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Research article

Economic Feasibility of Using SWHs instead of EWHs in Al-Baha Region of KSA

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Abstract

This work addresses the need of the Kingdom of Saudi Arabia to diversify its power, as well as tap the strong potentials of the Renewable Energy Sources in the western mountains (with the highest peak at 2000 m above sea level). In KSA households, water-heating requirements are typically met by Electrical Water Heaters(EWHs). In this study, a study considering the replacement of EWH by SWH in the highlands of Al-Baha region is presented. Analyses demonstrate that heating domestic water via solar thermal energy is simple, reliable, and cost-effective.

The results indicate that the payback period of the proposed suitable size of SWH for each housing unit category(thermosiphon system) is approximately five years, and the cost of fuel to produce energy of EWH that can be saved using SWH is calculated (nearly 2 million USD in year). In addition, this work assessed the environmental impact of using SWH instead of EWH. The annual energy produced by SWH is evaluated(150 GWh). Next, the emissions reduction from power plants due to SWH use is estimated (109393 tCO_2/year), demonstrating the positive environmental impact of SWH. **Copyright © IJSEE, all rights reserved.**

Keywords: Renewable Energy, Electric Water Heater, Solar Water Heater, Energy Conservation, environmental Impact, Gas Emission.

1. INTRODUCTION

The Kingdom of Saudi Arabia (KSA) has nearly one-fifth of the proven oil reserves in the world and is the world's largest producer and exporter of total petroleum products. The reserves of the KSA represent the largest energy amount of crude oil production in the world; in addition, the KSA has demonstrated reserves of natural

gas, being the fifth-largest natural gas producing country in the world, after Russia, Iran, Qatar, and the United States[1-6].
However, the KSA is the largest oil consumer in the Middle East, particularly in the field of transportation fuel and power generation, where the consumption of domestic fuel without controls threaten the position of the Kingdom in the global oil market. Because the economy of the KSA is primarily based on fossil fuels, in particular, the export of oil, the current patterns of energy demand, not only lead to a waste of valuable resources and causing excessive pollution but also make the country vulnerable to economic and social crises. In addition, the domestic consumption of energy may limit its exports of oil within a decade; this situation would have a severe impact on government spending.

The pattern of energy consumption in the KSA is not a sustainable pattern. The pattern is characteristic of high energy consumption, i.e., continued reliance on oil and gas in energy production, as well as the continued dominance of oil in the energy mix.

Energy is one of the key inputs in each of the production processes generating the output of the country and the services that improve people's living standards. Therefore, the need to diversify energy is one of the major energy challenges in Saudi Arabia, to determine the demand for energy and ensure the oil reserves are appropriate for the lucrative export market size. The Kingdom is working to develop alternative sources of energy, including nuclear energy and renewable energy, particularly solar thermal energy. Because the Kingdom has a total area of 2.15 million km^2, including four major geographic areas are the western mountains; and the central highlands, which stretches from the mountains to the centre of the country, desert areas and the coastal region, including the western sector along the Red Sea and the plains of the east coast. The KSA is working in a large-scale cooperation projects in research and development in the field of renewable energy since early in the mid-seventies of the last century.

Many studies[7-8] determined the capabilities of the available solar energy and old data from meteorological stations where the horizontal recording cosmic radiation (GHI) and sunshine duration for the period from 1970 to 1993 were measured, as well as in the atlas of solar radiation to Saudi Arabia. Overall, studies have shown that Saudi Arabia has a vast horizonal area subject to radiation quite suitable for cells photovoltaic (PV) and a large area of direct normal radiation (DNI), which is ideal for generating technologies for solar thermal and concentrated solar power (CSP) as well[9-13].

The KSA has a target to produce nearly half of its capacity from renewable energy sources by 2020 to meet domestic energy needs and free up oil and natural gas for export.

Therefore, this research study is consistent with Saudi Arabia's strategy to diversify its energy sources and pay particular attention to renewable energy sources, such as wind and solar power, because this research project focuses on the use of solar energy, rather than the use of electric energy produced mainly from fossil energy for water heating.

2. COLLECTION OF CLIMATE DATA

The climate in the Al-Baha region is strongly affected by its varying geographic features. In general, the climate is mild with temperatures ranging from 12 to 23 degrees Celsius. Due to its location 2500 meters above sea level, the climate is moderate in Al-Baha in summer and cold in winter. In the Tehama area of the province, which is on the coast, the climate is hot in the summer and warm in the winter. Humidity ranges from 52% to 67%. In contrast, in the mountainous region, which is known as As-Sarah, the weather is cooler in summer and winter. Rainfall in the mountainous region lies in the range of 229 to 581 mm. The average throughout the whole region is 100 to 250 mm annually[14,15].

Climatic data in Al-Baha region has been verified from the following three sources:

1) the weather station in Al-Baha Domestic Airport and World Bank (WB) data,

2) the available data in renewable energy studies software (RetScreen), and

3) data collected during the period of this study of the meteorological station that has been installed in the College of Engineering at Raghadan neighbourhood in the city of Al-Baha.

Few differences were found when comparing data from the three sources mentioned above, as shown in Figures1 and 2.

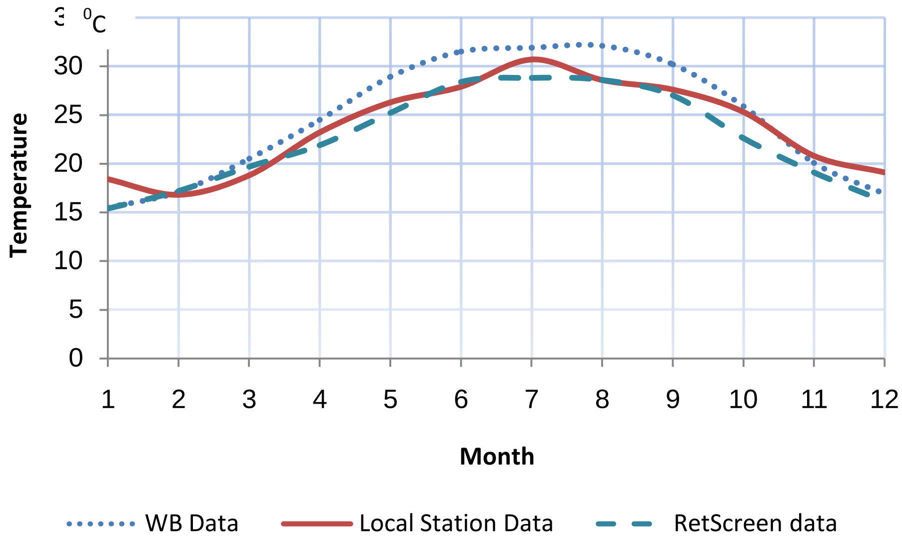

Fig. 1: Temperature in Al-Baha from WB , RetScreen and Local Station Sources

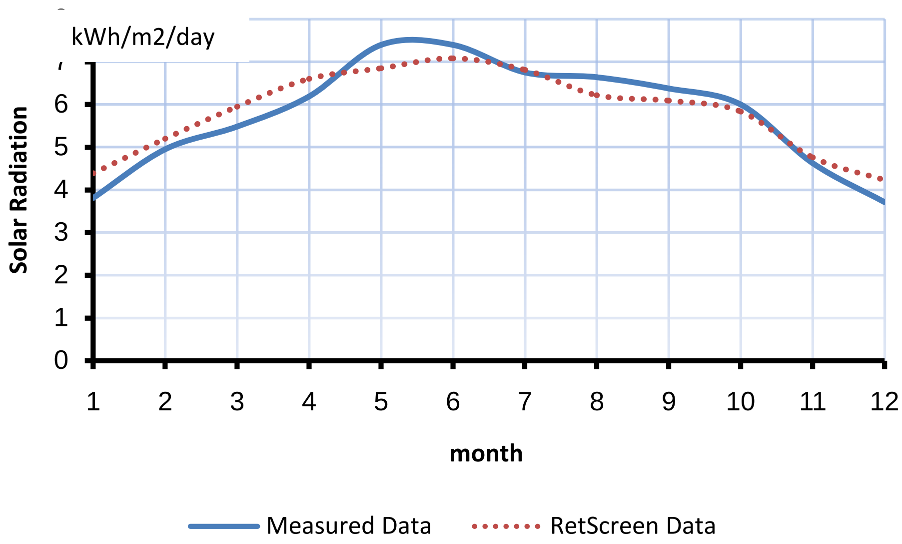

Fig. 2: Daily solar radiation in Al-Baha

The climatic data that were used in this study can be summarised as follows:

• Temperature typically changes during the year from 11 ° C to 35 ° C and rarely less than 7 degrees Celsius or more than 36 degrees Celsius.

• The length of the day varies greatly throughout the year: the shortest day is December 21 (day 10 hours and 54 minutes), and the longest day is June 20 (day 13 hours and 22 minutes).

• On average, cloudy conditions constitute 17% of the time, while most of the time, the sky is either partly cloudy or clear during the year.

• The possibility of rainfall varies throughout the year, with most rainfall occuring in 32% of the days. In addition, the possibility of less rainfall occurs 5% of the days.

• The relative humidity usually ranges from 13% (very dry) to 75% (wet) throughout the year, and rarely falls below 7% (very dry) or exceeds 95% (very wet).

• The dew point usually varies from -2 °C (dry) to 13 °C (very comfortable) and is rarely lower than -7 °C (dry) or above 18 °C (moderate moisture).

• Throughout the year, typical wind speeds vary from 0 m/s to 9 m/s (calm to a comfortable breeze), rarely exceeding 12 m/s (strong breeze). The highest average wind speed 5 m / s, at a time when average daily maximum wind speed is 9 m/s.

• The highest average temperature during the year is 31°C, and the lowest average temperature is 15 °C.

• Daily solar radiation ranges between 4.23 kWh/m^2 /day (minimum value) in December and 7.4 kWh/ m^2 /day (maximum value) in June.

3. ENERGY ESTIMATION OF EWHs CONSUMPTION

3.1 Methodology

Energy consumption of EWHs has been estimated by the following proposed approach:

First, housing units and population at the provincial level and at the level of Al-Baha region were estimated.

Second, housing units are classified to four categories; based on consumed hot water and according to number of installed EWHs in the units and number of habitants. In the first category, there is one EWH that supplies hot water for the kitchen and bathroom in the housing unit with the number of habitants of one or two persons. In the second category, there is one EWH that supplies hot water for the kitchen and bathroom in the housing unit with the number of habitants of three or more persons. In the third category, there are two EWHs in the housing unit: one supplies hot water for the kitchen, and the other supplies hot water for the bathroom. In the fourth category, there are three or more EWHs in the housing unit: one supplies hot water for the kitchen and the others supply hot water for several bathrooms.

Third, power meters are installed in several housing units type in Al-Baha to determine the power consumption of electrical water heaters. The types of housing units are: apartment, a floor in a traditional house, and villa. One or more electrical heaters are installed in each housing unit type, according to the housing units classification used in this study.

Fourth, energy measurements were recorded through the year of this study(2014-2015). Subsequently, the consumed energy by EWHs was calculated.

Fifth, electric energy for each type of housing units was calculated.

Sixth, the total electrical energy that used for domestic water heating in Al-Baha region was estimated.

3.2 Results and Discussion

Based on the above described approach and using the statistical information in [16], the total housing units = 75227, total households = 75490 and total persons = 406724.

Tables1 shows the consumed energy by the EWHs of the first, second, third, and fourth categories, respectively. In the first category, the EWHs consumed 1500 kWh per year on average, representing approximately 22% of the housing unit energy during the year. In the second category, the EWHs consumed 2000 kWh per year on average, representing approximately 32% of the housing unit energy during the year. In the third category the EWHs consumed approximately 2500 kWh per year on average, representing approximately 17% of the housing unit energy during the year. In the fourth category the EWHs consumed approximately 3500 kWh per year on average, representing approximately 22% of the housing unit energy during the year.

Note that the percentage values are affected by heating and cooling of the air inside the housing units during winter and summer, respectively.

Table 1: EWH consumption of all categories

	Monthly Consumed kWh By EWH				Operating hrs of EWH				Monthly Total consumed of the housing unit kWh				% of SWH from Total consumed			
Category	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Spring	120	160	190	260	4	7	7	9	500	500	1000	1000	24	32	20	23
Summer	120	160	190	260	4	6	7	9	600	600	1500	1600	20	27	10	15
autumn	130	200	240	330	5	6	8	1	500	550	1000	1200	26	36	17	22
winter	130	200	240	330	5	8	8	1	650	650	2000	2000	20	31	12	18

From the information of the housing units and the housing units classification, EWHs consumed 150 GWh/year on the level of the Al-Baha region as shown in Table 2. Calculations were performed according to the following sub-approach:

1) Determine the total housing units for each category from [16];

2) Use the average measured kWh/year to calculate the total annual consumed energy per year for each category

3) Sum the total annual consumed energies of all the categories.

Table 2: EWHs energy consumption in the Al-Baha Region

Category	Average consumed kWh/year	No. of housing units	Total consumed kWh/year $*10^6$
First	1500	35320	52.98
Second	2000	23258	46.516
Third	2500	7666	19.165
Fourth	3500	8943	31.3
Total consumed energy by the EWHs			150

4. SUGGESTED SOLAR WATER HEATERS TO USE IN THE AL-BAHA REGION

There are several types of SWHs[17-22] tools and techniques [23-33] to use along with the collected data and calculated energies in the previous sections in order to select and size SWHs for different load types. In this work, analysis was performed using RETScreen International software[29]. The RETScreen® International Solar Water Heating Model can easily evaluate the energy production, life-cycle costs and greenhouse gas emissions reduction for three basic applications: domestic hot water, industrial process heat and swimming pools (indoor and outdoor), ranging in size from small residential systems to large scale commercial, institutional and industrial systems.

The RETScreen Financial Analysis Model allows the user to input various financial parameters, such as discount rates, and automatically to calculate key financial feasibility indicators, such as internal rate of return, simple payback, and net present value. The model makes the following assumptions:

1. The initial investment year is year 0;
2. The costs and credits are given in year 0 terms, i.e, the inflation rate (or the escalation rate) is applied from year 1 onwards; and
3. The timing of cash flows occurs at the end of the year.

With the straight-line depreciation method, the financial analysis model assumes that the capitalised costs of the project, as specified by the depreciation tax basis, are depreciated with a constant rate over the depreciation period. The portion of initial costs not capitalised is deemed to be expensed during the year of construction, i.e. year 0. In this method, the following basic formulae are used:

$$CCA_0 = C\,(1-\delta) \qquad (1)$$

For year zero, and for subsequent years within the depreciation period:

$$\boldsymbol{CCA_n} = \frac{\boldsymbol{C\delta}}{\boldsymbol{N_d}} \qquad (2)$$

where;
N_d is the user-defined depreciation period in years

$\delta$is the depreciation tax basis used to specify which portion of the initial costs are capitalised and can be depreciated for tax purposes.
C is the total initial cost of the project

The annual CO_2 emission reduction is estimated in the GHG Emission Reduction Analysis worksheet. The reduction $\Delta CO_2$is calculated as follows:

$$\Delta_{CO2} = \left(e_{base} - e_{prop}\right)E_{prop}\left(1 - \lambda_{prop}\right)\left(1 - e_{cr}\right) \qquad (3)$$

where;
e_{base} is the base case GHG emission factor,
e_{prop} is the proposed case GHG emission factor,
E_{prop} is the proposed case annual electricity produced,
λ_{prop} is the fraction of electricity lost in transmission and distribution (T&D) for the proposed case, and
e_{cr} is the GHG emission reduction credit transaction fee.

4.1 Results of Analysis

There are various commercially available domestic size solar water heaters. However, based on the collected climate data for Al-Baha in this study, the thermosiphon systems are sufficient and inexpensive to use in the Al-Baha region. In these types of systems, heated potable water or transfer fluid relies on natural convection to move from the collector to storage. The thermosiphoning effect occurs because the density of water drops with the increase of the temperature. Therefore, by the action of the solar radiation absorbed, the water in the collector is heated and thus expands, thereby becoming less dense; as a result, the heated water rises through the collector and goes into the top of the storage tank[23] as shown in Fig.3.

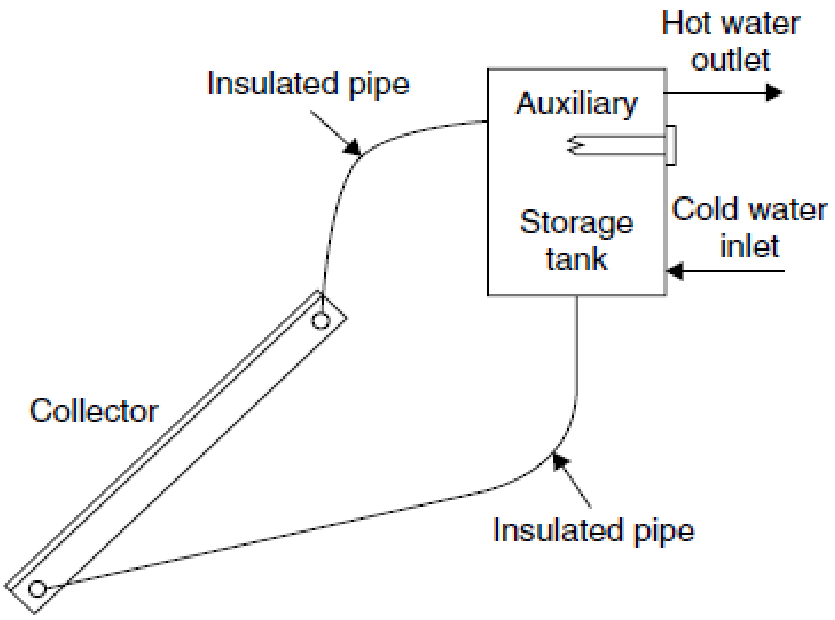

Fig.3: SWH thermosiphon system

To select the suitable size of the SWH for a unit housing, the categories and the climate data of Al-Baha region, the latitude of the Al-Baha region, the slope of solar collector, and the azimuth of solar collector factors should be considered. Accordingly, the suitable SWH size for each category is obtained from RetScreen analysis; the results are summarised in Tables 3. International prices of these SWH types can be estimated according to the storage system tank capacity (4 USD/litre) based on a survey conducted regarding the SWHs cost in this work.

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Table 3: Size of the SWH for the different categories

Occupants,	category	1	2	3	4
	persons	2	4	4	6
Occupancy rate	%	100	100	100	100
Daily hot water use	litre	80	140	200	300
Operating days per week	days	7	7	7	7
Required hot water temperature	C^0	60	60	60	60
Area of the collector	m^2	1	2	3	4
Capacity of SWH Tank	litre	80	150	200	320
Cost	USD	320	560	800	1200
Type of collector	Vacuum tube				

Using the RETScreen Financial Analysis Model, the simple payback was calculated. The model makes the following assumptions:

- The initial investment year is year 0;
- The costs and credits are given in year 0 terms, i.e., the inflation rate (or the escalation rate) is applied from year 1 onwards; and
- The timing of cash flows occurs at the end of the year.

Next, the estimated saved energy was calculated if the EWH was replaced by a SWH, as shown in Table 4.

Table 4: Saved Energy by using a SWH instead of an EWH

Category	Average saved kWh/year/unit	No. of housing units	Total saved on Al-Baha region level kWh/year × 10^6
First	1500	35320	52.98
Second	2000	23258	46.516
Third	2500	7666	19.165
Fourth	3500	8943	31.3
Total saved Energy by using SWHs			150

Next, the cumulative cash flow was calculated, with the following assumptions:

- The SWH life is 15 years
- The cash flows in USD
- A glazed vacuum tubes SWH type is used.
- Residential electricity tariff structure is used, as described in Table 5.

Table 5: Residential electricity tariff structure

KWh	Cost in SR	Cost in USD	Category
1- 2000	0.05	0.0133	1 and 2
2001- 4000	0.1	0.027	3
4001-6000	0.12	0.032	4

Two case studies were conducted: without and with electricity subsides by the Saudi government according to kWh tariff structure described in the Table above for each category. The first case considers the current cost per kWh of energy, where this cost subsidised by the government of the KSA. Fig.4 shows that payback period of categories 1 and 2 are out lifetime of SWH, payback period of categories 3 is 10.3 years and payback period of category 4 is 9.2 years.

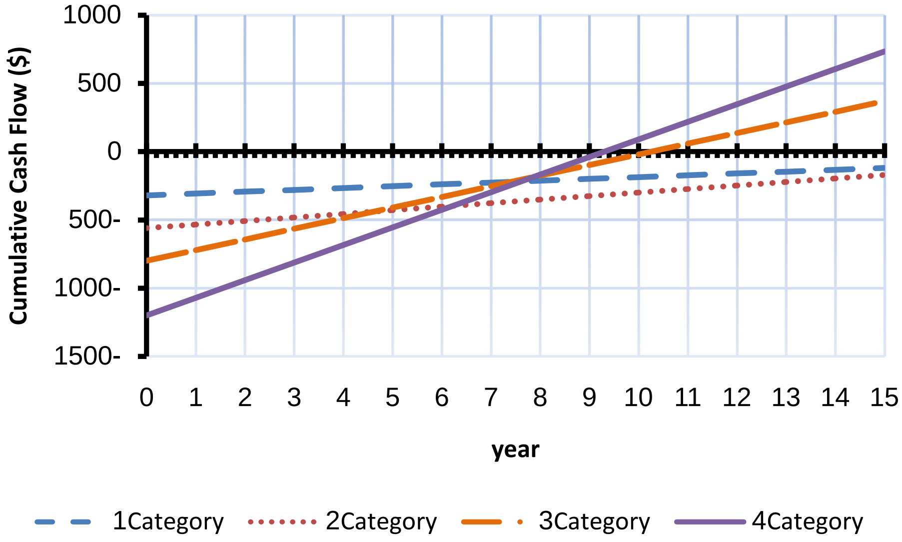

Fig.4: Payback periods of the proposed SWH with subsides of kWh

The second case considers the actual cost of kWh production as 0.056 USD (0.21 SR). Fig.5 shows that payback periods of the four categories are around 5 years.

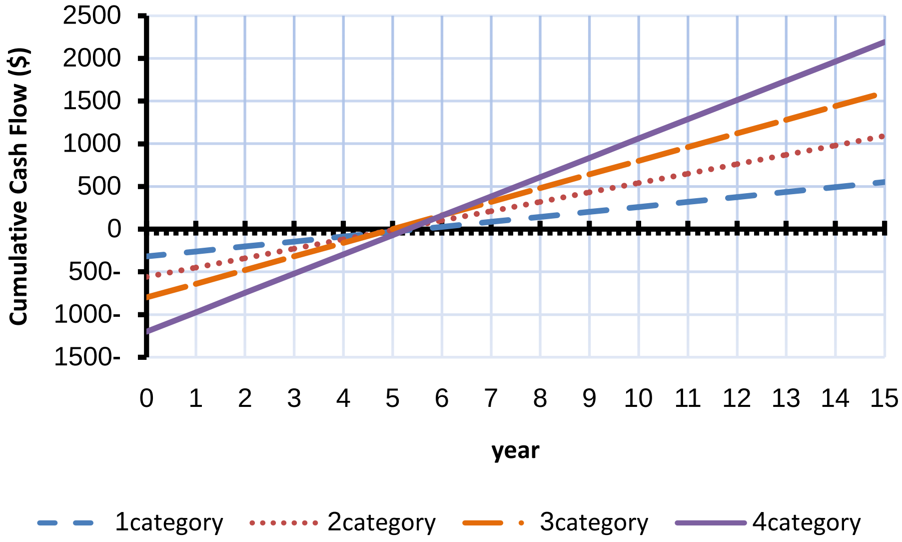

Fig.5: Payback period of the proposed SWH with actual price of kWh

5. ENVIRONMENTAL IMPACT

The principal areas of environmental concern related to electricity generated by thermal PS's would include but are not limited to, the following: water pollution, waste disposal, hazardous air pollutants, ambient air quality, and global climate change. It is well-known that thermal Power Stations (PSs) are considered as a main source of air pollution and greenhouse gases[34]. For developing countries, the environmental impact has lower priority than economic development due to the lack of resources, low income and other reasons given in [35]. Apparently

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wider use of renewable energy sources would lead to less electricity generated by thermal PSs, less gas emission, and higher energy saving in general. Saudi Arabia enjoys high level of solar radiation [36-37]. However, the use of Solar Energy Technologies is very small compared with the potentials. One of these Solar Energy Technologies is water solar heating.

The Highlands, having altitudes of 1500 m above sea level or higher, are situated between 18^0-21^0 latitude (North) and 41.0^0- 44.0^0 longitude. For these areas, the application of water solar heating is very promising, not only due to high solar radiation availability during the year but also due to the perfect match of solar radiation availability and hot water demand cause by the quite cold and usually dry winter in these areas.

Accordingly, by using Retscreen, the energy conservation that could be achieved if SWH is used instead of EWH is calculated. In addition, the fuel savings is calculated. Subsequently, the emission reduction is estimated, which establishes the Environmental Impact of the SWH.

In this work only the impacts of gas emission are considered, i.e., gases discharged by power plants, namely: SO_2, NOx and CO_2. The level and pattern of the impacts is actually dependant on the PS location, type and amount of electrical energy production. Because diesel PS locations are in or close to main cities, their impacts are highly hazardous to public health. This hazard is particularly acute because the Sulphur content in diesel is extremely high and the efficiency of most Diesel PS's is low. The impact of steam PS's may be less hazardous to public health, but their gas emission is greater, resulting in a contribution to the green house effect and ozone problems.

Of course, meeting water heating demand by SWH shall reduce the amount of electricity generated by thermal PS's, thereby reducing gas emissions. To evaluate this impact, RetScreen Model is also used in the analysis, considering the following assumptions:

1) The reference case is the electricity system,

2) The base line emission factor (excl. T&D) equals to 0.755 tCO_2 /MWh,

3) The transmission lines losses equal 3%,

4) Total GHG emission factor equals 0.779 tCO_2 / MWh.

The results in Table 6, shows the CO_2 reduction for each category and the Total CO_2 reduction yearly for Al-Baha region due the use of SWHs instead of EWHs.

Table 6: GHG Reduction due to the use of SWHs in Al-Baha region

Category	Average saved kWh/year	CO_2 Reduction, tCO_2 /year/house	No. of housing units	Total reduction tCO_2/year
First	1500	0.8	35320	28256
Second	2000	1.5	23258	34887
Third	2500	2.3	7666	17632
Fourth	3500	3.2	8943	28618
Total CO_2 reduction/year				**109393**

6. CONCLUSIONS AND RECOMMENDATIONS

Solar Water Heating technologies are simple, reliable, and cost-effective methods of harnessing the sun's energy to address the energy needs of homes and businesses. The payback period of the proposed suitable size of SWH for each housing unit category (thermosiphon system) is approximately five years. The annual energy produced by SWH is (150 GWh). Next, the cost of fuel necessary to meet heating demand is equal to 1950000 USD in year. Further the emissions reduction from power plants due to the use of SWHs is estimated as 109393 tCO_2/year, demonstrating the positive Environmental Impact of the use of SWH.

Having observed the above mentioned results, one may recommend the following:

- It is economically feasible for the household at the current level of electricity tariff to use a SWH instead of an EWH, especially for the group with high-consumption of hot water. However, for households of the first and second categories, the use a solar heater is economically inefficient in the current level of the electricity tariff. If the electricity tariff increases or subsidies for electricity prices are removed, then the use of SWH will be feasible economically for all categories.
- The payback period is notably short compared to other investment projects.
- There is a significant positive economic and environmental impact for SWH use.

7. FURTHER RESEARCH

This work can be considered as an initiative for further research work in this field and can lead to longer-term measurements and observations, including other hot water consumers, e.g., hospitals, hotels, and student hostels. Further research should cover other consumers of hot water, and long-term measurement should be performed. One should expect further reduction of emissions and fuel savings when using SWHs instead of EWHs.

8. AKNOWLEDGMENTS

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8. REFERENCES

[1]. U.S. Energy Information Administration (eia), February 26, 2013.

[2]. The Organization of the Petroleum Exporting Countries(OPEC)'s Annual Statistical Bulletin, 2012.

[3]. Saudi Aramco, US Energy Information Administration's annual Review, eia, 2011

[4] Glada Lahn and Paul Stevens "Burning Oil to Keep Cool -The Hidden Energy Crisis in Saudi Arabia" ,Chatham House, December 2011.

[5] Karen Frenken (ed.), " Irrigation in the Middle East Region in Figures, AQUASTAT Survey- 2008, FAQ Land and Water Division, KSA Chapter, 325-337., 2008.

[6] Imen Jeridi Bachellerie," Renewable Energy in the GCC Countries- Resources, Potential, and Prospects ", the Gulf Research Center ,2012.

[7] S.M. Shaahid and M.A. Elhadidy," Technical and Economic Assessment of Grid-Independent Hybrid Photovoltaic-Diesel-Battery Power Systems for Commercial loads in Desert Environment," Renewable and Sustainable Energy Reviews 11, 1794-1810. ,2007

[8] Geman Aerospace Center(DLR), Concentrating Solar Power,56-57, and W.E. Alnaser and N.W.Alnaser,"Solar and Wind Energy potentials in GCC Countries and Some related projects", Journal of Renewable Sustainable Energy(2009).

[9] IEA: CO2 Emissions from Fuel Combustion – Highlights, 2012.

[10] UNFCCC: Arab National Communication Reports, 2012.

[11] Abdel Gelil et al. “Energy in Arab Environment. : Green Economy ‐Sustainable Transition in a Changing Arab World”; Arab Forum for Environment and Development (AFED), Beirut, Lebanon, 2011.

[12] IHS global insight daily analysis, “Mecca to become first Saudi Arabian city to generate electricity from fossil fuel-renewables mix,”, 24 September 2012.

[13] Ibrahim El-Husseini, ...etal," A New Source of Power-The Potential for Renewable Energy in the MENARegion ", booz & Co, March 2010.

[14] World Bank Data Site, produced by the Climate Research Unit (CRU) of University of East Anglia(UEA).

[15]The report " Average Weather for Al-Baha, Saudi Arabia ", https// weatherspark.com

[16] Department of Statistics and Informations - detailed results of General Census of housing and population1431,2010.

[17] AlawajiS.H., "Evaluation of solar energy research and its applications in Saudi Arabia-20 years of experience", Renewable and Sustainable Energy Reviews, 5, pp.59–77. ,2001.

[18] El-shrkawy A. I., "Introduction of solar energy in Saudi Arabia: a case study", Journal of Engineering and Applied Sciences, 1,pp.41-55. ,1981.

[19] Baras A., Bamhair W., AlKhoshi Y., Alodan M., Engel-Cox J.,"Opportunities and challenges of solar energy in Saudi Arabia", World Renewable Energy Forum,14 May. ,2012.

[20] Al-Saleh Y., Upham P., Malik K.,"Renewable Energy Scenarios for the Kingdom of Saudi Arabia", Tyndall Working Paper, 125., 2008.

[21] Baharuddin A, Kamaruzzaman S, Ghoul MA, Othman MY, Zaharim A, Razali AM,"Economics of domestic solar hot water heating systems in Malaysia", European Journal of Scientific Research, 26 (1), pp. 20–8. ,2009.

[22] Chandrasekar B, Kandpal TC.," Solar water heating system in India. Renewable Energy", pp.19–32., 2004.

[23] ASHRAE, "Handbook of HVAC Application", ASHRAE, Atlanta, GA, 2007.

[24] ASHRAE," Handbook of Systems and Equipment", ASHRAE, Atlanta, GA., 2004.

[25] Philibert, C., "The Present and Future Use of Solar Thermal Energy as a Primary Source of Energy", International Energy Agency, Paris, France, 2005.

[26] Mekhilef S, Saidur R, Safari A., "A review on solar energy use in industries", *Renewable and Sustainable Energy Reviews*, 15(4), pp. 1777–90, 2011

[27] Abdelaziz EA, Saidur R, Mekhilef S., "A review on energy saving strategies in industrial sector", *Renewable and Sustainable Energy Reviews,*15(1), pp. 150–68, 2011.

[28]Hazza G., Al-AshwalA.,, "Economical Impact Assessment of Solar Heaters of Household Energy Consumption", *Sana'a University Journal of Science & Technology*, 3 (1), pp. 65-75. , 2006

[29] RETScreen® Software Online User Manual, www.retscreen.net.

[30] Al-Ashwal A., HazzaG., Al-Ashwal N., "Environmental Impact Assessment of Using Solar Heaters Instead of Electrical Heaters in the Highlands of Yemen", *World Renewable Energy Congress IX, Florence, Italy*, 19-25 Aug., 2006.

[31] Mirasgedis, S., Diakoulaki, D., Assimacopoulos, D., "Solar energy and the abatement of atmospheric emissions", *Renewable Energy*,7 (4), pp. 329–338,1996.

[32] Taborianski, V.M., Prado, R.T.A., "Comparative evaluation of the contribution of residential water heating systems to the variation of greenhouse gases stock in the atmosphere", *Building and Environment*, 39 (6), pp. 645–652. ,2004.

[33] Tsillingirides, G., Martinopoulos, G., Kyriakis, N., "Life cycle environmental impact of a thermosiphon domestic solar hot water system in comparison with electrical and gas heating". *Renewable Energy*, 29 (8), pp.1277–1288., 2004.

[34] Bernard E. A. Fisher, "Environmental Impact of Power Generation", The Royal Society of Chemistry, 1999.

[35] P J G Pearson, " Environmental Impacts of Electricity Generated by Developing Countries : Issues, Priorities and Carbon Dioxide Emissions", IEE Proceedings –A Vol. 140, No.1, January,1993.

[36] El-shrkawyA .I ,"Introduction of solar energy in Saudi Arabia: a case study", 1981.

[37] Al-Saleh Y., Upham P., Malik K., "Renewable Energy Scenarios for the Kingdom of Saudi Arabia", Tyndall Working Paper, Journal of Engineering and Applied Sciences, 1,pp.41-55., 2008