.com

Abstract

The Albanian National Strategy of Energy considers that in next ten years energy produced by solar collectors will reach the level of 1000 GW/(h y) Solar energy is one of the main alternative future sources of renewable energies in Albania. In sunny, warm locations, as Albania, the use of solar collectors to provide hot water for residential needs results to be very cost effective. Mean cost of a kWh thermal energy produced by conventional solar collectors is around 0.024 Euro and continues to drop, while the price of electrical energy supplied from the grid costs 0.1 Euro/kWh. One of the main factors determining the cost of hot water, for a given technology, is the mean solar energy available in the region. In this study it has been found that the most populated regions of Albania. Berat, Fier ,Kuçovë, Delvinë and Lushnjë are the regions with higher average annual insolation of 7.63 kWh and they have lower cost of energy 0.019 €/ KW h, while Elbasan, Shkodër, Kukës ,Korcë are the regions with lower average annual insolation of 4.6 kWh and they have higher average cost of energy 0.032€/ K. Cost saved every year has the lower value in Kukës 361 Euro/y. Berat, Fier ,Kuçovë, Delvinë, and Lushnjë are the regions with higher value of cost saved every year 436 Euro/y. In this study it has been given a map of distribution of costs of energy produced by solar collectors.

Keywords**:** *solar collectors, solar insolation, cost of heat, regional distribution of cost*

Introduction

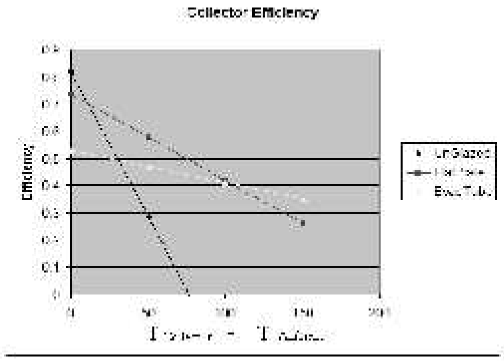
The geographic position of Albania and its Mediterranean climate provide favourable conditions for the successful development of solar energy. The high intensity of solar radiation and its duration, temperature and air humidity, etc., will contribute to this.
Albanians use electricity to heat water in their household. It is not only an expensive way to heat water, but it will simultaneously lead to a strong increase in the demand for electricity in the future. A number of programs are actually active worldwide to develop low energy houses using stand-alone renewable energy sources. The International Energy Agency (IEA) Solar Heating and Cooling Program approved in June 2008 the Task 40, Towards Net-Zero Energy Solar Buildings, with the aim to study and promote realistic designs for net and near net zero energy buildings [1] .The Advanced House Program was created by Natural Resources Canada in the early nineties. The goal was to develop low energy homes across Canada using various available technologies. Significant energy reductions were achieved, some up to 75% compared to a typical Canadian home.
This paper presents the cost and energy analysis of the use of solar collectors to supply electricity to houses or buildings in different regions of Albania differing from annual mean solar energy reaching the region. Technology considered was not changed during estimation.

Life cycle cost analysis

The life cycle cost analysis looks at the economics over the life of the product. Prices can be significantly different from year to year and depend on location, manufacturers, vendors, market fluctuations, etc. In order to compile the most accurate and realistic prices for the case study house designed, every effort was made to get up-to-date pricing from local vendors for the solar collectors.
This method is the aptly named “simple payback” method. However, this is simply the initial cost of the item divided by the annual cost savings due to the change. The method does not consider the time value of money, the effective interest rate or rising energy prices, or the replacement cost. More realistic and sophisticated analysis method which does consider the cash flow, annual inflation rate, annual discount rate electricity rate, annual electricity cost escalation rate is similar to the life cycle costs method [2] or Cash Flow Analysis method [3].
For the solar collectors, the ‘‘initial investment only” cost analysis is performed by considering only the initial costs of purchasing and installing the equipment. The flat plate solar collectors are actually the better financial option regardless of how many collectors are installed [6]. The flat plate solar collector considered is the model Baymak Essential X supplied by Baymak Group, Turkey. Absorber area of the collector is 1.88 m2 and heat efficiency for temperature difference of 40 degrees centigrade is 42.2 %.
It is known that heat efficiency of solar collectors is strongly dependent of site conditions, working temperatures end intensity of solar radiation. In figure 1 is shown a typical dependence of efficiency of different types of solar collectors. The performance of the glazed flat plate collector is better than the evacuated tube at low temperature and better than the unglazed at high temperatures.
This curve is for a collector with a selective coating on the absorber. Understanding the performance differences between these collectors, and the underlying reasons for these differences will allow you to make a better estimate of how your collector will behave, and allow you to make design changes that will improve its performance [7].

The initial cost of a glazed flat plate solar collector system is between 1.22 and 1.35 Euro per Watt, depending on the number of collectors, technology and producer.

Fig. 1.
Collector efficiency chart. These are for 3 sample collectors from the SRCC site. All data are for a solar radiation level of 800 /m^2) [7]



The initial investment payback time for flat plate solar collectors is calculated using the simple payback method, considering the cost of electrical energy saved from the grid and initial cost of an electric system with the same capacity of hot water. We focused on comparison between flat plate glazed solar collectors and electrical water heating systems due to the fact the these to systems are the most actually used in Albania. To compare two systems we used the methodology proposed by Solar Rating and Certificate Corporation SRCC [7]. SRCC has used a method to develop a consumer friendly, practical rating system. The intent is to present to consumers an easily understood comparison between solar hot water systems and conventional hot water systems.
Note that the performance any individual consumer will experience may differ due to location and hot water usage. The type of auxiliary system (e.g. gas or electric) utilized will have a large impact on the overall performance of the system. These differences arise because different types of auxiliary systems have varying standby losses and fuel conversion efficiencies. Although the auxiliary system may affect the solar system's performance, in many cases, the solar output is mostly independent of the auxiliary system used. The actual price of electrical energy supplied from the grid is 0.1 Euro per kWh, initial cost of an electric boiler is 200 Euros, replacement time 10 years, and the effectively is 90 to 95 %.
The Energy Factor (EF) and the Solar Energy Factor (SEF) can be used to compare different water heating systems with one another and to estimate typical yearly operating costs for the specified rating conditions as its performance rating for solar domestic water heating systems. Solar Energy Factor (SEF) is defined as the energy delivered by the system divided by the electrical or gas energy put into the system The SEF includes all of the specified conditions for EF test, plus several solar specific conditions.
The EF and SEF can be used to compare solar and electric system's energy use on a one-to-one basis. A higher SEF or EF indicates less conventional energy use, and consequently, lower operating cost. The EF for the SRCC standard electric auxiliary tank is 0.9. The SEF for flat plate glazed collectors is taken 2.36. For electric systems, the following calculation can be used:

$$\text{Yearly cost C} = \frac{\text{Initial cost}}{\text{Repacment time}} + 365 * \frac{\text{Energy delivered to the hot water per day}}{\text{EF(or SEF)}}$$
$$* \text{(Price of energy (euro per kWh)}$$

Energy delivered to the hot water load, using the SRCC rating conditions, is 43302 kJ/day or 12.03 kWh/day. In the case of flat plate glazed solar collectors initial cost is considered during the calculation of the price of heat produced by collector, so it must be omitted in the above equation. Cost saved every year by using solar collectors instead of electric systems is:

$$\Delta \mathrm{C} = \mathrm{C_E} - C_s$$

Where, ΔC is yearly saved cost, C_E and C_S are the yearly costs of energy for electric system and solar collector, respectively. This figure can be used as the energy cost savings basis for an economic analysis of a solar hot water system based on the assumptions for the standard (EF) and SRCC-OG 300 rating conditions (SEF). Other factors such as initial cost, maintenance, inflation, interest rate, and replacement costs also need to be considered when making an economic analysis. To estimate the annual operating cost of a solar collector system we need to know the mean annual solar energy for each site considered. We used two sources of data: ground insolation measured by local existing meteorological net and data base of NASA surface meteorology and solar energy.Radiation parameters were compared with data from the Baseline Surface Radiation Network. It is generally considered that quality measured data are more accurate than satellite-derived values. However, measurement uncertainties from calibration drift, operational uncertainties, or data gaps are unknown for ground site data sets. In 1989, the World Climate Research Program estimated that most routine-operation ground sites had "end-to-end" uncertainties from 6 to 12% [4]. The economics of a small solar collector system is determined by both the capital and operating costs. Operating costs include the costs associated with maintaining and operating the solar collector system over its useful life. In our estimation we have used a mean value of actual prices in local market

Calculated costs for different regions

Solar insolation observed in Albania fluctuates throughout the year, corresponding to seasonal and regional variation. Nearly the entire country receives an annual average of more than 4 kilowatt-hours (kWh) of solar energy per square meter per day. Many regions receive up to 7.63 kWh of solar energy daily. Table 1 shows monthly averaged direct normal radiation, annual average, months with maximal and minimal radiation and life cycle cost of heat energy produced by solar collector in different regions of Albania. Table 2 shows the differences in costs of hot water produced using two common technologies in producing hot water for domestic needs, electric hot water system and solar collector system. Figure 2 and figure 3 show the map of distribution regions where measurements and estimations were carried. For all regions analyzed, month with minimum average daily insolation is December, while month with maximal average daily insolation changes from one region to the other from May to July. The variation of insolation from one region to the other can be explained with variability of cloud cover. Albania is mountainous country characterized by fast changes of relief. The average Albanian household consumes an average of about 12 kWh of energy for producing hot water per day, meaning that the solar energy reaching a solar collector with an active area of two to 3 square meter could theoretically generate more than enough energy to supply the home, if the energy could be captured and used with no loss of energy and then be stored and used when needed. The life cycle cost analysis looks at the economics over the life of the product. Prices can be significantly different from year to year and depend on location, manufacturers, vendors, market fluctuations, etc. In order to compile the most accurate and realistic prices for the case study every effort was made to get up-to-date pricing from local vendors for the solar technologies. However, the values presented in the Table 1 must be considered only as more probable feasibility estimation.

Table 1.
Monthly averaged direct normal radiation, annual average, months with maximal and minimal radiation and life cycle cost of heat produced by solar collectors situated in different regions of Albania.

Region	Mean height over sea level m	Average daily insolation kWh/m^2/day				Average annual insolation kWh/m^2/day	Average Cost of energy €/ KW h
		Maximal	Month	Minimal	Month		
Tirana	84	9.39	July	2.78	December	5.89	0.025
Durrës	186	9.27	July	3.26	December	6.11	0.024
Elbasan	126	7.73	July	2.72	December	4.92	0.029
Shkodër	130	7.09	July	2.47	December	4.47	0.032
Kukës	339	6.22	July	2.30	December	4.05	0.036
Fier	17	8.32	May	6.67	December	7.61	0.019
Korcë	876	7.73	July	2.70	December	5.00	0.029
Vlorë	6	9.17	July	2.74	December	5.80	0.025
Gjirokastër	213	8.45	July	2.61	December	5.50	0.026
Himarë	60	9.14	July	2.70	December	5.76	0.025
Tropojë	1105	7.56	June	6.78	December	6.02	0.024
Tepelenë	732	7.34	June	5.09	December	6.09	0.024
Çorovodë	635	7.34	June	5.11	December	6.10	0.024
Ersekë	1100	7.33	June	5.15	December	6.12	0.024
Pogradec	720	7.33	June	5.15	December	6.12	0.024
Lushnjë	67	8.32	June	6.68	December	7.62	0.019
Berat	187	8.33	May	6.71	December	7.63	0.019
Kuçovë	80	8.32	May	6.71	December	7.63	0.019
Lezhë	413	7.13	May	5.55	December	6.30	0.023
Krujë	698	7.14	May	5.56	December	6.31	0.023
Peshkopi	698	7.30	June	5.87	December	6.52	0.022
Delvinë	60	8.37	May	6.42	December	7.63	0.019
Borsh	300	9.14	July	2.70	December	5.76	0.025
Dhërmi	60	9.15	July	2.71	December	5.77	0.025
Xarë	392	8.44	July	2.59	December	5.38	0.027
Burrel	320	7.30	June	5.83	December	6.50	0.022
Kavaje	16	7.13	May	5.54	December	6.30	0.023
Leskovik	1200	7.33	June	5.14	December	6.12	0.024
Pilur	800	9.14	July	2.70	December	5.76	0.025
Prrenjas	713	7.29	June	5.88	December	6.52	0.022
Puke	838	7.36	June	6.49	December	6.77	0.021
Rreshen	86	7.14	May	5.57	December	6.32	0.023

Shengjin	413	7.13	May	5.54	December	6.30	0.023
Average cost							0.024

The average cost of heat energy produced by solar collector technology for all regions considered is 0,024 Euro/kWh.The estimated cost of heat energy produced by solar collector technology is much lower than heat energy produced using an electrical system for producing hot water using electrical energy supplied from the grid, which actually in Albania is 0.11 – 0.12 Euro/kWh

Table 2**.**

Cost of heat energy, annual cost of hot water produced by electric system, annual cost of hot water produced by solar collector system and cost saved every year due to use osolar technologies for producing hot water for domestic use in different regions of Albania.

Region	Average Cost of energy €/ KW h	Annual cost of hot water Electric system Euro/y	Annual cost of hot water Solar collector system Euro/y	Cost saved every year Euro/y
Tirana	0.025	519	110	409
Durrës	0.024	519	105	414
Elbasan	0.029	519	127	392
Shkodër	0.032	519	141	378
Kukës	0.036	519	158	361
Fier	0.019	519	83	436
Korcë	0.029	519	127	392
Vlorë	0.025	519	110	409
Gjirokastër	0.026	519	114	405
Himarë	0.025	519	110	409
Tropojë	0.024	519	105	414
Tepelenë	0.024	519	105	414
Çorovodë	0.024	519	105	414
Ersekë	0.024	519	105	414
Pogradec	0.024	519	105	414
Lushnjë	0.019	519	83	436
Berat	0.019	519	83	436
Kuçovë	0.019	519	83	436
Lezhë	0.023	519	101	418
Krujë	0.023	519	101	418
Peshkopi	0.022	519	97	422
Delvinë	0.019	519	83	436
Borsh	0.025	519	110	409
Dhërmi	0.025	519	110	409
Xarë	0.027	519	119	400
Burrel	0.022	519	97	422
Kavaje	0.023	519	101	418
Leskovik	0.024	519	105	414

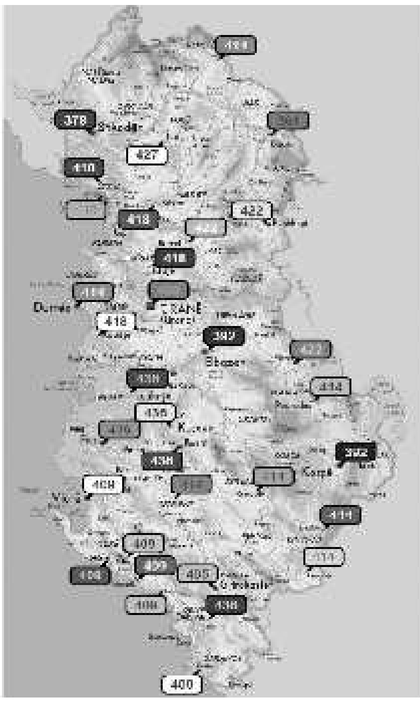
Pilur	0.025	519	110	409
Prrenjas	0.022	519	97	422
Puke	0.021	519	92	427
Rreshen	0.023	519	101	418
Shengjin	0.023	519	101	418
Average cost	0.024	519	105	414

Actually in Albania are installed more then 75 000 m^2 solar collectors. [8] The Albanian National Strategy of Energy consider that in next ten years energy produced by solar technologies will reach the level of 1000 GW/(h y) (around 125 MW_p installed power of thermal collectors)[5]**.** Another important factor that must be considered during any feasibility study for investments in solar technology for producing hot water is the variation of cost of hot water from one region to the other.The mean variation of cost of hot water by solar technologies for all regions of Albania considered is 15.2%. However, there are variations of cost as high as 50% compared with country's mean in the region of Kukesi. These data clearly demonstrate the need of a very careful approach to any project for application of solar collectors technology.

In Figure 2 and Figure 3 are shown the Average Cost of energy and Cost saved every year due to use of solar technologies for producing hot water for domestic use for each city given on table 1 and table 2.

Fig 2

Fig 3



Solar energy is one of the main future sources of renewable energies in Albania. The potentials of solar energy are very high, up to an annual average of 7.63 kWh/m2 per day. However, seasonality also has a significant impact on the availability of solar insolation. Also insolation varies of from one region to the other which can be explained with variability of cloud cover. Albania is mountainous country characterized by fast changes of relief Berat,

Kuçovë, Delvinë, Lushnja are the regions with higher average daily insolation, while Elbasan, Shkodër, Kukës are the regions with lower average daily insolation.
The average cost of electrical energy produced by solar collectors technology for all regions taken in consideration is 0,0240 Euro/kWh. Berat, Kuçovë, Delvinë, Lushnjë are the regions with lower cost of energy, while Elbasan, Shkodër, Kukës, and Korcë are the regions with higher average cost of energy. Another important factor that must be considered for investments in solar collectors is the variation of cost of electrical energy from one region to the other. The mean variation of cost of electrical energy for Albania is 17%. However, there are variations of cost as high as 46.3% compared with country's mean, as that observed in the region of Kukes.
These data clearly demonstrate the need of a very careful approach to any project for application of solar collectors.

Rating parameters

The following parameters are used for calculating the daily energy savings and the solar energy factor. These conditions are the same as those used in the U.S. Department of Energy test for water heaters (Federal Register volume 55 number 201 pages 42161 - 42177, October 17, 1990) except for the following:

- Since the DOE test does not cover solar water heaters, it specifies no solar radiation. Therefore, a 4,733 Wh/m^2 - day (1500 Btu/ft2 - day) solar radiation profile has been added as specified in SRCC document RM-1 "Methodology for Determining the Thermal Performance Rating for Solar Collectors".
- The draw profile has been set to begin at 9:30 AM solar time.
- An outdoor ambient temperature profile has been added as specified in SRCC document OG-300. The average air temperature is 14.4°C (58°F).

The amount of energy to be drawn from the system was obtained from the April 1994 GAMA Consumers' Directory of Certified Efficiency Ratings for Residential Heating and Water Heating Equipment (page 134).

Bibliography

[1] IEA-SHC. *Towards net zero energy solar buildings. Solar heating and cooling programme*; 2008. <http://www.iea-shc.org/task40/index.html> [accessed May 2009].
[2] *Ashrae Handbook – HVAC applications*. American Society of Heating. Refrigerating and air-conditioning engineers, Atlanta, GA, USA; 2007.
[3] *Ashrae Handbook – hvac applications.* American Society of Heating.Refrigerating and air-conditioning engineers, Atlanta, GA, USA; 1995.
[4] *Surface Meteorology and Solar Energy*, A renewable energy resource web site (release 6.0) http://eosweb.larc.nasa.gov/cgi-bin/sse/sse.cgi?pellumb.berberi@gmail.com+s05#s05, Accesed 10 May 2012
[5] National Agency of Natural Resources of Albania: Solar Energy Analysis.
[6] MITCHELL LECKNER, RADU ZMEUREANU, *Life cycle cost and energy analysis of a Net Zero Energy House with solar combisystem*, Applied Energy 88 (2011) 232–241
[7] http://www.solar-rating.org/facts/system_ratings.html, visited on June 20, 2012
[8] Renewable energy potentials of Albania visited on July 01, 2012.