CENTRE FOR RENEWABLE &
SUSTAINABLE ENERGY STUDIES

Solar Water Heating Technologies

Policy Brief

A.I. Buckley

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LIST OF ABBREVIATIONS

CRSES	Centre for Renewable and Sustainable Energy Studies
CSP	Concentrated solar power
DC	Direct current
DNI	Direct Normal Irradiation
GHI	Global Horizontal Irradiation
HFO	Heavy furnace oil
HP	High pressure
HTF	Heat transfer fluid
IEA	International Energy Agency
IRP	Integrated resource plan for electricity
LCOH	Levelised cost of heat
LP	Low pressure
LPG	Liquefied petroleum gas
MEPS	Minimum energy performance standards
NERSA	National Energy Regulator of South Africa
NRCS	National Regulator of Compulsory Specifications
PV	Photovoltaic
RE	Renewable Energy
REIPPPP	Renewable Energy Independent Power Producers Procurement Programme
SA	South Africa
SANS	South African National Standard
SESSA	Sustainable Energy Society of South Africa
SOE	State owned entity
ST	Solar thermal
SWH	Solar water heaters
TOU	Time of use
USA	United States of America

1. Introduction

This policy brief provides an overview of low temperature solar thermal (ST) technologies, specifically solar water heating, to inform policy. The report provides an overview of the international and local market of small to large-scale solar water heating installations

The basic principle for operation of ST systems is to transfer solar radiation into heat via a thermodynamic system, specifically a solar water heater (SWH). There are three conventional ways in which solar energy can be harvested for either producing heat or electricity with renewable energy systems:

- The light can be converted into heat through the use of low temperature (30 – 120 °C) solar thermal technologies, namely solar water heaters (SWH). This heat can then be used directly for producing hot water for residential and commercial applications or supplying industrial processes.
- The sun's light energy is focused using mirrors produce heat for generating steam in high temperatures (120 – 550 °C) solar thermal technologies, namely concentrated solar power (CSP) technologies. The steam is then used to drive a turbine, which generates electricity in utility scale power plants; however the steam can also directly be used in process heat applications.
- Solar photovoltaic (PV) systems use cells made from semi conducting materials, usually silicon, to directly convert the sunlight into electricity. PV modules consists of a number of PV cells and produce DC electricity. The DC electricity is converted to AC through the use of an inverter. The systems are implemented on a small-scale in residential and commercial application for offsetting electricity consumption from the grid and in larger utility-scale systems that feed electricity into the grid.

The topic of this policy brief is based on the first renewable energy system mentioned above.

1.1: Solar Energy Resource

The energy production and effectiveness of ST systems varies across the world depending on the irradiation (sunlight) that falls on a specific location throughout the year. Figure 1 illustrates the distribution of the average annual sum of global horizontal irradiance (GHI) across the world.

GHI is a combination of the direct normal irradiance (DNI) and the diffuse horizontal irradiance (DHI), where DNI is the light measured perpendicular to the light rays travelling in a straight line from the sun and DHI is the light that is scattered by molecules in the atmosphere (such as clouds). Therefore, tropical locations with a high rainfall in the summer months experience lower direct irradiance and higher diffused irradiance than drier regions and thus have a lower annual GHI.

Figure 2 illustrates the distribution of the average annual sum of global horizontal irradiance (GHI) for South Africa, specifically.

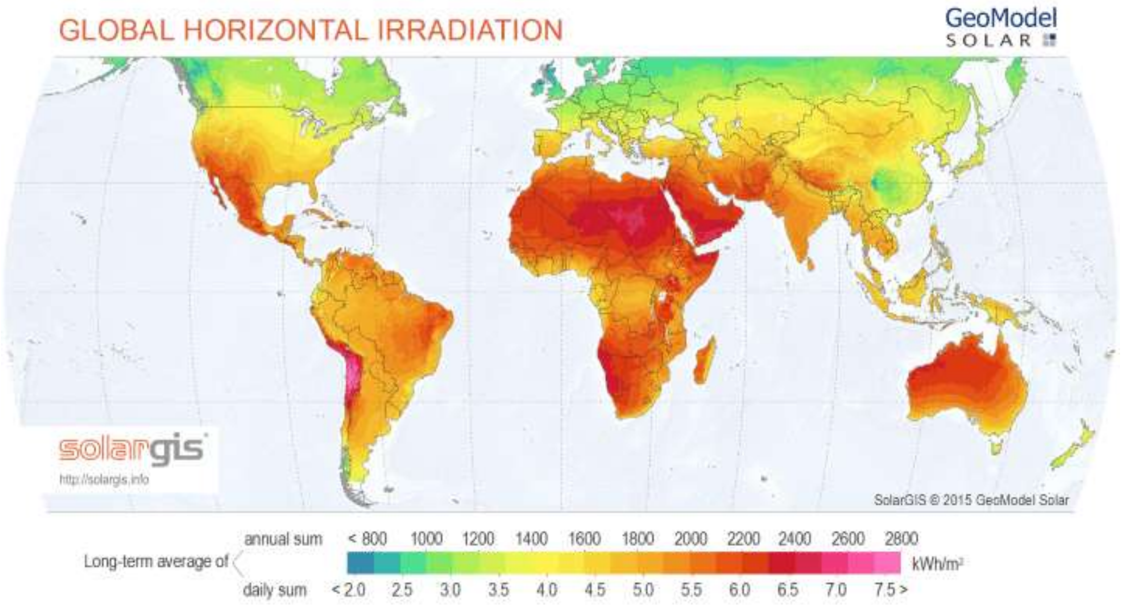

Figure 1: The global solar energy resource map of SA showing the GHI

(Anon., 2016)

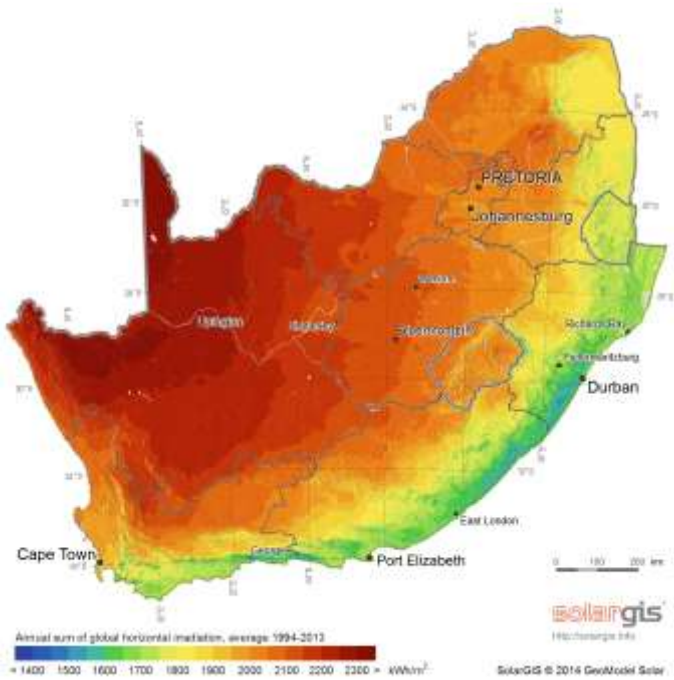

Figure 2: Solar energy resource map of SA showing the GHI in kWh/m^2 per year

(CRSES, 2014)

South Africa experiences an abundance of solar irradiance and exhibits great potential for the application of ST technologies. South Africa experience average solar irradiance levels ranging from 1 600 to 2 300 kWh/m^2 per year. This is significantly higher when compared to countries with a large number of ST installations such as Austria, which has an average annual solar irradiance of less than 1 300 kWh/m^2, as seen in Figure 1. As one of the leading countries for installed solar collectors in the world, Austria had 430 kW_{th} of solar water systems installed per 1 000 inhabitants in 2013 (Weiss, et al., 2015).

1.2: History of solar water heating

Solar water heating dates back to 1891 when it was first invented in the United States (Gravely, 2015) . These early examples of SWH were essentially boxes that were painted black and filled with water, however proved very inefficient for heating water, even under optimal environmental conditions due to a lack of insulation and heat retention and novice techniques of solar radiation absorption of systems.

During the same year, Clarence Kemp of Baltimore USA, developed an improved SWH which had better heat retention capabilities. His improvements allowed for the first SWH systems to become commercially viable on a wide scale to be viable for the first time. The first commercially available SWH incorporated the collection of hot water and storage in a single wooden box, known as a 'batch water heater'.

The first thermosiphon SWH was invented by William Bailey in 1909, which was a more ergonomic and compact design of the SWH of that time and later became a market leader in solar thermal energy. Thirty percent of homes in Pasadena California had solar powered hot water systems by the early half of the 20^{th} century, during which the solar industry in Florida was well developed and was a major manufacturer of solar water heating systems (Anon., 2015). The systems were confined to these states due to environmental conditions leading the water to freeze in other parts of the country.

The largest advancements in SWH technologies were made during the 1970's when the price of oil started to increase and the use of solar power in the space program sparked the onset of research into solar thermal technologies. Major advancements in SWH initiated in the late 1970's, coinciding with the initial identifying of the ration to climate change and fossil fuels. These advancements allowed for SWHs to be used in colder climates and included antifreeze/glycol systems during the 1980's. Selective black surfaces, which allows for more effective collection and storage of heat in SWHs, were developed by Israeli engineers and scientists during the 1950's, improving the overall efficiency of solar thermal technologies significantly.

Major advancements in solar thermal energy are being made all over the world with countries like Spain and Australia among the current market leaders.

1.3: Types of Solar Water Heating Systems

Solar water heating systems, also referred to as SWHs or low-temperature ST systems, are widely used around the world for producing hot water for domestic needs in residential applications. Low temperature ST technologies refer to conventional flat-plate and evacuated tube technologies which are used to produce hot water below 100 °C, and excludes concentrating solar power (CSP) technologies such Linear Fresnel and parabolic trough systems.

SWHs can be classified as direct or indirect. Direct systems, also referred to as open loop systems, circulate potable water through the collectors, before storing it in a tank for usage. These systems offer minimal or no freezing protection through the use of glycol, however it's the least costly. Indirect or closed loop systems make use of a heat exchanger to transfer the heat from the heat transfer fluid (HTF) to the potable water, which is stored in a storage tank.

The installation of ST systems at residences is commonly referred to as small-scale systems, which typically have a gross collector area installation of less than 5 m^2. These systems can be categorised as either pumped (active) or thermosiphon (passive); as well as direct or indirect heating systems, depending of the specific technology used and its design. Thermosiphon systems are commonly classified as low-pressure or passive systems which are gravity-fed. Pump systems are commonly referred to as high-pressure or active systems and are generally more expensive due to the need for additional components and materials of higher quality to handle the increased pressures.

Solar water heating systems are also implemented as large-scale systems within the commercial, business, institutional and industrial sectors for providing heat in domestic and process heat applications. Large-scale ST systems makes use of a larger number collectors which are installed in arrays. Large-scale ST systems have gross collector area of greater than 5 m^2 and are typically indirect, pump circulated (active) systems.

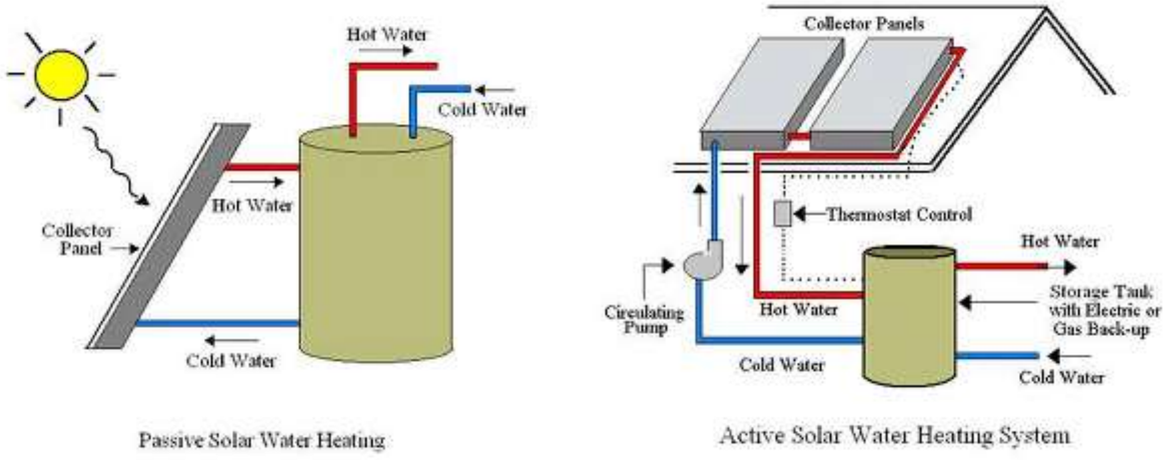

Figure 3: Different types of SWH systems

(Anon., 2019)

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2: Solar thermal installations internationally

The global cumulative solar thermal installation has increased significantly over the past years, which includes unglazed water collectors, flat-plate collectors, evacuated tube collectors and unglazed and glazed air collectors. The global cumulative solar thermal installation is shown from 2000 to 2017 in Figure 4 below.

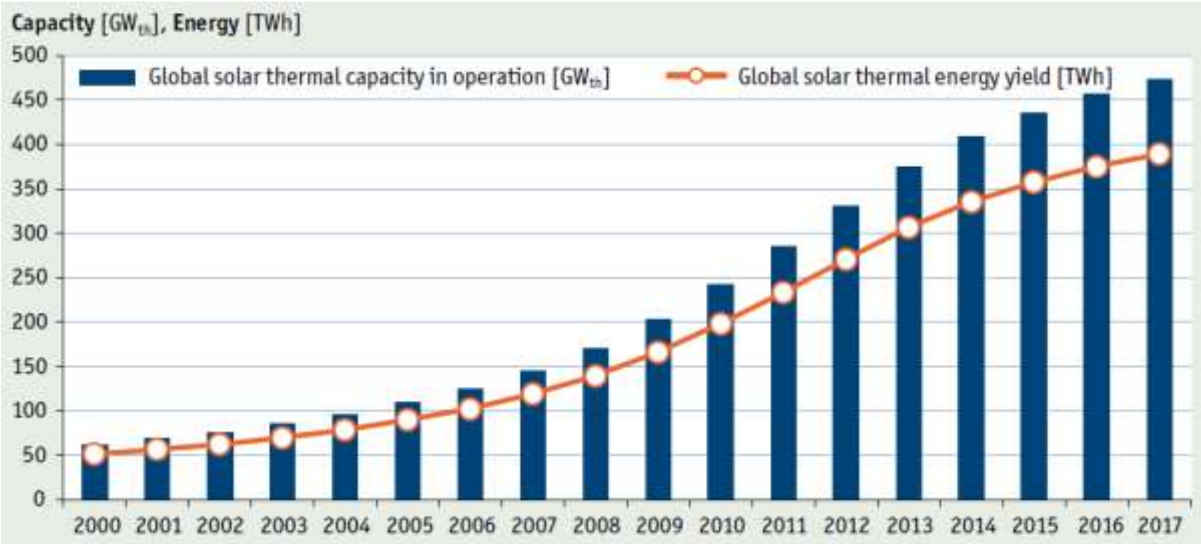

Figure 4: Global solar thermal capacity in operation and annual energy yields 2000 to 2017

(Weiss & Spörk-Dür, 2018)

The global ST installed capacities of glazed and unglazed water collectors grew from 62 GW_{th} (89 million m^2) in 2000 to 472 GW_{th} (675 million m^2) in 2017 (Weiss & Spörk-Dür, 2018). This corresponds to a growth of 6.6 times the installed capacity over the 17 year period. Furthermore, the resultant annual energy yields for the installed capacities amounted to 51 TWh in 2000 and 388 TWh in 2017 (Weiss & Spörk-Dür, 2018).

At the end of 2016, the total installed capacity was recorded as 457 GW_{th}, of which China (324.5 GW_{th}) and Europe (51.8 GW_{th}) accounted for 82.3% of the global solar thermal installations. This is a vast majority of the global installed capacity. Other regions of the world with accountable capacities of solar thermal installations include the USA and Canada (18.6 GW_{th}), the rest of Asia (12.1 GW_{th}), Latin America, the Middle East and North African region (NEMA) (6.8 GW_{th}), Australia and New Zealand (6.5 GW_{th}) and Sub-Sahara Africa (1.5 GW_{th}) (Weiss & Spörk-Dür, 2018).

Evacuated tube collectors account for 71.6% of the global ST capacity installed, while 22.1% are flat-plate collectors, 6.1% are unglazed water collectors and 0.3% are unglazed air collectors. The largest ST markets exists in China and Europe while Barbados, in the Caribbean region of North America, had the highest collector capacity in operation per inhabitant at the end of 2016, with 515 kW_{th} per 1 000 inhabitants. More than three quarters of the global installed ST capacity are thermosiphon systems (Weiss & Spörk-Dür, 2018).

3: Solar thermal installations in South Africa

This section provides a general overview and discussion of the current capacities of SWH installation across South Africa. It specifically discusses Eskom' SWH rebate programme and the impact it had on the local SWH market. Furthermore, this section of the report also describes the different types of solar water heating systems commonly installed in SA based on various applications and sector and provides an over of large-scale solar water heating installation in the country.

3.1: Eskom SWH Rebate Programmes

According to the International Energy Agency (IEA), a total collector area of 975 360 m^2 was recoded as installed and operation in South Africa at the end of 2008, amounting to a total capacity of 628.8 MW_{th} (Chang, Lin, Ross, & Chung, 2011).

Eskom launched a number of programs to promote energy efficiency and alternative energy sources to reach the energy savings targets set out by the South African government. The programme supported the government's White Paper on Renewable Energy Policy (2003), by targeting the provision of 10 000 GWh of electricity from renewable energy sources by 2013. The SWH rebate programmes in South Africa consisted of two phases.

The first was the Eskom's SWH rebate programme which was aimed at converting 925 000 electrical geysers to SWHs over a 5 year period (2008 - 2013) and targeted middle- to high-income groups (residential and commercial sectors), specifically using high pressure systems. The second was the National SWH Rebate Programme, which was aimed at installing one million SWH over a 5 year period (2010 - 2015) across high- middle- and low-income households for high- and low-pressure systems. NERSA allocated funds for the programmes development, marketing and the funding of incentives to customers to pay rebates for 5 years, after which the programme would be reviewed. Both programmes were managed by Eskom.

South Africa's SWH market was relevantly stagnant prior to 2008. Prior to the announcement of the SWH rebate programme, there were less than 20 SWH companies, by 2009 there were 100 companies and by 2010, once the NSWHP programme had been announced, the Sustainable Energy Society of South Africa (SESSA), had over 450 registered SWH members (Kritzinger & Covary, 2016). With the onset of load-shedding and launch of Eskom's SWH rebate programme in 2008, there was a rapid growth in the market.

During September 2012, Eskom reported that a total of 123 408 SWH systems were installed across the country, of which 38 731 were high-pressure (HP) systems and 84 677 were low-pressure (LP) systems. Cumulatively, this equates to a total of 60 GWh of savings per annum (Kritzinger &

Covary, 2016). By mid-2013, 52 013 HP systems had been installed through Eskom's subsidy (Hertzog, 2014).

Figure 5 shows a bar graph indicating the total number of HP SWH installed nationally through Eskom's rebate programme for each quarter of the year from 2008 to mid-2013. The black line in Figure 5 indicates the trend of the installations during the rebate programme.

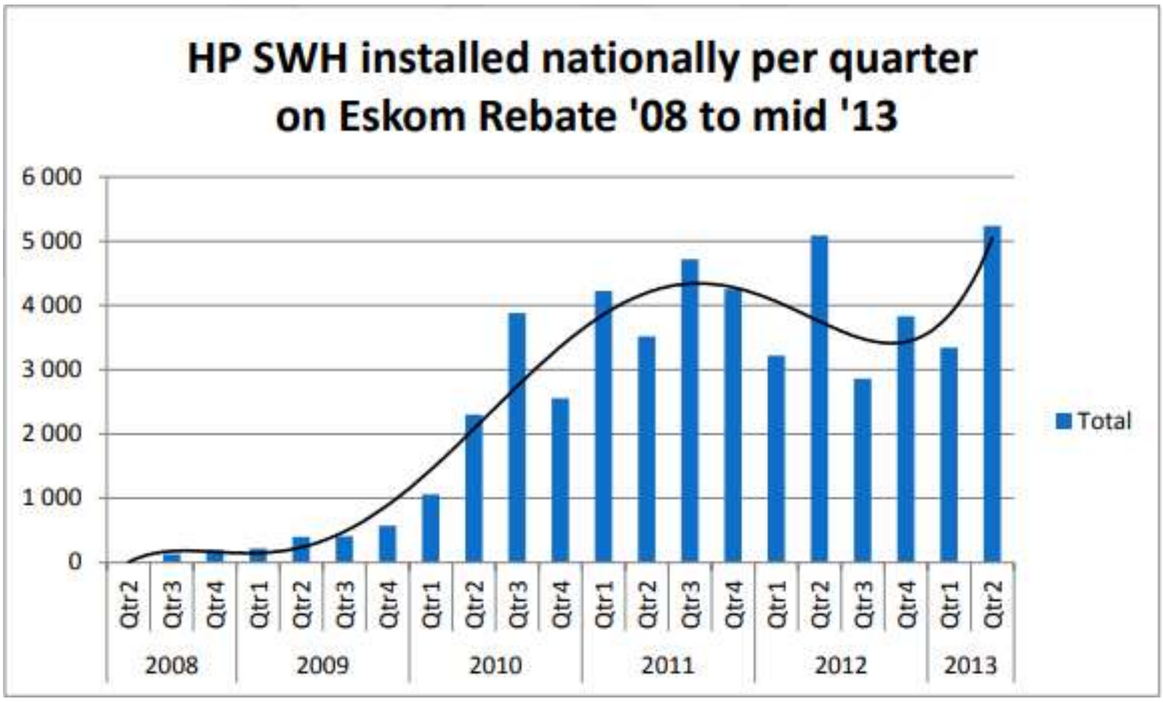

Figure 5: Total HP SWH installations per quarter thought Eskom SWH Rebate Programme

(Hertzog, 2014)

It can be seen from Figure 5 that there was a rapid increase in the installation of HP SWH through Eskom's rebate programme from 2010 until its termination in mid-2013, with around 2 500 to just over 5 000 systems being installed each quarter.

Figure 6 shows the total number of HP SWH installation through Eskom's rebate programme according to each province in SA.

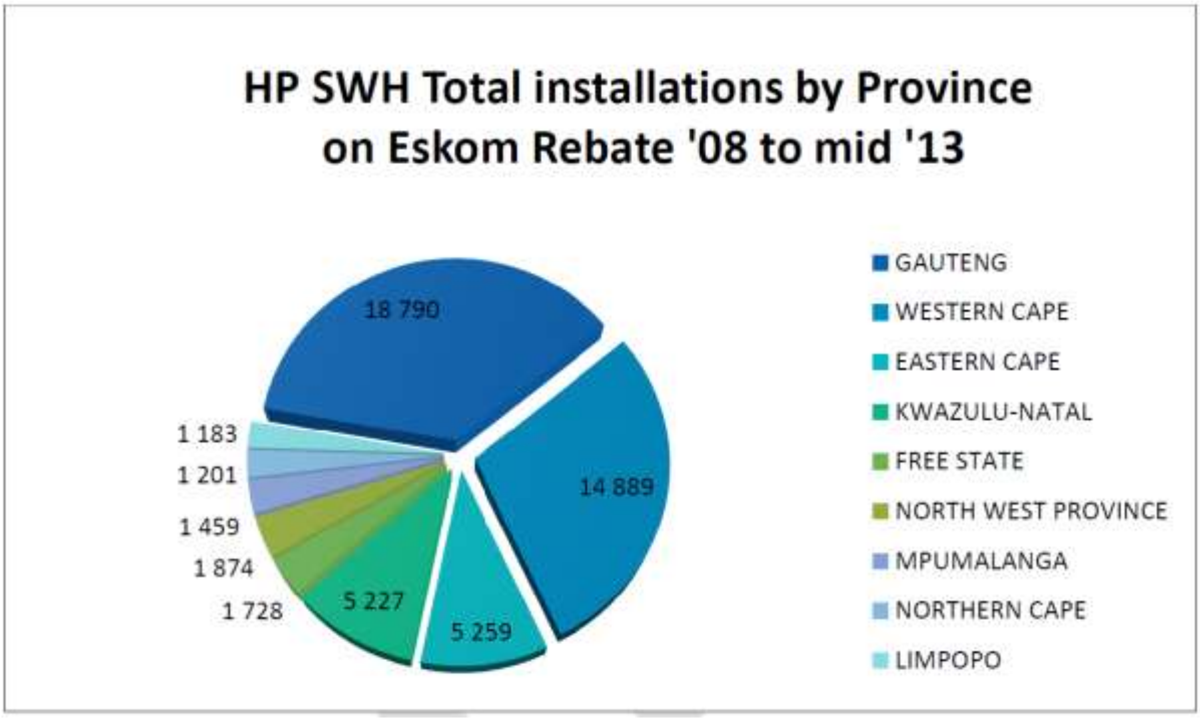

Figure 6: HP SWH installations through Eskom Rebate Programme per province from 2008 to 2013

(Hertzog, 2014)

It can be seen from Figure 6 that the largest number of HP SWHs installed through Eskom's rebate programme was locaed in the province of Gauteng, followed by the Western Cape. Eskom's rebate programmes for LP and HP systems came to an end in the beginning of 2013 and 2015, respectively, however the set out targets were not reached.

3.2: Types of ST installations and its applications

ST systems can vary significantly depending on their application. Residential systems are simple designs with minimal variation. Large-scale systems can vary significantly in design specially when used in process heat applications. The most common types of ST systems implemented in different sectors are described below.

Residential ST Installations (Small-scale)

Residential installations typically make use of thermosiphon (passive) systems, also referred to as LP SWHs, depending on the heat demand, since it is the most cost effective. It is commonly implemented in low-cost housing projects. Pumped systems, referred to as HP SWH, are also commonly installed in residential applications. These systems can be direct or indirect, depending of the climatic conditions in the region and customer preference. Residential systems are typically equipped with a secondary electrical resistive element for back-up heating on days when solar irradiation is low. Figure 7 shows a number of indirect, thermosiphon (LP) SWH installed at residences in South Africa.

Figure 7: Residential thermosiphon SWHs in Western Cape, South Africa

(AEE-INTEC, 2015)

Commercial ST Installations (Large-scale)

ST installations within the commercial sector (businesses, institutions, etc.) are typically pumped (HP) solar water heating systems with gross areas greater than 5 m^2. It is most common for these businesses or intuitions to implement pump driven, indirect ST systems, which includes mean back-up heating such as heat pumps, electrical resistive heating, etc.

Hot water production from these solar water heating systems could be intended for domestic use or facility functions and processes. These systems are typically used to complement existing heating systems such boilers or heat pumps and provided means off offsetting the use of conventional fuels while generating savings.

Industrial Solar Water Heating Installations (Large-scale)

The application of solar water heating systems within the industrial sector to supply process heat varies for each process application based on integration capabilities. The design of the solar water heating system will vary for each application, industry type, application, process temperature requirements and process layouts. These are typically large-scale pumped (HP) driven, indirect solar water heating solutions with a gross collector area greater than 5 m^2.

These systems are typically used to complement existing heating systems such boilers or heat pumps and provided means off offsetting the use of conventional fuels while generating savings. The solar water heating system serves as a means of offsetting the use of conventional fuel sources such as coal and electricity for generating heat and could be implemented for preheating in process for steam production. It is common practice to include heat recovery systems when implementing solar water heating solutions in process heat applications for further enhancing the energy efficiency of processes, where possible.

Figure 8 shows a generic schematic of a large-scale (HP) solar water heating system used for industrial application and the various system components and integration.

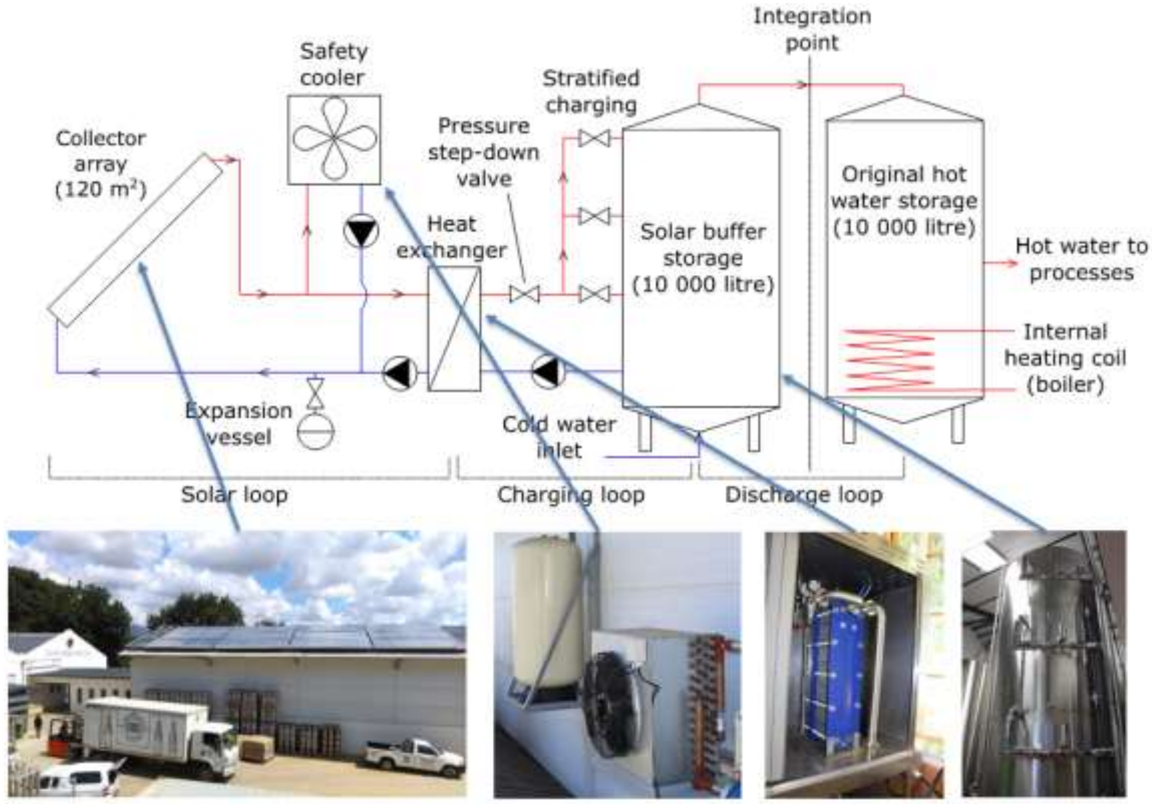

Figure 8: Large-scale solar water heating system used for industrial process heat at a brewery in Western Cape, South Africa

The use of ST technologies in centralised district heating is categorised as industrial/large scale solar water heating installations. The heat generated from the large-scale systems is sold to customers for space heating in buildings via dedicated distribution networks, which is a growing practice in European countries that experiences colder climates. These types of systems have the potential to be locally implemented to provide hot water in new developed residential areas.

3.3: Large-scale ST Installations for commercial and industrial applications

CRSES created, and is constantly updating, a database identifying large-scale solar thermal systems in South Africa. It should be noted that this database only accounts for large-scale solar thermal installations and projects (>10 m^2) and excludes single, small-scale residential systems (< 5 m^2) below this gross area. These large-scale systems are typically installed within the commercial and industrial sectors for domestic and process heat applications. There are 125 systems listed in the database, amounting to a total collector area of 28 213 m^2, installed between 2002 and 2016. In the analysis of the database installations were grouped into various collector area sizes namely: 10 - 50m^2, 50 - 125m^2, 125 - 250 m^2, 250 - 500 m^2 and larger than 500 m^2.

There are 125 systems listed in the database, amounting to a total collector area of 28 213 m^2, installed between 2002 and 2016. Figure 9, Figure 10, and Figure 11 categorise the individual systems based on a collector area range per province, per application, and per industrial sector, respectively.

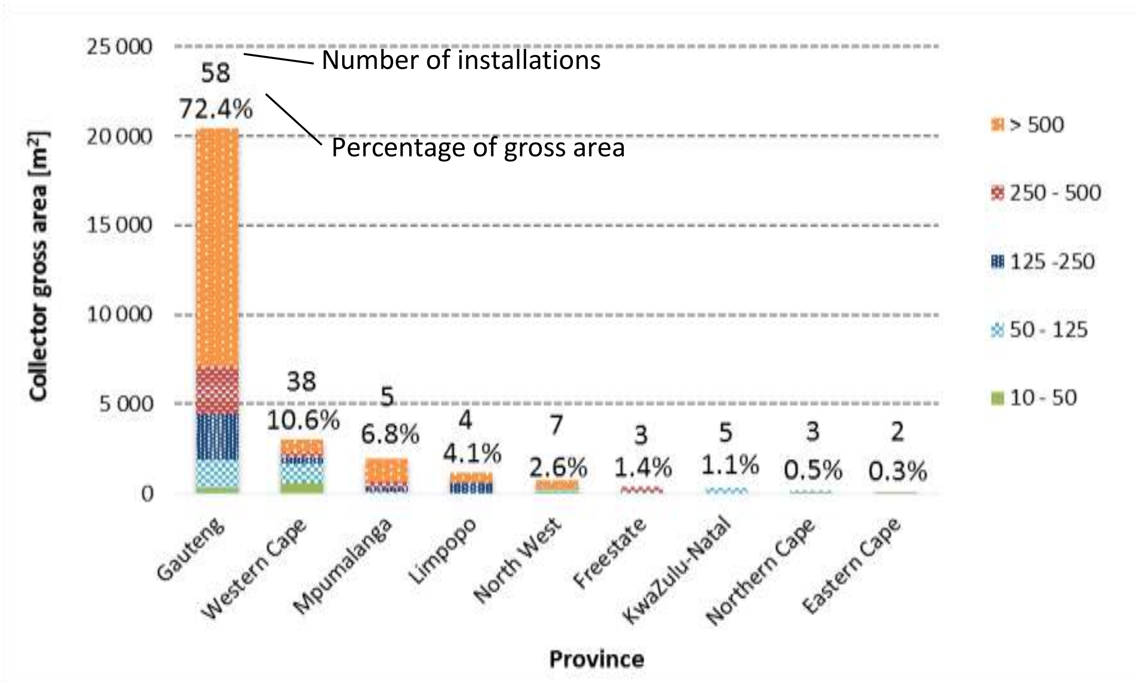

Figure 9: The total collector gross area of large-scale solar thermal systems installed per province in South Africa at the end of 2016

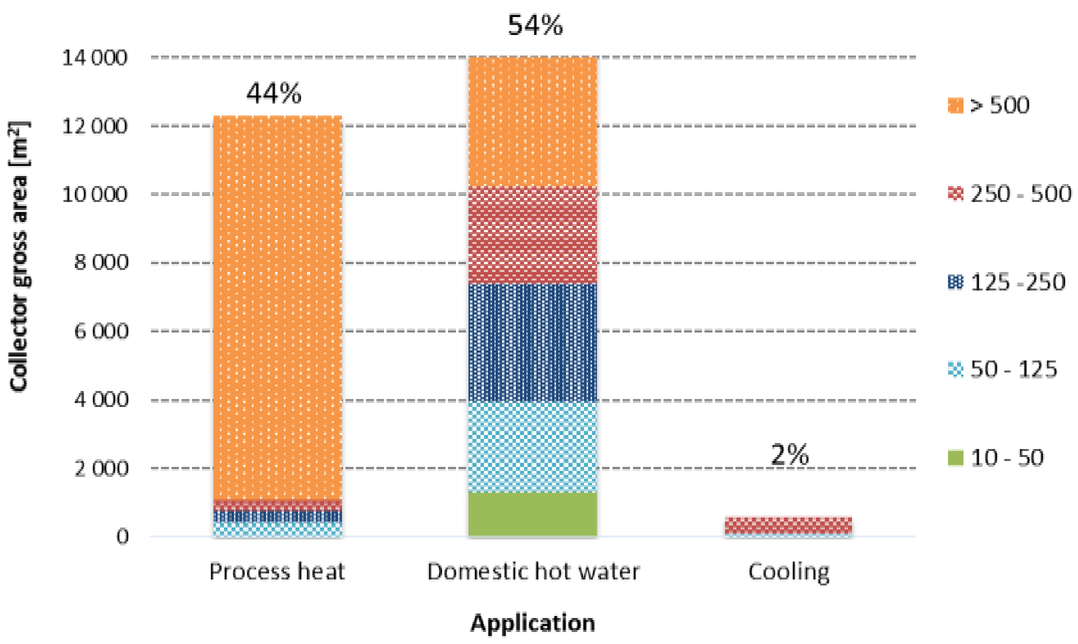

Figure 10: The total collector gross area of large-scale solar thermal systems installed in South Africa based on application at end of 2016

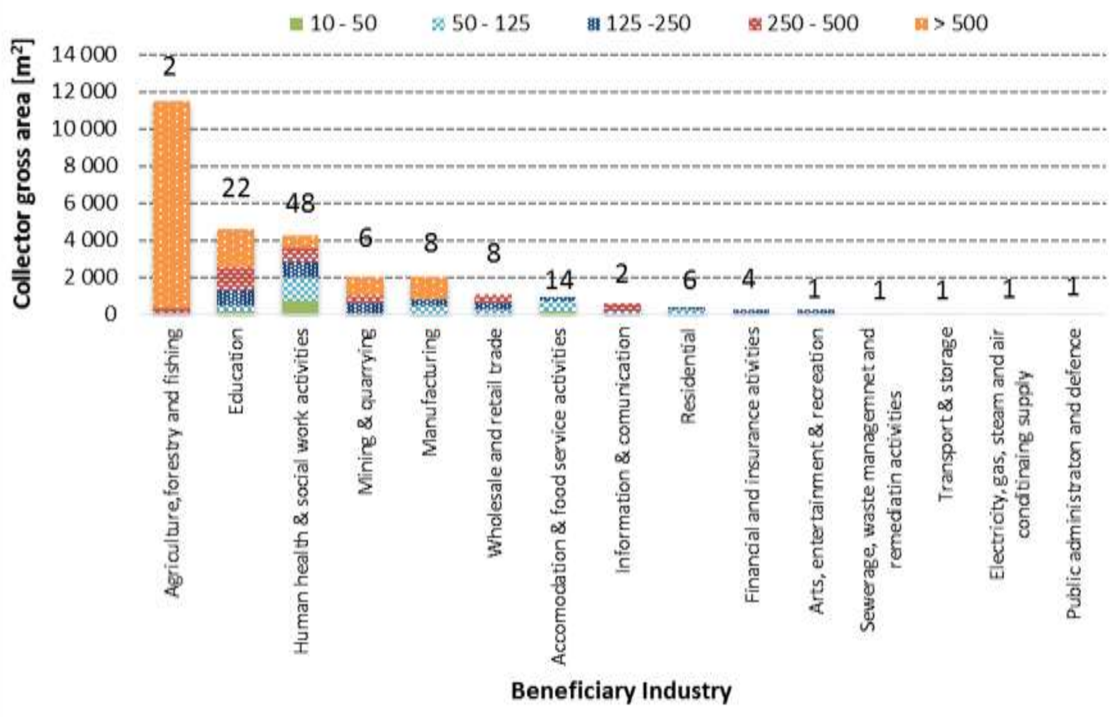

Figure 11: The total collector gross area installed in South Africa based on industry application at end of 2016

4: Relevant South African regulations and standards

Regulations had a major impact on the SWH industry. The development of regulations went in line with the growth in the industry with key regulations driven by programmes such as the Eskom rebate programme. The consequence of not having regulations in place at the start of the growth resulted in various negative effects on the industry and consumers. Some of these effects include the installation of low quality products prior to the establishment of and updating of key standards, the high cost of complying to standards following the implementation of system based testing, as opposed to component testing through the SABS mark scheme, at the South African Bureau of Standards and compliance issues related to the release of compulsory specifications for hot water storage units, VC9006.

4.1: Standards and regulations

SANS 10400 – Code of practice for application of the National Building Regulations

SANS 10400 was published and propagated as the national building code and was effective since September 2012. This standard relates the building design with regards to energy efficiency and maximum energy consumption per m^2 for different types of buildings. It governs the design, planning and supervision of new buildings in South Africa by setting out general principle and requirements.

SANS 10400-XA1 specifies the maximum energy consumption for specific buildings per m^2. This sections allows for more energy efficient constriction of buildings by setting minimum and maximum specifications for fenestration, roof insulation, double cavity wall construction, etc. This section stipulates that buildings are able to use energy efficiency to reduce the overall greenhouse gas emissions which is in accordance with the current requirements.

SANS 10400-XA2 specifies that at least 50% (by volume) of the annual average hot water heating requirements should be provided by means other than electrical resistance heating. The alternatives include, but is not limited to heat pumps, SWHs, heat recovery and renewable combustible fuels. This stimulates the SWH market as the buildings industry grows and the new building plans submitted for approval increases (Hertzog, 2014).

SANS 151 – Fixed electric storage water heaters

SANS 151 specifies the general, constructional and performance requirements that should be complied by all fixed electrical storage water heaters. Furthermore, it stipulates the means of testing and inspecting as well as the operational and installation instructions of devices. This standard is applicable to all fixed electric storage water heaters used in conjunctions with collectors for solar water heating.

VC 9006 – Compulsory specifications for hot water storage tanks for domestic use

VC 9006 provides the compulsory specifications for hot water storage tanks used in domestic applications. This includes fixed electrical storage water heaters, stand-alone water heaters with/without heat exchangers, SWHs or heat pumps and tanks with is solely used for storing hot water. These compulsory specifications were enforced by the National Regulator of Compulsory Specifications (NRCS) in the aim of reducing the electricity consumption for domestic hot water production in the country.

VC 9006 is in-line with the government's strategies to promote energy efficiency by eliminating inefficient energy appliance from the market. VC9006 stipulates that all fixed storage water heaters, including SWH storage tanks, should have a minimum energy efficiency rating of Class B when tested in accordance with SANS 151.

SANS 1307 – Domestic storage solar water heating systems

This standard specifies the requirements for integral, close-coupled and split domestic SWHs and includes the specific requirements for solar collectors in solar water heating systems. However, the standard is not applicable to SWHs for swimming pools, SWHs for commercial or industrial applications and instantaneous type domestic SWHs. A breakdown of SANS 1307 is given in Figure 12 below.

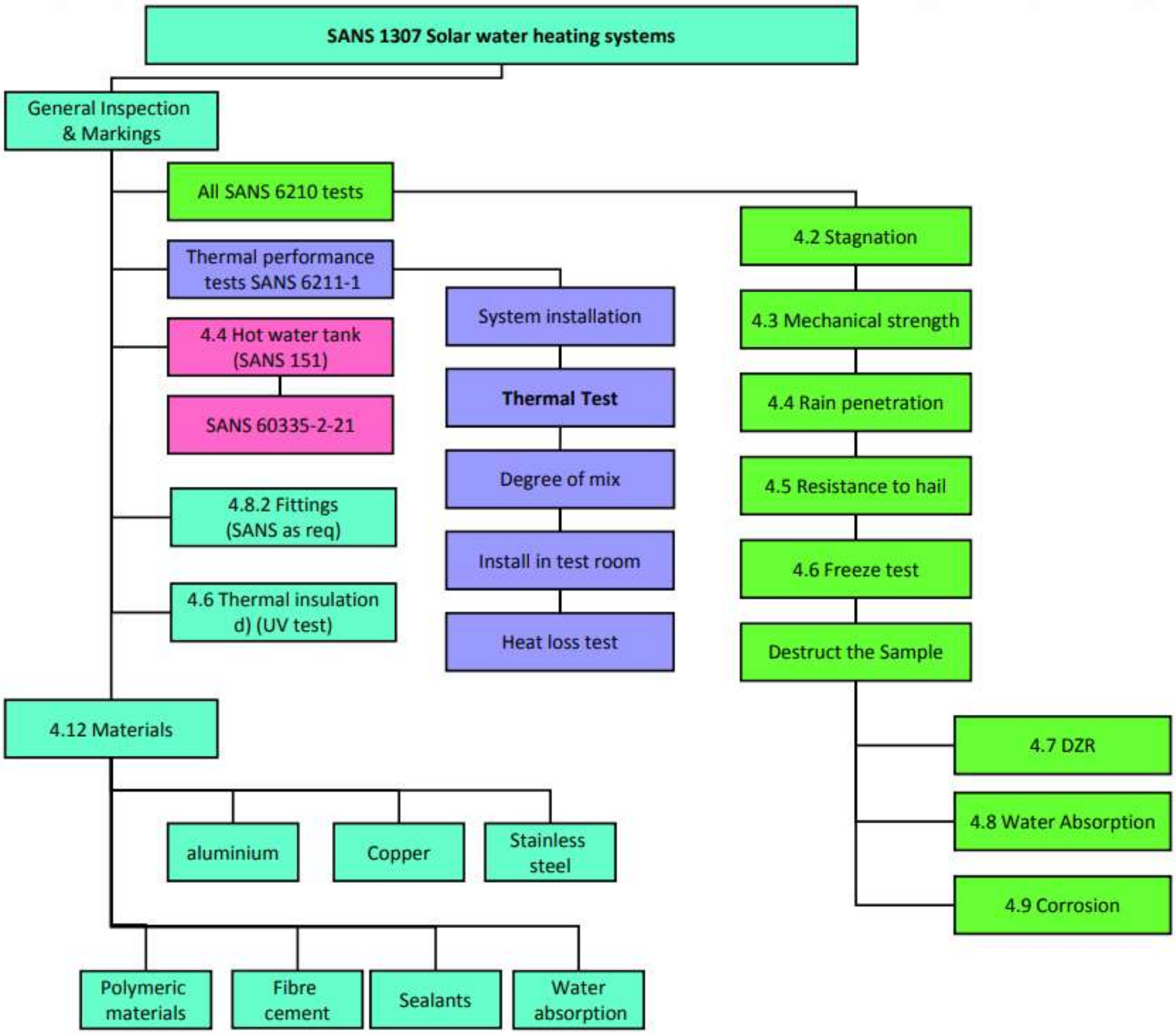

Figure 12: Breakdown of SANS 1307 with referenced standards/materials

(Strauss, 2013)

The standard makes reference to relevant standards for the material and testing of SWHs to insure the safety and quality of systems and installations. SANS 6210 relates to the required mechanical, general and safety tests. SANS 6211-1 relates to the thermal testing of solar collectors. The collector tank itself is however governed by SANS 151.

5: The business case for large-scale solar water heating in South Africa

5.1: Incentive Structure for ST in South Africa

Renewable Energy Income Tax Incentive

Section 12B of the Income Tax Act allows for provision for a capital allowance for movable assets used in the production of renewable energy. The incentive allows businesses for 100% accelerated depreciation of RE assets in the first financial year of its operation. The accelerated depreciation 12B tax incentive for RE installations allows businesses to deduct the full cost of their RE systems from their taxable income in the year of installation. This incentive is, however, not available for private persons with residential ST installations.

Energy Efficiency Income Tax Incentive

The section 12L of the Income Tax Act was passed in 2013 and allows for deduction in respect to energy efficiency measures by businesses. The 12L Tax incentive provides an allowance for businesses to implement energy efficiency savings. The incentive allows tax deduction for all energy carriers (not just electricity). However, this incentive excludes the energy generated from renewable energy sources such as ST technologies.

5.2: Cost of solar water heating in South Africa

The cost of solar water heating solutions has decreased over the years, especially after 2008 with onset of the Eskom's rebate programme which onset the growth of the local market and maturity of the technology within the country. It is important to differentiate between the cost of low-cost residential systems, which are typically thermosiphon systems, and large-scale systems which are pump driven systems used in commercial and industrial applications.

Thermosiphon systems are typically "off-the-shelf" products which can easily be integrated into existing residential hot water systems with additional plumbing and safety components by a qualified plumber. The cost of small-scale residential systems can range from R 20 000 to R 30 000 depending on the collector and storage chosen and are capable for supplying 50% to 80% of a household's hot water demand annually, depending on the hot water demand profile and the solar resource of the specific site. The savings generated by residential solar water heating is well understood and easily determined, therefore the part of the policy focuses on the business case for large-scale solar water heating systems in commercial and industrial applications only.

Large-scale solar water heating systems typically require advanced designs, improved materials and components that can withstand higher pressures, more system and safety components or custom made components to meet the specific process requirements. This considerably varies the cost of pumped ST systems depending on its specific application when compared to thermosiphon SWHs based on specific cost (ZAR/m^2), which is the total cost of a solar water heating installation per square of collector are installed.

The cost of large-scale solar water heating systems can vary significantly depending on its specific application with respect to the specific gross collector installed. The specific cost of large-scale solar water heating systems in SA was investigated by (Joubert, et al., 2016). The study uses database of 89 large-scale systems in SA installed from 2007 to 2015 to establish a relationship between the specific cost and the total collector for large-scale systems in the country, shown in Figure 13.

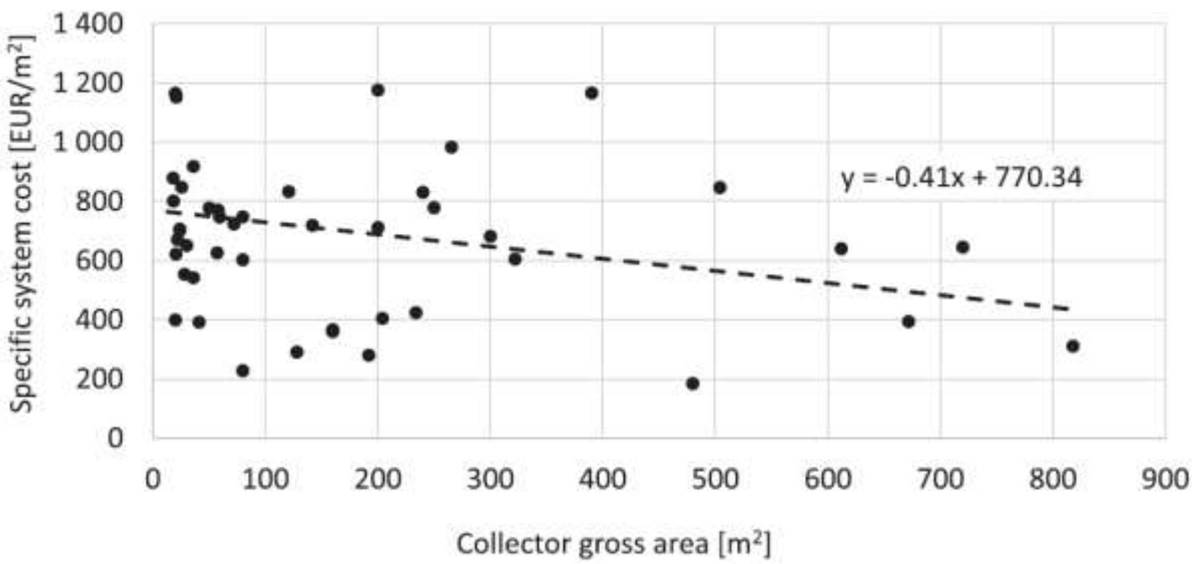

Figure 13: The relationship between specific cost relative to collector area installed of large-scale SWH systems in SA (Based on an exchange rate: 9.66 < ZAR/EURO < 15.3 from 2007 to 2015)

(Joubert, et al., 2016)

The study showed that large-scale systems in SA had an average specific cost of 603 EURO/m^2. This is very high compared to other countries, for example, Germany exhibit a specific cost of 400 EURO/m^2 in 2005 for system above 50 m^2 (Joubert, et al., 2016).

Figure 13 shows an overall trend that specific costs of large-scale solar water heating systems decreases with the increase in the size of the system. Figure 13 also shows that the cost for a system of a specific size can vary significantly, which is due to the high variability with respect to its application, quality and planning effort (Joubert, et al., 2016). For example, a system could compose of imported high quality collectors with storage while another could consist of low cost collectors using existing storage, for system with the same gross collector area.

5.3: Conventional fuel costs

The feasibility of large-scale solar water heating investments used to offset the usage of conventional fuels in commercial and industrial application will largely demand of the fuel(s) currently used for heat production. Generally, most commercial business demand on electricity for generating hot water or heat while industries in SA depend on a wide range of fuel sources such as coal, paraffin, LPG, diesel, petrol, HFO and electricity, amongst others, to generating heat through the use of boilers which required for processes.

When SWH solutions are used to reduce the use of low cost fuels such as coal, projects would typically present an unattractive financial feasibility with extended payback periods and low internal rate of returns on investments. This is solely due to the low cost of coal in SA and the relatively low levelised cost of heat (LCOH) it provides to consumers. The LCOH of fuel source is described as the cost of the specific fuel per kWh of heat it provides, ZAR/kWh, which is dependent on the calorific value of the specific fuel and efficiency of heating technology used. The calorific value of a fuel defined the energy contained in the fuel per unit mass or volume.

Table 1 shows the caloric for common conventional fuels and energy sources used for heat production within the residential, commercial and industrial sectors.

Table 1: The calorific values and cost of conventional fuels used in industrial processes for heat generation (Fuel prices for Dec 2016 adopted)

Fuel	Calorific value	Price
Coal	24.3 MJ/kg	1 021.83 ZAR/ton
HFO	41.6 MJ/litre	2.27 ZAR/litre
Paraffin	37.5 MJ/litre	8.07 ZAR/ litre
LPG	26.7 MJ/ litre	6.91 ZAR/ litre
Petrol	34.2 MJ/ litre	14.76 ZAR/litre
Diesel	38.1 MJ/ litre	12.96 ZAR/litre
Electricity	--	0.83 ZAR/kWh

(Motiang & Nembahe, 2017)

When using the figures in Table 1 to determine the LCOH of each of the energy sources above while taking the efficiency of the heat generation systems such as boilers and geysers, it will be established that coal provides the lowest LCOH of all energy sources available in SA due to it low cost. Coal used for hot water production is the most cost competitive fuel source when compared to solar water heating.

The LCOH of the conventional fuels sources was investigated by (Joubert, et al., 2016) based on three scenarios of constant annual increases in fuel costs, shown in Figure 14. The energy prices used in the study was for September 2015 with annual increase of 0%, 6% and 12% over 20 years and constant exchange rate of 15.30 ZAR/EURO.

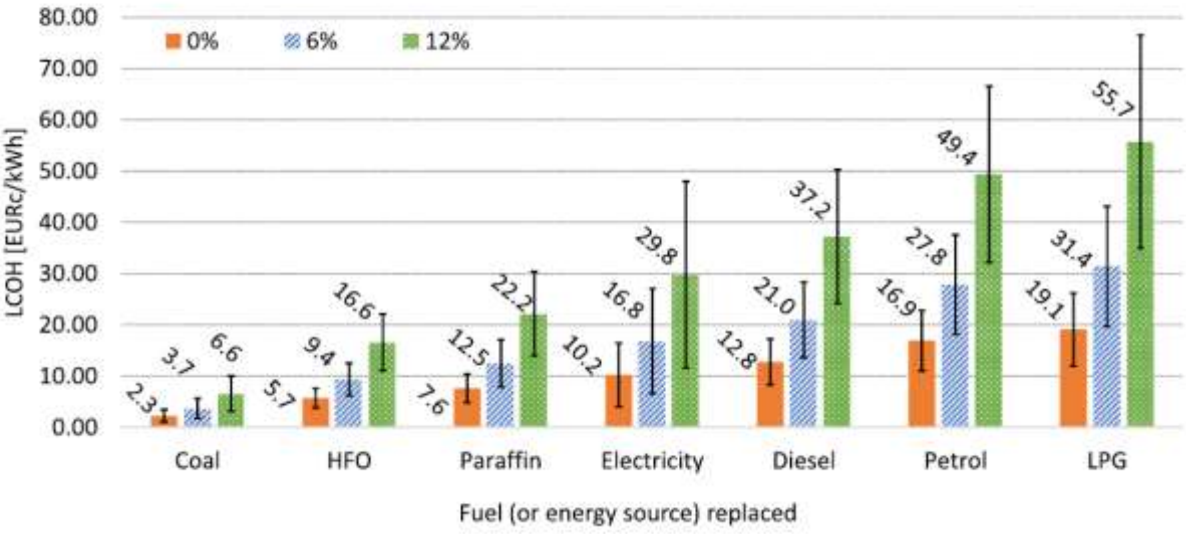

Figure 14: The LCOH of various conventional heat sources over 20 years based on the assumption that energy prices from September 2015 increases by 0%, 6% and 12% annually

(Joubert, et al., 2016)

Coal has a high calorific value with respect to cost and presents considerably low LCOH when compared to other fuels even under the assumption of a 12% increase in cost year-on-year, as shown in Figure 14. In many cases, solar water heating solutions will prove financially unfeasible when used to replace the use of these low cost fuel sources such as coal. Typically, large-scale solar water heating project presents a LCOH ranging from 6 - 10 EUROc/kWh, depending on a number of factors such as the investment cost, specific application, solar resources of the geographical location, financial subsidies and the heat demand of the beneficiary.

Figure 14 therefore shows that solar water heating investments has the ability to provide a better lower LCOH than most conventional fuels when assuming an increase in the fuels on a year-on-year basis, with the exception of coal. It should be noted that the feasibility of SWH investments will be dependent on the percentage increases in the costs of these fuels over the lifespan of the SWH system. However, under the high-end assumption of 12% and the low cost of coal in the country, SWH would likely prove financially unfeasible to offset the use of coal. The use of SWH to reduce the use of fuels such as LPG, petrol and diesel will in most cases prove financial feasible due its high cost and associated LCOH, indicative of financial savings.

All conventional fuel sources are susceptible to increases over the years. These increase will have a direct impact on the financial viability of SWH for offsetting the usage of these fuels. SWH system typically have a lifespan of 25 years and will produce heat at a fixed rate or LCOH over its lifespan. Therefore the year–on-year increase of the specific fuels' cost will dictate the financial feasibility of the SWH system.

5.4: The business case

The feasibility of a large-scale SWH system will depend on; the space available (strength, suitability, size); the design and application of the system (in relation to the specific heat and process requirements on the beneficiary); the system installation cost; the system operation and maintenance cost; financing options (such as grant or debt and tax incentives); the heat annual and daily heat demand; the plant availability and; the cost of fuel which will be offset by heat generation from the SWH system. These factors differ substantially between sites and ST projects within the commercial and industrial sectors, so the specifics can only be determined with certainty through a pre-feasibility study.

The most important factors influencing the feasibility of a large-scale SWH systems includes the;

- **capital cost** of the system;
- **LCOH (ZAR/kWh)** of fuel currently used for heat generation and;
- **heat generated** by the SWH system.

The study by (Joubert, et al., 2016) investigates the expected financial outcomes of large-scale SWH systems in South Africa. The study specifically looks into the amortisation periods of large-scale SWH investments, the required system cost to achieve amortisations periods of less than 5 years and the internal rate of return of large-scale SWH investments when used to offset the consumption of conventional fuels. The results of the study was based on a system cost of

603 EURO/m2, solar gains of 2 000 kWh/m2/year, an overall system efficiency of 45%, boiler efficiencies ranging from 40% to 80% and exchange rate of 15.30 ZAR/EURO.

The amortisation periods that can be expected when implementation large-scale solar water heating systems to offset the use of specific conventional energy sources is presented in Figure 15.

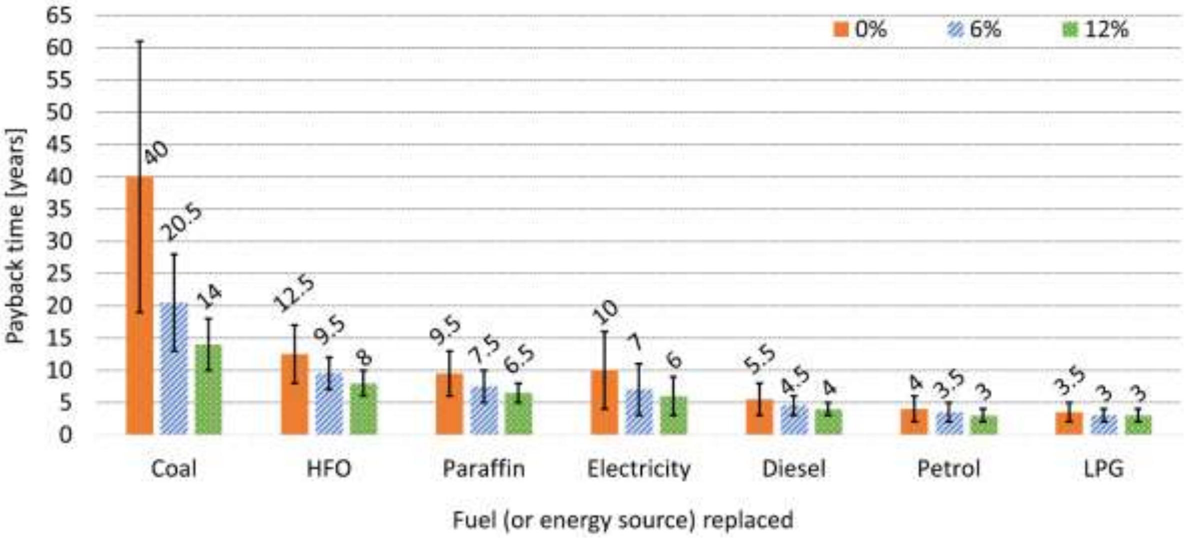

Figure 15: Amortisation periods of large-scale SWH projects when substituting conventional energy sources

(Joubert, et al., 2016)

The idea of an attractive investment may vary depending on sector and potential investors of the SWH system. An amortisation period of 5 years or less for SWH projects can be seen as a highly attractive financial investment. However, it can be seen from Figure 15 that 5 years is only achievable when replacing costly fuels such as diesel, petrol and LPG, based on a system cost of 603 EURO/m^2 of collector area installed.

In most cases, amortisation periods of 10 year or less is considered to be an attractive investment for SWH projects in South Africa. This is achievable for SWH systems used to offset the usage of most conventional energy, with the exception of coal. This is primarily due to the current low cost of coal in the country. The amortisation periods will however be vary depending on the specific application, the heat demand profile, solar resource availability and useful heat generation of the SWH system.

The specific costs (EURO/m^2) of SWH systems required for breaking-even after a 5 year period of the installation of the SWH system is presented in Figure 16 for the various conventional energy sources.

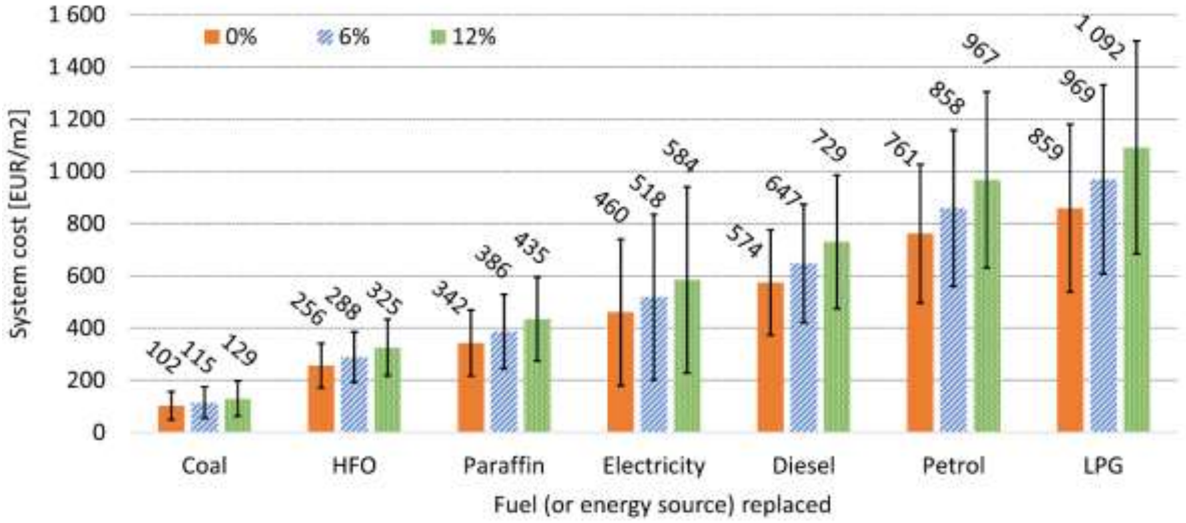

Figure 16: Required specific cost of SWH systems to achieve payback period of 5 years

(Joubert, et al., 2016)

As mentioned, the average specific cost of large-scale SHE systems is approximately 603 EURO/m^2. This again illustrates that replacing the use of diesel, petrol and LPG for heat generation by investing in a large-scale SWH system could have amortisation periods of 5 years or less. Figure 16 indicates system specific costs for achieving desirable investment, which can be targeted through revaluation of system to design to develop the most cost-effective, high quality SWH solutions for specific applications.

The Internal Rate of Return (IRR) of SWH projects when used to offset the use of conventional energy sources in shown below in Figure 17.

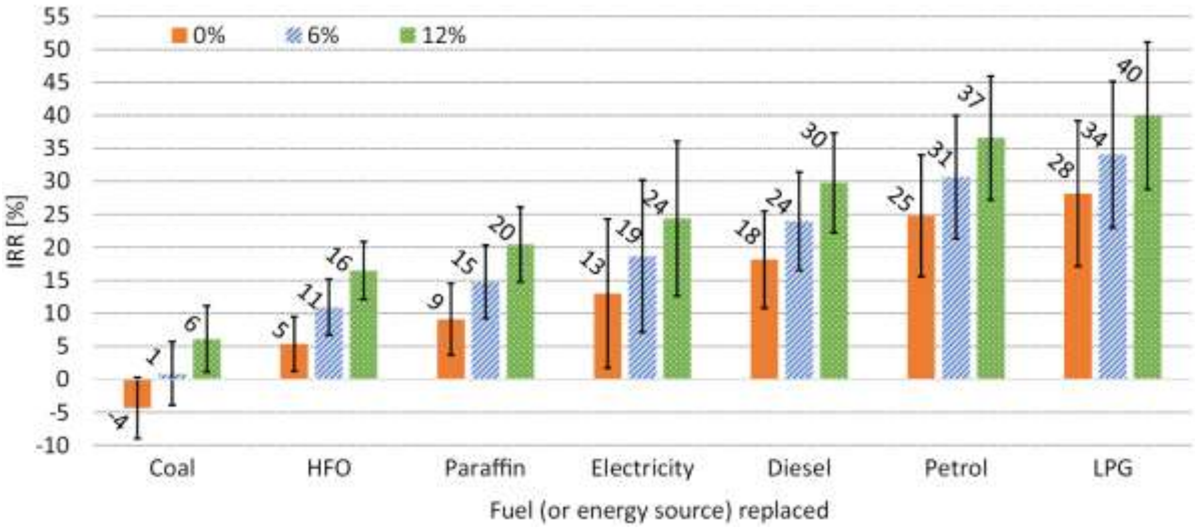

Figure 17: Internal rate of return (IRR) for a current large-scale system with service life 20 years replacing different conventional fuels.

(Joubert, et al., 2016)

In most cases, an IRR of 10% or more for SWH project is considered to be an attractive investment for SWH projects in South Africa, however would still vary for each potential investor. An IRR of 10% is achievable for SWH investments for offsetting the use of most conventional fuels, namely, LPG, petrol, diesel and electricity, under all assumptions for yearly increases in cost. This is achievable for paraffin and HFO as well, except under the assumption that the cost of these fuels will undergo a 0% yearly increase after 20 years of the SWH installation, which is highly unlikely.

5.5: Impact on the utility

Solar thermal installation can have a number of impacts on the national utility and grid. A number of impacts are listed below;

- Solar water heating systems will have a negative impact on the revenue of the utility as a result of a decrease in the dependence/demand of electricity for heat production within residential, commercial and industrial sectors;
- Residential ST system have the ability to reduce the electricity demand of residential sector from the grid, especially during peak times;
- Large-scale ST installation have the potential to reduce electricity consumption from the grid and alleviate demand on the grid;
- Improve energy security from the grid;
- Diversify the energy mix and reduces grid dependences across all sectors where implemented.

These impacts could be related to municipalities as well. It should be noted that the use of solar thermal within the industrial sector for process heat applications could also have significant impact, depending on scale, on conventional fuel (coal, HFO, LPG, paraffin, etc.) suppliers and markets in the country by reducing the sectors dependence on these fuels. The would have a negative impact on the revenues within the markets however improve energy efficiency, diversify energy mix, reduce carbon emission, generate financial savings and increased revenues throughout specific the industrial sectors.

Conclusions and Recommendations

After the rapid growth of SWH installation after 2008 with onset of Eskom's SWH rebate programme, the adoption of SWHs, both large- and small-scale respective sectors has been steady over the past years, largely driven by the new buildings codes set out in the SANS 10400. To date solar water heating has played a large role in diversifying the energy mix and reaching carbon footprint reduction targets across various sectors as set out the Integrated Resource Plan 2010. However, the uptake of SWH has to increase significantly over the next few years to play a larger role in the energy mix if the goals set out for 2030 in the IRP 2010 is to be achieved.

Small-small solar water heating for residential application

SWH has provided means of reducing the electricity dependence of the residential sectors on electricity and in turn fossil fuels by reducing the electricity demand of houses used for producing hot water by electrical geysers. Furthermore, it has significantly reduced the carbon emissions associated with the sector and has load provided mean of peak-shaving through reducing residential electricity during peak demand periods which has proven to be a target area for the national utility over the years.

For policy to support the growth of SWH within the residential sector of the country, a number of factors needs to be addressed. One of the key drivers of SWH within the residential rector is the availability and tax rebate programmes and financial incentives associated with the adoption of the technologies. National SWH rebate programmes and financial incentives has the potential to drive the growth of the SWH for households which in turn stimulates growth of the local market, provides job creation and reduces the cost of SWH technologies in the country. Creating awareness around SWHs and its potential benefits, which includes financial savings, less dependence on utility and reducing CO_2 emissions, amongst others, is a key factor to address for increasing the uptake SWHs within the residential sector.

The installation of low quality SWH technologies through the programme which has since become non-functional has also led to the technology having a bad reputation when compared to other energy efficient alternatives such as heat pumps. The local SWH market has also diminished after the end of the rebate programme, with many companies going out of business. These factors has led relatively low growth of SWH technologies in the residential sector. The SWH market and its uptake in the residential and commercial sector is expected to grow again once the rebate programme has been implemented, this time to be managed by the DoE, however quality of SWH technologies and installation work is a key issue to address through national standards and minimum energy performance standards (MEPS) going forward as part of the lessons learned through past programmes.

Large-scale solar water heating systems for commercial and industrial application

The uptake of large-scale solar water systems within the commercial and industrial sectors in largely dependent on the local SWH market and the cost project investment in the country. As businesses, willingness to adopt RE solutions such as solar water heating is driven by financial investment aspects such as capital cost, IRR, return on investment.

The availability of tax rebate programmes and financial incentives directed at business investments into HP solar water heating solution has the largest impact for driving the growth of the adoption on these technologies across the commercial and industrial sectors. This would in turn stimulate and grow the local HP SWH market leading to job creation, diversify the energy mix of the country associated with heat production and further reduce the carbon emissions of both sectors and associated local industries.

The increase in conventional fuel and carbon taxing also has the potential to stimulate the growth in investment towards RE alternatives such as solar water heating. Awareness creation around SWHs and its potential benefits, which includes financial savings, reducing dependence on fossil fuels and reducing CO_2 emissions, amongst others, is a key factor to address for increasing the uptake SWHs within the commercial and industrial sectors.

Eskom's HP SWH rebate programme provided a much needed boost for HP SWH systems in proving it capabilities and benefits, however policy should be more direct in terms of reducing the fossil fuel dependence, reducing carbon emissions and diversifying the energy mix within various local industries through the implementation of RE alternatives, specifically solar water heating.

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