Solar water heating system for residential consumers of Islamabad, Pakistan: A cost benefit analysis

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Abstract
The excessive usage of fossil fuels for water heating purposes in Pakistan causes both economic and environmental problems. A potential solution to limit this problem is the increased uptake of SWHS as an alternative source of energy for providing hot water, displacing fossil fuel usage. SWHS are a comparatively modern technology; increased public awareness regarding the benefits attached to it is required to increase its adoption. The economic evaluation of SWHS is an essential assessment to conclude the feasibility of this system that may enhance public awareness of benefits attached to its adoption. This study presents cost benefit analysis of SWHS in residential sector of Islamabad, Pakistan. The results indicate that if SWHS replaces electric power and natural gas for water heating, it can save 430.95 Euro and 67.81 Euro of energy cost per annum per household, respectively. Depending on the initial installation cost of SWHS, the payback period varies from 1.16 to 1.38 years for electric power and 6.95–8.27 years for natural gas powered conventional water heating systems. Similarly, it can save 14.21 MMBtu of natural gas and an electric power of 4163.98 kWh annually which in turn reduces the emission of 2206.9 Kg CO₂, 2.08 Kg SO₂ and 3.75 Kg NOₓ per year.

1. Introduction
Pakistan is facing severe energy challenges in recent years where existing energy resources are not enough to meet the current and future energy demand (Blok et al., 2015). Pakistan’s primary energy supplies are as shown in Fig. 1. 85.2% of the total energy mix of Pakistan is dependent on oil, natural gas and liquid petroleum gas (LPG) that accounts 44.465 million tonnes of oil equivalent (MTOE) of the total primary energy supplies of Pakistan. The second highest contribution in primary energy supplies is from hydroelectricity 9.2% followed by the share of coal 4.5% and nuclear energy 1.1% of total supplies. The total production rate of natural gas in Pakistan is 38.55BCM per year. The relative shares of natural gas consumption by various sectors in Pakistan are as shown in Fig. 2 where it can be noted that the power sector has appeared as the largest consumer of natural gas i.e.34.8%, followed by industries 24.60%, households 16.6%, Fertilizer 15.5%, transport sector (CNG) 4.40%, commercial 3.0%, and cement sector 1.0% (Usama and Ahmed, 2014).

During the last few years, due to the technological development and population growth, electricity consumption has increased enormously in Pakistan. Total electricity generation capacity in Pakistan is 14,056 MW and the average demand is 19,000 MW and the shortfall is between 5000 and 6000 MW in 2017. Unluckily, electricity generation in Pakistan is highly depending on fossil fuels. In FY 2016–17, various fossil fuels, such as crude oil and natural gas contributed to almost of 61% to electricity demand (Pakistan Energy Yearbook, FY. 2016–17). Fig. 3 shows the generation mix of electricity production in fiscal year 2016–17. It is evident that, on average, the household sector has been the largest consumer of electricity in Pakistan, accounting for 45.10% of total electricity consumption, followed by industrial 29.70%, agriculture 11.5%, commercial sector 7.20%, other government sector 6.0%, and streetlights 0.5% as shown in Fig. 4. The highest electricity demand comes from household sector in Pakistan that complicates the power supply system in handling load management during peak hours (Perwez and Sohail, 2014a, b). This complication can be minimised if solar energy that has huge potential in Pakistan, is utilized either fully or partially for some of the household energy requirements. In Pakistan, the average sunshine hours are almost 3000 h s–3300 h s per year and approximately 1 kW of solar irradiance is received for a square meter of its landmass and the same intensity of solar index remains for 6–7 h per day (Wakeel et al., 2017).
There are numerous applications of solar energy where it can be utilized directly by exploiting its thermal properties. Such technologies are comparatively simple to use, have reasonable operational cost, environment friendly and are easy to adopt. These technologies mainly include the application of solar energy for cooking, space heating/cooling, low temperature industrial fluids heating, heating of water for households/commercial applications and drying agricultural products under controlled temperature (Ulfat et al., 2012). Usages of renewable energy sources for space heating, heating of water for households/commercial applications and drying agricultural products under controlled temperature (Ulfat et al., 2012). Usages of renewable energy sources for space heating, heating of water for households/commercial applications and drying agricultural products under controlled temperature (Ulfat et al., 2012). Usages of renewable energy sources for space heating, heating of water for households/commercial applications and drying agricultural products under controlled temperature (Ulfat et al., 2012).

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