THE POTENTIAL OF LARGE-SCALE IMPLEMENTATION OF SOLAR THERMALTECHNOLOGIES IN SOUTH AFRICAN HOSPITALS

Mr Angelo Ian Buckley[1], Ms Karin Kritzinger[2]

Centre for Renewable and Sustainable Energy Studies[1]
Stellenbosch University, Corner of Banghoek & Joubert Streets, Stellenbosch, 7600
South Africa
Phone: +21 21 808 3605
E-Mail: buckley@sun.ac.za

Centre for Renewable and Sustainable Energy Studies[2]
Stellenbosch University, Corner of Banghoek & Joubert Streets, Stellenbosch, 7600
South Africa
Phone: +21 21 808 3605
E-Mail: karink@sun.ac.za

1 SUMMARY

This study investigates the potential for the large-scale roll-out and implementation of solar thermal (ST) technologies in South African hospitals to offset conventional fuel use and identifies challenges relating to this potential uptake. There are a total of 696 hospitals in South Africa (SA) with a total thermal energy demand for hot water of 370 GWh per year. A total installed collector area of 73 972 m^2 to 147 944 m^2 across all hospitals in SA would increase the overall ST capacity of all these hospitals to compensate for 20 to 40% of their combined annual thermal energy demand. The major limiting factor for the uptake of ST technologies in South African hospitals is the current wide spread use of coal fired boilers as well as heat-pumps, making the adoption of ST technologies less feasible from a financial perspective.

2 INTRODUCTION

This study investigates the potential for the large-scale roll-out and implementation of solar thermal (ST) technologies in hospitals in SA specifically relating to the use of solar water heating for the low temperature applications. The study focuses on public and privately owned, large and smaller hospitals in the country. Hospitals in SA typically have hot water temperature requirement of 60 °C, used for staff and patient ablution purposes and laundry. The study specifically investigates the penetration levels of ST technologies across the hospital sector in SA, assuming realistic solar fractions to identify the potential energy offset from conventional fuel sources, currently used by hospitals for producing hot water. The study also identifies the challenges relating to the uptake of ST technologies in South African hospitals.

3 OVERVIEW

The potential for ST systems varies across the world, depending on the irradiation. SA experiences an abundance of solar irradiance and exhibits great potential for the application of large-scale ST systems in industrial applications. This is clear from Figure 1 (left), illustrating the distribution of the average annual sum of global horizontal irradiance (GHI) in SA. A database that identifies all public and privately owned hospitals in SA was developed to establish the total number of hospital beds in the country. This database identified a total of 696 hospitals. This list excludes small clinics and healthcare facilities. The map in Figure 1 (right) displays the geographical location of the listed hospitals. The location of most of the hospitals in the country are in regions with the highest population density, such as Cape Town, Johannesburg and Durban, as expected.

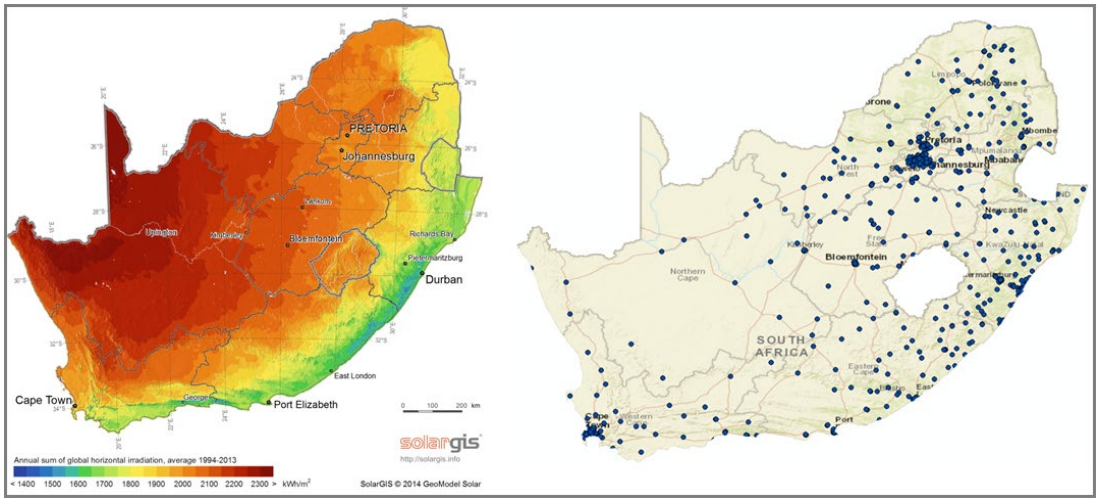

Figure 2:Solar resource map (GHI) of SA (left) and the GIS map of hospital locations in SA (right)

It is estimated that these 696 hospitals have approximately 126 490 beds in total, with a maximum bed count of 3 200 in a single hospital. The location of these hospitals can be seen in Figure 2. These include large provincial hospitals that are managed by the provincial health departments on a district level, as well as private hospitals owned by companies such as Netcare, Mediclinic, Life Healthcare and other hospital groups affiliated with the National Hospital Network.

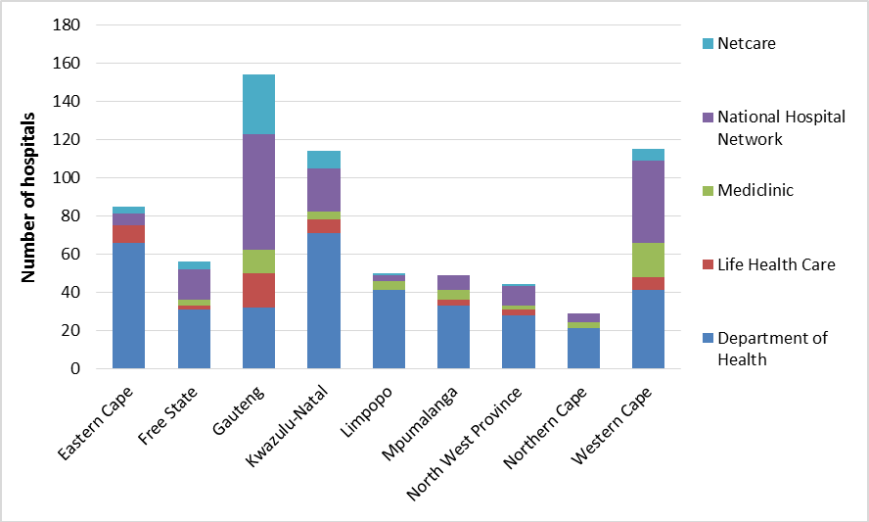

Figure 1: Number of hospitals per province in South Africa based on management

Most hospitals throughout SA are owned and managed by the respective provincial health departments (Department of Health), as seen in Figure 2. Privately owned hospitals make up approximately 48% of the total hospitals in the country based on the data sourced, and form the majority of the hospitals in the Western Cape (WC) and Gauteng. Provincial hospitals are in the majority in other provinces of SA.

4 CURRENT HEATING TECHNOLOGIES USED IN SOUTH AFRICAN HOSPITALS

The database of hospitals managed by the WC Department of Health was used to get an overview of current thermal technologies used by hospitals in SA. This database identifies the current heating technologies installed, number of beds and water consumption. Figure 3 shows the type of heating technologies employed by the

Department of Health hospitals in the WC. These hospitals make use of either coal-fired or electrical boilers, including electrical heat pumps and/or ST systems.

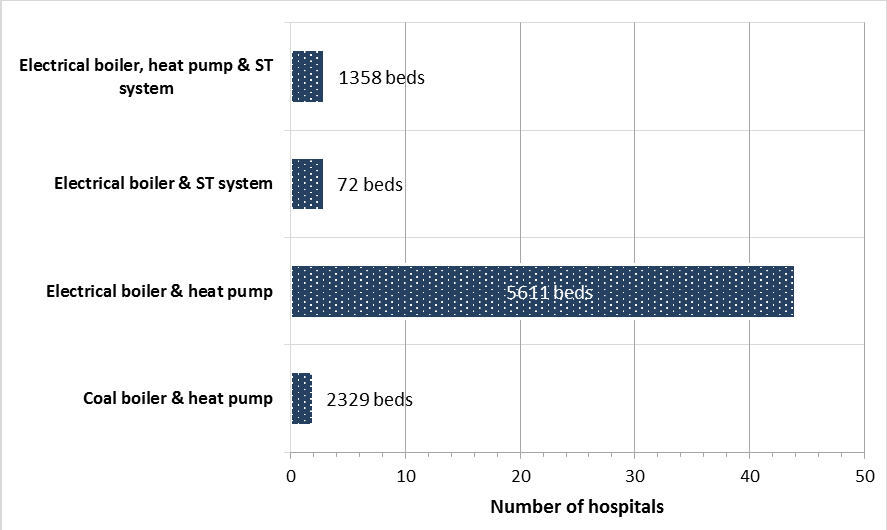

Figure 3: Thermal technologies used by hospitals managed by the WC Department of Health

Only two of the hospitals managed by the WC Department of Health makes use of coal boilers. See Figure 3. However, these two hospitals consists of the most beds per hospital, accounting for 2 320 beds (25%) of the total 9 370 beds managed by the department. Both of these hospitals have heat pumps installed as well. Fifty of the hospitals make use of electrical boilers. Of these, 44 also have heat pumps installed, 3 also have ST technologies installed, and 3 also have a ST system and heat pumps installed. Figure 3 shows that 49 of the hospitals managed by the WC Department of Health have heat pumps installed.

The large number of heat pumps in provincial hospitals makes the adoption of ST technologies at these hospitals challenging. The financial feasibility of ST technologies for the larger hospitals that make use of coal to meet their heat demand is also a challenge, since coal is a low-cost fuel source in SA, significantly cheaper than ST solutions when compared to the levelised cost of heat (LCOH) for each thermal energy source.

If this is the case for most provincial hospitals, which account for 52% of hospitals in SA, it will be difficult to prove the feasibility of ST systems for provincial hospitals. In cases where large heat pumps have been installed, much smaller ST systems would be the most sensible solution, although this option still carries the risk of presenting longer payback periods than normal, when compared to hospitals that solely depend on conventional electrical and coal boiler technologies.

On the other hand, privately owned facilities, such as hospitals owned by Mediclinic and Netcare, have installed renewable energy technologies, including ST and solar PV solutions. In many cases, these hospitals have installed combined solar and heat-pump systems, using electrical resistive heating as a back-up heat source. These systems demonstrate how the different technologies can effectively work together to supply the hot water needs of hospitals.

5 CURRENT SOLAR THERMAL APPLICATIONS AT SOUTH AFRICAN HOSPITALS

The large-scale ST database created during this study was redefined to identify all large-scale ST installations at hospitals in SA. It should be noted that this database was created through extensive market research and online information and its inclusion is subject to information being available to the researchers. Based on the information gathered in the database, there are 23 large-scale ST systems installed at hospitals within SA, equating to a total ST collector area of 1 333 m^2. Figure 4 displays the total collector area and number of systems per province,

based on the specific collector area range of each system. These systems range in a gross collector area from 10 to 250 m^2.

Most of the ST systems installed at hospitals in SA are in the WC, with 11 of the 23 recorded systems. See Figure 4. These WC systems account for 547 m^2, or 41%, of the total collector area installed in the country at hospitals. Gauteng has a total of seven recorded systems, amounting to a total installed collector area of 546 m^2. Other provinces, including the Free State, KwaZulu-Natal and the Northern Cape, have five recorded systems with a total collector area of 240 m^2, amounting to 18% of the total collector area installed at hospitals throughout the country. Furthermore, it is noticeable that most of these systems have a total gross collector area ranging from 50 m^2 to 125 m^2.

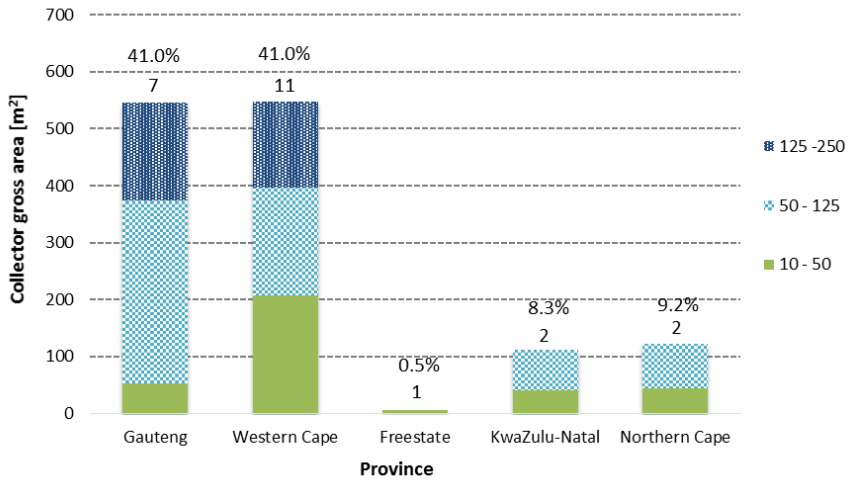

Figure 4: Large-scale ST system installed at hospitals in South Africa, per province

6 ANNUAL HEAT DEMAND OF HOSPITALS

Large hospitals around the world require thermal energy for a variety of purposes, including central heating, staff and patient ablutions, and in certain cases process steam. Some larger and older public hospitals in SA make use of process steam, generated in larger-scale boilers, to operate autoclaves for sterilisation, humidification, heating, and generating hot water for domestic purposes. Most of the newly built public and private hospitals in the country do not depend on these steam cycles and make use of more efficient technologies and cycles. This section of the report focuses on the hot water demand in hospitals in SA for domestic applications, including staff and patient ablutions.

The South African National Standard (SANS) 10252-1 states that hospitals in SA can be expected to have a daily water demand of 450 ℓ/bed and 550 ℓ/bed based on design considerations and general hospitals are expected to consume 130 to 140 ℓ/bed of hot water per day. Considering the hot water temperature requirement of 60 °C for most hospitals in SA, general hospitals can thus be expected to have a thermal energy requirement of 6,77 to 7,29 kWh/bed/day.

To get an overview of the expected annual thermal energy demand of all 696 hospitals identified in SA, based on daily hot water usage per bed as set out in SANS 10252-1, an extrapolation was done using the total number of beds accounted for in the database. The results are shown in Figure 5. It should be noted that this estimation assumes that all 696 hospitals consume hot water within the range that is set out in SANS 10252-1 for general hospitals and does not compensate for the variation in hot water usage based on different functions of hospitals.

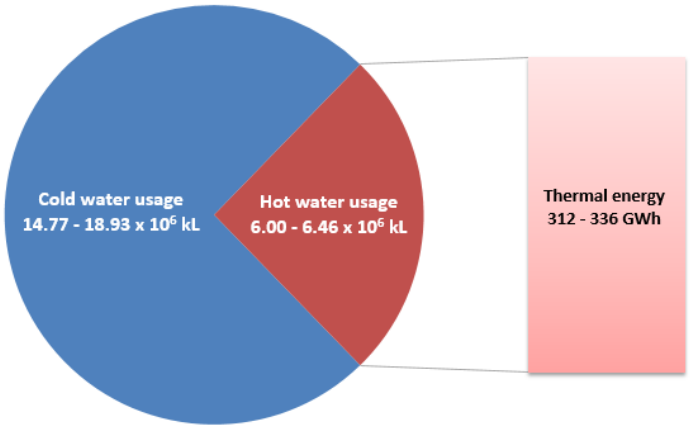

Figure 5: Annual heat demand of all hospitals for hot water production in South Africa

It is approximated that all 696 hospitals in SA have a combined thermal energy requirement of 312 to 336 GWh/year to heat the total hot water demand range to 60 °C for domestic purposes. This excludes heat requirements attributed to steam to operate autoclaves for sterilisation and humidification, and space heating.

As mentioned, the WC Department of health hospital database identifies key information, such as the average daily cold water consumption and electricity usage per bed, the number of beds and current heating technologies installed at each hospital. This database lists 52 hospitals managed by the WC Department of Health, including small and large hospitals. The average daily cold water consumption of each of the 52 hospitals is shown in Figure 6.

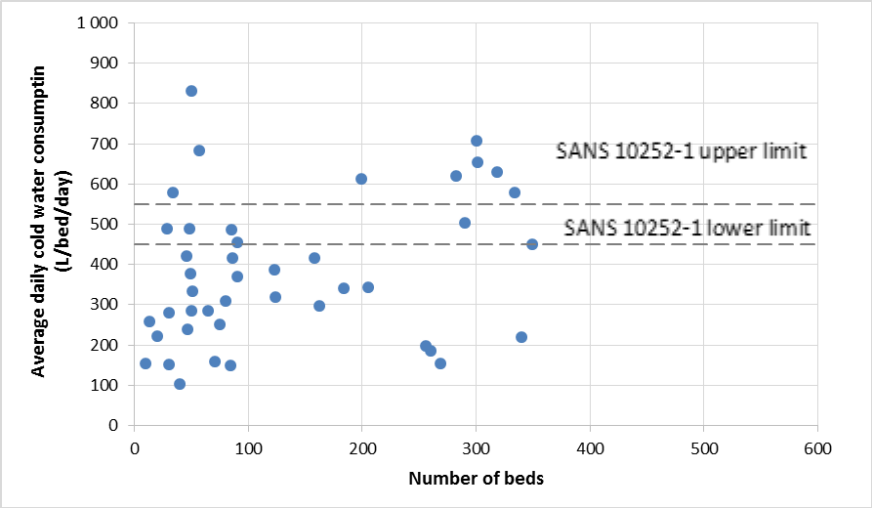

Figure 6: Average daily cold water consumption per bed for hospitals managed by the Western Cape Department of Health

Most provincial hospitals in the WC fall well below the lower limit specified presented in SANS 10252-1 (450ℓ/bed/day). See Figure 6. However, there are a number of hospitals that consume more than the 550 ℓ/bed/day. This variation in cold water usage could be related to the variation in services offered by each hospital, patient capacity, age of the infrastructure, geographical location, and whether it is situated in a rural or urban area. This makes estimating the cold and hot water demand difficult, as shown in Figure 5, as the heat demand will vary significantly for each hospital.

To get a more realistic estimation of the annual hot water demand and total thermal energy requirements of hospitals in SA, the relationship of the annual cold water consumption, based on the number of beds, was developed using the data of the WC Department of Health. The annual cold water consumption of these hospitals

and the linear relationship with the number of beds is shown in Figure 7 (left). Garcia-Sanz-Calcedo et al (2017) provides a quantification of cold and hot water consumption for human consumption and domestic use in hospitals, based on the number of beds as opposed to using a fixed ratio. The study makes use of the measured cold and hot water consumption of 13 public hospitals in Spain. The relationship identified for the average annual cold and hot water consumption for domestic use in hospitals based on the number of beds is shown in Figure 7 (right)

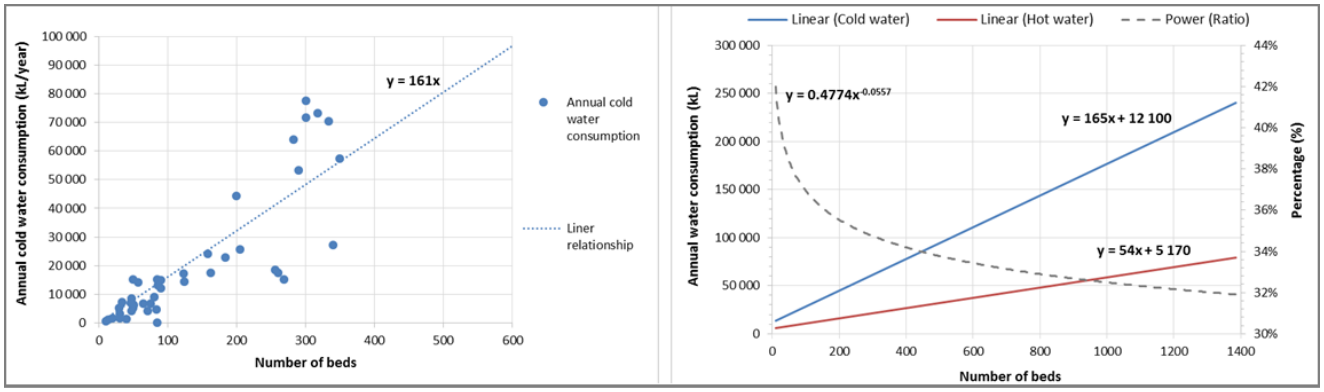

Figure 7: Annual cold water consumption of Western Cape Department of Health hospitals and linear relationship with number of beds (left) and relationship between the annual cold and hot water consumption in hospitals based on number of beds (right) (Source: Garcia-Sanz-Calcedo et al, 2017)

The linear relationship developed for the annual cold water consumption of hospitals in SA, shown in Figure 7 (left), and the relationship developed between the cold and hot water consumption of hospitals based on Garcia-Sanz-Calcedo et al. (2017), shown in Figure 7 (right), was used to develop a relation to the number of beds and the hot water consumption, shown in Figure 8. Furthermore, it was used to more accurately estimate the annual cold water, hot water and heat demand of the 696 hospitals identified in SA and, given in Table 1.

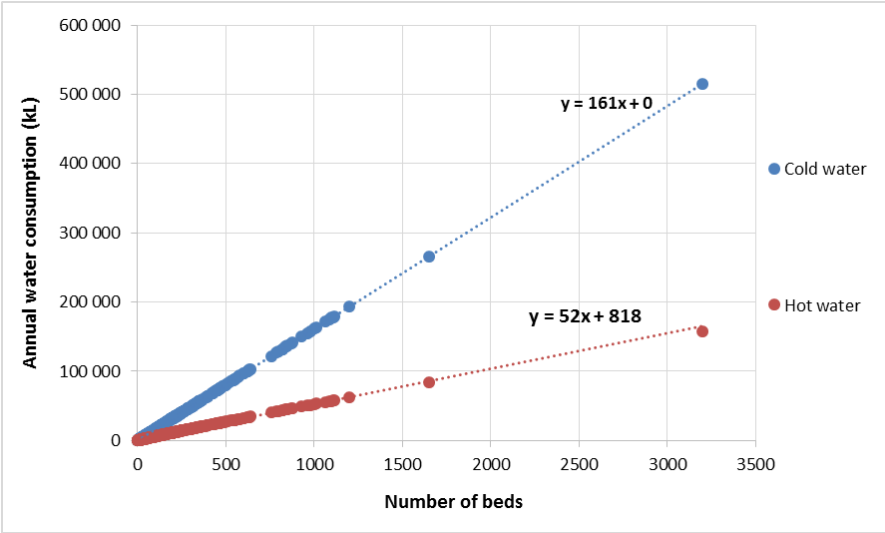

Figure 8: Annual cold and hot water consumption of 696 hospitals identified in South Africa

Table 1: Results of cold and hot water consumption and thermal energy requirements for the 696 hospitals in SA

Hot water	Annual consumption	7 099 964 kℓ
	Average daily hot water consumption per bed	154 ℓ/bed/day
Thermal energy	Annual thermal energy demand	370 GWh

Thus, based on a detailed assessment of existing cold water consumption and literature, the earlier estimation of the annual thermal energy demand for all hospitals in SA, which was 312 to 336 GWh (see Figure 5), was recalculated as 370 GWh. This represents a more accurate and realistic approach for determining the total thermal energy needs of hospitals and is used to investigate the potential for the large-scale application of ST technologies at hospitals in SA.

7 FINANCIAL CONSIDERATIONS

When considering the findings of this study and the large uptake of heat-pump systems in most of the provincial hospitals in the WC, ST projects may present extended amortisation times compared to those presented in Joubert et al. (2016). In Joubert et al. (2016), the amortisation times and LCOH of large-scale ST systems in SA for a system cost of € 603/m^2 and at an exchange rate of R15.30/€ was estimated. See Figure 9. The study shows the payback period for ST that can be expected when replacing conventional energy sources, based on different annual increases of 0 to 12% on the cost of these energy sources, which are commonly coal and electricity in South African hospitals.

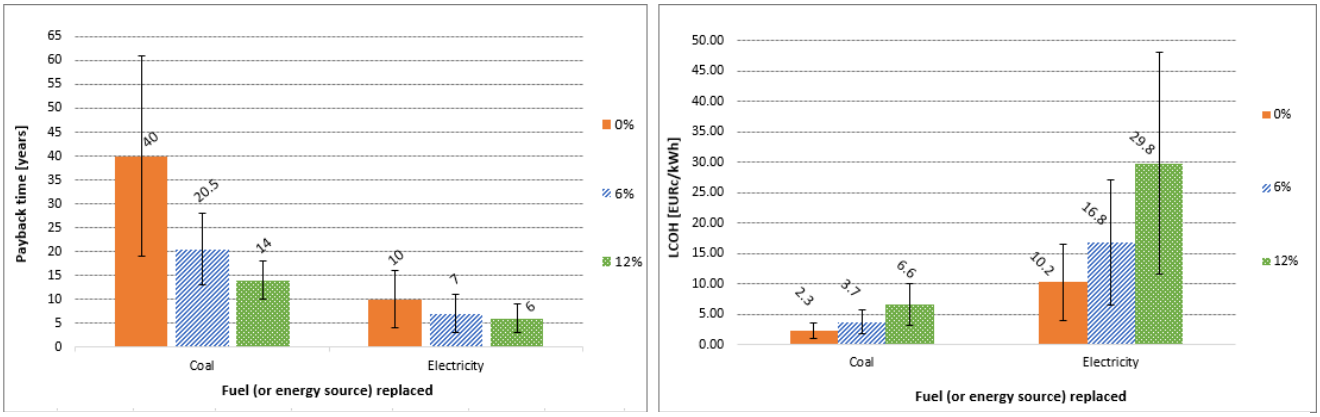

Figure 9: Amortisation times (left) and LCOH (right) of a current large-scale ST system

It can be assumed that most hospitals rely on electrical boilers for generating hot water in cases where heat pumps are not installed. In these cases, hospitals can be expected to invest in ST projects presenting simple payback periods ranging from 6 to 10 years. In the case of older, larger hospitals that still rely on coal for heating, projects with a simple payback period of 14 to 40 years can be expected, making the investment unfeasible.

Figure 9 shows that the LCOH of coal and electricity is 2,3 to 6,6 EUROc/kWh and 10,2 to 29,8 EUROc/kWh, respectively, based on the annual fuel increase of 0 to 12% and discount rate of 6% over 20 years (Joubert et al, 2016).

8 RESULTS

Figure 10 depicts the scale and size to which ST technologies would have to be implemented at hospitals in SA to achieve a different solar fraction of the total annual thermal energy demand of 370 GWh, as well as the current total collector area installed at hospitals in the country. Figure 10 was generated assuming an average specific gain of 1 000 kWh/m^2/year throughout the country where hospitals are located.

Currently, South African hospitals have a total installed collector area of 1 333 m^2, as indicated in Figure 4. This collector area only accounts for approximately 0,4% of the total annual thermal energy needs for producing domestic hot water in all hospitals the country, estimated at 370 GWh.

It can be realistically assumed that hospitals can feasibly increase their overall ST capacities to compensate for 20 to 40% of their combined annual thermal energy needs by way of enhancing the performance of installed heat-pump systems and also by reducing the industry's dependence on boilers and conventional fuel sources.

This would require the installation of approximately 73 972 m^2 to 147 944 m^2 of collector area throughout the 696 hospitals identified in SA.

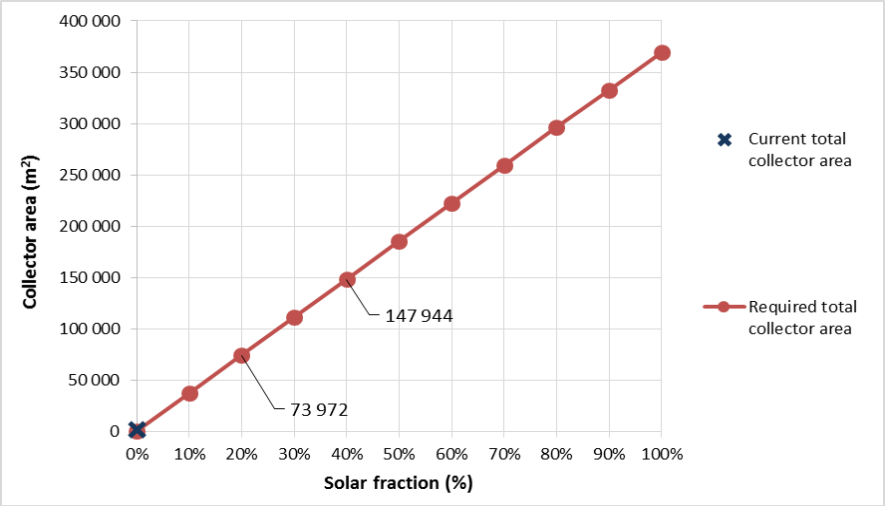

Figure 10: Relationship of total collector area and solar fraction of the total thermal energy needs of hospitals in SA

9 CHALLENGES FACING SOLAR THERMAL APPLIACATIONS IN HOSPITALS

There are a number of challenges impacting the uptake of ST technologies in hospitals in SA, including; most hospitals are not equipped with measuring instrumentation to record the hot water consumption, essential to characterise the hot water demand; A number of hospitals have installed solar photovoltaic (PV) systems which may reduce interest in investing in the use of ST technologies, even if these offer a further reduction in electricity consumption. Many hospitals have urgent problems with the maintenance of existing water systems, including corrosion of pipes and ineffective maintenance of leaks, outdated and less efficient heating technologies such as electrical and coal boilers in older hospitals and non-existent or poor insulation of piping and storage tanks, leading to preventable heat losses.

Some hospitals do not have enough space to install the large storage tanks that are required for ST systems. In some large hospitals, large storage tanks and boilers are located on the top floors of the building, making the removal and addition of these tanks very costly and labour intensive. Large and older hospital buildings have been constructed with asbestos roofs. Installers may be reluctant to mount solar collectors on asbestos roof areas owing to asbestos legislation and the serious health risks associated with asbestos work; and many public and private hospitals in the country have installed heat-pump systems in conjunction with conventional boiler technologies to reduce dependence on boilers and become more energy efficient.

10 CONCLUSION

Currently there are 23 ST systems installed at hospitals in SA, accounting for a total installed collector area of 1 333 m^2. Most of these systems are installed in Gauteng and the WC. Most hospitals currently make use of a combination of electric boiler and heat pump technologies for producing hot water. The use of coal boilers is seen in large, older hospitals in the country. A total installed collector area of 73 972 m^2 to 147 944 m^2 across all hospitals in SA could feasibly increase the overall ST capacity to compensate for 20 to 40% of the combined annual thermal energy needs for hot water. The major limiting factors for the uptake of ST technologies in hospitals are the current large-scale usage of heat-pumps and coal fired boiler technologies, with resultant challenges in making a financial feasibility argument. Other challenges include existing problems with hot and cold water supply systems in older hospitals, lack of understanding and awareness of ST technologies, competiveness and preference for other renewable energy and energy efficient technologies such as solar PV and heat-pumps. The prevalence of asbestos roofs and limited roof space were also identified as challenges.

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Name: Angelo
Surname: Buckley
Institute, company, organisation: Centre for Renewable and Sustainable Energy Studies, Stellenbosch University
Key activities: Research Engineer
Miscellaneous: Solar thermal and solar PV