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Dissemination of solar water heaters in South Africa

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Abstract
Global concern over a looming energy crisis, water scarcity and man-made climate change are driving a huge demand for clean technologies, which focus on preserving the earth's resources. In South Africa, the economy is very energy-intensive with coal being the main national energy supply. In view of the growing depletion of fossil fuel, it is important for South Africa to adopt a more sustainable energy mix. This study examines the potential for widespread dissemination of solar water heaters (SWHs) in South Africa. Barriers and constraints to market expansion are analyzed to determine strategies for overcoming these barriers. It is found that payback period of a SWH is shorter than the life-span of the system itself, indicating that SWHs are economically viable even with low production cost of electricity and thus represent a profitable investment proposition for end users, manufacturers and distributors. However, the subsidy programs offered by the government of South Africa may not be sufficient to facilitate diffusion. This is attributed to the high initial capital cost of the system and low affordability of the majority of the South Africa population with low income. Alternative financing mechanisms are required.

Keywords: solar water heater, South Africa, subsidy

Introduction

The level of greenhouse gas (GHG) emissions taking place today is staggering and unprecedented. Many scientists, geologists and academics believe that global warming and climate change have indeed reached their tipping point. In particular, the level and momentum of polar ice sheet degradation has stunned scientists. Applications of renewable energy technologies represent an opportunity for systemic change. They have the potential to empower governments and individuals to contribute to mitigate climate change, while at the same time facilitate employment and skill creation. Among the applications, solar water heating is a relatively simple technology which has been around for over fifty years but has demonstrated tremendous potential in reducing the level of GHG emissions. Thus, SWHs are rapidly becoming an integral part of worldwide measures to combat the effects of climate change. In 2008, the total capacity in operation worldwide was 150 683 MW_{th}, which corresponded to 215 262,126 m^2 of solar collector installed (Weiss *et al.*, 2010).

Since South Africa is located in the subtropical belt between latitude 22°S and 34°S, there is abundant sunshine throughout the year. It has one of the highest insolation rates in the world, between 4.5 kWh/m^2 and 6.5 kWh/m^2, and receives about 2 500 hours of sunshine a year (over 300 days of sunshine per year in some provinces) (Munzhedzi *et al.*, 2009). This high level of solar radiation enables solar water heating to be the least-cost method of meeting the national target for increased use of renewable energy technologies. However, it is known that SWHs are more expensive than conventional forms of hot water production by liquefied petroleum gas (LPG), natural gas or electricity. Support mechanisms such as subsidies have the effect of shortening the payback period, which would make the investment more attractive and therefore increase the likelihood of adoption.

This study utilized complementary elements of both desk and field research. Data was acquired through review of literature including journal papers, official publications and websites. In addition, a field survey was conducted using telephone calls followed up by e-mail questionnaires to approximately 20 SWH-related parties in South Africa, including manufacturers such as Suntank (Pty) Ltd, Solar Heat Exchangers cc, Genersys South Africa, Solar Harvest (Pty) Ltd, Kwikot (Pty) Ltd amongst others, as well as governmental and non-governmental institutions such as the Department of Energy, the Central Energy Fund (CEF), the Sustainable Energy Society of South Africa (SESSA) and Eskom. The survey aims to gain an in-depth understanding of barriers to widespread dissemination of SWHs in South Africa. Possible dissemination drivers are also proposed, which would assist policy-makers in formulating effective countermeasures and strategies.

Energy situation in South Africa

The South African economy is very energy-intensive and is dominated by the mining and manufacturing industries. The country uses a large amount of energy for every unit of output, requiring 0.24 tons of oil equivalent to produce US$1 000 of GDP at purchasing power parity. Energy efficiency is thus a crucial part of energy planning. Further, the national energy supply in South Africa has been dominated by coal, which contributes to about 70% of the primary energy supply and 92% of electricity production (Winkler *et al.,* 2006). Between 2002 and 2006, South Africa alone raised its coal production by more than half the world's increase in the equivalent volume or primary energy from other forms of new renewable energy since 1990 (Jefferson, 2008). However, the reliance on coal has resulted in high levels of GHG emission (379 million tons of carbon dioxide equivalent per year, or 8.61 tons per capita) (Banks *et al.,* 2006), making South Africa one of the top 20 GHG emitters in the world. Moreover, Winkler *et al.* (2006) predicted that future energy demand in South Africa will double by the year 2050. This magnitude of expansion in energy demand is neither feasible nor sustainable. The state-owned power utility, Eskom, would no longer have excess capacity it had and is struggling to keep up with peak demand, not to mention the great impact of fossil fuel consumption on the natural environment.

While electricity generated from coal in South Africa is among the cheapest in the world, its accessibility is still a problem for many of its citizens. In 2009, the accessibility was at a high of 91.7% in the Free State (the second smallest province in number of households) and a low of 69.8% in the Eastern Cape (the third largest province in number of households). Note that 13.5% of households also had their electricity cut because of non-payment. In addition, electricity consumption in South African households accounts for approximately 35% of peak demand with hot water production constituting 40% of that (Lumba *et al.,* 2010). To alleviate the burden on the national grid, Eskom launched a Demand Side Management Program in 2006. This program, which is to facilitate a more sustainable energy mix, focuses on reducing electricity demand by 3 000 MW by 2012, and a further 5 000 MW by 2025.

National policy of South Africa on SWHs

The government's White Paper on Renewable Energy Policy (2003) has supported the establishment of renewable energy technologies, targeting the provision of 10 000 GWh of electricity (or 4% of projected electricity demand) from renewable resources by 2013. SWHs could contribute up to 23% of this target. Note that currently less than 1% of electricity generated in the country originates from renewable energy technologies (Visagie *et al.,* 2006). According to the latest report by the International Energy Agency (IEA), Weiss *et al.* (2010) mentioned that the total collector area installed and operating in South Africa was 975 360 m^2 by the end of 2008 and the total capacity of all these systems combined was 682.8 MW_{th}.

It is considered that the delivery of SWHs could potentially reduce the overall national energy demand and the load at critical peak times of the day in South Africa. The SWH industry, however, is faced with constraints in terms of standardization, awareness, affordability and financing which impede widespread dissemination. In particular, the high upfront capital cost of a system is of great concerns. Thus, there is a significant body of knowledge in both industry and academia to support the modelling and development of SWHs in South Africa. In 2003, SolaSure (the solar water heating division, SESSA) was established for the delivery of services in the SWH industry. Several task groups were initiated to address the following: (1) quality control and testing; (2) standards and testing facilities/procedures; (3) marketing and membership; (4) interaction with Eskom; (5) research and development; and (6) interaction with international bodies (Visagie *et al.,* 2006). The CEF also assisted SolaSure in executing these tasks. Some initiatives were made to develop the skill base of the industry. These included in-house training by individual companies and Eskom, and national programs granted by the Energy Sector Education and

Training Authority (ESETA).

Since SWHs have considerable potential to leverage electricity savings and reduce GHG emissions, some promotion programs were initiated by some local governments, such as the Kuyasa low-cost housing project, the Johannesburg Climate Legacy SWH project at Oude Molen, and the Driftsands SWH housing project (Visagie *et al.,* 2006). Further, Eskom has granted rebates of up to 30% (the maximum incentive amount at ZAR 5 000) on accredited systems since 2008. Under the current initiative, each system is measured and allocated an amount of rebate calculated according to the energy footprint measured by the South African Bureau of Standards (SABS). To receive rebates, homeowners must take delivery of systems by official Eskom suppliers. To become an official Eskom supplier one must offer a five-year guarantee, have a proven track record of viability, a certificate from the SABS and a membership with SESSA. It is noted the application process still foresees to have the customer pay the full cost of the system upfront and claim the rebate thereafter. In 2010, Eskom announced an increase in rebates for high-pressure solar thermal systems. The aim of this new program is to encourage as many South Africans as possible to move away from electric geysers (4.2 million in the country), and replace them with SWHs (76 873 operating units in 2009). Residential homeowners or tenants could be granted a cash rebate of up to ZAR 12 500. This would make SWHs more affordable to consumers, particularly for the rapid emergence of a non-white middle class.

SWH market

A questionnaire survey was conducted by Eskom (2009). It intended to gather technical, financial and operational information about the SWH industry in South Africa. Although there are over 100 suppliers in SESSA, only 39 suppliers gave some inputs to the process, revealing that many of the suppliers were not active. From the historical data of the SWH industry, significant growth took place during the periods 1979-1983 and 2005-2008. The area of solar collector installed hit the 100 000 m^2 mark in 2008. However, the growth was accommodated by the industry with very little additional capital equipment apart from additional warehousing space for companies importing SWHs.

In the South African market, both glazed and unglazed flat-plate solar collectors have been adopted for most SWHs. Domestic manufacturers can meet about 60% of the local demand in 2009. The evacuated tube solar collectors, which are mainly imported from China and Germany, came on to the market in 2005 and only accounted for slightly over 5% sales of glazed solar collectors. For the relationship between glazed and unglazed solar collectors, a remarkable fact is that the sales of glazed solar collectors have always been 20%-30% those of unglazed solar collectors, as shown in Figure 1. Presumably it was because unglazed solar collectors have been used mainly in luxury swimming pool applications. In 2008, the area of solar collector installed was about 100 000 m^2 and 21 000 m^2 for unglazed and glazed solar collectors, respectively. However, a greater impact on sales of unglazed solar collectors could be expected due to the recent economic recession. Furthermore, the size of glazed solar collector systems (domestic SWHs) is linked to a hot water usage profile and the number of people living in a household. Since electric auxiliary heating is usually not available in all areas, Holm (2005) indicated that a weighted national average would require 4.69 m^2 of solar collector installed per household. This corresponds to the major market share of 200-litre SWHs (68%) in South Africa. In 2009, the number of households was estimated to be about 13 812 000 (SSA, 2010). For the potential SWH demand, this would create a demand of about 64.8 million square metres (100% market penetration) or 19.4 million square metres (30% market penetration). However, for the real potential SWH market in South Africa, the dissemination barriers (such as affordability) should be further taken into account.

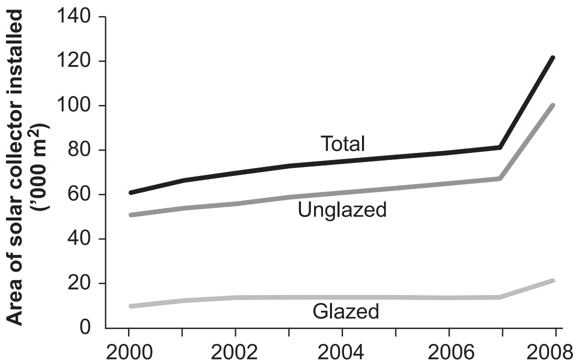

Figure 1: Area of solar collector installed per annum
Source: IEA

Dissemination barriers

Dissemination of SWHs in South Africa is associated with a number of factors, which include corporate social responsibility (GHG emission and global climate change), consumer awareness (supporting education and information programs), economic considerations (financial incentives, cost of electricity, capital cost, income and expenditure), technical support (training program, quality assurance and standards), strategic marketing (brand image and entire value chain) and regulations (housing project) (Visagie *et al.,* 2006; Eskom, 2009). In particular, the economic feasibility of SWHs is considered vital for market expansion. For income sources, most households in South Africa are dependent on salaries (a low of 49.1% in Eastern Cape and a high of 76.6% in Western Cape). However, grants also constituted another major income source. The national average was 43.7% in 2009 (a low of 28.9% in Gauteng and a high of 57.7% in Limpopo). In some provinces (Eastern Cape, Limpopo, Northern Cape and Free State), grants were the main source of income for many households (SSA, 2010).

Sidiras and Koukios (2004) pointed out that one of the major dissemination barriers for SWHs among households is other investment priorities. If the capital cost is less than a specific fraction of family income, the household might be willing to invest in the purchase of a SWH. In South Africa, expenditure on housing, transport and food dominated household consumption (close to 60% of the total), especially for low-income households which allocated a higher proportion of their expenditure to food, non-alcoholic beverages, clothing and footwear (SSA, 2008). Thus, a high initial capital cost of a SWH would be the biggest hurdle to market expansion. Visagie and Prasad (2006) indicated that the housing plans made by the government of South Africa should include extra grant for SWH installation. Then SWHs could become affordable to the poor and fitted in new housing as well as retrofitted in old ones. The Clean Development Mechanism (CDM) also provides a financing mechanism. This could potentially make SWHs more accessible to the less well-off majority of the population

Chang *et al.* (2009) indicated that the ownership and architectural type of buildings would limit the space available for SWH installation. Apartments and community housing are the major types of housing in urban Taiwan. It would be difficult to install a standalone SWH in those types of buildings. In South Africa, the full and partial ownership of housing were 56.0% and 10.9% in 2009, respectively; with 20.9% of the households being rented (SSA, 2010). In terms of type of dwelling, most houses were built with bricks (63.5%) or traditional materials (10.2%); and SWHs can thus be installed on the roof of houses. Furthermore, it is also known that there are many informal housing settlements with a single water tap situated outside in South Africa. This would be a significant barrier.

To reinforce a product's intrinsic features in South Africa, the SABS has issued the SABS Approved Mark. An independent certification is conducted by a third party. Thus, the mark is considered a highly recognizable symbol of credibility and a powerful marketing tool. For SWHs, establishment of a standard is also one of the key factors contributing to a positive acceptance of the consumers. South African standard (SANS 6211-2:2003) is in compliance with the existing local and international standards, which includes one-day outdoor and three one-day indoor basic thermal performance tests for SWHs with specified conditions and apparatus. The SWH performance indicator is given as the ratio of incoming solar energy on solar collector area and useful heat absorbed by a SWH. SWH products bearing the SABS Approved Mark meet the required quality and minimum performance. Further, thermal performance of a SWH should be associated with quality of solar collectors. However, there are no South African standards for quality testing of solar collectors at this moment. This could be a serious obstacle in developing solar collector products for both local and international markets. In addition, it is important to increase knowledge related to SWHs. Skill training workshops for local SWH manufacturers and installers are required for quality products and installation.

Financial analysis

As mentioned, the local market of SWHs in South Africa has been mainly impeded by the financial barrier. The potential for widespread dissemination of SWHs is essentially associated with economic profitability. Under this circumstance, some lesions can be learned from Taiwan market development. Indeed, the well orchestrated and concerted efforts (the long-term subsidy programs, 1986-1991, 2000-present) put forward by the government of Taiwan have played a significant role in market expansion of SWHs during the last few decades (Chang *et al.,* 2011). Furthermore, payback period is considered a critical element in the consumer adoption decision process. In this study, a net energy analysis for SWHs by Sidiras and Koukios (2004) was adopted, in which the payback period is calculated using the balance between the present-time cost of the system (initial plus yearly costs including operation, repair and maintenance), and the benefits from conventional energy savings with reference to the present time. For the initial capital cost, the estimated unit price of a SWH (Eskom, 2009) is shown in Figure 2.

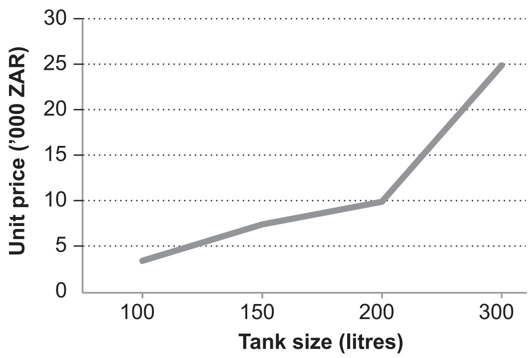

Figure 2: Unit price of SWHs
Source: Eskom (2009)

As can be seen the average unit price increases with tank size, particularly for the 300-litre system. This is not consistent with the study by Chang *et al.* (2009), in which the unit price of a SWH decreases with a larger area of solar collectors installed. Then in terms of cost breakdown, Holm (2005) indicated that the local manufacturers were reluctant to share information. However, the average price of a glazed solar collector system in South Africa was estimated to be 3 736 ZAR/m^2. Materials and labour accounted for 31.2% and 16% of the price, respectively. In addition, the cost of distribution, installation and maintenance of systems represented almost a third of the total installation cost.

The benefit of using a SWH (output energy of solar collectors) instead of traditional alternatives (fuel price) can be realized in terms of the monetary value of electricity saving. In South Africa, the average annual domestic electricity consumption for hot water heating was about 3 400 kWh. With the solar insolation and sunshine duration taken into account, there could be about 60% of hot water production (approximately 2 000 kWh) covered by SWHs (Ross, 2010). However, due to low electricity cost, the yearly benefit is estimated to be only about ZAR 1 100. Furthermore, the discount rate (cost of system less discount by subsidy or tax rebate) and inflation rate could be also included in the payback period calculation (Sidiras *et al.,* 2004). Ross (2010) pointed out that the payback period of SWHs in South Africa is estimated be 4 years while their lifetime could be up to 25 years, indicating the feasibility of SWH expansion in South Africa. However, the vast majority of South Africans with lower disposable incomes still cannot afford the high capital cost of SWHs without subsidy. Thus, alternative financing methods need to be implemented to make SWHs more accessible to the general public. For example, SWHs could be offered on a lease basis where repayments are less than the electricity savings, so effectively the end user is getting a system for free or for a very small monthly repayment sum.

Conclusions

This study aims to gain insight into what factors influence the consumer adoption decision process, which in turn, determines possible dissemination of SWHs in South Africa. As expected, economic considerations are the key factors. Current subsidy programs are not sufficient to facilitate diffusion. Alternative financing mechanisms such as third-party financing as well as low-interest loans and access to credit for SWH purchases should be considered. This would make SWHs more competitive with traditional electric water heating systems. Indeed, the greatest benefit for South Africa is that SWHs can serve the greatest need. The challenge is how to make SWHs available to the people who need it the most, the population with low income. Thus, the Government of South Africa should lead by example and have government buildings fitted with SWHs, to encourage the general populace to adopt. The installation of SWHs should be made mandatory in all housing being constructed by the government.

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