Process System Engineering and Sustainability

Drita Lokaj-Qerimi, Cvete Dimitrieska, Igor Andreevski, Sanja Popovska-Vasilevska

Abstract-The inevitable increase in population and the economic development that must necessarily occur, have serious implications for the environment, because energy generation processes are polluting and harmful to the ecosystem. If the energy consumption continues to grow as previously, than as a result we have: Tightening of resources, Climate change and Hazards/disposals. Solar energy is a sustainable energy supply technology due to the renewable nature of solar radiation. The utilization of "zero emission" technologies plays a significant role in the reduction of hydrocarbons use and the reduction of CO_2 emissions. This paper intends putting together all data relevant for some of the Kosovo Towns regarding the solar hot water energy potential and used f–chart method to estimate the annual solar contribution.

Keywords: renewable energy, solar energy, energy potential, solar contribution.

---

1 Introduction

Energy is considered to be a key player in the generation of wealth and also a significant component in economic development. This makes energy resources extremely significant for every country in the world. In bringing energy needs and energy availability into balance, there are two main elements: energy demand and energy supply. In this regard, every country aims to attain such a balance and hence develop policies and strategies.

There is an intimate connection between energy and the environment. A society seeking sustainable development ideally must utilize only energy resources that cause no environmental impact (e.g., that release no emissions to the environment). Clearly, a strong relation exists between energy efficiency and environmental impact since, for the same services or products, less resource utilization and pollution is normally associated with increased energy efficiency.

Reliability of supply, promotion of investments in the sector, environmental preservation and further development of the energy market are the main strategic goals of the new European strategy for energy sector in the EU. A number of important objectives derive from these goals, including the so-called 20% - 20% - 20%. This means: 20% reduction of gas emissions that create the 'greenhouse' effect, 20% increase of the participation of renewable sources in energy consumption, and 20% improvement of energy efficiency.

Kosovo is a signatory of the Energy Community Treaty for South Eastern Europe with equal rights and obligations. Under this treaty, Kosovo is obliged to increase the energy efficiency at 9% until 2018, based on consumption during 2006/2007.

- *Drita Lokaj-Qerimi, University of Prishtina "Hasan Prishtina", Kosovo,* *drita_lokaj@hotmail.com*.
- *Cvete Dimitrieska, University "St.Kliment Ohridski", Macedonia,* *cvete.stefanovska@tfb.uklo.edu.mk*.
- *Igor Andreevski, University "St.Kliment Ohridski", Macedonia,* *igor.andreevski@uklo.edu.mk*
- *Sanja Popovska-Vasilevska, University "St.Kliment Ohridski", Macedonia.* *pvsanja@yahoo.com*

Achievements on this goal will be reported every three (3) years and increased efficiency should be 1% per year or 3% in 3 years [1].

To provide a more complete support for all those who want to design, finance, install and utilize solar energy for sanitary hot water or to produce electricity from solar energy, besides other things, are required to posses data with the following information:

- Solar radiation on the optimum horizontal and sloping (tilt) plains for the specific area / location where solar panels will be installed;
- Other climate conditions of the region / location, including average temperatures of air, water, etc..,

In this paper, the solar water heater [SWH] system, case study for the Kosovo towns, consists of a flat plate collector panel 4[m2] and a hot water cylinder 200[l]. The annual solar contribution for Kosovo Towns is between 0.59% - 65.6%.

2 Energy Potential of Solar Energy Utilization for some of the Kosovo Towns

In order to design systems using solar energy, it is required to know a number of climate parameters (variables), including:

The average daily radiation in solar collector planes, which is used to calculate the collector efficiency and solar energy absorbed by it; Sky temperature, which is used to calculate the energy, absorbed by collectors without cover, and radiation losses in the area surrounding the pools;

Cold water temperature that is used to determine the thermal load, which the system should cover / handle, and Heating load (except for pools). The amount of solar radiation that reaches each point of the Earth's surface varies depending on these factors:

- Geographical position,
- The time during the day,

- Season,
- Geographical location and local climate conditions.

2.1 Horizontal solar energy radiation potential plane

Data of solar energy, latitude, longitude, altitude and the average monthly for different Kosovo towns according to the European Commission database are given following :

TABLE 1
MONTHLLY AND YEARLLY SOLAR IRADIATION IN HORIZONTAL PLANE

Location	Monthly and yearly solar iradiation in horizontal plane [kWh/m²]												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Podujeva	42.8	57.9	114.0	142.2	173.9	198.3	210.5	189.4	128.1	93	53.4	35.3	1438.1
Prishtina	44.0	60.76	117.1	143.4	176.4	198	212.9	190.3	129.3	93.9	54.3	36.6	1456.3
Mitrovica	44.6	59.7	116.2	142.2	177.0	198.6	212.6	190.3	128.1	93.9	52.8	37.5	1452.7
Peja	44.6	59.0	112.8	137.4	171.4	189.9	206.1	184.4	122.7	89.6	50.1	36.2	1405.2
Prizreni	45.8	60.4	111.9	141.6	177.0	198.9	217.3	192.5	130.2	93.9	54.9	37.5	1463.6
Gjakova	46.8	62.4	118.1	148.5	186	208.8	224.7	199.0	134.7	96.7	53.1	36.6	1514.7
Ferizaj	45.3	61.0	115.9	142.2	172.0	195.9	211.4	189.1	128.1	93.3	54.3	37.5	1445.4

TABLE 2
DATA FOR LONGITUDE, LATITUDE AND ALTITUDE

Location	Calculated for locations:		
	Latitude	Longitude	Altitude
Podujeva	N 42°54'38"	E 21°11'44"	618m
Prishtina	N 42°39'46"	E 21°9'55"	607m
Mitrovica	N 42°53'29"	E 20°51'57"	507m
Peja	N 42°39'33"	E 20°17'19"	514m
Prizreni	N 42°12'54"	E 20°44'29"	421m
Gjakova	N 42°23'3"	E 20°25'42"	362m
Ferizaj	N 42°22'12"	E 21°8'53"	575m

2.2 Monthly average total radiation on a tilted surface

The amount of insulation on a terrestrial surface at a given location and time depends on the orientation and slope of the surface.

In the case of flat-plate collectors installed at a certain fixed angle, system designers need to have data about the solar radiation on the surface of the collector.

Most measured data, however, are for either normal incidence or horizontal. Using the isotropic diffuse assumption, we can estimate the monthly average radiation incident on the collector. A collector is to be installed in Kosovo towns, the effects of sloping the receiving plane 45^0 to the east.

TABLE 3
MONTHLLY AND YEARLY SOLAR RADIATION ON A TILTED SURFACE

Location	Monthly and yearly averagetotal radiation on a tilted surface [kWh/m²]												
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Podujeva	73.3	86.6	142.9	143.3	166.0	170.1	203.6	224.4	207.0	178.6	90.4	60.0	1746.8
Prishtina	75.9	92.0	147.3	144.5	168.2	169.6	205.9	225.2	208.5	180.1	92.0	62.9	1772.7
Mitrovica	78.0	90.0	146.3	143.3	168.6	170.3	205.9	225.6	207.3	181.1	88.9	65.8	1771.5
Peja	77.5	88.6	140.6	137.8	162.0	163.9	198.9	216.8	197.2	168.2	81.9	62.0	1695.0
Prizreni	79.8	90.8	138.7	142.1	167.7	170.0	209.9	227.5	209.4	178.2	92.5	64.5	1771.5
Gjakova	82.6	95.0	148.5	149.9	177.9	178.5	217.9	237.0	218.4	186.5	88.6	62.4	1843.4
Ferizaj	78.6	92.2	145.0	142.9	164.0	167.7	204.0	222.9	205.7	177.3	91.4	64.8	1756.7

2.1.2 *Kosovo Solar Map horizontal radiation plane*

According to satellite data, the intensity of solar radiation on the territory of Kosovo is shown on the solar mapping presented in Fig.1.

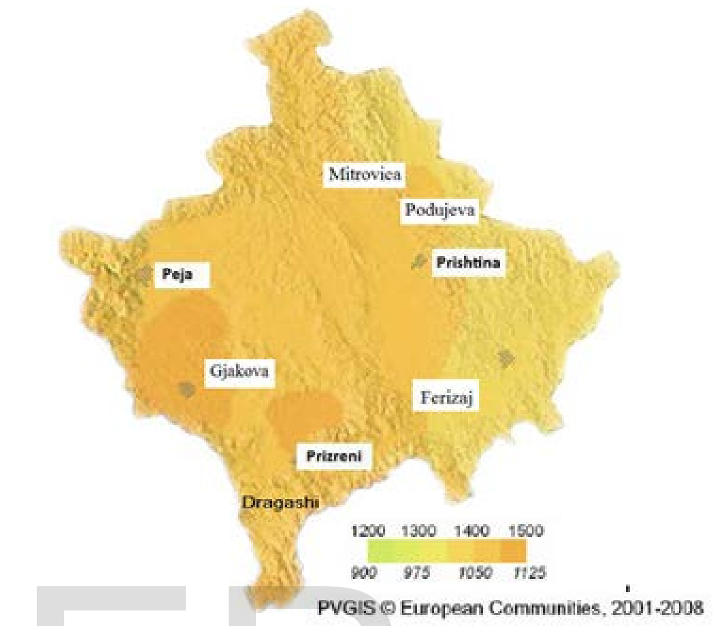

Fig.1. Kosovo solar radiation map - horizontal inclined plan

According COWI (Evaluation Study for Renewable Energy in Kosovo, COWI A / S, 2008) theoretical potential of solar energy in Kosovo is as follows:

TABLE 4
THEORETICAL POTENTIAL OF SOLAR ENERGY IN SOME KOSOVO TOWNS

Location	Surface [km²]	Solar irradiation	
		kWh/m² year	MWh/ year
Podujeva	633	1746.8	1105720.6
Prishtina	33457	1772.7	59308621.7
Mitrovica	460	1771.5	814889.5
Peja	603	1695.1	1022096.4
Prizreni	640	1771.5	1133761.2
Gjakova	586.9	1843.4	1081918.7
Ferizaj	345	1756.7	606061.1

Solar radiation potential in Kosovo Towns are provides good opportunities for introducing solar year isolated systems where electrical grid is missing. As we can see in Tables 1-4 and Fig. 1 Gjakova has more opportunities than other cities, while Peja has less opportunity than other cities.

2.3 Average air temperatures

Among the factors that affect the calculation of the solar energy systems (especially for those of medium and larger sizes), data from meteorological stations closest to the location of planned construction / installation of the specific solar energy systems are required.

Table 5 shows values for, average monthly and annual temperatures according to estimates from the European Commission.

TABLE 5
AVERAGE 24-HOURS DAILY TEMPERATURES FOR EVERY MOUNTH [^{0}C]

Location	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Year
Podujeva	-0.5	0.4	5.1	10.1	15.1	18.8	21.5	21.7	16.4	11.3	6.0	0.9	10.6
Prishtina	-0.3	0.6	5.4	10.3	15.3	19.1	22.0	22.3	16.9	11.6	6.1	0.8	10.9
Mitrovica	0.5	1.7	6.3	11.0	16.1	20.2	23.2	23.3	17.7	12.5	6.8	1.9	11.7
Peja	0.8	2.1	6.5	11.2	16.2	20.2	23.1	23.5	17.8	12.7	7.4	2.5	12.0
Prizreni	1.0	1.8	6.8	11.4	16.8	21.0	24.2	24.2	18.5	12.9	7.4	2.1	12.3
Gjakova	2.7	3.6	8.0	12.6	17.3	21.1	24.1	24.7	19.1	14.3	9.1	4.2	13.4
Ferizaj	-0.2	0.8	5.7	10.6	15.8	19.6	22.5	22.5	17.2	11.6	6.2	0.8	11.1

3 SUN PATH DIAGRAM

Kosovo has Latitude between 41°50′58′′and 43°51′42′′. Fig. 2 shows the sun's path plotted on a horizontal plane for latitude 42°N, called a sun pathdiagram, use the diagram to find the position of the sun in the sky at any time of the year. [4]

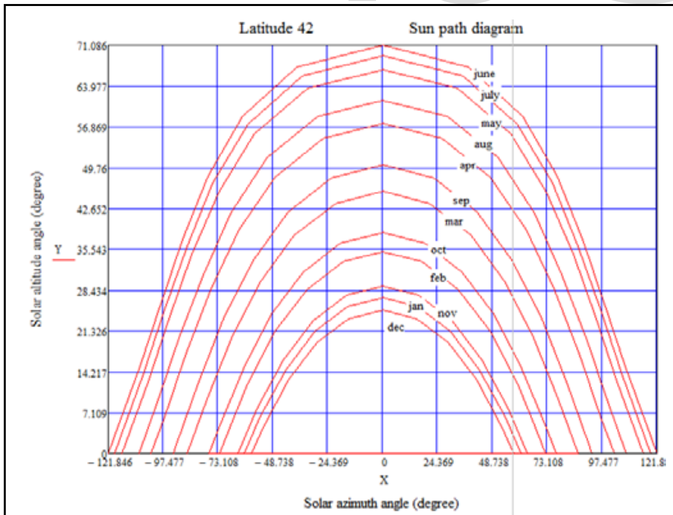

Fig.2. Sun path diagram for 42°N latitude

In a two-dimensional plot, only two independent parameters can be used to correlate the other parameters; Such diagrams show the complete variations of hour angle and declination for a full year, all necessary calculations are made step by step by J. Duffie and W. Beckman.

The solar altitude angle is the angle between the sun's rays and a horizontal plane, the mathematical expression for the solar altitude angle is:

$$\sin(\alpha) = \cos(\phi) = \sin(L)\cdot\sin(\delta) + \cos(L)\cdot\cos(\delta)\cdot\cos(h) \qquad (1)$$

where:

L - local longitude,
δ - declination,
h - hour angle.

The solar azimuth angle, is the angle of the sun's rays measured in the horizontal plane from due south (true south) for the Northern Hemisphere or due north for the Southern Hemisphere; westward is designated as positive. The mathematical expression for the solar azimuth angle is:

$$\sin(z) = \cos(\delta)\cdot\sin(h)/\cos(\alpha) \qquad (2)$$

The sun's position in the sky changes from day to day and from hour to hour. It is common knowledge that the sun is higher in the sky in the summer than in winter. On June 21 the sun is at its most northerly position with respect to the earth. This is called the summer solstice and during this day the daytime is at a maximum. Six months later, on December 21, the winter solstice, the reverse is true and the sun is at its most southerly position. In the middle of the six-month range, on March 21 and September 21, the length of the day is equal to the length of the night. These are called spring and fall equinoxes, respectively. The summer and winter solstices are the opposite in the Southern Hemisphere; that is, summer solstice is on December 21 and winter solstice is on June 21.

Also the day Langh is an imprtant factor for solar energy, the day length is twice the sunset hour, since the solar noon is at the middle of the sunrise and sunset hours. Therefore, the length of the day in hours is:

$$Day \quad length = \frac{2}{15}\cos^{-1}\left[-\tan(L)\cdot\tan(\delta)\right] \qquad (3)$$

According to the calculation, the longest Day length in year is in June, and the shortest Day length is in December. It should be noted that, the Podujva has the biggest latitude L=42°53′N and has the biggest Day length with 7.535 sunset and -7.535 sunrise in June, and the Prizereni has the smaller latitude L=42°12′N with the shortest Day length with sunset 4.492 and -4.492 sunrise in December.

4 SOLAR WATER HEATING SYSTEM SPECIFICATION

Solar water heating systems (SWH) are the simplest and most widely used solar energy collection and utilization devices. They are intended to supply hot water for domestic use and are based on natural circulation or so called thermosyphon principle. They supply hot water at a temperature of about 50^{0}C and consist of a collector, storage tank and connecting pipes Fig.3. Data regarding the location of the SWH system under study include the longitude, latitude, altitude, annual solar radiation, and annual average air temperature, are presented before.

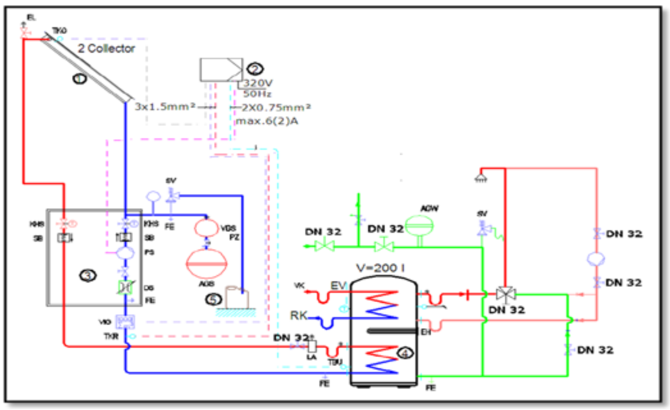

Fig.3 Solar Water System

The SWH system is the flat plate collector type, which is the typical solar system used in Kosovo Towns for water heating purposes. The collector consists of copper tubes extended with copper foils and in order to boost absorbency, sprayed with black solar powder. A layer of expanded polyurethane is sprayed at the back of the collector for insulation. The sides of the collector are insulated with rock wool. The back cover of the collector is galvanized steel, while the sides consist of aluminum. The front area of the collector is covered with a single solar glass.

Calculation for Collector number:

$$n = (Q / q \cdot \eta) / S = 2[colector] \quad (4)$$

The amount of heat per day is:

$$Q = G \cdot C_p (T_{\max} - T_{\min}) / 1000 = 9.05 [kWh/day] \quad (5)$$

where:
G=200[l] - the volume of the boiler,
$T_{\min} = 11[^\circ C]$ - the temperature in the boiler entry (of water supply),
$T_{\max} = 50[^\circ C]$ - the temperature at the exit of the boiler,
$C_p = 1.16[Wh/kgK]$ - specific water termokapacitet,
$\eta = 0.77$ - utilization coefficient,
$p = 1.9[m^2]$ - effective area of the collector,
$q = 4[kWh/m^2 day]$ - the capacity of sunlight.

The storage tank is well insulated to reduce thermal losses to the environment and is equipped with a heat exchanger for heating the water with auxiliary energy. The auxiliary can be either electricity or diesel. The household considered is of four person's family (50 litres per person); whereas the technical characteristics of the SWH system under study are summarized in Table 6.

TABLE 6
SPECIFIKATIONS OF THE SWH SYSTEM

Colector type	Flat – Plate, Cupper tube with cupper foils
$F_R U_L$	$8.42[Wm^{-2}K]$
$F_R(\tau\alpha)n$	0.77
Colector inclination	45^0
Tank capacity	200(litra)
Hot water temperature	50^0
Hot water demand/day	200[l] (4 persons)
Colector area	4[m²]

To find the annual solar contribution we use f-chart method

5 THE F- CHART METHOD

The purpose of the method is to calculate f, the fraction of the hot water load that is provided by the solar heating system (solar fraction). The method enables the calculation of the monthly amount of energy delivered by hotwater systems with storage, given monthly values of incident solar radiation, ambient temperature and load. [4],[7].
The mains water temperature T_m and the minimum acceptable hot-water temperature T_w both affect the performance of solar water heating systems. Both T_m and T_w affect the average system operating temperature level and thus also the collector energy losses. The fraction f of the monthly total load supplied by the solar space and water heating system:

$$f = 1.029 \cdot Y - 0.065 \cdot X - 0.245 \cdot Y^2 + 0.0018 X^2 + 0.0215 Y^3 \quad (6)$$

The energy contribution for the month is the product of *fi* and the monthly heating and hot-water load *Li*. The fraction of the annual SWH load supplied by solar energy *F* is the sum of the monthly solar energy contributions divided by the annual load.

$$F = \sum f_i \cdot L_i / \sum L_i \quad (7)$$

4.1 Case study

Solar water heating system is to be designed for a house in Kosovo towns, (with latitude Table 2). The collectors considered for this purpose have two covers with $F_R U_L$ and $F_R(\tau\alpha)n$ (Table 6). The collectors are to face east at a slope of 45°. The water heating load is 200 liters/day heated from 11 to 50°C. The tank is a cylinder 0.50 m diameter and 1.16 m high, a loss coefficient of 0.62[W/m²]. Estimate the fraction of the month heating load supplied by solar energy for this system with a collector area of 4 m². The radiation on the collector $\overline{H}_T[kWh/m^2]$ Table 4, and $(\tau\alpha)n/(\tau\alpha) = 0.94$.

Figure 4 shows the diagram for fraction *f* of the monthly total load supplied by the solar water heating system.

ISSN 2229-5518

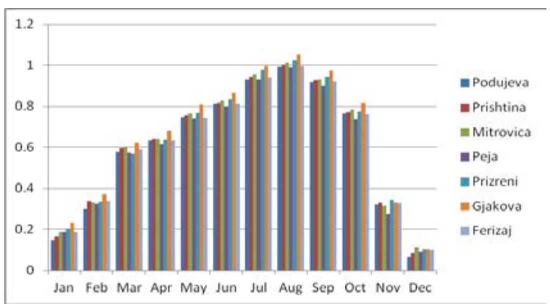

Fig.4.The fraction *f* of the monthly total load supplied by water heating system

Table 7 shows that the annual solar contribution for some Kosovo Towns, is between 59.8%-65.6%.

TABLE 7
ANNUAL SOLAR CONTRIBUTION FOR KOSOVO TOWNS

Location	Annual solar contribution	
	kWh/year	%
Podujeva	2209.992	60.3
Prishtina	2258.571	61.6
Mitrovica	2283.582	62.3
Peja	2192.668	59.8
Prizreni	2299.331	62.7
Gjakova	2405.137	65.6
Ferizaj	2252.19	61.4

5 CONCLUSION

Energy is considered a prime agent in the generation of wealth and a significant factor in economic development. The importance of energy in economic development is recognized universally and historical data verify that there is a strong relationship between the availability of energy and economic activity. Although in the early 1970s, after the oil crisis, the concern was on the cost of energy, during the past two decades the risk and reality of environmental degradation have become more apparent.

The growing evidence of environmental problems is due to a combination of several factors since the environmental impact of human activities has grown dramatically. This is due to the increase of the world population, energy consumption, and industrial activity.

Achieving solutions to the environmental problems that humanity faces today requires long-term potential actions for sustainable development. In this respect, renewable energy resources appear to be one of the most efficient and effective solutions.

A few years ago, most environmental analysis and legal control instruments concentrated on conventional pollutants such as sulfur dioxide (SO2), nitrogen oxides (NOx), particulates, and carbon monoxide (CO) [2].

Recently, however, environmental concern has extended to the control of hazard ous air pollutants, which are usually toxic chemical substances harmful even in small doses, as well as to other globally significant pollutants such as carbon dioxide (CO_2).

A significant contribution to the CO_2 emitted to the atmosphere is attributed to fossil fuel combustion. Kosovo mostly used coal for primary energy [1].

In this paper we have find the position of the sun in the sky at any time of the year for latitude L=42^0N, we have calculate solar opportunity, solar contributions for some Towns in Kosovo. Based on the result, we can conclude that: altogether with a good technological base, creates favorable conditions for the exploitation of solar energy in Kosovo.

The most important benefit of renewable energy systems is the decrease in environmental pollution. This is achieved by the reduction of air emissions due to the substitution of electricity and conventional fuels.

The most important effects of air pollutants on the human and natural environment are their impact on the public health, agriculture, and on ecosystems.

REFERENCES

[1]. Annual Energy Balance of Republic of Kosovo for the year 2015 Prishtinë, 2014.

[2]. Annual Energy - International Energy Agency (December 19 2008) 2006.

[3]. Bundesministerium für Wirtschaft und Technologie (August 2010) Energie in Deutschland, aktualisierte Ausgabe.

[4]. J. Duffie and W. Beckman, "Solar Engineering of Thermal Processes" 1991.

[5]. IPCC (2007) Climate Change 2007 – The physical science basis, contribution of working group Ito the fourth assessment report of the intergovernmental panel on climate change.

[6]. S. Kalogirou, "Solar energy engineering processes and systems", 2009.

[7]. PVGIS © European Communities, 2001-2012