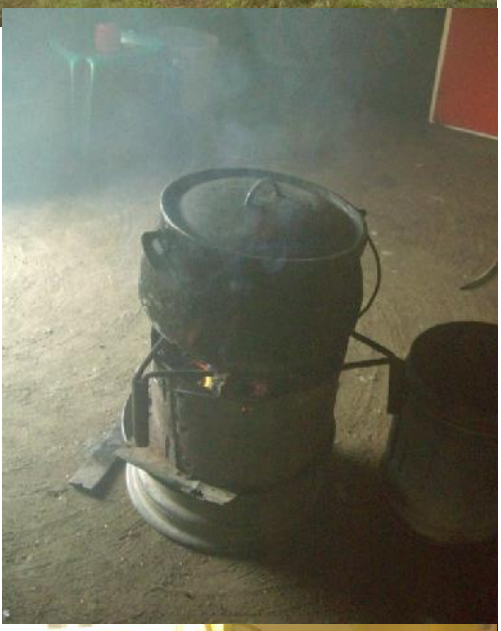
4. Thermal Energy Services with SOLAR WATER HEATING

Sustainable Thermal Energy Service Partnerships

Xavier Lemaire | Daniel Kerr

UCL ENERGY INSTITUTE

STEPs
Sustainable Thermal Energy Service Partnerships



FOREWORD

The use of solar water heaters in developing countries has the potential to be an area of significant market growth, and a significant contributor to sustainability in many areas of the developing world. Most developing countries have high levels of insolation, and therefore have the potential to make good use of solar thermal technology for water heating, industrial process heat and power generation.

Solar water heating has been a growth sector across the developing world, with countries such as China and South Africa developing large portfolios of manufacturers, distributors and sales companies for the technology. In particular, small island developing states have found excellent utility in the technology, as they tend to have a heavy fossil-fuel presence in their energy balance, which can be expensive due to transport costs and remoteness. Using solar water heating has the twin benefits in this situation of reducing both import requirements, and therefore financial burdens, as well as improving sustainability.

This paper focuses on the potential of dissemination of solar water heating to benefit developing countries; the dominant technology formats, case studies on previous solar thermal projects and lessons learned, and business models for solar water heating companies are covered.

- Xavier Lemaire & Daniel Kerr

Acronyms

BOOT – Build-Own-Operate-Transfer

SWH – Solar Water Heater

UNEP – United Nations Environment Programme

GEF – Global Environment Fund

PROSOL – The Tunisian Solar Programme

kWth/MWth – Kilowatt-thermal/megawatt-thermal

LPG – Liquefied Petroleum Gas

FY – Financial Year

IEA – International Energy Agency

SHC – Solar Heating and Cooking

UNDP – United Nations Development Programme

MME – Ministry of Mines and Energy

PV – Photovoltaics

GDP – Gross Domestic Product

kWh – Kilowatt-hours

STEG – Tunisian Company of Electricity and Gas (Société Tunisienne de l'Electricité et du Gaz)

TND – Tunisian Dinar

USD – United States Dollar

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Solar Water Heating

Introduction

Solar water heaters as a product have the potential to contribute to energy demand reduction in developing countries. This exists both as a household-scale technology, and in industrial applications such as desalination and industrial process heat. A number of developing countries, particularly those in Africa and in the Caribbean, have demonstrated the potential of solar water heating technology to be widely disseminated, and within reach for poorer communities. South Africa in particular has targeted solar water heating at a large scale for social housing projects and township households.

Major market development for solar water heating in the developing world has remained concentrated in a few countries, with the most successful examples incorporating the lead in development from state agencies. North African countries such as Tunisia have developed a functioning solar water heating market with minimal subsidies, whilst countries like South Africa have offered greater subsidies on installations and equipment to create a sustainable market.

Types of Solar Water Heating Installations

Solar water heating technology generally refers to the dominant *flat-plate solar collector design*. This features a series of thin water-carrying tubes, using capillary action to transfer heated water to a central tank at the top of the system, for connecting to internal plumbing. Other types of solar water heater use evacuated heat transfer tubes, or heat-conducting fluid in place of water, and rather than relying on capillary action to move water use an electric pump to operate the hot water system.

Evacuated tube collectors address the inherent issue of heat loss to the environment in flat-plate solar collector technology, through reducing heat losses through convection. Whilst this is the most efficient technology type used for solar water heating for thermal energy, this design requires also some degree of maintenance, and is relatively complex to produce. In particular, evacuated designs and heat-transfer fluid utilising designs relies on a more complex manufacturing process, and introduce additional wear components. This in turn increases the maintenance burden for these designs, in particular maintaining vacuum tube integrity, and ensuring the continued operation of the water pump if present (Marken, 2009).

An example of a flat-plate solar water heater available in South Africa. Image: https://solaradvice.co.za/flat-plate-solar-water-heating/

Simpler designs for solar water heaters operate on similar scientific principles, but use alternative materials adapted to local manufacturing conditions and material availability, and these products have achieved some commercial success, particularly in Sub-Saharan African countries. Examples include galvanised steel and "chicken-wire" collector designs used in Guatemala, as well as plastic-tube based designs using polycarbonate tubing and a UV-filtering coating in Brazil. Enabling designs for solar water heating equipment that can be manufactured locally in the developing world, and enabling the manufacture of flat-plate collector designs, are both key areas of market growth in the solar water heating sector in developing countries. (Juanicó & Di Lalla 2013, Gadgil 2007)

The Market Opportunity for SWH in Developing Countries

Developing countries can have high levels of insolation, and a consistent demand across income segments of the population for water heating. Industrial process heat is a sector where solar water heating could have an impact, as is institutional process heat, for example heat exchangers for hospital refrigeration, and hot water for use in health centres and schools.

The residential hot water market in particular is one where solar water heating could be widely disseminated. The case studies below illustrate that specific interventions in the domestic hot water market can lead to sustained market development for solar water heating technology. This brings a range of benefits when applied to the household sector. Hot water energy demand, particularly in rural communities, is often served via traditional biomass fuels, with middle-income populations using electricity where available most often (Milton, 2006, Menanteau, 2007). Substituting biomass fuel use for solar water heating for the hot water demand of a household alleviates the issues with using biomass fuel, including indoor air pollution and the time burden on the household for fuel collection. More advanced biomass-derived fuels, such as charcoal, and petroleum products like kerosene, could also be supplanted in the hot water demand role by solar water heating.

But rural communities have traditionally been targeted less with solar water heating interventions, and market-based case studies or projects in rural areas are rare. Some government provision of solar heating and cooling products for health centres and schools, for example, does exist, like the Indian National Rural Health Mission's renewable energy component, providing small solar systems as well as solar water heating to health centres in rural areas of the country, as a substitute for diesel generating sets. Solar refrigeration has also been used in health contexts for vaccination refrigeration, notably in countries such as India and Nigeria. (Climate Parliament 2011, Rikoto et al 2015)

While upfront costs are high for solar water heating technology, the alleviation of fuel costs on households in conjunction with the other, non-commercial benefits, present a strong business case for solar water heating in urban markets. Communities that predominantly use electricity for meeting their water heating energy demand, like the growing middle classes in Sub-Saharan Africa and South-East Asia, could stand to make considerable savings over time from switching from (often inefficient) electric water heating to solar water heating. (GEF 2008, UNEP 2015)

Case Studies on SWH Dissemination in Developing Countries

The cases below illustrate examples of projects and markets that tackle the challenges of market and business development for solar water heating, across a variety of geographic regions and income brackets.

Case A: Solar Water Heating Market in China

China is both the world's leading manufacturer of solar water heaters and the world's largest solar water heating market. Whilst diffusion of solar water heaters per head of population is lower than some other countries covered in the case studies below, absolute numbers of solar water heater installations far outstrip other developed and developing nations.

As of 2016, 324.5GW_{th} of solar water heater capacity was installed in the country. China also accounted for the vast majority of new solar collector installations in 2016, with 27.7 GW_{th} installed in the country through the year.

The Chinese solar water heating market is predicated on significant indigenous manufacturing capacity for solar water heaters. In particular, evacuated tube collectors have been the dominant technology manufactured in the country, which has contributed to global trends of this technology outstripping flat-plate collectors in terms of overall installed area. 86% of new solar collector area installed in China in 2016 was evacuated tube collectors. In terms of application, domestic hot water systems continue to dominate the market in China, although larger industrial systems have been increasing in installed area in recent years, as well as large systems for district heating. Two district heating systems, of 75,000m^2 and 9,000m^2 were installed in Inner Mongolia and Tibet respectively for district heating in 2016, as well as a 3,300m^2 collector array in Tibet for providing industrial process heat to the Heli Lithium Company (IEA SHC, 2018).

Market growth in China has followed a different path to many other countries, in that immense domestic heat demand drove the growth of the market initially. Incentive policies from the government followed this initial market growth, specifically subsidies for rural solar thermal installations, and mandatory installation requirements for urban buildings. Diffusion in small cities and rural areas has been strong following these policies, although the expansion of the urban market remains a challenge. Theories behind this lack of penetration suggest that technology improvements in terms of heat output and consistency of service are required to meet the demands of urban consumers in primary cities (Yu & Gibbs, 2018).This context differs from the majority of cases seen in other developing countries and transition economies, in that government incentives were the initial driver of market growth in the country. The scale of domestic demand in the Chinese market instead drove the natural growth of the market, alongside significant investment from the government and private sector into indigenous manufacturing capacity for solar water heaters. In addition, the continued growth of the market in the country has not been led (or directed) by the government or regulatory bodies, but instead by private-sector companies and market pressures, including the continued demand in urban areas through rapid urbanisation (Huang et al, 2018).

Further reading for Case A:

Yu & Gibbs (2018) *Encircling Cities From Rural Areas? Barriers to the Diffusion of Solar Water Heaters In China's Urban Market*. Available at: https://sciencetrends.com/encircling-cities-from-rural-areas-barriers-to-the-diffusion-of-solar-water-heaters-in-chinas-urban-market/

Urban, Geall & Wang (2016) Solar PV and solar water heaters in China: Different pathways to low carbon energy. *Renewable and Sustainable Energy Reviews*, Vol. 64, pp. 531 – 542. Available at: https://eprints.soas.ac.uk/22666/1/Urban_22666.pdf

Case B: South Africa – The One Million Solar Water Heaters Program

The South African National Solar Water Heating Program was initially promulgated by the government in 2009, with the national utility ESKOM as the main implementing agency. The objective of the program was to greatly accelerate the pace of solar water heater dissemination in the country, targeting a reduction in peak power demand as the primary goal, given the prevalence of electric water heaters in the country previously and their use at peak times. Funding for the installations under the program was substantial, R1.6 billion (~USD101.2 million)[1] in FY2014/5, with a further R700 million (~USD44.2 million) for FY2015/6. As of January 2014, approximately 400,000 solar water heaters had been installed nationally under the program. (Parliamentary Monitoring Group of South Africa, 2014, South African Department of Energy, 2015)

However, this number of installations did not meet the one million solar water heaters promised by the government. The program was significantly restructured in 2014, with the Department of Energy now taking full responsibility for the program, contracting with ESKOM as an installer, but also with local producers on a much greater scale. Municipality involvement in the program was also increased, with municipalities having individual targets and budgets for the solar water heating rollout. Under this revised contracting model, local components of installations have been increased through a 70% mandatory minimum target being legislated for, which came into effect on July 7th, 2014. (Parliamentary Monitoring Group of South Africa 2014, National Treasury of South Africa 2014). Previously, imported components and systems for solar water heating made up the majority of the installations.

Solar water heaters on homes in Kuyasa, South Africa, installed as part of the CDM project for the township. (Source: https://energygeographies.wordpress.com/south-africa/)

[1] Exchange rate as of 29.2.16, 15.82 ZAR = 1 USD.

The program was supported by direct grants to the implementing agency, ESKOM, from the government for installations on new and existing household infrastructure. The program also covered high-pressure industrial water heating as well as community installations, but residential low-pressure systems were the main technology targeted. This centralised top-down approach, with a state agency directly utilising state funds for installations with very little consumer component, was a possible contributor to the imbalanced targeting of installation areas by ESKOM, which has been identified as a problem area for the project. Indeed, electricity consumption reduction (the solar water heating programme was part of a larger push for greater demand side management in the country) was a major target for the program; however installations have been skewed towards areas of the country with the lowest electricity consumption (Eastern Cape, Kwazulu-Natal etc.), due to differing priorities between the commissioning agency (the Department of Energy), interested in demand-side management, and the installation agency (ESKOM), interested in meeting installation number targets, meaning the impact on electricity consumption is lower than projected. (South African Department of Energy, 2015)

Further reading for Case B:

Kritzinger & Covary (2016) *Review of South Africa's Solar Water Heating Rebate Programme*. Available at: https://www.researchgate.net/publication/308168429_Review_of_South_Africa's_Solar_Water_Heating_Rebate_Programme

South Africa Department of Energy (2018) *The National Solar Water Heater Programme*. Available at: https://solarwaterheating-programme.co.za/

Curry, Cherni & Mapako (2017) The potential and reality of the solar water heater programme in South African townships: Lessons from the City of Tshwane. *Energy Policy*, Vol. 106, pp. 75 – 84.

Case C: The Solar Water Heating Industry in Barbados

The solar water heating market in Barbados has been developing since the 1970s, and is one of the more successful case studies in developing a robust market for the technology. As of 2009, there were approximately 45,000 units installed in the country, or two-fifths of households, and by 2012 this had grown to 50,000 installations[2] (Climate and Development Knowledge Network 2012).As with many small island developing states, Barbados is in a good position to take advantage of solar water heating technology, rather than continuing to rely on imported fossil fuels for water heating in households and industry.

[2] Climate & Development Knowledge Network (2012*) Inside Story: Seizing the Sunshine – Barbados' Thriving Solar Water Heater Industry*. Available at: http://cdkn.org/resource/cdkn-inside-story-seizing-the-sunshine-barbados-thriving-solar-water-heater-industry/

A number of barriers have been addressed to effectively developing a market for the technology, namely the high up-front cost of SWH systems, access to start-up capital for businesses, and building consumer awareness. Improving affordability was the major target of the initial government interventions in the sector, such as the 1974 Fiscal Incentives Act, reducing taxation on solar water heating components by 20%, and also increasing taxes on electric water heaters to 30% in an effort to improve competitiveness of the solar water heater technology.

Government support and clear, long-term policy and regulatory framework have been major contributors to the development of the market in Barbados. From 1980-1992, and from 1996 onwards, the Homeowner Tax Benefit was in effect for solar water heating installations, allowing a maximum of USD1,750 to be deductible for the cost of the installation. In addition, mandatory government purchasing of solar water heaters for state housing has been in place since 1977. This sort of long-standing commitment promotes confidence in both investors and consumers. The private sector in turn has developed methods to improve consumer confidence in solar water heating, as well as increase accessibility in terms of financing. This is mostly through the provision of credit facilities for consumers, alleviating the burden of high up-front costs of the technology. In addition, the country has implemented robust regulations for quality control of solar water heating equipment, which improves consumer confidence in the technology, through the delivery of high-quality, well-performing products (Perlack & Hinds 2003, Climate & Development Knowledge Network 2012).

Further reading for Case C:

Husbands (2016) *The History and Development of the Solar Hot Water Industry in Barbados*. Available at: http://solardynamicslimited.com/wp-content/uploads/2016/10/Histor-Solar-Water-Heating-Industry-Barbados.pdf

Rogers (2016) Development of innovation systems for small island states: A functional analysis of the Barbados solar water heater industry. *Energy for Sustainable Development*, Vol. 31, pp. 143 – 151.

Case D: Solar Water Heating in Turkey

As an example of a developed solar thermal/solar water heating market, Turkey is prominent in that the market has succeeded with only minimal interventions financially from the government. This is in part due to the country's excellent solar resource, allowing installations to operate effectively and reducing payback times. A commitment to solar water heating use in public housing projects has also driven market development. In total, it is estimated that there are around 90 large factories, and 700-800 retailers for solar water heating equipment in Turkey. Vacuum tube solar water heaters have been a particular area of growth of the market in recent times: market share for newly-installed systems for these technologies increased from 7% to 33% between 2007 and 2013.

There are many reasons behind the sustained development of the Turkish solar water heating market. Access to consumer finance is high among companies in the country, in part driven by a reasonable climate of access to business finance. This allows consumers to pay on more flexible terms, reducing up-front cost barriers. A stable and lasting commitment to the technology from the Turkish government has been another factor. Utilising the technology in public projects and supporting dissemination in rural areas through micro-finance has given confidence to the market, and stable regulation allows for more robust and de-risked business planning. (IEA SHC, 2015)

Further reading for Case D:

IEA SHC (2016) *Country Report – Turkey: Status of Solar Heating/Cooling and Solar Buildings 2016*. Available at: http://www.iea-shc.org/country-report-turkey

Aydin, Eichholtz & Yönder (2018) The economics of residential solar water heaters in emerging economies: The case of Turkey. *Energy Economics*, Vol. 75, pp. 285 – 299.

OME (2012) *Solar Thermal in the Mediterranean Region: Solar Thermal Action Plan*. Available at: https://www.b2match.eu/system/stworkshop2013/files/STAP.pdf?1357834608

Case E: PROSOL in Tunisia

The Tunisian PROSOL program is a prominent success cases for solar water heating dissemination in developing countries. The program was initiated in 2004, and has contributed to significant growth in the Tunisian solar water heaters market through the application of innovative end-user financing schemes and improving credit access, both to consumers and installers. Over the period of 2004 to 2010, over 363,000 square metres of solar water heating capacity were installed, financed through USD73 million of local bank loans, facilitated through the funders of the project, notably UNEP and the Italian government. As of 2012, Tunisia had a total installed capacity of approximately 447.5 MWth of solar water heaters, with a penetration rate of 41.57kWth/1,000 inhabitants[3]. Over 119,000 solar water systems were installed over the first two phases of the program, totalling roughly 355,350 m2 of collector area. Progress with the PROSOL project was meant to continue, with targets of 750,000 m2 of new capacity to be installed between 2010 and 2014; however, the Arab Spring of 2012 and resulting unrest has curtailed advancement of the project significantly. (Climate Finance Options 2013, UNEP 2015)

[3] From Climate Policy Initiative (2012) *San Giorgio Group Case Study: Prosol Tunisia*. Available at: http://climatepolicyinitiative.org/wp-content/uploads/2012/08/Prosol-Tunisia-SGG-Case-Study.pdf

One prominent factor behind the program's wide-ranging success is the financing facilities available to end-users provided through the program. Through partnership with the Tunisian government and state electricity agency, systems were able to be purchased at a subsidised rate (pegged to a former state LPG subsidy of 20% of system cost) of USD75/square metre of heater. More importantly, these subsidised purchases were backed up by a system of on-bill financing for repayments for the solar water heating systems, allowing consumers to buy SWH cheaply, and pay back over long periods. This financing was initially underwritten by UNEP and the Tunisian Government, but following the success of the first phase of the program market confidence grew, and financial institutions were encouraged to offer loans to consumers to purchase new systems, increasing the financial services market for energy services in the process. (Touhani & Hannane 2011)

Further reading for Case E:

See CASEs on STEPs website : *Business Models for the-Delivery of Modern Thermal Energy Services: The Cases of Ghana and Tunisia*, Econoler.

Key Features from Case Studies

Country	To what level was government involved in market development?	Existence of a commercial hot water market?	Income level and effect on market development	Capacity to develop SWH markets
China	Low – initially growth in the market was led by private-sector agents, with government and regulators stepping in to encourage continued growth of the market.	High – market for commercial hot water is well established; private-sector sales of water heaters to domestic sector strong.	Medium – huge indigenous manufacturing capacity has enabled affordability without financing for many consumers in urban areas. Rural consumers formerly subsidised.	High – well-developed market with strong indigenous base, as well as world-leading export capacity.
South Africa	High – government housing mandated to use solar water heating products, state electricity company ESKOM primary installer.	Medium – electric water heaters common for meeting heating demand in the country on a commercial basis.	Medium – middle-income country with high levels of government investment in the sector. Consumer finance access low, as with commercial financing for business development.	Medium – government program stalled over restructuring, capacity in local governments traditionally low for technology; state-led interventions primary market development vector.

Barbados	Medium – government commitment to technology in regulation and public works supported early market development, transitioning to a more commercial basis.	Low – development of water heating market has developed in tandem with solar water heating market, primary method of meeting hot water demand.	Medium – small-island developing state with government support for technology increases affordability for consumers. Consumer-side financing options available.	Medium – market developed with relatively little intervention from state, capacity in private sector developed to a point of sustainable commercial market.
Turkey	Low – existing commercial market for solar water heating has developed further, some government support from public projects, access to credit and middle-income status main market driver.	High – commercial and industrial hot water markets well-established using electric water heaters.	Medium-High. Middle-income country with developed consumer financing market has enabled commercial SWH market.	High – commercial water heating sector well developed, as is commercial SWH sector. Capacity and experience in commercial and government financing institutions for the technology.
Tunisia	Medium – state electricity agency integrated with program through on-bill financing, government underwrote end-user financing stage of program initially but has since stopped.	Medium – market exists for commercial electric water heating, which has been driver of SWH market development to offset electricity consumption.	Medium – middle-income country with a moderately developed consumer finance sector. Government equipped to finance SWH development with donor support.	High – solar resource excellent for technology development; sector is continuing to grow in capacity following PROSOL program.

GDP/Capita of Selected Countries vs Subsidy Levels

Country	GDP/Capita (USD) (2013)	Level of Subsidy Typical for SWH in Market
China	5,721.7	Variable, formerly ~9-11% in rural areas[4]
South Africa	14,917.15	100%
Barbados	6,617.91	Up to USD1,750 (~50%)
Turkey	10,971.66	Unsubsidised
Tunisia	4,216.69	20%

[4] https://www.solarthermalworld.org/content/china-subsidy-scheme-energy-efficient-products

Business Models for SWH Companies and Financing Models

The success or failure of a solar water heating project or company is often down to the particular combination of business and financing models used in the organisation or project's operations. Without a clear financing model for equipment and installations, solar water heaters, much like many other renewable energy technologies for thermal energy, tend to be beyond reach, from an affordability perspective, for a large number of users. In terms of targets for solar water heater financing, there are two main paths: financing the purchase of solar water heater systems by end-users, and financing manufacturing and retail companies for solar water heaters to grow in the market.

There have been a wide variety of approaches to tackling the affordability issue in developing countries. As with other renewable thermal energy technologies, and renewable energy technologies in general, *direct capital subsidies* have been used in a number of cases to directly install and purchase solar water heaters in homes in rural and peri-urban communities. Possibly the most visible example of this is the South African "One Million Solar Water Heaters" program, which is directly financed through the government. However, as with other renewable energy technologies, direct subsidies have a number of disadvantages regarding solar thermal. Whilst, for example, the high up-front cost factor is mitigated with a subsidy of around 50% of the capital costs in South Africa, maintenance and servicing of the installations is often ignored in directly-subsidised programs such as the South African program, leading to a higher-than-desired rate of failure of installations. In addition, the lack of a concept of ownership of the system for the user can lead to a lack of buy-in in terms of maintenance responsibility and operational responsibility, possibly leading to poor operational practices and early system failures.

Micro-credit models are applicable to solar water heaters given the scale of initial investment usually required (USD80-100) for an installed system (Bland et al 2010, UNDP/MME Namibia 2005). Users can take out a micro-loan from a financing company in order to pay an installing company for the system, and repay the loan, sometimes on a flexible basis, over a period of 6 months to 2 years in most circumstances. The critical factor of any micro-credit system, particularly for solar water heaters given the relatively high up-front costs compared to other renewable thermal technologies, is designing a flexible and appropriate payback period for the credits, tailored to the financial circumstances of the user or user cohort. This is predominantly useful in ensuring that rates of default on the micro-credit are minimised, and is an approach used commonly in micro-credit arrangements for other renewable technology, such as solar home systems with PV.

Allowing users to pay back over a flexible period at a flexible rate also allows users who are normally unable to acquire commercial loans due to financial circumstances or a non-smooth income (for example, agricultural workers whose primary income comes during harvest season), to have access to credit, and therefore the solar water heater itself. The challenges exist in servicing users who have a low credit-worthiness or a high credit-risk, for example agricultural workers, to the same level that more credit-suitable (in the eyes of the company) consumers are, so that access to solar water heating technology is presented on a level playing field.

The primary disadvantages of micro-credits for solar water heating are applicable despite the technology: that initially funding a micro-credit institution requires significant capital, most commonly from donors, development organisations or governments, and despite the available means of minimising defaults non-payments will still happen, with financial planning for the micro-credit organisation/company needing to reflect this.

Fee-for-service models can also be used for solar water heating services. With an energy service company installing the SWH system, and maintaining ownership of the system, then charging a monthly fee for the use of the system by the household, the user can reduce their existing energy use burden for water heating, at a price that is most often much more affordable than loan repayments or direct system purchases. With the energy service company maintaining system ownership, this can also be useful regarding maintenance of the system, and ensuring that the performance of the system remains good over time. Maintenance of renewable energy systems is a factor often overlooked in business planning and sector analysis, and with the fee-for-service business model, this requirement can be mainstreamed.

Few countries have used a fee-for-service business model to great effect in improving dissemination of solar water heater technology, for example, Tunisia uses a form of fee-for-service for solar water heaters. The Tunisian example of on-bill financing is particularly applicable, with users paying a small monthly fee for the use of the solar water heater, and maintenance responsibility mainstreamed into the installing company, the state utility STEG's, operations. Other projects include the Government of India's area-based energy service company approach to providing solar water heating in four regions in the country; the Renewable Energy and Energy Efficiency Partnership conducted research into promoting fee-for-service provision of solar water heating services in the Caribbean and Brazil, from 2005 to 2006. (Mercados 2010, REEEP 2018)

There are several avenues that can be utilised to support solar water heating market and business development with policy. Supply-side mechanisms are commonly used for other renewable energy technologies, for example clean cookstoves and LPG cooking equipment. These measures commonly include accreditation for equipment and national standards for renewable energy products and equipment. However, if the regulatory framework is not already in place to assess new solar water heater models, then this can be expensive to introduce, given the need for personnel, training and laboratory space. *Accreditation and national standards* help to raise the quality of renewable energy installations more generally, and these measures have been shown to support greater market development, for example in the Tunisian case above.

The *quality* of solar water heating installations is a factor that has affected numerous developing-world projects using the technology. The early development of the South African case study below was impacted by a not-insignificant failure rate of installations due to low-quality components. Ensuring the quality of installations is an important decision to be taken when establishing solar water heating projects; this can be accomplished through instituting national technical standards for solar water heating components, and creating a robust technical testing and certification framework. Local manufacturing and design of components for solar water heaters can aid with achieving useful regulation, as does having a trained installer base at a local level. Through using a fully local production chain for solar water heating equipment, quality can be ensured at all stages of the manufacturing process by local regulators. This assumes that the country in question has the capacity for a suitable manufacturing industry for solar water heating products and components: serious quality risks may be present if this is not the case. An example of this is the Zimbabwean solar water heating industry, which had a high local manufacturing requirement, but where economic challenges and a lack of capacity led to low-quality products, leading to rusted and non-functional installations.[5]

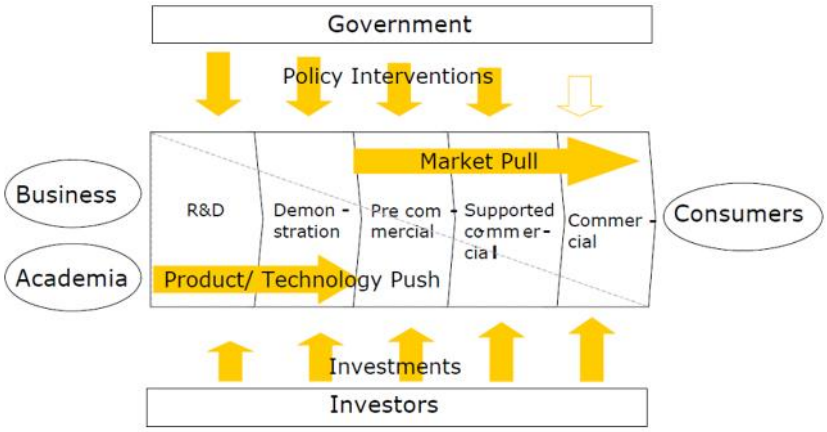
Taxation is another regulatory mechanism that can be used to promote solar water heating market growth. This can take the form of positive tax incentives to promote solar water heaters equipment, such as reducing import duties and VAT exemption. Measures to discourage the market dominance of alternative water heating technologies, such as electric boilers, can also be introduced, for example higher taxation on these technologies. The goal of these kinds of financial measures is to bring down solar water heating technology, allowing the newer solar water heater technology to compete within the established market.

[5] Hove, Mubvakure & Schwarzlmuller (2007) *Final Report on the Survey on Demand of Solar Water Heaters in the Institutional Sector*. Available at: http://www.solarthermalworld.org/sites/gstec/files/Zimbabwe%20SWH%20institutional%20sector.pdf

Building regulation is another powerful and complimentary tool for creating a solar water heating market in both the developed and developing world. For example, the Barcelona Municipal Council's decision in 1999, extended to the whole of Spain in 2006, to include solar water heating equipment in all new and renovated buildings, with a 60% target for hot water energy consumption to be provided by solar water heaters, had a huge effect on the market. Total installed capacity in Barcelona itself jumped from 1,650m^2 in 1998 to 19,600m^2 in 2004, clearly demonstrating the effect that the Barcelona Solar Hot Water Ordinance (as the instrument) had on the market. Financing in the case of Barcelona was achieved through zero-interest loans from the Instituto de Crédito Oficial (national credit bank), implying a robust financing mechanism needs to be in place to achieve this kind of success (Menanteau, 2007). These ordinances are still in effect, and as of 2014 total installed capacity per 1,000 inhabitants in the city had increased by over 4,000% from its level in 2000, from 1.1 m^2 to over 40 m^2.[6]

It is also important to note the complementarity of instruments in achieving market growth for solar water heating, as with any renewable technology. Supporting access to solar water heating equipment, for example through distribution on a government scale, is irrelevant without also improving consumer affordability of equipment, through any of the financing mechanisms described above. In terms of project design and targeting interventions in the solar water heating sector, considering the stage of development of the target market, both for the technology and more widely, is useful for success. In initial-stage market, public sector funding in conjunction with a strong policy commitment to the technology has been shown to deliver results at scale. The solar water heating sector in Barbados is a good example of this: a strong policy commitment from the late 1970s onwards, as well as direct subsidies for the cost of the equipment, led to the market transitioning to the stronger, commercially-led basis it exists in currently. In middle-income countries such as Turkey, support from the government has mostly come indirectly, in terms of driving demand with public commitments to solar water heater installation in public buildings. However, the market has benefited from stable regulatory support for the technology, which has given confidence to lenders backing solar water heating businesses, and allowed market development to reach its current point. (Perlack & Hinds 2003, Climate & Development Knowledge Network 2012, IEA SHC, 2015

[6] Rocky Mountain Institute (2014) *Barcelona: Spain's Ciudad del Sol*. Available at: http://blog.rmi.org/blog_2014_08_05_barcelona_spains_ciudad_del_sol



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Conclusions

This paper seeks to present a variety of measures to promote, and experiences in promoting, the greater diffusion of solar water heating technology in the developing world. Reaching higher levels of market penetration from an undeveloped basis, from the case studies analysed above, seems to be achievable reliably only with intervention from state or third-sector actors. However, past the level of initial project intervention, there are different ways to support and grow solar water heating markets, at a market, policy and regulatory level, so that further development can be market-driven, without the dangers of distorting markets through further non-market intervention in the sector. These include either partial or full subsidy schemes for developing an initial market, mandatory installation requirements for new or existing buildings (for example, government institutions or the health sector), or the development of indigenous manufacturing capacity through government investment to reduce overall costs of systems.

Finally it is worth noting that compulsory measures such as those used in the Spanish and South African cases above, where public buildings were mandated to use solar water heating, led to a significant boost to the market, and created a technology and operations base for solar water heating products, leading to an improved state of the market for the technology in the longer term. It has also to be noted that solar water heating markets can be found mainly in middle-income countries where this device saves money over time; where middle class electric heating costs are a concern (like in South Africa, Barbados, Turkey)– then there is a commercial market for the technology. In the poorest areas/ developing countries, where rural households use wood to heat water and do not pay for this wood or where access to water is problematic, to try to develop a solar water heaters market, to reach beyond the most affluent middle class may not be considered as a priority.

Questions & Answers

Identifying the Target Market and Market Conditions

Depending on the size of the target market, the income level of the consumers present in the market, and prevailing market conditions such as pertinent regulations and pre-existing actors different business models or policy mechanisms can be relevant to developing business and the solar water heating market. Choosing to target a particular market, or a particular segment of a market (for example, rural consumers or rural organisations such as schools or health centres), allows for a tailoring of approach to that market, improving the chances of creating a sustainable market presence. Examples of projects that have targeted large consumers in rural areas, such as health facilities, include the Indian National Rural Health Mission. Other examples include the Chinese market, which targeted urban consumers with mandatory installation targets to develop the urban market. Features of the target market that should be assessed include the income level of consumers in the market, and the current energy use of consumers for thermal energy services in the market, in order to best target interventions.

Distinct and different approaches to different areas in the same country or region are often needed with solar water heating. The most notable example of this comes in the urban-rural divide, with significant differences in approach needed in order to effectively manage a business targeting these communities. Rural areas of developing countries, for example, are often less affluent than urban areas, and therefore a business will need to provide some form or assistance, in terms of credit or longer-term service arrangements (BOOT (Build-Own-Operate-Transfer) contracts, fee-for-service), to improve affordability for rural communities. Urban communities generally require less of a credit intervention, as is seen in more urbanised cases above such as Turkey, but still benefit from a services-based approach rather than a sales-based approach, as is seen in the Tunisian and Turkish cases. Whilst is it difficult to determine a suitable consumer income level that will sustain a solar water heating market, countries such as Tunisia had a GDP/capita of ~USD4,300 in 2013, suggesting that low-middle income countries such as Tunisia have sufficient consumer resources to support market-based solar water heating interventions.

Adapted business models

The prevailing conditions in a target market dictate to a large extent which business model is going to be most, or at least more, successful in the market. Consumer income is the primary driving factor behind this: for example, a direct purchase model where consumers pay the full price for a solar water heater system up-front is not going to be applicable in a market where the vast majority of consumers cannot afford this. Business models such as fee-for-service or longer-term micro-credit arrangements are much more suited to markets with lower average consumer incomes, spreading the cost of solar water systems to bring them within the range of affordability for these consumers. Definitions of low-income are generally in the USD 2,000 – 4,000 per capita range, significantly lower than what would be necessary to purchase a solar water heater system outright, or to take standard consumer credit for.[7]

[7] Figure from https://www.imf.org/external/np/pp/eng/2014/060314.pdf

However, even high-income countries such as the United Kingdom commonly have some form of credit arrangement to spread the comparatively higher cost of solar water heaters. The Chinese market had a split approach between rural and urban consumers, encouraging rural market development with subsidies, whilst mandating installations in the urban market on a private basis. Examples of lower-income countries where credit arrangements have benefited consumers include the long-term credit offered through the Tunisian state program, repayable via the consumer's electricity bill over time. Average monthly salaries in the country are approximately 2,410 TND (USD 1,200). (SalaryExplorer 2016)

Particularly in middle-income markets with a developed electric water heating sector, an important point when conveying the benefits of solar water heating is making the business case for the technology. This can be promoted in a number of ways. Financial benefits seem to be the most effective in terms of convincing consumers and companies to invest in a solar water heater: a clear case for saving money over time for investing in the technology has helped markets such as Tunisia and Turkey grow significantly. Companies such as SolarVenti (a Danish solar water heating company) are marketing solar water heating in Turkey based directly on the energy saving and cost saving benefits of the system [Bodrum Bulletin, n.d.) Other benefits, such as public health through promoting replacement of biomass-fired stoves with solar water heaters, or promoting home comfort and efficiency, can also be used to help make the business case for solar water heating, as is the case with the South African market, although public health improvement was not the main goal of the government's main dissemination program.

On the consumer-side, factors such as income levels of target consumers, their energy consumption patterns for thermal energy, prevailing market conditions for their current fuel choices and so on, are all factors that need to be analysed in order to fully understand the conditions under which your business/project will operate. Prevalent prices of other thermal energy sources currently in use by consumers in the market can help inform the price-point of solar water heating equipment and installation.

The Enabling Environment for Solar Water Heaters

As with any business sector, an analysis of the policy and regulatory climate of the target market can help businesses and projects establish a presence quickly, as well as achieve scale more easily. Understanding the regulatory environment that exists in the targeted market for solar water heating can aid in developing a robust business platform. Regulatory support for solar water heating, as described above, can take the form of tax incentives for solar water heating equipment, or tax disincentives for other water heating technologies, as well as certification and testing regimes in conjunction with standards systems for solar water heating technology. Understanding whether these standards exist, and ensuring that marketed products of the business adhere and are of high quality according to these standards, can help establish a positive market position for a business. Conversely, a lack of regulation can lead to a lack of market confidence in solar water heating technology, as was the case in the Zimbabwean sector.

In addition, understanding these factors leads to the key decision of which financial and business models to operate under, or which policy mechanisms to use to best promote market growth. For example, low-income communities, such as rural agricultural communities, may benefit more from a fee-for-service or micro-credit approach than urban communities, due to income levels, as has been seen in the South African case. Policy mechanisms such as state-funded micro-credits or feed-in tariffs can be tailored to serve the consumers and businesses they are targeting also. For example, in the Tunisian PROSOL case, micro-credit interest rates were set at below market level (6-7% contra 13%) in an effort to incentivise end-users to take part in the micro-finance program.

This dramatically reduced the levelised cost of electricity (LCOE) of solar water heating in the market, from USD0.097/kWh to USD0.073/kWh over the course of the program. Developing world solar water heating feed-in tariff rates are rare, and countries that have experimented with feed-in tariffs such as South Africa did not have a dedicated tariff rate for solar water heaters. Countries such as the UK set their feed-in tariff rate for solar water heater at 19.51 pence/kWh (USD0.28/kWh), suggesting even in developed markets, a reasonably high tariff rate benefits the technology.

The Tunisian case above is also important in highlighting the role of partnerships, particularly public-private partnerships for increasing dissemination of renewable energy technologies. This has been particularly relevant in the country for its solar water heater program, with one of the key factors for success being the partnership with the state electricity agency. This partnership, in particularly “piggy-backing” on existing payments infrastructure through regular electricity bills, has enabled the government program to reach significantly more consumers than other, similar programs in other countries.

Middle-income markets, for example Turkey, have benefitted from different regulatory measures to, for example, South Africa. Turkish regulation has focused on the quality of installations through certification of both installers and equipment, and large-scale tax incentives for solar water heating production at a local level, and importation. South Africa has predominantly focused on developing local manufacturing capacity and ensuring that the utilisation of local components is more favourable through import duties on imported solar water heater equipment, in order to develop a local market presence more effectively.

Creating a stable market with the potential for growth for solar water heating can be assisted immensely through appropriate regulatory measures. The key points are to create a lasting regulatory presence in the market through long-term commitment, ensure that regulation is appropriately light-handed in order to ensure no unbalancing of the market, and develop appropriate solutions to the challenges facing the solar water heating market in the context being addressed.

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