

COMPARING ECONOMIC FEASIBILITY OF DOMESTIC SOLAR WATER HEATER INSTALLATION IN MAJOR CITIES OF PAKISTAN

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ABSTRACT

Adequate and consistent energy supply is often regarded as a major factor in the development of any country. To add to this, the depletion of fossil fuels has also emphasised the need for alternate renewable energy solutions to meet global energy needs without inflicting any serious environmental impacts. Solar energy is globally acknowledged for its vast potential, as a source of providing most of the heating, cooling and electricity needs of the world. One of the most effective uses of solar energy is water heating. The use of solar energy to heat water has been proven to be a very economical, efficient and environmental friendly option for domestic as well as commercial applications. This study compares the feasibility of domestic solar water heater installation in three major cities of Pakistan i.e. Lahore, Karachi and Peshawar. The results show the solar water heater installation is most feasible in Peshawar, among the three selected cities.

KEYWORDS

Renewable, energy, solar, heating, simulation

1. INTRODUCTION

Adequate and consistent energy supply is often regarded as a major factor in the development of any country. It is therefore, extremely important to slowly move away from the vulnerable energy resources and towards sustainable energy resources like solar, wind, biomass etc.

The depletion of fossil fuels has emphasised the need for alternate renewable energy solutions to meet global energy needs without inflicting any serious environmental impacts. The only viable solution to this issue is the transition towards renewable energy sources which definitely holds the potential to meet global energy requirements in a sustainable way.

Solar energy is globally acknowledged for its vast potential, as a source of providing most of the heating, cooling and electricity needs of the world. One of the most effective uses of solar energy is water heating. The use of solar energy to heat water has been proven to be a very economical, efficient and environmental friendly option for domestic as well as commercial applications. In many regions, solar water heaters have been found to be capable to meeting up to two-thirds of the total hot water requirements and hence considerably reducing the energy cost as well as the associated environmental impacts. The efficiency and reliability of solar water heating systems have significantly increased over the last three decades while the cost has come down. The factors like advancement in designs and materials have especially contributed in rapid increase in the global use of domestic solar water heaters, during the last ten years. [1].

The present work aims to compare the feasibility of domestic solar water heater installation in three major cities of Pakistan i.e. Lahore, Karachi and Peshawar. RETScreen simulation tool has been used for the purpose of analysis and the following aspects have been compared for the three selected cities:

1. Possible extent of reliance on Solar Water Heater
2. Suitable backup
3. Natural gas savings
4. Payback period
5. Internal rate of return
6. Net present value
7. Risk Analysis

2. LITERATURE REVIEW

Solar water heaters are normally made up of collectors, storage tanks, and, depending on the system, electric pumps. There are three basic types of collectors: flat plate, evacuated-tube, and concentrating. On the basis of water circulation systems, classification is done as active and passive solar water heater. The active heaters are those having electric pumps to circulate the water while the passive ones do not have any such machinery involved. The most common type of solar collectors i.e. flat plate collectors are also divided into two types; thermosyphon and built-in-storage. Among these, the built-in-storage solar water heaters are more popular, mainly because of [2]:

1. Higher efficiency- which results from the fact that firstly, the water flow through the pipes incurs no heat losses and secondly, there is no loss of efficiency unlike in case of thermosyphon system where poor bond conductance between the tubes and plate causes the loss in efficiency.
2. Compact structure- which presents a relatively more aesthetically pleasing look than the thermosyphon system.
3. Cost effectiveness- which is due to the simpler design and less parts involved in built-in-storage heaters.

Ever since their invention, significant research and development has been witnessed in solar water heating technology. Samara Sadrin et al [3] presented an innovative automated design of solar water heating system which would keep supplying hot water until the temperature of water inside the storage tank stayed above a certain, pre-determined level. When the water temperature fell below the pre-set level, the backup electric water heater system would start working for meeting the hot water demands of the users. P. Rhushi Prasad et al [4] conducted experimental analysis of flat plate collector and compared the performance with tracking collector. Experiments were conducted for a week during which the atmospheric conditions were almost uniform and data was collected both for fixed and tracked conditions of the flat plate collector. For both conditions, the efficiency of the system was calculated. The comparison of the acquired results favoured the use of tracking as the efficiency was 21% higher in that case. Krisztina Uzuneanu et al [5] described optimum tilt angle for solar collectors with low concentration ratio. The performance of solar energy system was analyzed with various tilt angles for compound parabolic collectors CPC with different concentration ratios.

Pakistan has huge demand for water heating in domestic and industrial sectors. It is reported that almost 44% of the total primary energy in Pakistan goes into domestic sector. Hot water also

accounts for a considerable chunk of energy consumed in domestic sector. Similarly industrial sector also demands an enormous amount of hot water and the current practice of using fuel to heat water substantially increases the overall cost of the industrial processes. The local textile industry has been the backbone of Pakistan's economy. It contributes more than 60% to the total export earnings of the country, accounts for 46% of the total manufacturing and provides employment to 38% of the manufacturing labour force. According to estimates, water heating is responsible for around 70% of the overall energy consumption in textile industries [6].

3. METHODOLOGY

This study involves the feasibility comparison of solar water heater installation in three major cities of Pakistan i.e. Karachi, Peshawar and Lahore. For the purpose of this research, solar hot water system was designed for a family of six with base case as gas geyser, to fulfil the hot water requirements during winter season, which was 60% efficient. The hot water consumption was taken to be ~50 litre per person per day at the temperature of 60°C. Vacuum tube solar water heater was used for comparison, while the roof area was taken to be 80 m² with the useable roof space allowed for solar water heating system to be 25m². The average cost of electricity and natural gas was taken to be 13 and 550 Rs. per unit, respectively. Reasonable assumptions were made for other factors, for the purpose of simulation.

The method 2 of the RETScreen tool was used for assessing the economical and environmental implications of installing domestic solar water heater in Karachi, Peshawar and Hyderabad. RETScreen is a freeware tool that was created by the Natural Resources Canada, Government of Canada for the techno-economic analysis of renewable energy and energy efficiency projects. It is a validated software and its results have proven to be within 6% of actual values.

The following aspects were compared for the three selected cities:

1. Possible extent of reliance on Solar Water Heater
2. Suitable backup
3. Natural gas savings
4. Payback period
5. Internal rate of return
6. Net present value
7. Risk Analysis

4. RESULTS AND DISCUSSION

4.1. Possible extent of reliance on Solar Water Heater and suitable backup

The proportion of solar water heating versus the backup heating depends on the factors like available space for solar water heater, financial constraints, type of solar water heating system used, number of collectors etc. In the given case for three cities of Pakistan, the results of RETSCREEN calculation suggest the following proportion of solar and backup fraction for water heating:

Table 1. Available solar fraction for each city

City	Solar Fraction (%)	Backup Needed (%)
Lahore	90	10
Karachi	100	0
Peshawar	96	4

Therefore, the SWH system in Lahore needs 10% of the total heating demand to be fulfilled by a backup system, SWH system in Peshawar needs 4 % while there is no need for any backup system for the same SWH system in Karachi, which shows the possibility of total reliance on SWH system in Karachi.

Regarding the backup options of Natural gas or Electricity, the analysis based on RETSCREEN calculations is as follows:

Table 2. Analysis of suitable backup option for each city.

<i>City</i>	<i>Proposed Backup Type</i>	<i>Annual cost savings (PKR)</i>	<i>Annual life cycle savings (PKR/yr)</i>	<i>Suggested Backup on the basis of annual cost and life cycle savings</i>
Lahore	Natural gas	5972	5481	Natural Gas
	Electricity	2123	-2,237	
Karachi	Natural gas	5,888	N/A	
	Electricity	5,888		
Peshawar	Natural gas	6621	6,783	Natural Gas
	Electricity	4783	3,099	

Considering the Annual fuel savings, Annual cost savings and Annual life cycle savings, the above given analysis suggests Natural gas to be the backup for left over fraction for water heating in Lahore and Peshawar. The system of same specifications in Karachi needs no backup as the available solar fraction in this case is 100%.

4.2. Natural gas savings in proposed case compared to the base case

The following table compares the natural gas savings from proposed SWH system installation in Lahore, Karachi and Peshawar.

Table 3. Comparison of Natural gas savings

<i>City</i>	Base Case Annual Natural gas (mmBTU)	Proposed Case Annual Natural gas (mmBTU)	Natural gas savings (mmBTU)
<i>Lahore</i>	12	1.2	10.8
<i>Karachi</i>	11.2	0.0	11.2
<i>Peshawar</i>	12.6	0.6	12.0

The results show that among the three cities, the SWH system installation in Peshawar gives the maximum amount on natural gas savings.

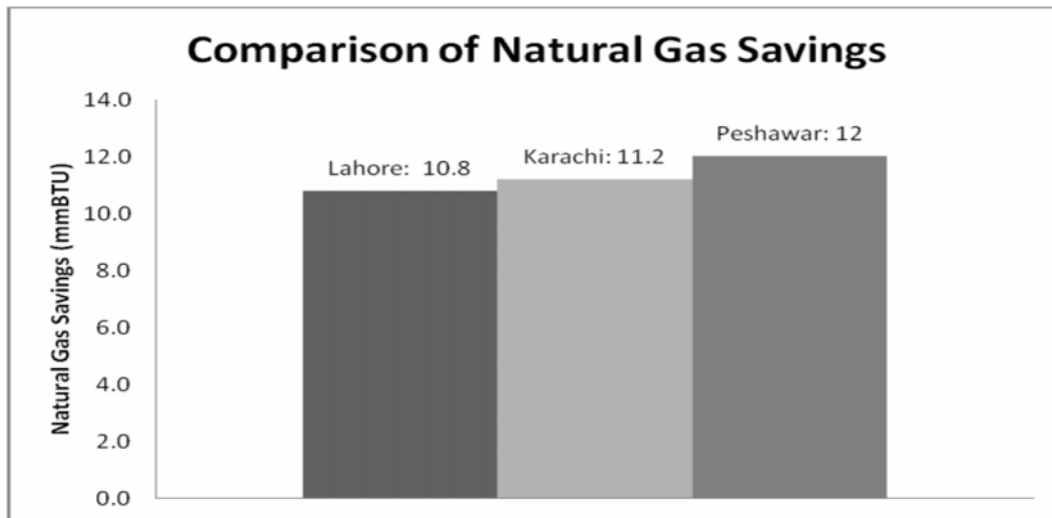


Figure 1. Comparison of Natural gas savings

4.3. Payback period

The following graph shows a comparison between the simple payback period of a SWH system, installed in Lahore, Karachi and Peshawar. The comparison shows that the SWH system installed in Peshawar is most feasible since it gives the shortest simple payback period among the three cities considered.

Similarly, the comparison between the equity payback period also shows that the SWH system installed in Peshawar is most feasible as it gives the shortest equity payback period.

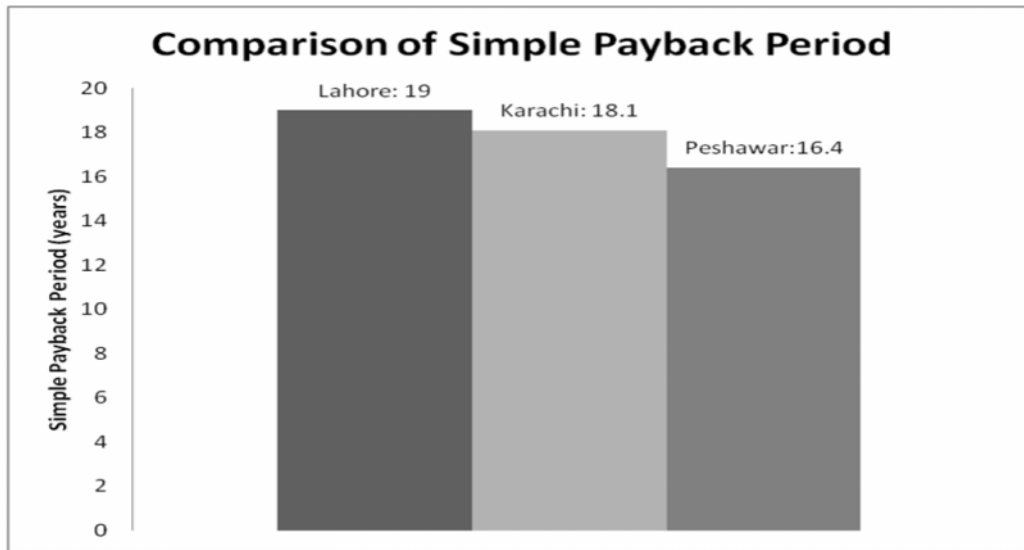


Figure 2. Comparison of simple payback period

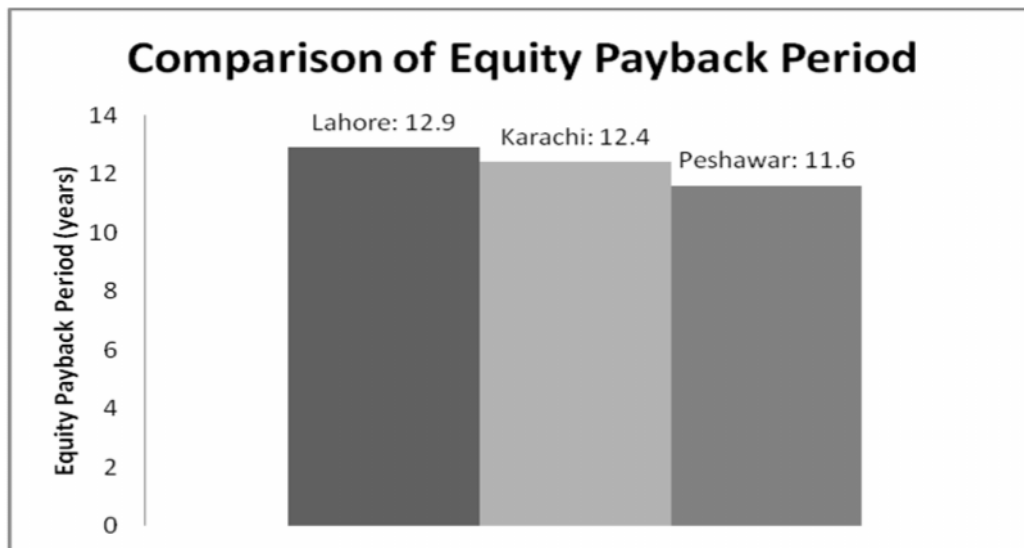


Figure 3. Comparison of equity payback period

4.4. Internal rate of return, Net present value

The comparison between the IRR depicts that the SWH system installed in Peshawar gives the highest IRR among the three cities considered and hence is most feasible.

Similarly, the comparison between the Net present value (NPV) of the proposed SWH system also shows that the SWH system installed in Peshawar is most cost effective since it gives the highest NPV among the three cities considered.

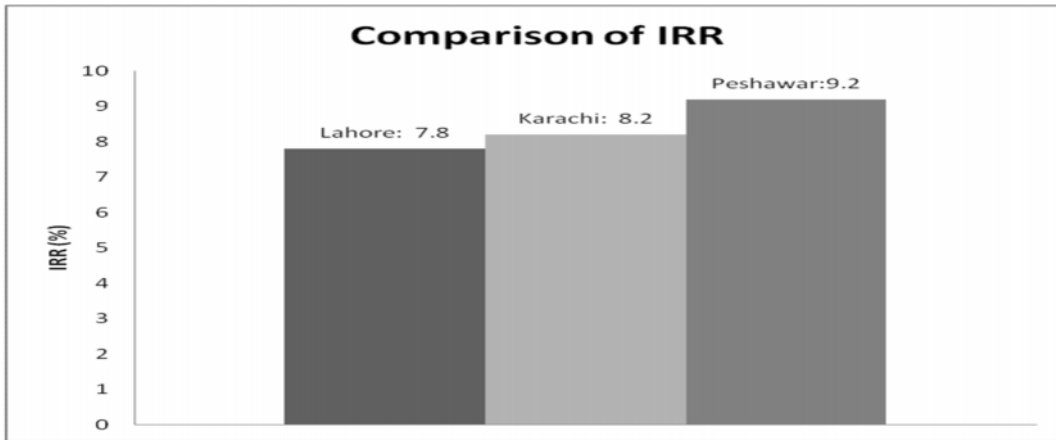


Figure 4. Comparison of IRR

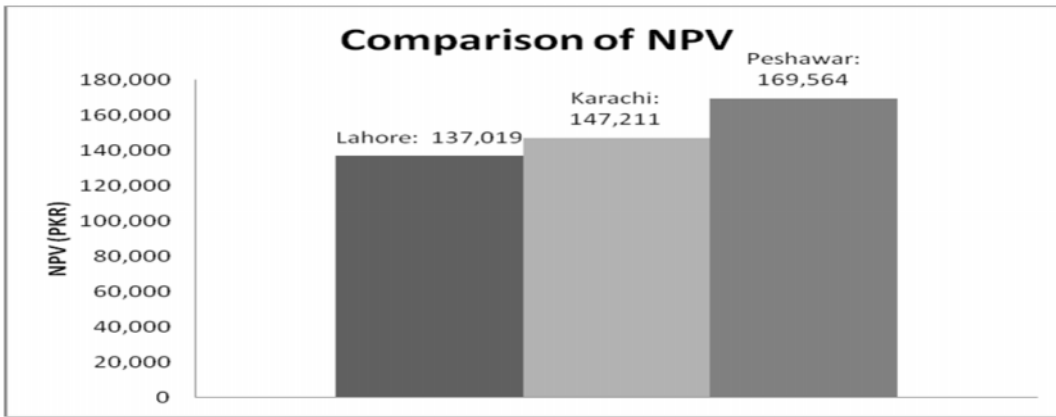


Figure 5. Comparison of NPV

4.5. Sensitivity analysis

At a threshold value of 19 years and sensitivity range of 20%, the following results have been calculated by RETSCREEN for installation of the proposed SWH system in Lahore, Karachi and Peshawar.

For all three cities, the results show that the project is feasible even with deflections up to + -20% in fuel costs and initial costs.

Fuel cost - base case		Initial costs				PKR
		60,507	68,070	75,634	83,197	90,760
PKR		-20%	-10%	0%	10%	20%
5,297	-20%	14.5	15.7	16.8	17.9	18.9
5,959	-10%	12.5	13.6	14.6	15.6	16.5
6,622	0%	10.9	11.9	12.9	13.8	14.7
7,284	10%	9.7	10.7	11.5	12.4	13.2
7,946	20%	8.8	9.6	10.5	11.2	12.0

Figure 6. Sensitivity analysis for SWH project in Lahore

Fuel cost - base case		60,507	Initial costs			PKR
PKR		-20%	68,070	75,634	83,197	90,760
			-10%	0%	10%	20%
4,940	-20%	13.5	14.7	15.8	16.8	17.8
5,558	-10%	11.8	12.9	13.9	14.9	15.8
6,175	0%	10.5	11.5	12.4	13.3	14.2
6,793	10%	9.5	10.4	11.3	12.1	12.9
7,410	20%	8.6	9.5	10.3	11.1	11.8

Figure 7. Sensitivity analysis for SWH project in Karachi

Fuel cost - base case		60,507	Initial costs			PKR
PKR		-20%	68,070	75,634	83,197	90,760
			-10%	0%	10%	20%
5,545	-20%	12.7	13.8	14.8	15.8	16.8
6,238	-10%	12.7	13.8	14.8	15.8	14.8
6,931	0%	9.7	10.7	11.6	12.4	14.8
7,625	10%	8.7	9.6	10.4	11.2	12.0
8,318	20%	7.9	8.7	9.5	10.2	10.9

Figure 8. Sensitivity analysis for SWH project in Peshawar

5. CONCLUSIONS

The RETScreen analysis conducted for the solar water heater installation in three major cities of Pakistan i.e. Karachi, Lahore and Peshawar depicts clear results in favour of Peshawar. All the economic aspects show that the system will be most beneficial, if installed in Peshawar. However if seen individually, the installation is feasible for all three cities.

REFERENCES

- [1] R.A. Jabbar, M. Asif, "Techno-Economical Analysis of Built-in-Storage Solar Water Heating System in Pakistan"
- [2] Annual investment in renewable energy: 1995-2003; Renewable Energy World; February 2005.
- [3] Samara Sadrin, Maherin Hossain, Ehsanul Mohith, "Alternative solar water heater for domestic purpose"
- [4.] P. Rhushi Prasad, H.V. Byregowda, P.B. Gangavati, "Experiment Analysis of Flat Plate Collector and Comparison of Performance with Tracking Collector" European Journal of Scientific Research, ISSN 1450-216X Vol.40 No.1 (2010), pp.144 -155, EuroJournals Publishing, Inc. 2010.
- [5] Krisztina Uzuneanu, Alexandrina Teodoru, Tanase Panait, "Optimum Tilt Angle for Solar Collectors with Low Concentration Ratio"
- [6] Encyclopaedia of energy, Volume 5, Academic press, London, 2004.

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