The calculation of appropriate surfaces for installation of solar thermal collectors and solar panels, case study city of Pristine

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Abstract. In Kosovo participation of renewable resources is very symbolic, most of the generated electricity produced from fossil fuel, a part of the energy comes from the import. Pristina is ranked among the most polluted sites and this is mainly: by transport, old power plants, and fossil fuel use as a heating fuel for winter seasons.

Therefore, the aim of this paper is the use of solar energy knowing that the average sun duration for the city of Pristine is 5.44[h], while the average horizontal irradiation is 3.79[kWh/m²] per day. In this paper, the first step is analyzing and mapping of appropriate surfaces for installation of solar thermal collectors and solar panels.

To realize the demand for sanitary hot water for the city of Pristine, need total gross surface area: **186,084.5** [m^2], for the number of inhabitants 210,282, was taken the total of residential household in Pristine with around 38,289 units, and the average number of people per house 5 occupants.

While to realize the demand for electricity for 38,289 residential household with 5 members, a minimum of 199.1028 [MWp] is required, if we take the panel monocrystalline with 400[Wp], we need a total of 497,757 panels with an area of **981,120.9** [m^2].

It means that to realize the demand: for electricity and sanitary hot water, from solar energy, for the city of Pristina requires total gross surface area **1,167,205.4** [m^2].

Keywords: Renewable Energy, PV, Solar Thermal Energy, Domestic Hot Water, Saving Electricity, CO_2 Reduction.

1 Introduction

Kosovo is landlocked in the central Balkan Peninsula. With its strategic position in the Balkans, it serves as an important link in the connection between central and south Europe, the Adriatic Sea, and Black Sea. With an area of 10,908 [km^2]. it is one of the

smallest countries in Europe. Kosovo lies between latitudes 41°50’58’’and 43°51’42’’N, and longitudes 20°01’30 and 21°48’02 E [9].

Pristine is the capital city, and the biggest city in Kosovo. Located at coordinates 42°40'0" North and 21°10'0"East. The surface of the Municipality of Pristine is about 523 [km^2]. The climate is continental, with cold winters and hot summers, the precipitation average of about 600 mm per year. The average sun duration for the city of Pristine is 5.44[h], while the average horizontal irradiation is 3.79 [kWh/m^2] per day.

The electricity generation capacities in Kosovo are mainly from power plants which account for 90.02% of the installation capacity or 87.36% of the operating capacity, and the rest are hydropower plants and renewable energy sources (hydropower plants, wind farms and photovoltaic panels).

The participation of household customers in the total billed consumption still remains dominant with about 57.06%, in the district of Prishtina the realized consumption is 32% or 1,688,271MWh of the total consumption.

Therefore, the purpose of this paper is to calculate for the city of Prishtina the appropriate surfaces for installation of solar thermal collectors and solar panels, in order to reduce energy demand. It is imperative to try and globalize the use of renewable energy to the maximum we can, the use of solar energy for sanitary heating of water and energy is certainly extremely beneficial to our environment.

2 Mapping of Appropriate Surfaces for Installation of Solar

To estimate how much energy could be generated from the sun on a surface, we first calculate the area to see how many solar panels could be placed on it. There are various rooftop measuring tools online or software which we can use to calculate appropriate surface. In this work we have use AutoCad software which is so accurate to done the measuring, while the recordings were taken from the Geodesy Sector in Pristina.

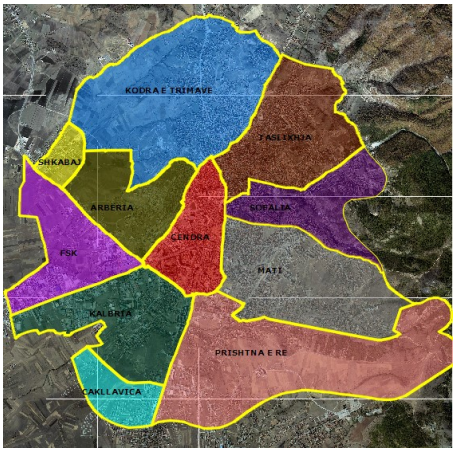

Fig.1. Map of Pristine dived in some area [1].

To analyze the appropriate roof space for solar collector installation, the division of the city into some areas is made, after that we have use AutoCAD software to done the measuring the roof space. The suitable surface is taken the part turned from the south by removing all the part that have possible obstacles on the roof.

In the figure below is presented the city center - dominate the high buildings, multiple residential building, this area includes: the Cathedral, National Library, a part of the University Campus, market, where in these areas is not recommended the application of solar collectors. The appropriate surface for installation of solar collectors is 297403.46m^2, Fig.2.

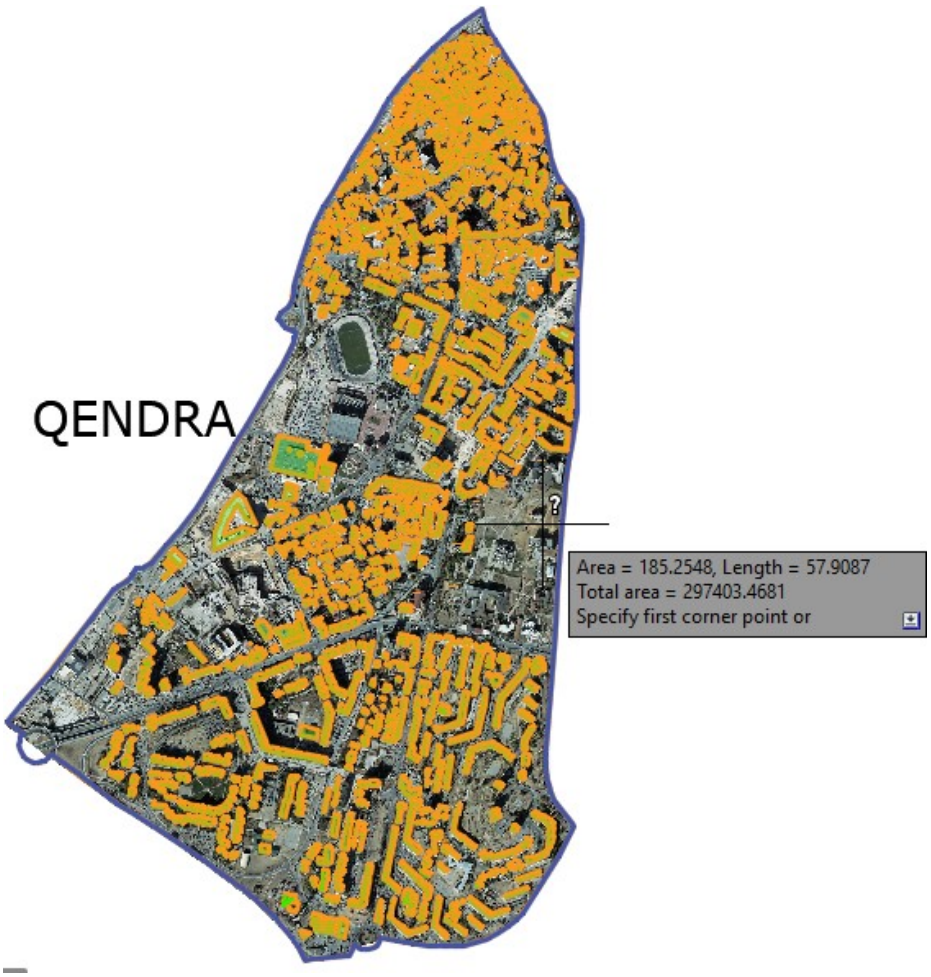

Fig. 2. The Mapping roof surfaces in city center of Pristine

In the same way is calculated the appropriate area for all parts of city, the results are presented in the table below.

Table 1. Appropriate surface

Locaion	$[m^2]$
New Pristine	86957.54
Taskixhe	340393.562
Shkabaj	17041.61
Mati	295747.7
Arbëria	126272.42
Sofali	129128.352
KSF Zonë	32249.95
Çagllavica	47511.0034
Kalabria	103484.204
Kodra e trimava	305276.95
The city center	297403.46
Total	**1781467**

From the table, we can be seen that the appropriate surface of calculated is 1,781,467 $[m^2]$. For additional accuracy when calculating your usable roof area with software the object should be looked at closely to analyze obstacles if they can be eliminated.

3 Annual Solar Thermal Heat Production and Value

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 possess 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.,

Table 1.1 shows values for **latitude**, **longitude**, average monthly and annual temperatures, Insolation, Horizontal Irradiation, and average total radiation on a tilted surface according to estimates by the European Commission, and Hydrometeorological Institute of Kosovo.

Table 2. Calculation for location of Pristina: Latitude - N 42 °39'46, Longitude - E 21°9' 55"

Monthly and yearly average total radiation on a tilted surface $\overline{H}_T$ [kWh/m²]													
Pristine	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Annual**
Daily	3.031	3.857	4.187	4.299	4.646	5.178	5.518	5.467	4.697	3.972	2.937	2.585	4.198
Monthly	93.96	107.99	129.80	128.97	144.01	155.34	171.06	169.48	140.92	123.13	88.12	80.14	1532.93
Horizontal Irradiation [kW·h/m²]													
Daily	1.64	2.44	3.41	4.31	5.24	6.18	6.44	5.70	4.15	2.80	1.75	1.38	3.79
Monthly	50.90	68.44	105.68	129.37	162.60	185.65	199.69	176.83	124.51	87.03	52.68	42.90	1386.32

Insolation [h]													
Daily	2.39	3.41	4.71	5.72	7.12	7.60	9.26	8.71	6.25	4.60	3.37	2.15	5.44
Monthly	74.10	95.70	146.14	171.76	220.3	228.05	287.03	269.95	187.6	142.48	100.89	66.62	165.48
Average 24-hours daily temperatures for every month [^{0} C]													
Average	*-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*

The demand for domestic hot water is calculated for a family with five people. The average of sanitary hot water per person ranges from 30 to 50 liters, in the calculations 40 liters per person is taken, so the number of persons (5) should be multiplied with 40 liters.

$$G = 5 \cdot 40 = 200[l / day] \quad (1)$$

Where:[3]

G=200*[l]* - the volume of the boiler,
T_{min}=12°C - the temperature in the boiler entry (of water supply),
T_{max}=60°C - the temperature at the exit of the boiler,
C_p=1.16[Wh/kgK] - specific capacity of water,
h=0.81 - utilization coefficient [8],
p=2.23[m²] - effective area of the collector [8],
q=4.1[kWh/m²day] - the capacity of sunlight.

$$Q = \frac{G \cdot C_p (T_{max} - T_{min})}{1000} = \frac{200 \cdot 1.16 \cdot (60 - 12)}{1000} = 11.14[kWh / day] \quad (2)$$

Collector area:

$$S = \frac{Q}{q \cdot \eta} = 3.35[m^2] \quad (3)$$

The number of collectors:

$$n = \frac{S}{p} = 2 \text{ collectors.} \quad (4)$$

For this case, we have used TSOL 2018 software, to gained data for: solar fraction, solar contribution, CO2 avoided, collector temperature, financial analysis etc. For simulation the desired DHW temperature is taken 45°C. The schematic of the simulated system is shown in Fig. 3.1.

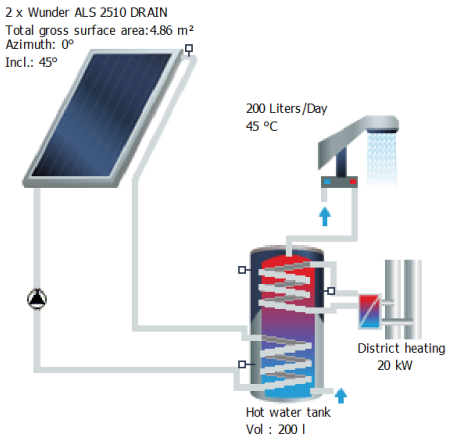

Fig. 3. Schematic of solar system for DHW

It should be noted that the solar panels tilt angle was 45º, the type of collector in our case we have taken **Solimpks Solar Energy Crop [7],**

Type **Wunder ALS 2510 DRAIN**, azimuth angle 0 °. The result we can see in Figure below. The results are presented in Figure below.

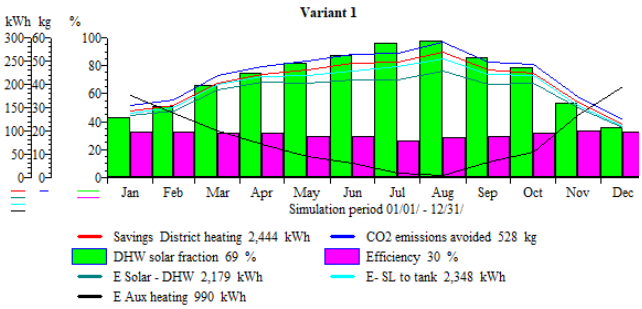

Fig. 4. Annual simulations

Based in this calculation we can conclude that: to realize the demand for sanitary hot water for a residential house with 5 persons need 2 collectors with total active solar surface area 4.86[m²]. The data from the Kosovo Agency of Statistics the number of residential households in Pristine is 38,289[5].

Then, the total suitable surface, to realize the demand with sanitary hot water for Pristina city, is 186,084.5 [m²] with 76,578 collectors.

4 Annual Solar PV Electricity, Production and Value

To estimate how much energy your solar PV project could generate, simply find its location on the map below. In this paper is calculated for house in city of Pristina with Location: Aktash 42°39’26.06’’N, 21° 9’57.03’’E the street “Behije Dashi” that presented in the figure below.

Fig. 5. a) Photovoltaic Power potential,
b) The roof surface which is appropriate for installing solar panels

Relying on the "Net metering" support scheme, this house at the moment that produces more energy than it consumes then injects the surplus into the electricity grid, and when there is cloudy weather or at night this injected energy is compensated.

Based on our data, for an average family with 5 persons, require minimum 5.2kWp, with number of PV Modules 13 and PV Generator surface 25.6 m^2 and one Inverter.

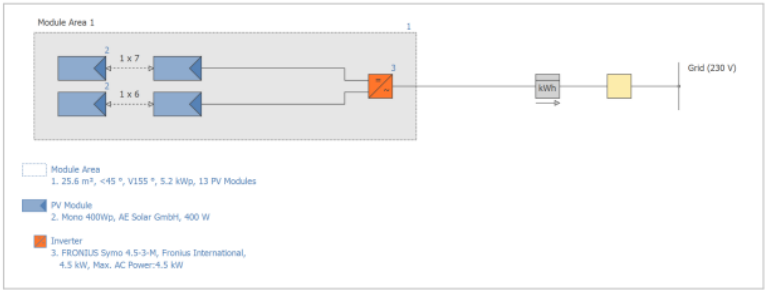

Fig 6. Schematic of PV solar system[10]

To supply with electricity all of residential households in Pristine, the number for residential house is 38, 289.

Table 3.

Parameters	A house	All of residential house
PV Generator Power AC grid [kWh]	5253	201 132 117
Annual Yield [kWh/kWp]	1010.12	38 676 484 .68
CO_2 Emissions avoided[kg/year]	3145	120 418 905
Number of PV Modules	13	497 757
PV Generator Surface [m^2]	25.6	981 120.9

The house presented above is connected to the 0.4kV line. In the tariff group 4/02. In this tariff group we have, high tariff in which the price per kWh is 0.0675 €, while the low tariff per kWh is 0.0289 €. By multiplying the electricity that could be generated annually (5253 kWh) by the value of that electricity (0.0675 € per kWh), we estimate that we could reduce the electricity bill by roughly € 354.5775 per year.

5 Conclusion

The goal of the paper is to enable to provide information regarding the application of solar energy, case study for the city of Prishtina.

To locate suitable locations for the installation of solar collectors serving sanitary hot water, and PV panels for electricity, for 38289 residential house the first step is to

divide the city in some areas, and after that, to calculate appropriate roof space the software AutoCAD is used.

- Appropriate surface for the city is 1781467 m^2.
  - The total suitable surface, to realize the demand with sanitary hot water for Pristina city, is 186084.5 [m²] with 76578 collectors.
  - The total suitable surface, to realize the demand electricity for Pristina city, is 981120.9[m²] with 497 757 panels.

As a general conclusion it can be suggested that: to provide sanitary hot water and electricity from solar energy for 38289 households in the city of Prishtina requires, space area of 1166282.9 [m2], based on our measurements Pristine have enough roof space for the installation solar systems.

CO_2 Emissions avoided is (69127.5 +120 418 905) [kg/year], that is another very important factor, when it is known that the city of Prishtina has high pollution.

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