# SOLAR ENERGY IN AGRI-PROCESSING

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**Abstract**

This overview paper presents the case for greater solar energy uptake in South Africa's agri-processing sector. It focuses specifically on solar PV for packhouses and solar thermal for processing heat. The paper identifies key constraints that limit the uptake of solar energy technologies and the development of the local solar industry. It highlights (a) opportunities for the agri-processing and the solar industry; (b) key barriers that policy makers need to address to unlock the economic development potential enabled by a greater uptake of solar energy; and (c) potential focus areas for researchers and developers to unlock the solar energy opportunity and particularly that in South African food value chains.

*Keywords: solar PV; solar thermal; agri-processing; infant industry; sustainable development; GHG mitigation*

## 1. Introduction

### *1.1. Background*

A study on the resource use and emissions of the Western Cape economy highlighted the food value chain as a focus area for improved resource efficiency, greenhouse gas (GHG) emission reductions and overall (sustainable) economic development [1]. This is due to the food value chain's substantial energy and non-energy-related GHG emissions, and considerable potential for labour absorption. Subsequent, more detailed analysis of value chains for a range of food commodities [2] identified energy inputs for (a) cooling of agricultural produce during storage, and (b) for heating and cooling during processing as key GHG emissions "hotspots". Promoting the uptake of low-carbon, renewable energy, and particularly solar energy, in agri-processing was thus identified as a strategy for GHG reductions to improve the sustainability and (international) competitiveness of Western Cape (and by extension South African) food value chains.

### *1.2. Aim*

This paper presents insights from two businesses cases developed for solar energy interventions to reduce the carbon intensity of food value chains, namely solar photovoltaic (PV) systems on packhouses [3] and solar thermal energy in agri-processing [4].

### *1.3. Audience and key messages*

This overview paper has three intended audiences: (a) industry (agri-processing and those providing solar technology), (b) policy makers at national and local government level, and (c) researchers and developers of solar technology. For the solar industry, the paper explains why the agri-processing sector is a key sector for uptake and outlines the support available to the (solar) industry. For the agri-processing industry, it highlights when solar energy is a financially feasible alternative to established energy sources. For policy makers, the paper highlights the opportunity that solar energy (within agri-processing) has to enable local economic development and key steps that can be taken to more fully realise this opportunity. For all three of these, the paper indicates where policy and regulations aid in (or hinder) the uptake of solar technologies. For researchers and developers, the focus areas for the development of solar technologies (for the food value chain) and particular gaps and needs in the South African context are identified.

## 2. Agri-processing

### *2.1. What is agri-processing and why focus on agri-processing?*

Agri-processing is seen as any value addition to agricultural resources. It can include all sectors based on agricultural resources including (but not limited to): food and beverages, textiles, leather and wood products. Among the various manufacturing sectors in the economy, agri-processing has the largest output multipliers (i.e. increase in economic output in the entire economy due to an increase in output of a specific sector) [1].

Agri-processing has been highlighted as a key sector for growth by the Western Cape Government as part of its project Khulisa, which aims to accelerate growth in key sectors in the Western

Cape economy where the Western Cape has a competitive advantage [5] Nationally, efforts are also directed to support growth in this sector, among others, through the Department of Trade and Industry's Industrial Policy Action Plan [6] and through the Department of Rural Development and Land Reform's agri-park programme [7]. Thus, as a key sector envisioned to grow, there is an opportunity to enable growth in this sector consistent with sustainable development principles through the simultaneous uptake of solar energy.

Given the findings of initial work on focus areas for GHG emission reductions in the Western Cape economy (outlined in Section 1.1), this paper focuses on the food and beverages sectors within the food value chain. However, many of the findings are relevant to the other agri-processing sectors (highlighted above in the first paragraph of this section), where these have similar characteristics (outlined in section 2.2 below) that make solar energy a good fit.

### *2.2. Why solar energy in food and beverages?*

Two solar energy opportunities were highlighted as strategic interventions for increased uptake in the food and beverages sector, namely:

- Solar PV on packhouses
- Solar thermal for processing heat.

For food products, a key consideration is ensuring that produce remains fresh. For many products, this is done through cold-chain management. With a large fruit sector in the Western Cape that has numerous refrigerated packhouses, this was seen as a significant opportunity for solar PV application. This is due to cooling being the largest energy need of packhouses. As solar PV produces energy both during the time of day and the season when cooling needs are greatest, solar PV is a logical choice (less so for citrus packhouses as citrus is harvested in winter). Additionally, solar PV absorbs energy, thus if it is mounted on the roof of a building that requires cooling, the PV system inherently decreases the energy needs for cooling. Additionally, with pressure from international markets to lower the carbon footprint of products such as fruit, solar technology presents a key opportunity to improve the competitiveness of Western Cape fruit exports. With climate change expected to increase the number of hot days in the Western Cape, the importance of cold-chain management is likely to increase [8].

Solar thermal is seen as a key opportunity as the majority (79 %) of the food and beverages sectors' demand for energy is for low temperature heat [9], which solar thermal is able to supply most economically [10]. The replacement of, typically fossil-based, fuel with renewable solar thermal energy represents a good opportunity to lower the carbon intensity of products from the food and beverages sectors and to provide greater energy security for companies in this sector.

## 3. Solar Potential in South Africa

South Africa has significant solar energy potential. The country has some of the highest irradiance in the world with Global Horizontal Irradiation (GHI) over 1450 kWh/m$^2$ for the entire country and (DNI), which is relevant to focussing solar thermal applications, ranging from 1400 kWh/m$^2$ DNI to over 3000 kWh/m$^2$ [11]. The potential for solar applications is greater inland and in the western half of South Africa and most notably in the Northern Cape for solar thermal applications.

When considering the solar thermal systems installed internationally, South Africa has significantly fewer (1 055 MW$_{th}$) solar thermal installations than Austria (3 541 MW$_{th}$) and Germany (12 281 MW$_{th}$) [12]. However, these counties have significantly less solar potential with Austria below 1400 kWh/m$^2$ DNI and Germany having less than 1300 kWh/m$^2$ DNI [11]. This suggests that South Africa has sufficient solar resources to provide a greater share of the South African energy mix. Due to the compatibility with the energy needs of the food and beverages sector (as described in section 2.2 above), it can be expected that solar resources can provide a greater share of the energy inputs into agri-processing, and, given an enabling environment, there is potential for the development of the local solar industry.

## 4. Case studies

Evidence that the opportunities highlighted above are real, and not just hypothetical, is evidenced by companies that have already successfully implemented these solar technologies at industrial scale. These "case studies" are summarised in this section, highlighting (where known) the benefits realised by the companies.

### *4.1. Solar PV on packhouses*

A business case was developed for a model apple packhouse representing a typical pome fruit packhouse [3]. The case was examined under a range of scenarios considering:

- Two installation sizes: large (500 kW$_p$) and small (10 kW$_p$)
- Two tariff structures: George Municipality's imbedded generation and Eskom's Ruraflex
- Three financing options: self-financed; 80 % loan (10 year loan at 18 %) and 80 % loan (10 year loan at 10 %)
- Two tariff increases: 10 % per annum or 13 % per annum for 5 years and then 8 % thereafter.

The financial feasibility of the solar PV system under all these scenarios was considered in terms of (a) simple payback, (b) net present value, and (c) internal rate of return.

The analysis showed that:

- Economies of scale are significant:

  Large (500kW$_p$) systems are financially viable in all scenarios considered, with 8 – 13 years of 'free energy' once the system is paid off based on simple payback. The net present value would be R0.5 – R4.1 million on a R8.1 million system and the internal rate of return greater than 18 % in all scenarios.

- Financing is key to unlocking the full potential of solar PV:

  Even small systems (≤10 kWp) are financially viable under the right financing conditions. The small system would have 5 – 10 years of 'free energy' once the system is paid off on simple payback. However, positive net present values occur only under favourable (i.e. 10 %) loan terms, while the internal rate of return ranges from 11-21 % thus small systems would be financially viable when these returns are accepted.

The conditions for financial viability were thus demonstrated albeit for a modelled packhouse. However, the benefits achieved in practice at four different packhouse are summarised Table 1, reinforcing that solar PV on packhouses can be a viable opportunity with real uptake and financial and environmental benefits (i.e. energy and hence cost savings and GHG emission reductions, respectively).

| Packhouse Owner | Ceres Fruit Growers | Ceres Koelkamers | ArbeidsVreugd Fruit Packers | Stellenpak Fruit Packers |
|---|---|---|---|---|
| Town | Ceres | Ceres | Villiersdorp | Paarl |
| System size | 986 kW$_p$ | 508 kW$_p$ | 450 kW$_p$ | 420 kW$_p$ |
| Power generated / annum | 1 690 MWh | 848 MWh | 743 MWh | 600 MWh |
| Electricity reduction / annum | 6 % | 11 % | (R38 million savings over 25 year lifetime) | 15 % |
| $CO_2e$ avoided / annum | 1 622 tonnes | 839 tonnes | 733 tonnes | 576 tonnes |

**Table 1. Existing Solar PV installations on packhouses**

*4.2. Solar thermal for process heat*

As the agri-processing sector's main energy demand is for heat, rather than using solar energy and turning it into electricity (through PV) and then back to heat, it makes sense to capture the solar energy as heat directly and avoid the efficiency losses with each conversion.

Joubert, et al. [13] collated the information on large (> 50m$^2$) solar thermal systems in South Africa. The database included seven industrial scale installations that utilise solar energy for process heat. The basic information on these installations (obtained from the authors) is presented in Table 2. Again, these practical examples show that solar thermal energy for industrial scale heating is thus a viable opportunity with real uptake in the South African context.

| Owner | Industry sector | Collector | Year | Gross area [m$^2$] | Storage volume [litre] |
|---|---|---|---|---|---|
| BMW Manufacturing | Automobile | Evacuated tube | 2012 | 200 | 24 200 |
| Tanker Services, Imperial Logistics | Logistics | Evacuated tube | 2013 | 67.5 | 5 000 |
| Cape Brewing Company | Food & Beverage | Flat-plate | 2015 | 120.6 | 10 000 |
| Floraland | Flowers | Flat-plate | 2012 | 288 | 20 000 |
| ACA Threads | Rubber | Evacuated tube | 2013 | 100 | 22 000 |
| Fairview Cheese | Dairy | Evacuated tube | 2012 | 90 | 4 000 |
| Quality Filtration System | Water Treatment | Evacuated tube | 2012 | 75 | 2 000 |

**Table 2: Large (>50m$^2$) solar thermal installations in South Africa providing process heat**

## 5. Barriers

In spite of the strong case for greater uptake of solar technology in South Africa, and in the food and beverage sector in particular, there are still some key constraints limiting greater uptake. The most prominent of these are discussed below.

*5.1. Regulatory barriers*

Often regulations have unintended consequences that deter economic development in some sectors. Two such instances that are seen to be hindering greater uptake of solar technology in South Africa are:

- Feed-in tariffs and regulations for small scale embedded generation (SSEG);
- The systems (rather than component) testing methodology for solar thermal systems adopted by the South African Bureau of Standards (SABS).

*5.1.1. Feed-in tariffs & by-laws (solar PV)*

There is a need to regulate the connection and feed-in of generators as this could have serious risks to grid maintenance personnel, as well as to the stability of the grid in general. However, as the uptake of renewable technologies increases, the grid needs to be adapted to these realities. The ability to connect a renewable energy system to the grid is not yet universal. As shown in Figure 1, the most notable limitation is for low voltage connections supplied directly by Eskom, which is currently still prohibited. Numerous municipalities have also yet to set up the required regulations to allow connection to the grid and the sale of excess electricity.

The sale of excess electricity (to the grid) enables investors in solar PV systems to more rapidly recover the initial capital cost, thus strengthening the business case for investment in solar PV. Without changes to the inhibiting regulations outlined above, the uptake of solar PV will be limited to only those companies that have large on-site electricity needs (where the business case is made on the basis of cost savings), thus limiting the more general uptake of solar PV.

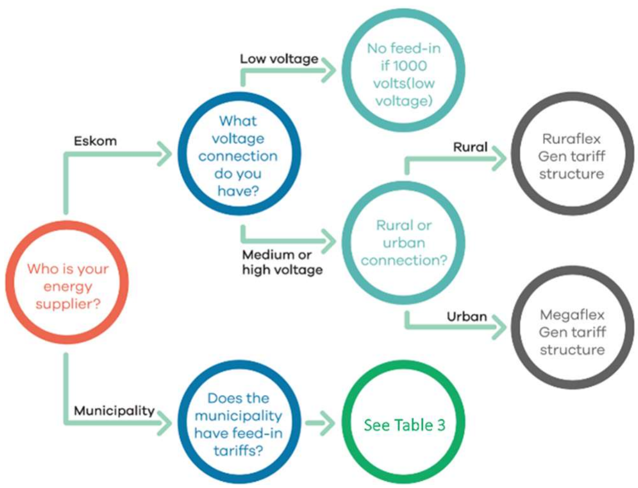



**Figure 1: When you can generate electricity and feed-in**

### *5.1.2. Systems testing (solar thermal)*

The SABS' systems testing policy has limited competition in the solar thermal space and inhibited local manufacturing of solar thermal components and systems. This is most notable in the residential solar water heating market, where a number of government programmes require(d) SABS certified systems to be installed. The SABS testing policy means that an entire system needs to be certified. If a component is changed, the system needs to be re-certified, as it is considered a 'different system'. The full case for component testing is laid out in detail elsewhere [14]. In summary, systems rather than component testing prevents local manufacturers from being able to specialise in specific components and to provide assurance that these perform well, thus discouraging local manufacturing for the solar thermal market. Systems testing limits the ability of new and small companies to enter the market as systems testing is both costly and takes a significant amount of time. The limited competition ultimately results in higher charges to end-users.

For large solar thermal systems, the impact is less direct, as large systems are designed for specific applications. Without locally accredited components, designers have to rely on internationally accredited components to ensure the systems they design are able to perform as required. As a result, the costs of installations increase as either local components need accreditation overseas or internationally accredited components need to be imported. The resulting high cost of large scale solar thermal systems thus weakens the business case and limits the uptake of solar thermal systems at industrial scale.

### *5.2. Business awareness and perception*

A further constraint to the uptake of solar technologies is that the technology is perceived to be (a) costly and (b) unreliable or untested. The general status quo for most businesses the availability of relatively low cost electricity from the grid. There is thus limited incentive to consider alternative solutions. However, in recent years, the cost of renewables has fallen significantly, while electricity costs have soared. Furthermore, load-shedding has occurred as the national utility faced shortfalls in (the availability of) generating capacity. The challenge that proponents of solar technologies face is to clearly communicate the ability of solar technologies to address these issues cost-effectively and reliably.

*Capital cost* is often cited as a constraint, particularly for solar thermal systems. Capital cost is typically higher for existing facilities that require retrofits. The case is thus more readily made for solar technology on new build. However, although solar systems may cost a significant amount to install, once established, they require no fuel to keep them going. Solar technologies thus have significant cost saving potential and protect against fluctuating fuel prices allowing greater certainty for future planning. Financing and innovative financing models, such as those provided by energy service companies (ESCOs) can enable financial viability. (The enabling nature of the former was highlighted for solar PV in section 4.1. ESCOs are discussed in more detail in section 6.6)

Technologies are considered to be more *credible* when local case studies exist, as solutions are (often considered to be) context specific. Existing case studies (such as those presented in Section 4) provide demonstrable evidence of the applicability of solar PV and solar thermal technologies in the South African context. However, these are still relatively few in number and are not well publicised. Greater uptake of these technologies, as well as greater awareness of successful installations and their benefits, is required to overcome perceptions of solar technologies that inhibit greater uptake.

### *5.3. Infant industry*

One of the fundamental economic arguments for industry support is that the industry is an "infant industry" i.e. in its first stages of establishment and not yet cost competitive with international competitors. This is the case for solar technology industry in South Africa as shown in the most recent solar worldwide report [15]. In this report, the costs of solar thermal systems are compared across countries as summarised in Figures 2 and 3. (In these figures, the levelised cost of heat (LCOH) is indicated with a green diamond and grey blocks with reference to the scale on the right, while the specific cost is presented as box and whisker plots with reference to the scale on the left.) For small domestic systems (Figure 2), South Africa is the second most expensive (both in system cost and LCOH terms) after Australia. For large domestic systems (Figure 3), South Africa seems to fare better, but the countries compared are not the same as those compared for the case of small domestic systems. When considering the countries common across the two comparisons, all remain cheaper than South Africa. These findings are in spite of the South African systems having greater solar energy yield (available supporting data not shown) than the other countries in the comparison.

The lack of cost competitiveness is further supported by the significant range in scope of bids provided by service companies in response to the Cape Brewing Company's (CBC) request for proposal as shown by Joubert et al. [13]. This is summarised in Figure 4, where the ten bids received by CBC are compared: the cheapest proposal is less than half of the most expensive proposal. The variation is further evident in the differing compositions of cost proposals varying across bids, showing inconsistency in the proposed systems. This variation is also reflected in the cost comparison by Solar Heat Worldwide (Figures 2 and 3), where the ranges in costs of South African systems are some of the largest reported. This high variation in costs seems to indicate that the industry is still learning about solar thermal technology. As the industry installs more units, it should move along the learning curve and become more efficient and cost competitive, and ultimately become a well-established industry able to compete with established industries around the world. However, until it is established, one can argue for government for this infant industry.

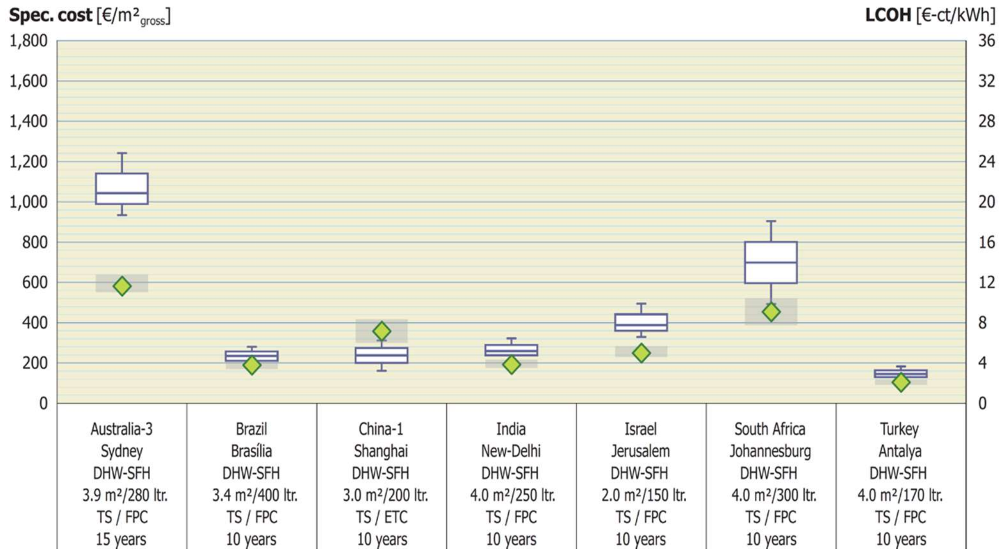



**Figure 2: Specific investment costs and levelised costs of solar thermal generated heat for small thermosiphon domestic hot water systems. Source: Solar Worldwide [15]**

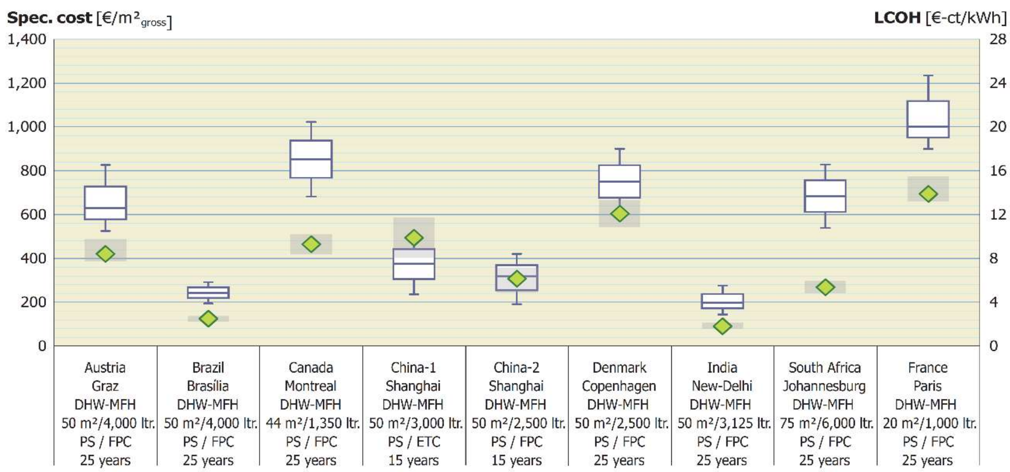
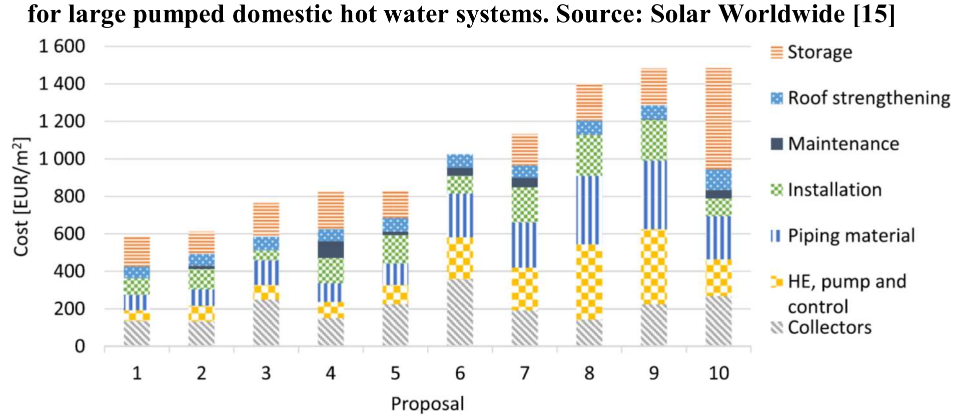



**Figure 3: Specific investment costs and levelised costs of solar thermal generated heat for large pumped domestic hot water systems. Source: Solar Worldwide [15]**




| | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| LCOH [EURc/kWh] | 7.0 | 8.4 | 7.3 | 8.9 | 7.9 | 8.6 | 15.1 | 17.9 | 18.8 | 13.1 |
| IRR [%] | 18.7 | 15.8 | 18.2 | 15.0 | 16.7 | 15.5 | 8.4 | 6.7 | 6.2 | 10.1 |
| Payback [years] | 8.6 | 9.6 | 8.8 | 10.0 | 9.3 | 9.8 | 13.5 | 14.8 | 15.2 | 12.5 |

**Figure 4: CBC tender proposals with component breakdown (exchange rate ZAR/EUR = 15.3). Table below graph shows calculated levelised costs of heat (LCOH), internal rate of return (IRR) and payback period. Source: Joubert, et al. [10]**

## 6. Industry Support

In recognition of the strategic opportunity that renewable solar energy could provide, a number of programmes have been established to help develop the sector and overcome the barriers that the market faces. Some key Western Cape and national programmes are highlighted below.

### *6.1. The Western Cape Energy Game Changer*

The Western Cape Government has identified a number of focus areas (called “game changers”) for economic development, job creation and improved welfare in the Western Cape during 2014-2019 term of office.) One of these focus areas - the energy game changer [16] - has five objectives:

- Increase rooftop PV in Western Cape to135 MW.
- Enhance uptake of solar water heaters to 155 000 by 2020.
- Government buildings to reduce energy by 30 % by 2020.
- Enhanced load management: to reduce peak demand to minimise the likelihood and impact of load shedding.
- Roll-out of independent power producers (IPPs) and liquefied natural gas (LNG): to increase the diversity of electricity supply in the Western Cape.

This programme thus clearly advocates for solar energy technology both directly in the first two objectives, while solar energy technology would also be a key enabler for the third and fourth objectives.

### *6.2. The GreenCape Sector Development Agency*

GreenCape is a non-profit organisation established by the Western Cape Government and the City of Cape Town. GreenCape’s goal is to unlock the investment and job creation potential of green technologies and services, and thereby contribute to improving the resource efficiency, carbon intensity and resilience of the local economy. In addition to undertaking a range of activities to support companies in the renewable energy value chain, GreenCape is one of the key partners of the energy game changer.

| # | Municipality | Small Scale Embedded Generation tariffs | Rules, regulations & by-laws |
|---|---|---|---|
| 1 | Beaufort West | Yes | In progress |
| 2 | Bergrivier | No | In progress |
| 3 | City of Cape Town | Yes | Yes |
| 4 | Drakenstein | Yes | Yes |
| 5 | George | Yes | Yes |
| 6 | Mossel Bay | Yes | Yes |
| 7 | Oudtshoorn | In progress | In progress |
| 8 | Overstrand | Yes | In progress |
| 9 | Saldanha Bay | No | In progress |
| 10 | Stellenbosch | Yes | Yes |
| 11 | Swartland | Yes | Yes |
| 12 | Theewaterskloof | In progress | In progress |

**Table 3: Western Cape Municipalities that currently allow small scale embedded generation**

To this end, GreenCape has developed tariff guidelines for municipalities in the Western Cape. This would allow companies purchasing electricity through municipalities to legally connect renewable electricity sources, such as solar PV, to the municipal grid and feed in electricity at a set tariff. The 12 (of 25) municipalities that allow embedded generation in the Western Cape to date are shown in Table 3, showing that significant progress has already been made.

### *6.3. SANEDI*

The South African National Energy Development Institute (SANEDI) was created to deliver the National Energy Efficiency Strategy (NEES) of 2005. This strategy set a target of reducing national primary energy consumption by 12 % by 2015 through promoting the uptake of green energy and energy efficiency. NEES is currently under review and is expected to incorporate the establishment of guidelines for small scale embedded generation (SSEG) for South African municipalities.

SANEDI consists of six research centres. It is also responsible for the certification of energy efficiency of installations for the section 12i and 12l income tax rebates. These are key incentives to encourage energy efficiency and renewable energy such as solar PV and solar thermal systems. These incentives show a clear signal from government encouraging energy efficiency and renewable energy uptake. However, uptake of these incentives has been limited primarily due to the costs of monitoring and verification being considered too onerous relative to the financial incentive (industry sources, personal communication).

For industrial heating the SANEDI/SAGEN (South African-German Energy Programme) publication on co-generation in South Africa [17] is of interest. It summarises the status quo and provides best practice principles for combined heat and power. It also highlights the importance of considering the energy needs of the entire system, not isolated parts, as heating and cooling needs of different sub-components can complement each other (e.g. cooling hot streams by pre-heating cold streams).

### *6.4. SOLTRAIN*

One of leaders in the promotion of solar thermal uptake is the Southern African Solar Thermal Training and Demonstration Initiative (SOLTRAIN), which is co-ordinated by AEE Intec (Institute for Sustainable Technologies, Austria). A key component is the Solar Thermal Technology Platform, which launched the South African Solar Thermal Technology Road Map (SA-STTRM) [18]. This roadmap (which was established in conjunction with stakeholders from science, government, financial institutions and industry) is set to make Solar Heating and Cooling (SHC) more competitive to unlock the social and environmental benefits inherent in solar thermal technologies. The SA-STTRM is envisioned to be a sub-component of the broader Solar Energy Technology Roadmap, which is being compiled jointly by the Department of Energy (DoE) and the Department of Science and Technology (DST) and is still to be released.

The SA-STTRM has a vision of 0.5 $m^2$ solar thermal collector per capita by 2030 (currently at 0.03$m^2$ per capita.) While the industrial / commercial sector's contribution is relatively small, it is envisioned to grow significantly from just over 10 000 $m^2$ to just under 4 000 000 $m^2$ in 2030 (almost 40 000 % increase over 15 years). The importance of agricultural value chain for the uptake of solar energy is also re-emphasised as the SA-STTRM suggests introducing legislation requiring the pre-heating of inputs to agricultural processes specifically as a key method to encourage the uptake of solar thermal technology.

### *6.5. Energy research centres*

Substantial research capability is available in South African tertiary education institutions. These can provide research support to the South African industry. Among the large number at the various institutions that develop solar technology is the Solar Thermal Energy Research Group (STERG) at the University of Stellenbosch. For all, it is key that the investment by government in research and education at tertiary institutions results in an accrual to the South African economy. A key focus area would be the development of low cost local components and systems to enable a cost-competitive local industry.

### *6.6. Financing & ESCOs*

To address the capital cost constraints that potential implementers face, some innovated solutions have come to the fore. Most notable of these are Energy Service Companies (ESCOs). ESCOs typically install (renewable) energy and energy efficiency technologies for companies and then retain ownership of the assets while selling energy to the company at a lower cost than the company originally paid. Alternatively, ESCOs remove investment risk through energy performance contracts whereby a minimum decrease in energy cost is required or the ESCO is penalised, thus limiting the downside risk to companies.

Traditional financing institutions (e.g. banks) have also come to realise the strong business case renewable technologies provide and have developed financing packages focussed on increasing renewable energy uptake through lower interest costs for specific renewable energy investments.

## 7. Conclusions

### *7.1. Conclusions for industry*

#### *7.1.1. Agri-processing industry*

Solar PV is a sensible investment when significant energy needs, such as cooling, arise during the day. Solar heating is a viable alternative to conventional heating sources. Both these opportunities have been demonstrated to be applicable to the South African context as evidenced in a number of installations that are providing cost savings and other benefits. To overcome capital cost constraints, loan finance and energy performance contracts, such as those offered by ESCOs, could enable uptake.

#### *7.1.2. Solar technology industry*

Currently, the solar energy industry is relatively undeveloped which means there are significant opportunities to grow with remarkable growth envisioned for the solar thermal industry by the SA-STTRM. A key growth area for solar thermal has been identified as the agri-processing sector as most of the energy requirements are for low temperature heat. In addition, the importance of considering energy needs at a systems level has been highlighted as different processes' heating and cooling needs can supplement each other. Thus facilities that require heating and cooling may be of particular interest for uptake (e.g. dairies and cheese factories that require heating for their production processes and for cleaning, and then cold storage of products). Cooling needs for livestock housing (e.g. for chickens, pigs, cows etc.) is also expected to be increase due to potential changes in climate. (There is already a greater incidence of large-scale livestock losses due to sustained above average temperatures over summer).

Currently, solar technology is not well understood in most industries. This gap needs to be bridged through clear and transparent communication about the costs, benefits and practical implications of these technologies in order to promote (more rapid) uptake.

### *7.2. Conclusions for policy makers*

Particular regulations are constraining the uptake and local development the solar technologies considered in this paper. For solar PV, it is the lack of universal feed-in regulations and tariffs, while the development of the local solar thermal industry is being hampered by the policy of systems, rather than component, testing.

As the solar industry is currently an "infant industry" in South Africa, support is required to enable viable businesses that are able to grow and make a sizeable contribution to the economic growth and job creation. Key to this is ensuring cost competitiveness that is not based on government subsidies, but rather on comprehensive support such as that provided SOLTRAIN that aims, amongst others, to increase the competitiveness of local experts through free training and technical support to help establish the local expertise to service the sector and share learnings from international experience. SOLTRAIN also showcases local examples of installations to demonstrate their applicability to the local climate and conditions. This indicates that where an enabling environment is created, economic growth in the sector is realised.

*7.3. Conclusions for researchers and developers*

To support economic development and job creation, continued work is required (a) to develop low cost local components and systems to enable the development of a cost-competitive local solar industry, and (b) to develop, and demonstrate, integrated solar energy systems for heating and cooling to enable cost-competitive manufacturing (e.g. in food and beverage sectors).

Within the food value chain, improved cold chain management is expected to be key to avoid product losses and maintain quality, particularly in the face of greater temperature variability and potentially higher (summer) temperatures. While large scale stationary systems are already feasible and being implemented, financially viable end-to-end value chain, mobile and smaller scale solutions are required. Particularly for small- and micro-enterprises, mobile solar cooling solutions may be a key enabler and hence area of focus for innovation relevant to (enabling economic development in) the South African, and wider African, context.

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