MINIMIZING NATURAL GAS CONSUMPTION THROUGH SOLAR WATER HEATING

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ABSTRACT

Natural gas has 43.2 % share in Pakistan's energy-mix, while 18.7 % of the total natural gas is being consumed by the domestic sector. Statistical data shows that over the last ten years gas consumption by the domestic sector has increased from 144 to 232 billion cubic feet. Pakistan is facing extreme shortage of natural gas, especially in winters due to increased demand in domestic sector for space- and water-heating. Utilization of solar energy resource can effectively contribute towards shifting natural gas utilization from domestic to industrial sector of the country. This study helped analyze the quantity of natural gas saved and GHG reduction and economic benefits obtained due to shifting to solar water heating. Results of the study showed that by utilizing single unit of evacuated tube solar water heater in Quetta, 7.7 mmBtu of natural gas can be saved with net present value (NPV) of PKR 243,310 and 10 tones of GHG is saved from entering into the atmosphere.

Keywords: *RETScreen, evacuated tube solar water heater, net present value.*

1. INTRODUCTION

Natural gas is contributing a significant amount to Pakistan's energy mix, and its major portion is utilized in domestic sector (18.7 %). For distribution, domestic sector is being given priority by the government, and its consumption of gas has increased to 232 billion cubic feet. As a result of this, production sector (industry) is suffering greatly, especially in winter season due to excessive utilizations of natural gas for household water heating. Therefore, energy and industry sectors are facing severe gas load shedding. Excessive utilization of fossil fuels to meet increasing energy demands has led to environmental, economic and energy security issues for future regarding these conventional energy resources. Depleting fossil fuel reserves are polluting the environment seriously, as well as causing health problems, reduced life-expectancy and infant mortality (Kampa and Castanas, 2008). Energy sector plays a significant role in this regard as production, distribution and consumption of energy causes environmentally harmful effects. There is, thus, a need to focus on energy resources that are secure, easily available, environmentally favorable and cost-effective.

Geographical location, climatic condition and topography of Pakistan are ideal for utilizing available solar resources that can be conveniently converted using energy conversion technologies. Most parts of the country receives 7.6 hours of sunshine for more than 300 days/year, i.e., 5-7 kWh/(m^2/day) of average solar radiations. These figures indicate that Pakistan is generously blessed in terms of solar potential. This vast solar potential can be utilized beneficially for solar-energy applications, such as solar water heating, photovoltaic, desalination and crop drying (Shaikh, et al., 2013).

Serious energy crisis in the country demand revolutionary steps to be taken with proper planning. In order to improve the economic condition of the country, it is necessary to apportion natural gas for production (industry) and power sectors instead of non-production (domestic) sector. In order to achieve this, some of the domestic hot water demand should be met using solar thermal technologies. Although due to shortage of gas supply and decrease in the price of solar-water heaters, there installations are increasing, but there is still a need for a significant increase.

In this research, RETScreen software was used to analyze the quantity of natural gas saved by using evacuated tube solar water heater in Quetta city. RETScreen software has good research penetration (Connolly, et al., 2010) and researchers have investigated its features in details (Lee, et al., 2012; Markovic, et al., 2011). RETScreen software has been extensively utilized for the analysis of renewable energy technologies in different parts of world (Harder and Gibson, 2011; Thompson and Duggirala, 2009). Literature endorses successful utilization of RETScreen in solar thermal technology as well (Gastli and Charabi, 2011; Stevanovic and Pucar, 2012).

2. CASE STUDY

In order to study the advantages of solar water heating in Quetta city of Pakistan was selected as the target area for research. The annual average daily air temperature of Quetta city is 15.7°C, which is relatively lower than that of many other major cities of the country (Karachi, Hyderabad, Lahore, Multan, Peshawar and Islamabad). This annual average daily air temperature indicates that Quetta has greater heating demand than other cities because of large temperature difference between ambient and required water temperature.

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Figure-1: Pakistan Map Indicating the Position of the Selected City

Table-1: Climatic Conditions of Quetta City

Months	Air temperature (°C)	Relative humidity (%)	Wind speed (m/s)	Earth temperature (°C)
January	3.7	56.0	4.3	6.5
February	6.0	47.5	4.6	9.2
March	11.1	37.7	4.6	15.6
April	16.6	26.1	4.5	23.6
May	21.0	18.4	5.0	29.5
June	25.6	21.0	4.7	33.8
July	27.9	38.3	4.4	34.0
August	26.4	41.9	4.2	32.1
September	21.1	24.4	4.4	28.9
October	14.6	20.3	4.6	21.5
November	9.2	28.1	4.2	14.5
December	5.1	44.5	4.3	8.7

2.1 Climatic Data

Quetta city lies on 30°15'N latitude and 66°55'E longitude, and is the Provincial Capital and largest city of Balochistan Province of Pakistan. The population of the city is around 865,125. Location of Quetta city on Pakistan's map is shown in Figure-1. The detailed analysis of the weather of Quetta city is made from RETScreen software's climate data section (Table-1). The software has unique assistance of obtaining data from ground monitoring stations, as well as NASA's satellite database. The monthly variations of annual daily average solar radiations on horizontal and tilted surfaces are shown in Figure-2.

The temperature data showed that monthly average values of air temperature varied from minimum 3.7°C to a maximum value of 27.9°C; the low annual average values indicated the severity of heating requirement; while the high solar-radiation values indicated good potential for solar energy technologies.

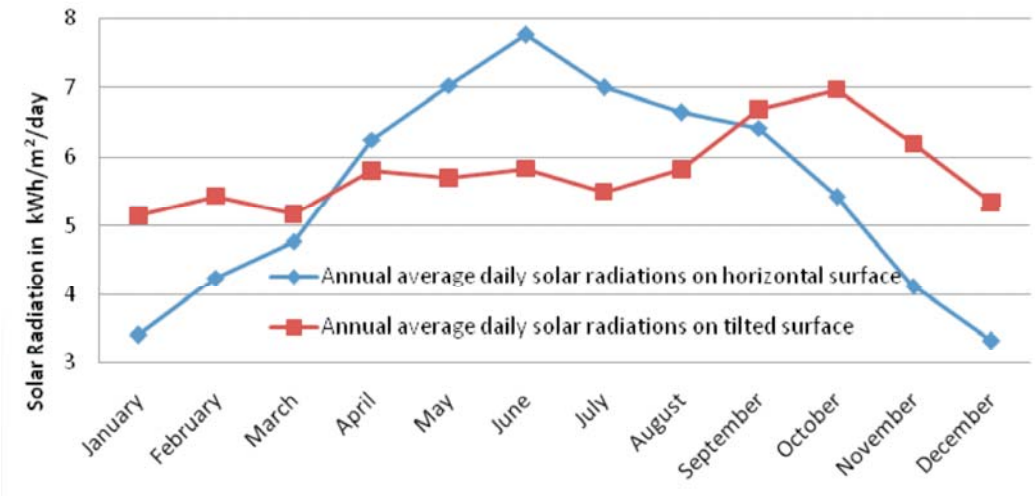

Figure-2 : Annual Average Daily Solar Radiations on Horizontal and Tilted Surfaces

Table-2: Parameter Used in the RETScreen Software

Parameters	Value
Occupants	6
Daily hot water usage (L/day)	300
Hot water temperature (°C)	50
Solar water heater	
Type	Evacuated
Gross area per solar collector (m^2)	1.68
Aperture area per solar collector (m^2)	1.49
Number of collectors	3
Capacity (kW)	3.12
Miscellaneous losses (%)	3
Balance of system & miscellaneous	
Storage capacity per square meter (L/m^2)	75
Fuel type	Natural gas
Financial parameters	
Project life	25 yr

2.2 Software Parameters

RETScreen software has special importance for renewable as well as for solar thermal applications. The software provided comprehensive analysis schemes in a user friendly manner with higher degree of accuracy.

The case study utilizes typical family of 6 members for analysis. In order to ensure hot-water availability, solar water heating system always uses some back up. For this case study, natural gas heating system (natural gas geyser) was taken as backup. The parameters for basic scenario are listed in Table-2.

3. RESULTS AND DISCUSSION

Under this case study, analysis was made as to how much benefits, in terms of saving natural gas units, and net GHG reductions, would be obtained by utilizing evacuated tube solar water heater for a household having a family size of 6 persons. RETScreen had been previously utilized for economic analysis of solar water heating (SWH) projects (Houri, 2006; Fantidis, et al., 2012).

These analyses involved calculations of conventionally utilized natural gas geyser system (base case) compared to solar water heating unit (proposed case). The RETScreen advance energy

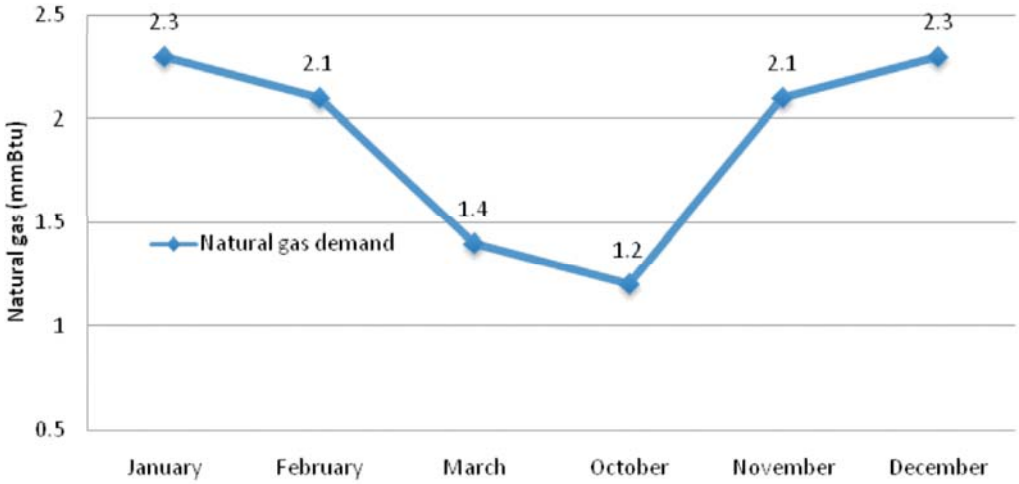

Figure-3 : Natural Gas Demand in Different Months of Winter Season

Table-3: RETScreen Simulation Results

Sr. No	Parameter	Value
1	Solar fraction	67 %
2	NPV	PKR 243,310
3	Equity Pay Back	8.2 Years
4	IRR	15.6 %
5	Gas consumption units (Geyser)	11.4
6	Gas consumption units(SWH)	3.7 mmBtu
7	Net GHG reductions	10 tCO_2

simulations, show the heating energy load for different months of winter season Figure-3. It can be seen that have heating requirements are maximum in December and January, as air temperature is minimum in these months (Table-1); while heating requirements are minimum for the month of October, where air temperature is maximum among selected months of the winter season. Table-3 shows that if natural gas based geyser is replaced with evacuated tube solar water heater, the gas consumption reduces from 11.4 mmBtu to 3.7 mmBtu, and 7.7 mmBtu of natural gas can be saved. It must be noted that if the number of panels are increased the proposed case heating can be reduced. This may not be beneficial in terms of economic parameters and will cause problems in cloudy days when sufficient solar energy is not available and uneven load (extra persons). Figure-2 indicates that our annual heating cost decreases from PKR 6,273 to PKR 2,048 by using solar water heaters. Solar fraction covered by a solar water heater is 67 %, as given in Table-3. The net present value (NPV) of solar water heating unit, internal rate of return (IRR), equity pay back and net GHG reductions are given in Table-3.

These figures show that utilizing a solar water heater is an attractive option to be considered for Pakistan, especially in current situation where natural gas prices have spiked.

3. CONCLUSION

The study investigated a practical solution to overcome the shortfalls of natural gas, which is major energy resource in Pakistan's energy mix. Using the RETScreen software advance energy simulations analysis for typical evacuated tube collector in Quetta, it was found that evacuated tube collector utilization is beneficial in Quetta. If a typical family of six members used evacuated tube collector, it can save more than 7.7 mmBtu of natural gas annually with NPV of PKR 243,310. Moreover, the evacuated tube collector covers 67 % of the total water heating demand.

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