SOLAR HEAT FOR INDUSTRY
SOUTH AFRICA

Solar Payback

CONTENTS

ACKNOWLEDGEMENT AND AUTHORS

Editors: Jan Knaack (German Solar Association, BSW), Dr Peter Klein (Council for Scientific and Industrial research, CSIR), Dr Karen Surridge (South African National Development Agency, SANEDI), Markus Wolf (Previously South African German Chamber of Commerce, AHK), Pedro Horta (Fraunhofer Institute for Solar Energy)

Acknowledgements: Sashay Ramdharee (South African National Cleaner Production Centre, NCPC), Henry Laing (Ozone Business Consulting, O_3BC)

About Solar Payback

The objective of the three-year Solar Payback project is to promote the use of Solar Heat for Industrial Processes (SHIP) in four countries: South Africa, India, Mexico and Brazil.

As part of the International Climate Protection Initiative (IKI), the project raises awareness of the technical and economic potential of SHIP technologies through clear and transparent information about the costs and benefits of SHIP applications, and helps to create reference systems. Solar Payback also collaborates with financial institutions to develop models that assist different actors and investors in accessing financing.

www.solar-payback.com

Economic Support

Solar Payback is a project that is part of the International Initiative for Climate Protection (IKI). The Federal Ministry of the Environment, Protection of Nature, Public Works and Nuclear Safety (BMUB) encourages the initiative by decision of the German Parliament.

Project Coordinator

BSW - Bundesverband Solarwirtschaft e.V.
– German Solar Association –
Lietzenburger Straße 53
10719 Berlin
Germany

EXECUTIVE SUMMARY

The industrial sector in South Africa is the largest consumer of energy, accounting for 37.3% of final energy consumption. Industrial energy use is predominantly thermal with process heating estimated to account for two thirds of energy end-use. Currently, this thermal energy is primarily supplied by fossil fuels, which contribute to greenhouse gas emissions. In order for South Africa to achieve its emissions reduction targets it is critical to decarbonise the supply of process heat in combination with the decarbonisation of the electricity sector.

The use of solar thermal systems to supply process heat for industry at temperatures below 400°C has the potential to reduce emissions, whilst improving industrial competitiveness and achieving a diversified energy mix. Currently solar thermal technologies have been considered for power generation (CSP) in South Africa, but these technologies have not been widely utilised to supply solar heat for industrial processes (SHIP). South Africa's extensive solar resource, coupled with the most developed economy on the African continent, presents significant opportunities for growth in the SHIP market. This report presents an overview of the industrial sectors in South Africa that have a high potential for SHIP deployment.

Industrial energy consumption within South Africa is contextualised in Chapter 1 of this report through a macro-economic analysis. Energy policies and incentive schemes that relate to SHIP are also discussed. Chapter 2 presents a description of solar thermal technologies for industrial process heat. This includes a description of relevant technologies for the production of hot water or steam up to 400°C. An overview of the local solar thermal industry is also provided.

Chapter 3 presents an analysis of the South African landscape of industrial sectors that require heat at low (<150°C) and medium (150–400°C) temperature ranges. A study of steam demand from package boilers in South Africa, highlights the food and beverage sector as the best opportunity for SHIP integration, with an estimated steam demand of 17.3 PJ/pa. The food and beverage sector is also one of the largest industrial sectors in South Africa and has been experiencing sustained growth over the past 15 years. Opportunities also exist for SHIP integration in the textiles, chemicals, paper and pulp and automotive sectors.

The typical project development process for SHIP plants is outlined in Chapter 4, while Chapter 5 presents a profitability analysis for an exemplary SHIP project making use of the calculation tool developed by the Solar Payback project.

Finally, the conclusions and recommendations from this report are presented in Chapter 6. A key barrier to the development of a SHIP market in South Africa is the low costs of competing fossil fuel energy sources such as coal and natural gas. Large boiler systems are typically coal fired, whilst smaller companies tend to make use of more expensive petroleum-based fuels such as fuel oil or paraffin. High initial investment costs for SHIP plants remain a challenge to small and medium sized companies, who typically require financing of plants. General recommendations are provided to increase the SHIP market share. In particular, the potential of heat Energy Service Companies (ESCO) is highlighted as a possible mechanism to increase SHIP uptake.

CHAPTER 1

THE MACROECONOMIC FRAMEWORK AND ENERGY POLICY IN SOUTH AFRICA

1.1 Introduction

South Africa (SA) is located in the sun-belt and therefore has an extensive solar resource, with annual solar irradiation in many industrial areas in the order of 2,000 kWh/m2. Due to the high solar resource there is already a widespread utilisation of solar power for electricity generation but surprisingly only a small niche market for large solar thermal (ST) applications. The most common types of large ST installations in SA, with a gross collector area exceeding $10m^2$, are for domestic hot water purposes with a share of 69% of the total installed capacity, while the usage for solar heat in industrial processes (SHIP) accounts only for only 7% (Joubert, Hess, & Van Niekerk, 2016).

The preconditions and the potential for SHIP in SA are very good due the high solar resource, combined with a strong economy and existing infrastructure. South Africa has the most developed and well-established economy on the African continent, which results in a number of possible commercial users for SHIP from a range of industries. Despite these promising characteristics, the market for SHIP installations in SA is in its infancy, with a limited number of plants and a general low level of awareness amongst industry regarding the potential for SHIP deployment. Due to the rapid decrease in the cost of photovoltaic (PV) panels many companies who deal with renewable energy sources first look into the mainstream 'plug and play' PV power solutions. Another challenge for SHIP installations is the extensive use of coal for process heating purposes, which constitutes a challenge for the economic competition of SHIP installations, due to low coal prices from a large domestic coal industry.

The fact that the SHIP market in SA is not mature presents an obstacle to getting a critical mass in the deployment of plants. The project Solar Payback aims at assisting SA to realise its large SHIP potential through raising the awareness of the technological and economic benefits of solar thermal technologies. This enabling study considers the framework conditions for SHIP in SA and identifies the country's key industries with a high SHIP potential.

1.2 The Economic and Industry Development in South Africa

In 1994, South Africa re-joined the international trade markets and is now one of the dominating economies and driving force on the African continent. It is populated with almost 56 million (2016) people and it has the third highest gross domestic product (GDP) on the African continent, amounting to 295,456 million USD and a GDP per capita of 5,274.5 USD (World Bank, n.d.). For more than five years the GDP growth rate was below 2% and in the last two years it dropped below 1%. These rates were highly unsatisfactory as the population growth rate was higher, resulting in a decrease in the general living standard. A significant challenge in the country is the high unemployment rate that exceeds 26%. The latest monthly inflation rates were 4.4% in January 2018 and 4.0% in February 2018, which is in a satisfactory range (StatsSA, n.d.)

In general, the economy is diversified and the industrial sector's structure is similar to international developed countries. However, South Africa's economy is generally characterized by strong opposites and fundamental structural problems. This is shown by the Global Competitiveness Index 2017/18 of the World Economic Forum in which South Africa fell from rank 47 (2016/17) to rank number 61 of 137 evaluated countries. Nevertheless, ranking 61 still makes South Africa the third best rated African country.

The national currency, South African Rand (ZAR), lost value compared to the Euro over recent years. The currency is volatile and sensitive to public policy announcements and decisions, as well as to movements on the international financial markets, resulting in high currency fluctuations causing problems for the economy as project planning with imported goods becomes more unpredictable. The current prime lending rate is 10%, which is relatively high compared to western countries and sets a substantial burden for bank financed investments and especially for renewable energy projects, which usually have a higher CAPEX than conventional energy investments. The level of direct foreign investments has shown a downward trend over the last couple years, and in the last census in 2016 it was at 2.25 billion USD (World Bank, n.d.).

In April 2017, the credit rating of South Africa has been downgraded by Standard's & Poor (S&P) and Fitch to BB+ which is better known in public as "junk status".

Table I: South Africa's credit rating by international Rating Agencies	
Standard & Poor's	BB, stable
Moody's	Baa3, stable
Fitch	BB+-, stable
Trading Economics Rating	49, non-investment grade speculative

In the country rating of Euler Hermes, the export credit insurance of the Federal Republic of Germany, South Africa is assigned to country category 4 (category 0 = lowest risk, category 7 = highest risk) in 2018. Euler Hermes defines the South African market as "medium risk" with a stable outlook and no formal coverage restrictions. Critical points mentioned are the high unemployment rate, the unequal income distribution, the insufficient education system as well as the growing budget deficit and the weak exchange rate.

South Africa's most important trade partner is China, while the European Union (EU) is another important trade partner of South Africa, importing 20% of the country's exports. At the same time the EU delivers about 30% of the imports of South Africa. Among the EU countries Germany and the United Kingdom are the leading trade partners. South Africa's foreign trade is strongly shaped by its raw material exports, which makes the economy to some stage vulnerable due to international raw material price fluctuations. Also, South Africa has no major oil sources, which makes it dependent on the world market price for crude oil imports.

Due to the fluctuating character of the economy and its development, it is quite difficult to predict a prefund economic outlook. The governmental outlook during the last years was always quite optimistic but finally could not achieve its predictions. Due to the downgrading of the rating agencies, prospectively, it will be even more difficult to uplift the economic growth. However, since 17th December 2017, Cyril Ramaphosa became the new President and with him a lot of hope to economical improvements raised.

Table II: Economic Forecast 2018–2020 Outlook (tradingeconomics.com)

	Actual	**Q1/2018**	**Q2/2018**	**Q3/2018**	**Q4/2018**	**2020**
GDP Growth Rate (in %)	3.1	2.5	2.0	1.5	1.9	2.1
Unemployment Rate (in %)	26.7	28	27.8	27	27	24
Inflation Rate (in %)	4.0	4.4	4.6	4.8	4.9	5.1
Competitiveness Index (points out of 7)	4.32					4.45
Balance of Trade (in mil ZAR)	-27,700	-565	-5434	-7176	472	-1700
Government Debt to GDP (in %)	53.1	54	54	54	54	56

1.3 Energy Policies in South Africa

South Africa's energy policy in the past focused heavily on issues of security of energy supply and self-reliance. With the publication of the White Paper on Energy (1998), and the White Paper of Renewable Energy (2003), more focus was placed on pursuing energy supply security through greater diversification. This was one of the earliest indications that the government would promote cleaner energy (such as solar thermal) and diversify away from coal. The National Strategy on Climate Change of 2011 looked more specifically on emissions and South Africa is now deliberating on implementation of a carbon tax and carbon budget.

At present, there are no policies directly targeting Solar Heat for Industrial Processes (SHIP). Efforts are still under way to produce a solar energy technology roadmap that does include SHIP. Once the potential benefit to the country is demonstrated in this manner, the merits of introducing supportive policies will be clear. Solar water heating in the residential and commercial sector, does enjoy some policy support as it is a more mature sector in South Africa than the solar process heating sector. The South African Government's National Development Plan 2030 has a target of 3 million solar water heaters by 2030.

1.3.1 Carbon Budgets and Tax Policy

South Africa made a voluntary commitment to reduce its greenhouse gas (GHG) emissions by 34% in 2020 and 42% in 2025 relative to business-as-usual (BAU). This was reaffirmed in its Intended Nationally Determined Contribution (INDC) submission to the United Nations Framework Convention on Climate Change UNFCCC, which stated emissions should peak in 2025 within a range of 398-614 MtCO2e; plateau for a decade; and then decline to between 212-428 MtCO2e by 2050. Two measures are envisaged to contribute to achieve this goal. The first is a Carbon tax which is currently the subject of a bill to be deliberated by lawmakers. The second measure involves a series of carbon budgets designed by the Department of Environmental Affairs (DEA) to provide a GHG emissions allowance or cap, against which physical emissions arising from the operations of a company during a defined time period will be tracked. In the period to 2020, the carbon budgets will not be a compliance instrument but rather will be used to increase understanding of the emissions profile of participating companies, and to establish monitoring, reporting, and verification (MRV) processes. Beyond 2020, they are intended to become compulsory.

1.3.2 Industrial Policy Action Plan

The Industrial Policy Action Plan (IPAP) stems from the National Industrial Policy Framework (NIPF) that was adopted by government in January 2007 and set out government's board approach to industrialisation. IPAP identified significant opportunities to develop new green and energy efficient industries and related services in South Africa, and highlights that the country's manufacturing sector will need to improve its energy efficiency. IPAP identifies key sectors, many of which are relevant to SHIP, namely: agro-processing (including food and beverage); chemicals, plastics and pharmaceuticals; clothing, textiles, leather and footwear; and automotive products and components.

1.4 Incentive Programmes and Financing

Table 1 outlines incentive programmes and financing schemes, beneficial to SHIP projects.

TABLE 1: Relevant Incentive Schemes Identified

Instrument	Name	Impact/effect
Tax	Carbon Tax Bill	Increases the competitiveness of clean technologies such as SHIP by placing a price on carbon emissions. The tax will be phased in over a period of time to allow for smooth transition in adopting cleaner and more efficient technologies and behaviours. The proposed initial marginal carbon tax rate will be R120 per tonne of CO2e (carbon dioxide equivalent). However, up to 2020 a series of basic tax-free allowances will be made available that will see companies effectively pay between 6-48 ZAR/tCO2e.
Tax incentive	Section 12B of the Income Tax Act of 1962	Provides for a capital allowance for assets used in the production of renewable energy. It allows for a deduction/depreciation on a 100% basis (<1 MW) in the first year or 50%/30%/20% (>1MW) over 3 years in respect to a qualifying asset owned by the taxpayer. Assuming a company tax rate of 28%, the use of accelerated depreciation improves the economics of investing in solar thermal plants in comparison to maintaining the status quo and burning fossil fuels or using electricity. It is recommended that a company applies for a binding ruling from the South African Revenue Service (SARS) before investing in solar equipment to determine if they qualify for deductions under the 12B Act amendment.
Incentive	Manufacturing Competitiveness Enhancement Programme (MCEP)	The objective of Manufacturing Competitiveness Enhancement Programme (MCEP) is to improve and promote enterprise competitiveness and job retention. MCEP consists of two programmes, namely: The Production Incentive (managed by DTI) and the Industrial Financing Loan facility (managed by IDC). https://www.thedti.gov.za/DownloadFileAction?id=670&filename=pi_guidelines_2012_2013.pdf
Production support/ incentive	Agro-Processing Support Scheme (APSS)	The scheme offers a 20-30% cost sharing grant to a maximum of twenty million rand (R20 million) over a two (2) year investment period, with at last claim to be submitted within six (6) months after the final approved milestone. https://www.thedti.gov.za/news2017/Agro-Processing_Support_Scheme_Guidelines.pdf
Incentive	Production Incentive Programme (PIP)	The Production Incentive Programme (PIP) is aimed at structurally changing the Clothing, Textiles, Footwear, Leather and Leather Goods manufacturing industries by providing funding assistance to invest in competitiveness improvement interventions. An Upgrade Grant can be used for the following qualifying expenditure: upgrading of existing plant and equipment; acquisition of new plant and equipment which will have the effect of improving the overall competitiveness of the applicant (SHIP may potentially improve the competitiveness of any textile factory with lower energy costs). Details on how to apply the PIP may be found here: http://www.ctcp.co.za/tmp/PIP GUIDELINES 2016-2017.pdf

Support on Climate Change/Energy Efficiency Strategy from National Cleaner Production Centre (NCPC)

The NCPC supports industry in quantifying opportunities for improving energy and resource efficiency (i.e. energy, water, waste reduction). This programme is funded through the Department of Trade and Industry (DTI) with the specialised energy component supported by the United Nations Industrial Development Organization (UNIDO). Although the core focus is not exclusively solar heating, the programme is well-positioned to identify industrial processes that may be made more competitive using solar-based process heat and recommending these interventions to their client companies. Upon request, the programme is able to access funds from the DTI/UNIDO to support investigations into where client companies may use solar process heating to improve profitability. This service offering is provided under the NCPC programmes that give effect to the country's policies on improving energy and resource efficiency.

1.5 Industrial Energy Usage in South Africa

As shown in Figure 1 final energy consumption in South Africa has been experiencing sustained growth between 2000 and 2015. The industrial sector is currently the largest energy consumer, accounting for 37.3% of final energy consumption.

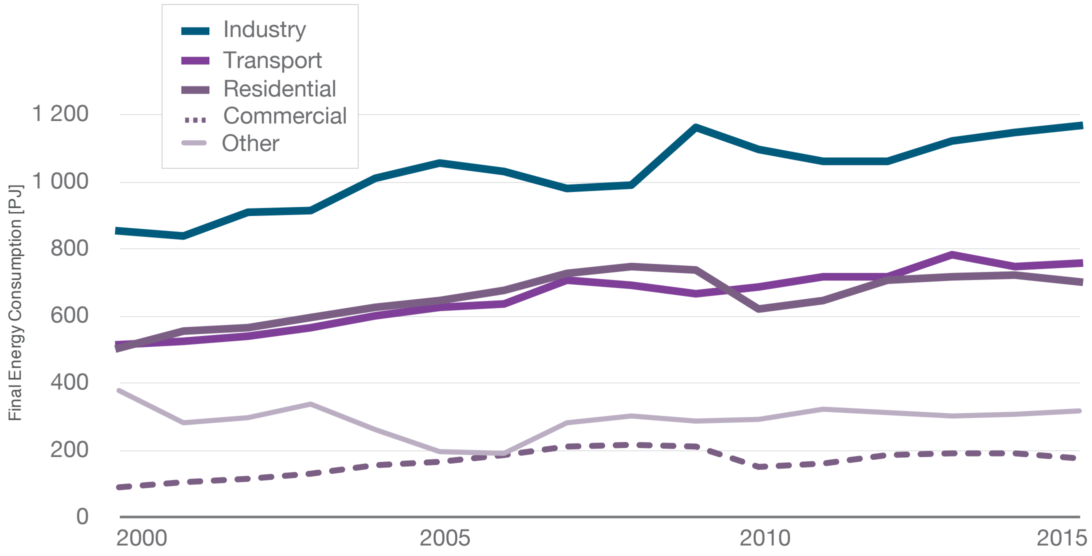


FIGURE 1: Final energy consumption in South Africa per sector (PJ) from 2000 to 2016

Source 1: International Energy Agency Energy Balances for South Africa

The latest available energy balances from the International Energy Agency for South Africa are for the year 2015 and indicate that the industrial sector consumed 1167 PJ of energy. Fuel accounted for 730 PJ (62.5%) of the industrial energy consumption and electricity 438 PJ (37.5%). Due to the availability of local coal reserves coal is the dominant fuel that is used in industry with 476 PJ consumed in 2015.

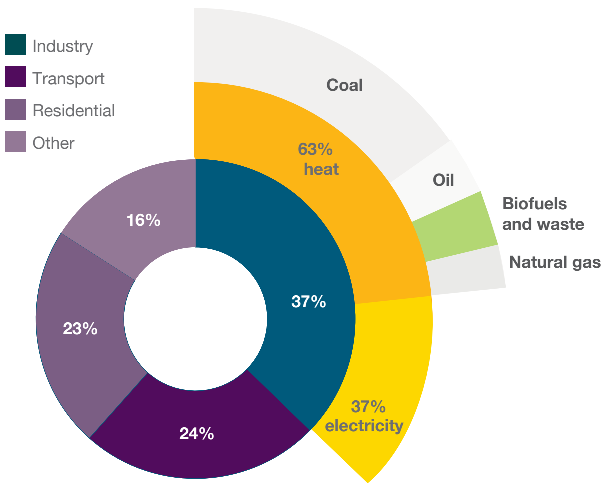


FIGURE 2: Final energy consumption for South Africa in 2015 (total: 3131 PJ)

Source 2: International Energy Agency Energy Balances for South Africa

Thermal energy is the dominant end-use of energy in the industrial sector. Fossil fuels are primarily used in the industrial sector for process heating, while the end-use of electricity is diverse, but includes significant amounts of heating and cooling in a number of industries. As shown in Figure 3, the South African Department of Energy (DoE) estimates that overall 71% of energy end use in the industrial sector is for thermal applications.

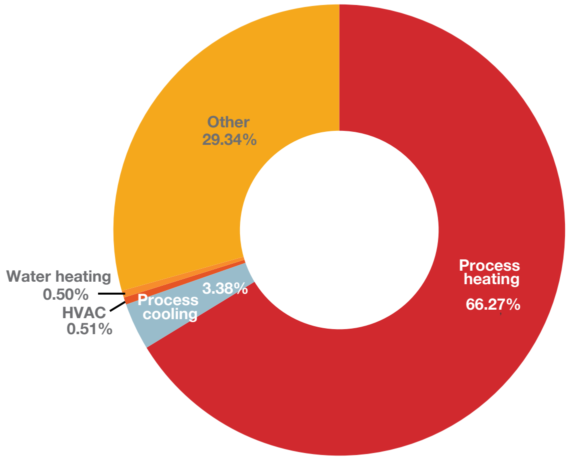


FIGURE 3: End use of energy in the industrial sector

Source 3: (Department of Energy, 2016)

1.6 Energy Costs in South Africa

The economic viability of a solar thermal system is dependent on the fuel offset from competing heating systems, typically steam boilers. Table 2 provides an overview of the estimated heating costs for different energy carriers used for process heating in mid-2017. Input energy costs are based on the calorific value of the energy carrier, whilst steam/heat costs are calculated assuming a 60-80% conversion and distribution efficiency.

TABLE 2: Indicative energy costs for process heating in mid-2017

Energy Source	Cost (ZAR)	Unit	Cost[1] (ZAR/GJ)	kg CO_2 per kWh input energy[2]	Input cost (ZAR/kWh)	Heat cost (ZAR/kWh)	
						80%	60%
Coal Gauteng[3]	0.9	kg	34	0.34	0.12	0.15	0.20
Coal Western Cape[3]	1.5	kg	57	0.34	0.20	0.25	0.33
SASOL Gas C5[4]	90	GJ	90	0.20	0.32	0.41	0.54
SASOL Gas C3[4]	124	GJ	124	0.20	0.45	0.56	0.74
SASOL Gas C1[4]	149	GJ	149	0.20	0.54	0.67	0.89
Heavy Fuel Oil (HFO)[5]	5.2	litre	126	0.28	0.45	0.57	0.76
Paraffin[6]	7.14	litre	190	0.26	0.69	0.86	1.14
Electricity Eskom Night Save[7]	0.65	kWh	180	1.06	0.65	0.81	1.08
Electricity City Power[8]	1.14	kWh	317	1.06	1.14	1.43	1.90
Diesel[6]	11.6	litre	304	0.27	1.09	1.37	1.82
Liquefied Petroleum Gas (LPG)[6]	18.81	kg	408	0.23	1.47	1.84	2.45

1 Conversion factors (Department of Environmental Affairs, 2017), prices exclusive of VAT; 2 Based on (Intergovernmental Panel on Climate Change, 2006); 3 Grade B assumed, transportation costs estimated and included, ash disposal excluded ; 4 Assumed Gauteng zone, C1: 0-0.4 TJ p.a. C3: 4-40 TJ p.a. C5: 400-4000 TJ p.a. (Department of Energy, 2016) ; 5 Average market price per supplier; 6 (South African Petroleum Industry Association, 2017), VAT excluded for LPG price.; 7 Average of summer and winter tariffs for Eskom Night Save industrial customers (0.5-66kVA in Gauteng), excludes average peak demand charge of 71 ZAR/kVA/m and 42 ZAR/kVA/m network charge (Eskom, 2017); 8 Average of summer and winter tariffs for City Power industrial customers (1-33 kVA in Johannesburg), excludes peak demand charge of 160 ZAR/kVA/m (MV) and 4322 ZAR/m service and capacity charge (City Power Johannesburg, 2016)

The low cost of coal as an energy carrier indicates why it is extensively used in boiler systems across South African industries. South African coal prices are strongly dependent on location due to transport costs, with prices lowest in areas near to the mines, predominantly in the Mpumalanga province.

As an alternative to coal, companies located in regions that are connected to the gas distribution network can make use of gas as a low-cost energy carrier. A description of the gas infrastructure is provided in Section 1.7 and excludes many industrial areas. Smaller companies are also likely to use Heavy Fuel Oil (HFO) or paraffin as an alternative energy carrier to coal, due to the logistics of coal supply, storage and ash disposal.

1.6.1 Outlook on Future Energy Cost Developments

Rising energy costs should be taken into consideration when analysing the value of a solar thermal system. In Figure 4 (a)/(b) the historic prices of key energy carriers are presented in real terms over the past 10 years to exclude the effects of inflation. Therefore, any Levelized Cost of Heat (LCOH) analysis should be conducted in real terms not nominal. Over the past 10 years, inflation has averaged to approximately 6% p.a. in South Africa, leading to rising energy prices in nominal terms. Real energy costs, however, fixed in Dec 2016 ZAR, present a more descriptive picture by adjusting for inflation.

South Africa is a net importer of crude oil. According to DoE, in excess of 60% of products that are refined in South Africa are produced from imported crude oil, while 36% is produced by coal-to-liquid (CTL) and gas-to-liquid (GTL) synthetic fuels (Department of Energy, 2017). Costs of diesel, paraffin, HFO, and Liquefied Petroleum Gas (LPG) are dependent on the international oil price and the ZAR/USD exchange rate, which is particularly volatile. This exposes companies that utilise petroleum fuels to a significant price uncertainty. As shown in Figure 4(a), the real price for petroleum-based fuels has varied significantly about the average real value since 2006.

The Energy Information Administration (EIA) in the U.S. predicts a recovery in the oil price over the next 20 years for the reference case, which is in line with OPEC predictions (EIA, 2017). However, as shown in Figure 4(b), there is a significant variation between the high and low oil price predictions, indicating significant uncertainty in future oil prices. A recovery in the oil price and a continued depreciation of the ZAR/USD exchange rate will lead to rising real fuel prices.

Typically, industrial customers in South Africa utilise coal that is a higher calorific grade than that which Eskom utilises. As shown in Figure 4 (a), the estimated price of industrial coal in Gauteng of 900 ZAR/ton is now in line with Free On Board (FOB) export coal costs. As large coal mines in the Central Basin coalfields of Witbank, Highveld and Ermelo become depleted, new mines will have to be established in more remote areas, which could lead to rising coal prices. Increasing fuel prices and deteriorating transport infrastructure could also further increase the coal price for local industrial customers.

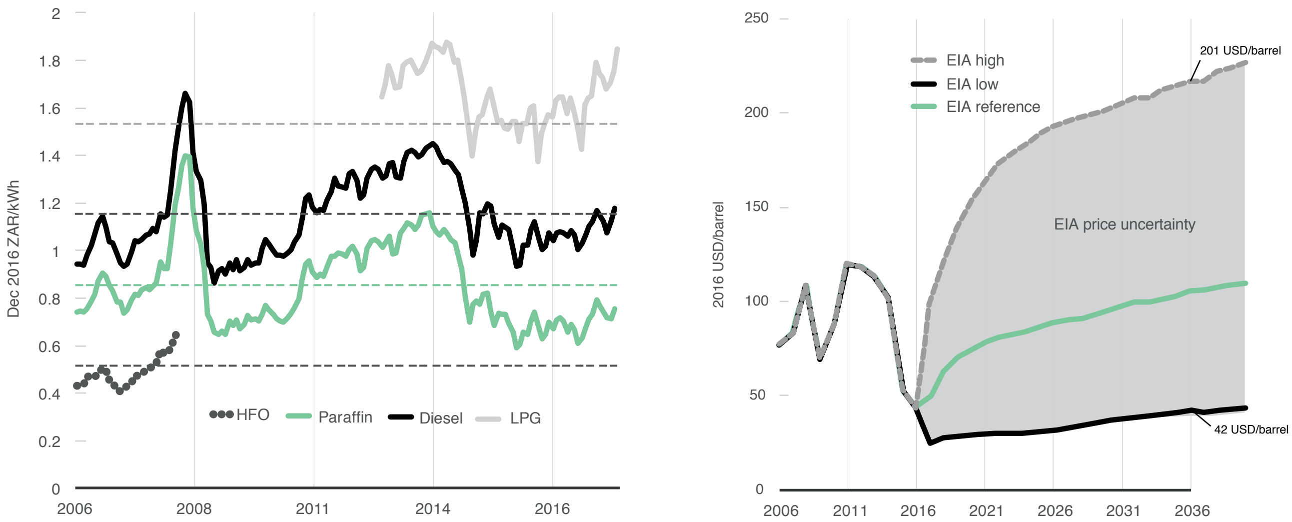


FIGURE 4: Petroleum fuel costs: (a) Historical (dashed lines indicate average) (b) Projected international oil price

Source 4: (South African Petroleum Industry Association, 2017), (EIA, 2017)

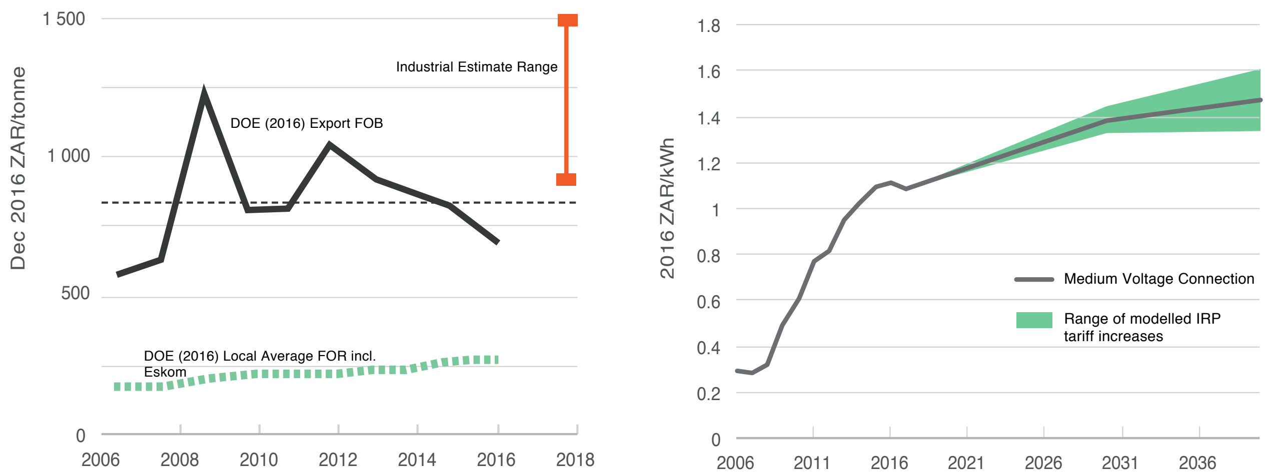


FIGURE 5: (a) Historical local and export coal prices (b) Historical and projected electricity prices

Source 5:(Department of Energy, 2016), (City Power Johannesburg, 2016), (CSIR, 2017)

Subsequent to rolling electricity blackouts in 2008 due to insufficient generation capacity, Eskom began a large capacity expansion programme. As shown in Figure 4(b), this has led to rapid increases in real electricity prices. Models from the CSIR Energy Centre that served as comments to the draft Integrated Resource Plan 2016 indicate that the average price of electricity generation in the country will continue to increase (CSIR, 2017). The tariffs presented in Figure 4 (b) are based on the prices for industrial customers from City Power Johannesburg, which are higher than for Eskom direct industrial customers. The projected increases are scaled from the CSIR model for predicted prices in average electricity costs. The results show that industrial customers can expect above inflation increases in electricity prices over the next 20 years.

In 2012, the maximum natural gas price was regulated by NERSA (National Energy Regulator of South Africa). Thus, there is limited historical data based on the new pricing methodology. Currently, this pricing methodology is based on a blend of several energy carriers, namely: coal (37%), diesel (24%), electricity (37%), LPG (1%) and HFO (1%) (Sasol, 2017). Therefore, rising costs in the aforementioned energy carriers will lead to rising natural gas costs as well, which introduces a high level of uncertainty into prices.

1.6.2 Effect of Carbon Tax

The amount of CO_2 emissions for each energy source is presented in Table 2. It should be noted that electricity has the highest carbon intensity due to heavy reliance on nationally grid-connected coal fired power generation in South Africa. Assuming 120 ZAR/tCO2, the costs of electricity will increase at 0.13 ZAR/kWh above predictions. Natural gas and LPG are the least affected by carbon tax. A summary of the key energy data is presented in Table 3.

TABLE 3: Summary of Key Energy Data

Energy price estimations	**Price development**
Inflation (avg. index 2016)/ (avg. index 2006)	1.84
Inflation (avg. index 2016)/ (avg. index 2011)	1.31
Average inflation (2006-2016)	6.2%
Historical increases (2006-2016, excluding inflation)	
Export coal (ZAR/kWh, Dec 2006-Dec 2016)	+ 72%
International oil price (USD/b, avg 2006- avg 2016)	- 43%
Paraffin (ZAR/kWh, Dec 2006-Dec 2016)	- 14%
Electricity (City Power, avg. Energy Charge)	+ 279%
Projections (2016-2040, excluding inflation)	
International oil price (USD/b) – EIA reference	+ 150%
International oil price (USD/b) – EIA high	+ 416%
International oil price (USD/b) – EIA low	- 1%
Electricity (City Power, avg. Energy Charge) – low increase based on CSIR 2016 draft IRP comments	+ 24%
Electricity (City Power, avg. Energy Charge) – high increase based on CSIR 2016 draft IRP comments	+ 49%
Increase in Input Energy Costs due to Carbon Tax	
Electricity	0.13 ZAR/kWh
Coal	0.04 ZAR/kWh
Liquefied Petroleum Gas	0.03 ZAR/kWh

Source 6: Own research

1.7 Energy Infrastructure for Industrial Facilities

Due to historically low costs, electricity and coal developed as the dominant energy carriers in South Africa for a wide range of energy-related services. Partly because of this, South Africa has a well-developed transmission grid that enables delivery of electricity to all major demand centres in the country. Over 40% of all electricity generated by the national utility (Eskom) is sold to municipalities. This indicates the important role of municipalities in terms of electricity distribution. The cost of electricity to industrial customers varies (sometimes significantly) based on whether the supply is from the national utility or from the relevant local municipality.

The cost of coal is strongly dependent on the transport required from mines, which are typically located in the Mpumalanga province. Therefore, the transport costs of coal for steam boilers in Cape Town (estimated 600-800 ZAR/ton) are significantly higher than in Gauteng (estimated 100-200 ZAR/ton). Transport by rail is one of the cheapest options for moving coal from mining operations to destinations at industrial operations. These favourable freight costs are only possible if industries are located in close proximity to main railway routes.

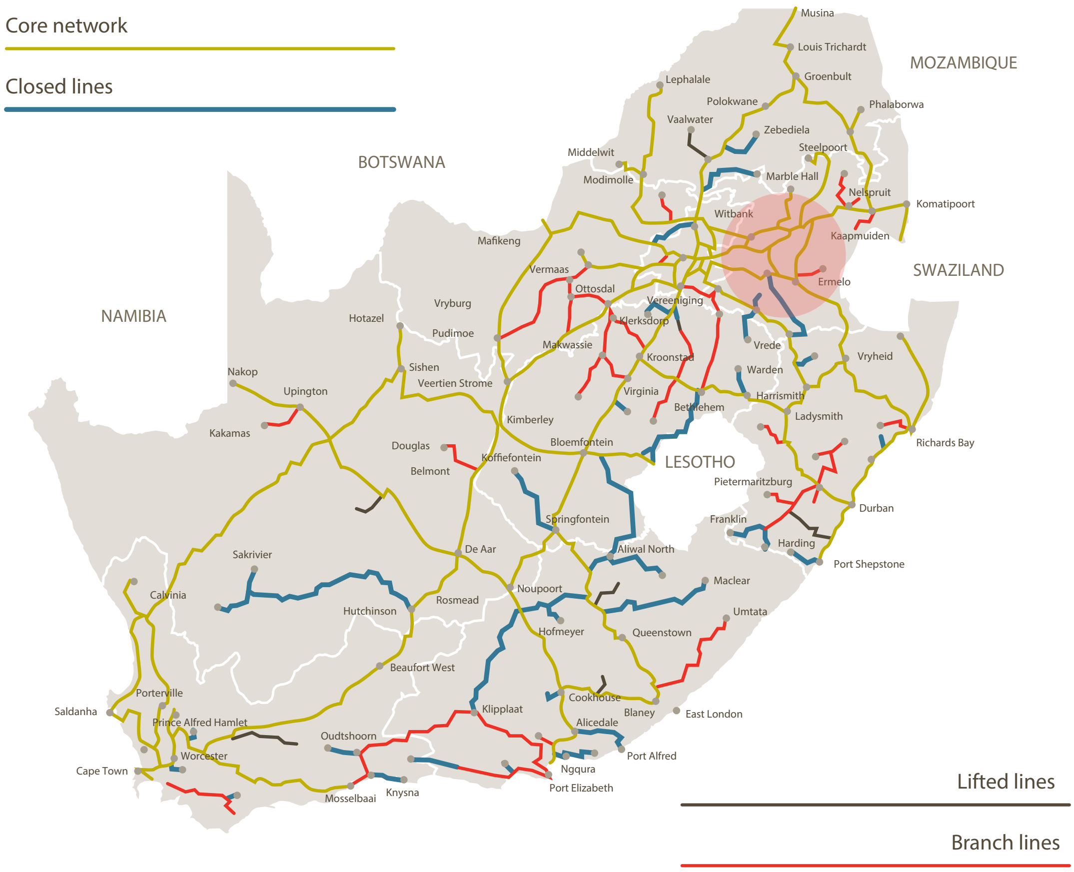


FIGURE 6: Transnet Railway Network ▪ Coal basin region

Source 7: Transnet

Process heating using natural gas presents a credible low-cost option for process heating. However, the gas supply network is far from reaching the geographical footprint of the electricity, road and rail networks. The gas network was clearly designed for delivering product from the country's national ports to major gas and petrochemical processing hubs particularly Secunda (in Mpumalanga Province) that hosts many of the operations of Sasol (South Africa's largest petroleum and chemicals processing company). Figure 7 shows the current extent of the gas supply network in South Africa.

Although the transmission network is mostly owned by Transnet and PetroSAa few other entities have access to the majority of these pipelines as well. The prices for products or energy carriers sourced from these networks are regulated by NERSA.

Since South Africa does not make use of extensive district heating networks, they are not considered in this study. The regulated price of petroleum products is based on assigned demarcated zones. Therefore, the costs of these fuels are typically more expensive inland due to transportation from the refineries. However, South Africa has well developed pipelines from the refineries to Gauteng. For example, the cost increase for inland diesel is in the order of 3.4% over coastal regions.

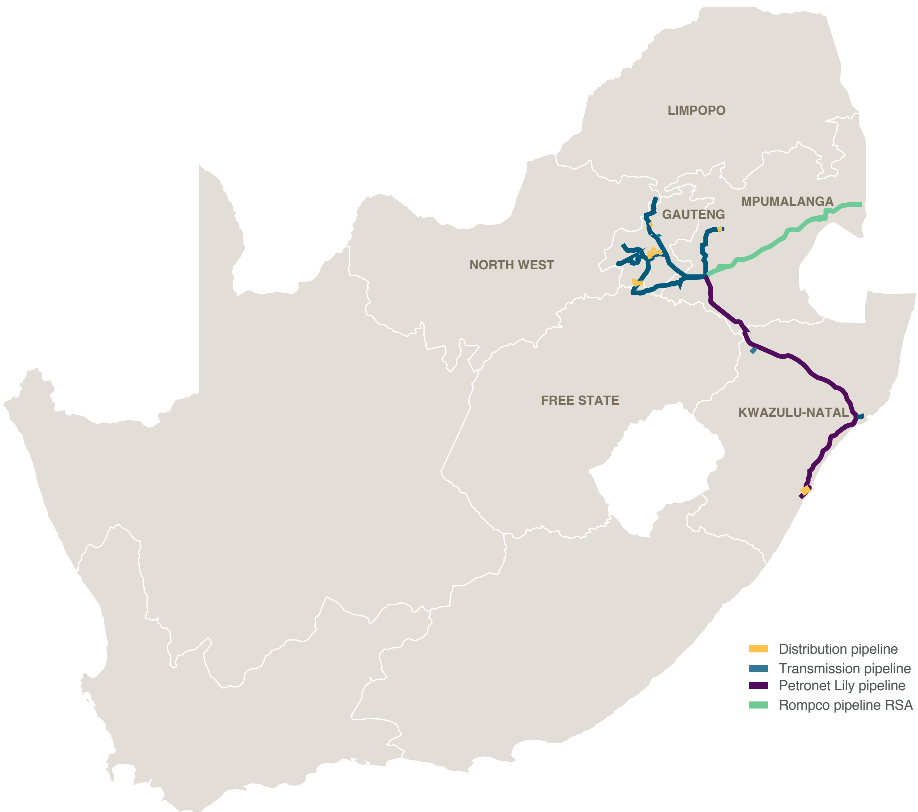


FIGURE 7a: Gas distribution networks in South Africa

Source 8: (SASOL, 2012)

FIGURE 7b: Gas reticulation network in Gauteng (owned by Egoli Gas)

Source 8: (SASOL, 2012)

1.8 Solar Potential

South Africa is located in the sun-belt and therefore has an extensive solar resource. Maps of Global Horizontal Irradiation (GHI) and Direct Normal Irradiation (DNI) for South Africa are presented in Figure 8. Manufacturing is concentrated in the Gauteng province, which is the smallest of South Africa's nine provinces accounting for only 1.4% of the country's land area. The GHI values in Gauteng exceed 2000 kWh/m^2/yr., which is a favourable solar resource compared to several industrial plants around the world where solar systems have been implemented. An optimally tilted, north facing, flat plate collector in Johannesburg would generate approximately 1.6 MWh$_{th}$/m^2/yr. (assuming 70% collector efficiency).

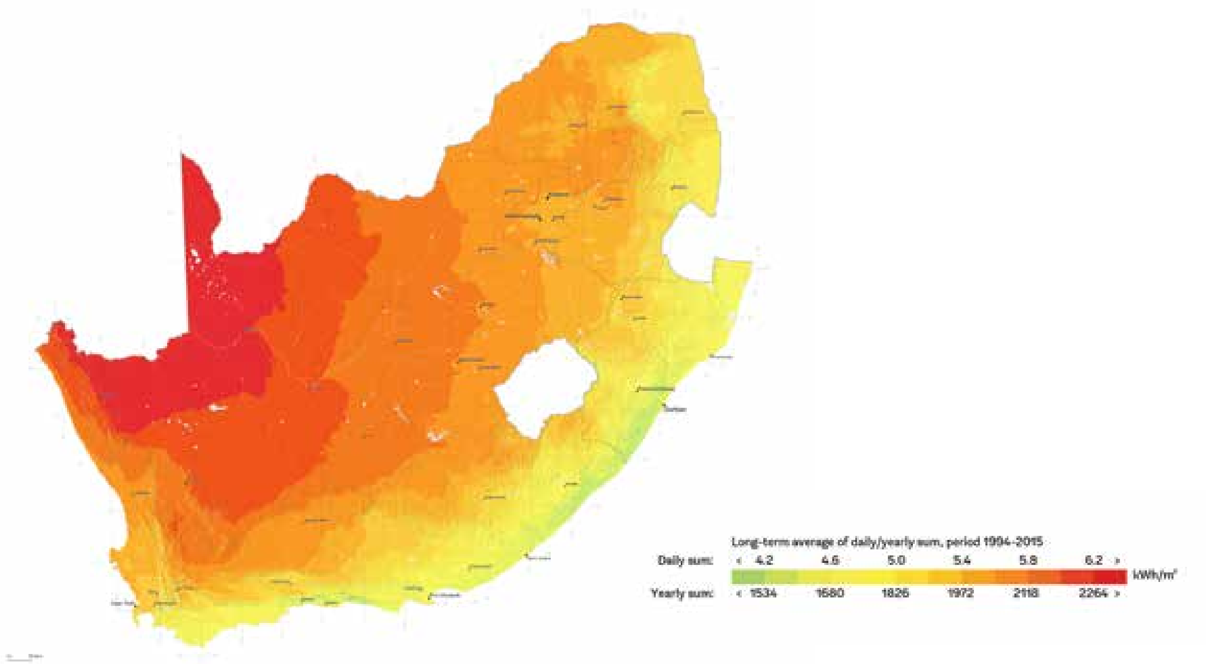


FIGURE 8A: Annual Global Horizontal Irradiation (GHI)

Source 9: The World Bank, Solar resource data: Solargis

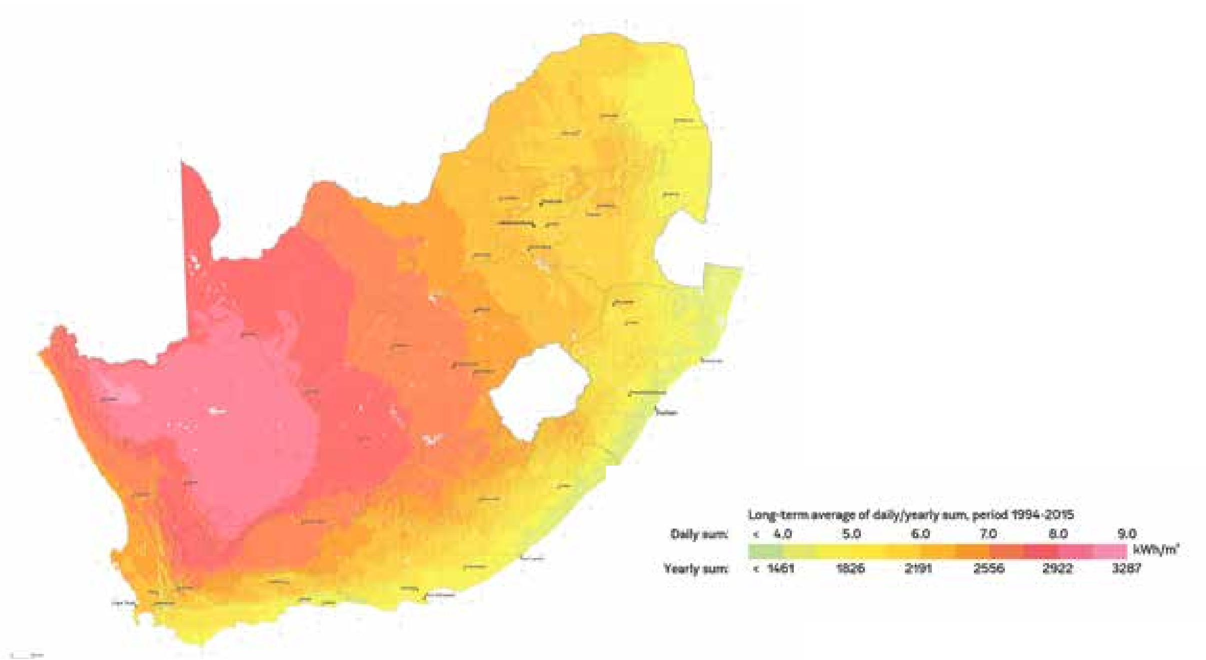


FIGURE 8B: Direct Normal Irradiation (DNI) for South Africa

Source 10: The World Bank, Solar resource data: Solargis

Conclusions of the Energy and Policy Landscape in South Africa

- South Africa's climate policies aim at a reduction of CO_2 emissions by 42% relative to BAU by 2025.
- A proposed carbon tax could increase the costs of fossil fuel generated energy, though implementation steps are yet not known.
- Incentives such as accelerated depreciation (Section 12B of the Income Tax Act of 1962), or incentives for manufacturing and agro-processing as well as energy efficiency programmes exist and could stimulate investments in new technologies.
- Energy costs for industry vary significantly based on energy source. Local coal is the cheapest source, whilst other sources such as gas, oil and LPG often depend on international fuel prices and transport infrastructure. Coal in the Mpumalanga and Gauteng regions is the cheapest energy source, LPG is the most expensive.
- Prices for coal and electricity will likely increase due to the depletion of existing coal mines, the exploration of new coal mines and transport logistics to those resources as well as the construction of new power generation plants.
- There is uncertainty in the future price of gas and petroleum fuels.
- The gas network will have to be extended for South Africa-wide distribution.
- South Africa has an excellent solar potential of 1.8 to 2.3 MWh/m^2 solar irradiation (GHI) in major industrial areas.

CHAPTER 2

SOLAR THERMAL MARKET FOR INDUSTRIAL PROCESSES

2.1 Description of Solar Thermal Technologies for Industrial Processes

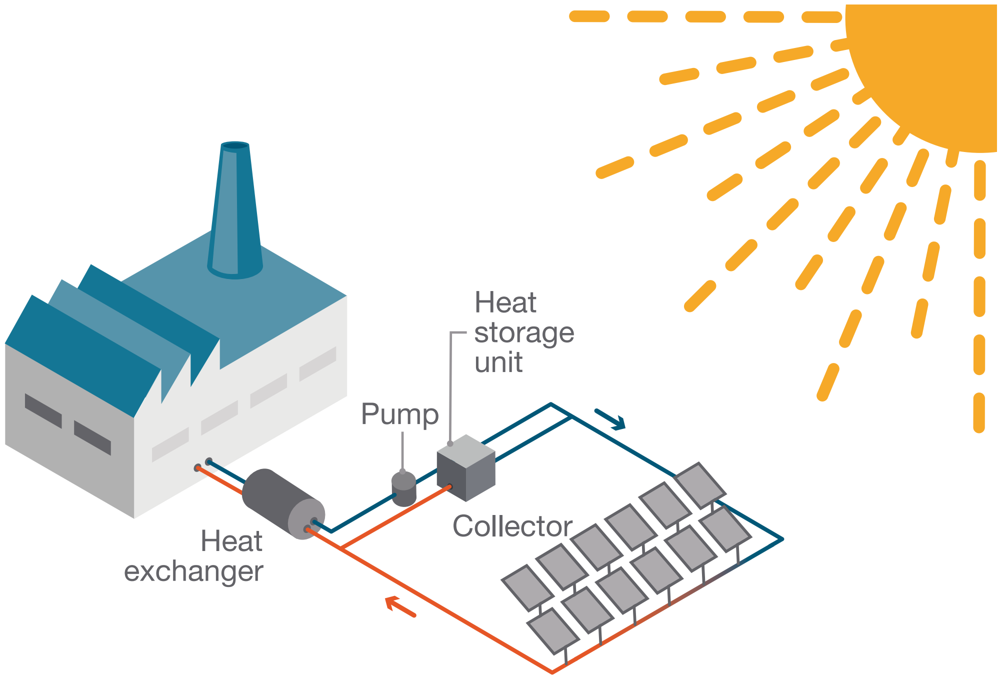


FIGURE 9: Scheme of a SHIP plant

Source 11: Solar Payback 2017

Solar thermal collectors convert solar radiation into usable heat. SHIP is the acronym for Solar Heat for Industrial Processes and describes systems which provide solar heat in a factory. Figure 9 shows a SHIP plant were the solar collector field heats a process fluid and a heat exchanger transfers this heat to a supply a system or production process in the factory as hot water, air flow or steam. Storage units also make it possible to use the generated heat at night-time. Usually solar thermal energy only supports an existing heating process and is optimized according to the demand at times of maximum irradiation, especially during the summer.

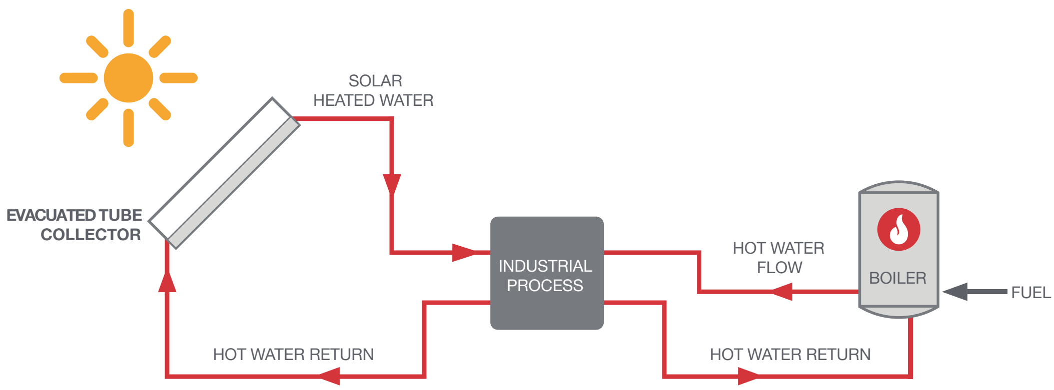


FIGURE 10: Simplified illustration of process heat circle

Source 12: Solar Payback 2017, IRENA

Exposed to the sun, the collector heats up a heat transfer liquid (either hot air, water, water with glycol for frost protection or thermo oil). The collectors are connected to the production process or to a storage tank, either directly or via a heat exchanger. Electric pumps move the heat transfer liquid within the solar circle.

There are a number of collector technologies available on the market that supply heat at different temperature levels and can, therefore, be used in different processes. They can be classified in stationary and concentrating collectors.

Stationary collectors are orientated towards the sun on fixed racks. They can be unglazed, air, flat plate, and evacuated tube collectors.

Concentrating collectors work on the principle of reflecting and concentrating direct solar radiation at its focus (a point or line), thereby using the concentrated solar radiation as a high temperature thermal energy source to produce process heat. The mirror elements that reflect and concentrate solar radiation vary in geometry and size. To facilitate concentration of direct normal irradiation (DNI), the mirrors need to be continuously tracked following the path of the sun in single or two-axes.

Fresnel and parabolic trough collectors are 1-axis tracking systems. Concentrating dish collectors are mostly 2 axis tracking solutions. Thus, they make sense in areas with a lot of direct solar irradiation. They can generate heat with temperatures of up to 400°C and even higher for electricity production and can be operated by pressurized water or thermal oil.

TABLE 4: Overview of collector types for solar process heat generation

Source 13: Own research

Air collector

Air collectors use air to transport heat. Various types of air collectors either use glazed, unglazed or vacuum tubes to collect usable heat. They either rely on natural convection or use fans to transport the air via a well-insulated tube system. In industrial processes air collectors are well suited to drying processes providing hot air at between 20 to 70°C.

Photo: Grammer

Flat plate collector

Flat plate collectors use water to transport heat to the heat exchanger, the storage tank or the production process. They consist of an insulated case containing a metallic absorber which has an absorber sheet and a piping system below to transport the heat. The casing is covered with a single or double glass plate alternatively antireflective coated to reduce transmission losses. They achieve operating temperatures between 30 and 90°C and are produced in many countries. For solar process heat applications, usually large-scale collectors are used. Evacuated flat plate collectors can supply even higher temperatures due to reduced convection losses.

Photo: E3 Energy group

Evacuated tube collector

Evacuated tube collectors use vacuum as an insulation to protect the absorber from the environment. Double-glass evacuated tube collectors consist of two tubes which are evacuated between them; single-glass evacuated tube collectors consist of one evacuated tube. With direct flow types the heat transfer liquid flows through the tube. With so-called heat pipe or U-pipe collectors a separated circuit inside the tube transports the heat collected to the top of the tube. Inside the header the energy is transferred to the heating circuit.

To improve efficiency, some types of evacuated tube collectors are equipped with a reflective metal sheet behind the tubes that are called compound parabolic concentrators (CPC). Evacuated tube collectors can deliver temperatures between 50 and 150°C.

Photo: Himin

Parabolic Trough Collectors

In parabolic trough collectors bent mirrors reflect the sunlight to the receiver tubes. The mirrors or troughs are mostly aligned on a north-south axis and rotates from east to west to track the sun along its daily path. Temperatures of up to 400°C can be produced and direct steam generation is possible. The temperature level depends on the size of the parabolic trough and the evacuation of the receiver tube.

Photo: Amul Fed Dairy

Linear Fresnel Collectors

Fresnel collectors concentrate the sun with several flat mirrors that track the sunlight on one axis onto a central receiver tube. The single mirrors are easy to replace and the exposure to wind is only minimal. There are Fresnel collectors that have a secondary mirror that is placed above the receiver tube to reflect light back down to the absorber. Temperatures of up to 400°C can be produced and direct steam generation is possible.

Photo: Industrial Solar

Concentrating Dish Collector

Parabolic Dishes concentrate solar irradiation on one spot and produce high temperatures up to 400°C depending on the size of the mirror field and the evacuation of the receiver tube. Examples are Scheffler dishes used for cooking in India. The tracking via two axes requires a high level of precision.

Photo: ARS Glasstech

2.2 Temperature Ranges

Industrial process temperatures typically vary according to the respective production process. They are classified into three ranges (see Figure 11): first below 150°C (called low temperature), a second range of 150°C to 400°C (medium temperature) and above 400°C (high temperature). Many industrial processes in the chemical, food and beverage, machinery, mining, textile, and wood industry use temperatures that can be easily generated with solar thermal technologies either as hot water or steam. Since fixed costs dominate the overall cost structure of solar thermal energy, processes that have a summer peak load as well as those that can be applied all year long are of special interest for the use of solar thermal applications. Economics improve, the higher the costs for competing energy sources are.

Which solar thermal collector type is used depends greatly on the temperature level required. In some applications, e.g. for washing or drying processes, only a low temperature of about 50°C is needed. For this temperature mainly, flat plate collectors or air collectors are used. Numerous industrial processes require temperature levels up to 95°C. Both evacuated tube collectors and improved flat plate collectors are able to provide this temperature level with a very good efficiency. Higher temperature levels can be reached if vacuum is used for insulation, either evacuated flat plate or evacuated tube collectors are collector types which are used with industrial applications up to 150°C.

Above approximately 140°C the solar radiation must be concentrated. The higher concentration factors of parabolic trough, linear Fresnel collectors or concentrating dish systems provide operating temperatures up to 400°C. For most applications more than one collector type could be used. The criteria are available space, economics, and location among others.

INDUSTRY	LOW Below 150 °C	MEDIUM 150 to 400 °C	HIGH > 400 °C
Chemical	• Boiling	• Distilling	
Food and beverage	• Drying • Boiling • Pasteurising • Sterilising		
Machinery	• Cleaning • Drying		
Mining	• Copper electrolytic refining • Mineral drying processes	• Nitrate melting	
Textile	• Washing • Bleaching	• Dyeing	
Wood	• Steaming • Pickling • Cooking	• Compression • Drying	

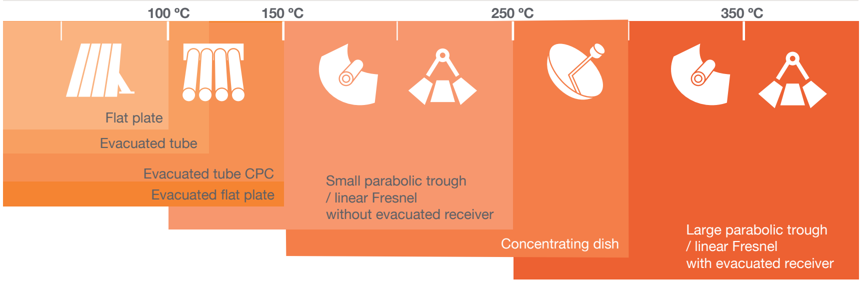


FIGURE 11: Collector temperature ranges, applications and technologies

Source 14: Solar Payback 2017, IEA/SHC 2012-2016

2.3 Local Solar Thermal Technologies

2.3.1 Solar Thermal Industry Overview and Players

This section outlines the identified companies that are active in the solar thermal industry in South Africa. The notable players are described below along with significant projects. According to Joubert et. al (2016) there are 89 large scale solar thermal systems in South Africa, where the collector area exceeds 10 m^2. However, the dominant applications are for hot water supply (domestic and staff ablutions account for 80 systems). Currently, only 7% of the installed collector area is for industrial process heating and 4 % for industrial cooling.

Solar Heat Exchangers: installs solar water heating, heat pumps, swimming pool heating and underfloor heating. Significant projects include a 540 m^2 flat plate solar collector system installed at Anglo Platinum in Brakfontein and a 1220 m^2 flat plat solar collector installed in Twistdraai, Secunda.

Holms and Friends: provides consulting and design services, including component selection, for solar water heating systems. Notable projects include a 612 m^2 system with vented storage at University of Pretoria's Prinshof student residences a similar 812 m^2 system installed at the Boekenhout and Olienhout residences.

KAYEMA Energy Solutions: designed and installed a 200 m^2 solar thermal system at the Standard Bank building in Braamfontein. The system is a hybrid system using solar thermal, heat pump and electrical technologies. It is one of the largest of its kind in Southern Africa.

GENERGY: is an EPC (Engineering, Procurement, Construction) company. This company has a portfolio of hot water production plants as well as rooftop photovoltaic projects. Notable projects include a 504 m^2 evacuated tube collector system installed at Xtrata Elands Mine and a 390 m^2 flat plat panel collector system installed at the BHP Billiton Wolwekrans colliery.

REACH Renewable: has designed and installed the first industrial size Linear Fresnel system providing a solar cooling system for the telecommunication industry. This system was installed at the MTN Headquarters Datacentre in Roodepoort, Johannesburg. REACH provides solar heating, air conditioning and power generation solutions offering consulting, design, import and implementation services.

GREENCON: is a company belonging to HBC Group. This company was responsible for installing a 200 m^2 flat plate solar collector system at the BMW manufacturing plant in Rosslyn, north of Pretoria. The water that is heated by the system is used to achieve optimum temperatures for the paint application process.

SOLARZONE: provides a range of services including solar water heating, heat pumps, solar cooling and underfloor heating. This company installed a 720 m^2 array of flat plate solar collectors at Ceres Correctional Prison in the Cape. The system is complete with 50 000 litres of water storage and saves the prison 617 580 kWh in energy for hot water annually.

SONNENKRAFT SA: is an international company with presence in South Africa supplying solar energy equipment. Sonnenkraft SA successfully designed and installed a 22 000 litre solar system with 322 m^2 of flat plate solar collectors (Blackdot Energy, 2016).

E3 Energy: this group of companies provides engineering, project execution and finance for the renewable energy industry. They focus on heating cooling and power. In 2015 they won a tender to install a 120m^2 solar water heating system at Cape Brewing Company (CBC) in the Western Cape (E3 Energy , 2017).

BBEnergy: known as BBE, is a power and energy management company. The company has constructed South Africa's first locally developed linear Fresnel demonstration plant at its premises in Johannesburg. In 2012 BBE obtained approval and funding from Eskom to construct similar systems at Gold Fields and AngloGold Ashanti mines as part of Eskom's budget for Integrated Demand Management (BIZCO Business Consulting, 2012).

2.3.2 South Africa Specific Information

Most of the companies described in the previous section perform Engineering, Procurement and Construction (EPC). Thus, project planning and implementation is all done in-house and turn-key solutions are provided. Hardware and components are procured by these companies from multiple manufactures both locally and abroad. Thus, a client seeking to implement a solar solution does not need to be concerned with several specific manufacturers because the EPC contractor will design a system and provide a bill of quantities with components from specific manufacturers.

Manufacturers and distributers of solar system hardware and components are distributed worldwide. Secon, based in the UK, distributes products from Resol, PAW and Solarmetaflex which have been used for South African projects. Sonnenkraft, an international company with South African presence, manufactures and distributes its own range of collectors, heat pumps, tanks and other components and hardware needed in solar thermal projects. The company's products have been used in a number of local projects.

The main two components of solar water heaters, the collectors and the geysers, are generally manufactured by separate companies in South Africa. There are very few, if any, local manufacturers that manufacture complete factory-made systems comprising of all components. Thus, it is the norm in South Africa for components to be sourced separately and combined into integrated systems by EPCs on site (Hertzog, 2012).

2.3.3 Cost of large Scale Solar Thermal Projects

The total cost of large solar thermal projects is somewhat dependent on the collector gross area, with a larger area achieving a lower cost per square meter of collector area. An analysis of South African projects up to 2016 has shown that the price of such systems ranges between EUR 400-800 per square meter of collector area. A trend-line and equation has been fitted to this data indicating the dependence of the price on collector gross area. As shown in Figure 12 there is a wide variation in plant costs even for similar collector areas.

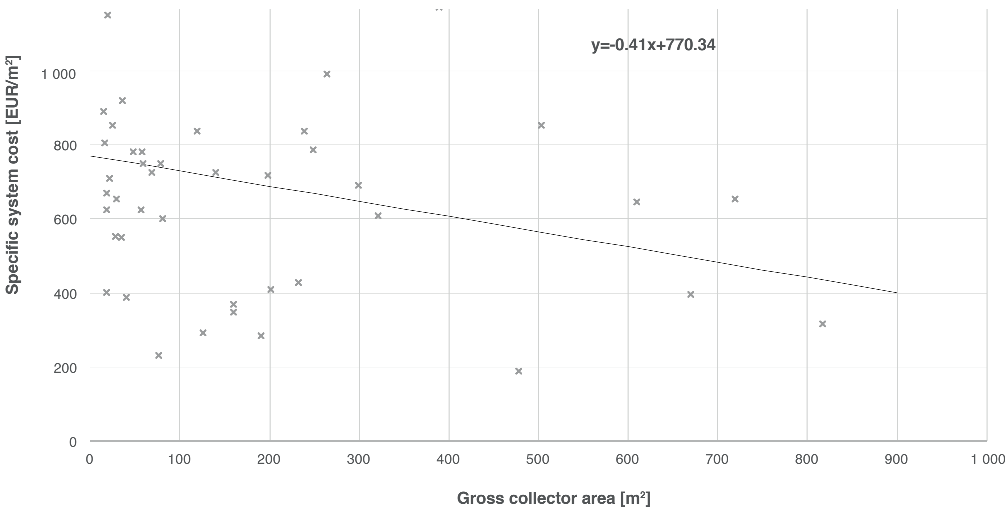


FIGURE 12: Estimated system costs

Source 15: (Joubert, Hess, & Van Niekerk, 2016)

2.3.4 Quality Standards, Certification and Norms

The local norm in South Africa is to manufacture solar water heating components separately, in opposition to complete factory-made systems. Therefore, it is the South African practice to ensure that quality standards are met through component testing rather than international practice of system testing (Hertzog, 2012).

In light of this component testing approach, the SABS has a product services department that offers a scheme for solar water heating component manufacturers to obtain a qualification certificate. This scheme enables the industry to demonstrate compliance through independent qualification. Related certifications for this qualification certificate include the following:

- ISO 9806-2:1995 – Test methods for solar collectors -- Part 2: Qualification test procedures
- ISO 9806-3:1995 – Test methods for solar collectors -- Part 3: Thermal performance of unglazed liquid heating collectors (sensible heat transfer only) including pressure drop
- ISO/TR 10217:1989 – Solar energy -- Water heating systems -- Guide to material selection with regard to internal corrosion

A more comprehensive list may be obtained from the SABS website https://www.sabs.co.za/Sectors-and-Services/Sectors/Solar/solar_ac.asp (SABS, 2017).

The qualifications and certification of solar thermal installers in South Africa is based on the National Qualifications Framework (NQF) by the South African Qualifications Authority (SAQA). There are two standards that are applicable to installers for certification:

- SANS 10106:2006 - The installation, maintenance, repair and replacement of domestic solar water heating systems
- SANS 10254:2004: The installation, maintenance, replacement and repair of fixed electric storage water heating systems (Global Solar Water Heating Market Transformation and Strengthening Initiative, 2012)

In addition to these standards, the SABS provides a range of standards that are relevant to the solar water heating industry which include standards concerning quality management systems, test methods for specific materials and parts, qualification tests for mechanical parts, testing of thermal performance. A list of these standards can be obtained from the SABS website https://www.sabs.co.za/Sectors-and-Services/Sectors/Solar/solar_sp.asp (SABS, 2017).

Conclusions on Solar Thermal for Industrial Applications in South Africa

- Different collector technologies exist for providing diverse temperature levels which can be used for many industrial processes. The complexity of installation and the integration increases with temperature demand.
- South Africa's solar industry has some existing experience with large scale projects, although most systems are small thermosyphon water heaters. Nevertheless, a number of companies have planned and designed 89 larger projects, mainly for hot water use for staff ablutions and some cooling plants, with the largest one covering 1220 m^2 collector area. Though most technologies have been flat plate collectors, a linear Fresnel has also been erected.
- Most companies in the sector work as EPC contractors have realized large solar systems with components procured both locally as well as abroad. South Africa has its own collector production facilities.
- The relative costs of the projects decline with the size of the collector area and have been between Euro 400 and 800 per m^2 in documented projects.
- International standards (ISO) apply for collectors but installers have to comply with local installation standards to certify for the installation of regular solar systems.

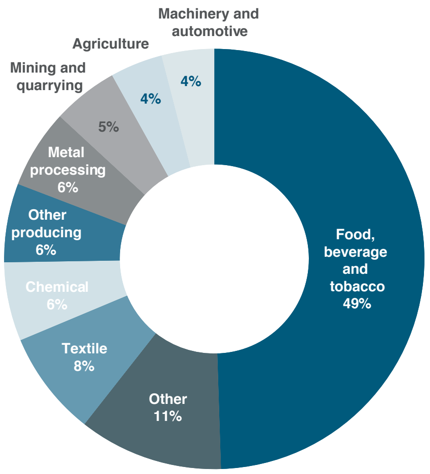
CHAPTER 3

INDUSTRY LANDSCAPE AT LOW AND MID TEMPERATURE LEVELS

3.1 Global Context of Industries Implementing SHIP

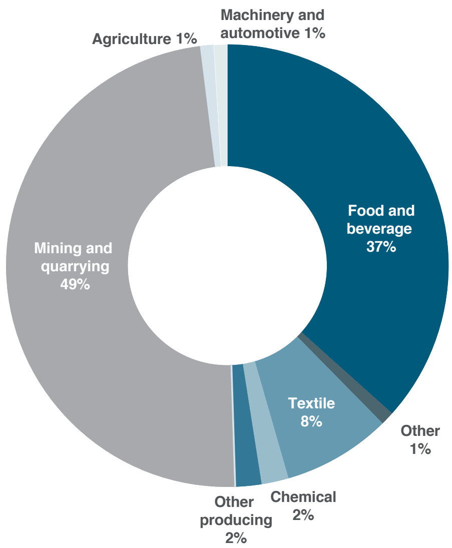
The global context of industries that have adopted Solar Heat for Industrial Processes (SHIP) technologies demonstrates target sectors that have favourable conditions (both technological and economic) for investment into SHIP technology. According to the SHIP database of the IEA Task 49, there are 271 large scale solar thermal plants documented, with a total installed collector power of 270 MW_{th} by March 2018 (Weiss & Spork-Dur, 2018). Figure 13 presents the breakdown of sectors that have implemented SHIP technology, both by number of plants and installed capacity in m^2. The results show that the food, beverage and tobacco sector have the highest number of plants and installed capacity. The average size of plants in the mining and quarrying and textiles sectors are the largest, with a smaller number of plants yielding a higher overall installed capacity.

FIGURE 13: Identification of target industries from IEA Task 49 database of global SHIP plants



a) Number of plants per IEA task 49 (2017)

Source 16: IEA Task 49 SHIP plant database (http://ship-plants.info/) as presented by (Weiss & Spork-Dur, 2018)



b) Installed collector power(MW_{th})

Source 17: IEA Task 49 SHIP plant database (http://ship-plants.info/)

The grade of heat source required by different industries is critical when analysing their suitability for SHIP integration. The previous chapter illustrated which solar collector technologies are best suited to different operating temperature ranges in the various industries considered for SHIP. A more detailed description of the temperature ranges required by different industries is shown in Figure 14. Industries such as iron and steel, non-ferrous metals and non-metallic minerals require the majority of heat at temperatures not suitable to economic SHIP integration. Therefore, these sectors are not further considered in this report.

Common industrial processes that have a high potential for solar thermal integration include sterilizing, pasteurising, drying, hydrolysing, distillation, evaporation, washing and cleaning and polymerisation (Environmental and Energy Study Institute, 2011). A breakdown of these processes for various manufacturing sub-sectors is provided in Appendix A. In this report, further analysis of the South African food and beverage, textiles chemicals and paper and pulp sectors is provided, as these sectors utilise a range of processes that are suited to solar thermal integration.

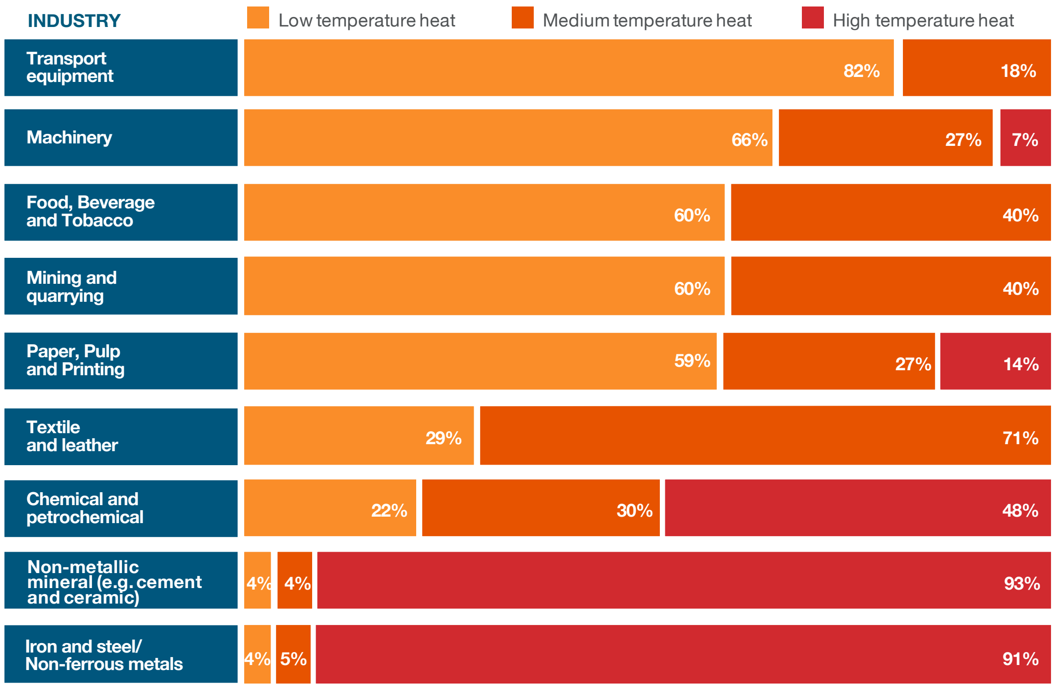


FIGURE 14: Typical breakdown of heat demand within different industries

Source 18: Saygin 2014

3.2 Local Industry Landscape in Target Industries

3.2.1 Analysis of Steam Usage in the Target Sectors

Steam is the dominant heat transfer medium in industrial applications that require heat at temperatures below 400°C. In many plants, although the steam is the primary heat transfer fluid form a centralised boiler system, the actual process temperature required is lower than 100°C. Currently no detailed statistics exist in South Africa with respect to industrial heat demand. Therefore, as part of the report a high-level analysis was conducted to determine the demand for steam within the target industries for SHIP with South Africa. Due to the extensive use of steam for low grade process heating, the identification of steam demand is the best indicator of potential for solar thermal applications.

Experts within the steam boiler field were consulted to get an indicative view of the installed heating capacity in the industrial sector. Conservative estimates of usage were then utilised to calculate the energy demand for steam (in PJ) within target SHIP sectors. Boilers across all sectors were conservatively assumed to operate at an annual capacity factor of 22%. This is based on a single 8h shift, 5 days a week, excluding public holidays (245 days per year). Should boilers in a specific industry operate with a higher capacity factor, then the energy consumption would be larger and breakdown of Figure 15 would shift. Large boilers would likely run at higher capacity factors. Therefore, these numbers should not be considered as absolute but rather indicative of the demand for steam in different industries. A further detailed study on heat demand in South African industries is still required.

This sectoral analysis does not include general industries where there remains significant steam demand that is spread across a range of different companies or laundries and government buildings such as hospitals, where steam is also extensively utilised. Large boilers exceeding 16 MW in the sugar, chemicals and paper and pulp industries are not included in this analysis. Thus, boilers used by large companies such as Sasol Limited (petrochemical), Sappi Limited (paper and pulp), Tongaat Hulett (sugar/agri-processing) are not included. The results show conclusively that for the sectors that were studied in this work steam consumption is dominant in the food and beverage sector with an estimated steam energy consumption of 17.3 PJ annually.

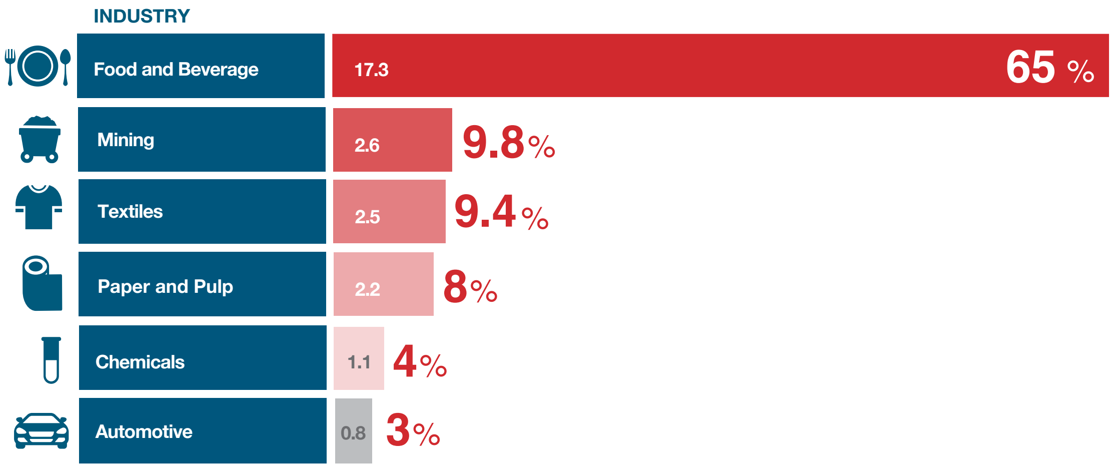


FIGURE 15: Breakdown of calculated steam demand (Total annual steam demand: 26. 5 PJ)

Source 19: Own Research 2017

3.2.2 Comparison of Steam Energy Demand with other Available Data Sources

It should be cautioned that the sectoral breakdown of installed boiler capacities changes over time as boilers are sold between companies. For example, boilers from the textile industry could have migrated into other industries due to a reduction in the industry size due to competition from imported goods. Furthermore, the analysis only considers steam demand, however, there are additional applications where low-grade heat is required that does not utilise steam as the heat transfer medium. Therefore, a consideration of the steam usage within industries is conservative of the overall thermal energy demand below 400°C.

The calculated steam demand in Figure 15 can be converted into input energy consumption by assuming a boiler conversion efficiency (estimated to be 75%). Thus the 26.5 PJ of steam demand equates to an input energy requirement of 35.3 PJ. Table 5 presents a comparison of the current data against Energy Balances available from the South African TIMES model (SATIM), a multi-sector energy-economic modelling framework from the Energy Research Centre (ERC) at the University of Cape Town (Energy Research Centre, 2014). A recent study by the WWF and the Centre for Renewable and Sustainable Energy Studies (CRSES) at Stellenbosch University estimated the potential for solar thermal in the agri-processing and textiles sector based on the energy balances from the SATIM model and the Department of Energy (WWF, 2017).

The estimates of energy usage differ between the current work and the SATIM model for a number of reasons. In the current work energy demand is estimated from installed boiler capacities, assuming a 22% capacity factor. Should a boiler operate at a higher capacity factor it would utilise more energy. Another area is that this work only considered smaller package boilers below 16 MW. Thus, very large boilers are excluded in the current analysis. These very large boilers are likely to be operated continuously throughout the year. The exclusion of large boilers provides a better indication of the potential heat demand that can be supplied by solar thermal. For example, the space required to replace a 30 MW boiler with solar thermal at an industrial plant could prove excessive. Finally, it should be noted that the SATIM model includes all energy consumed by the sector and not only boiler heat. This includes other forms of process heating as well as non-process heating applications.

TABLE 5: Comparison of estimated energy usage in sectors

Industry Sector	Current Research Fuel[1] [PJ]	SATIM (2006) Fuel excl. biomass [PJ]	SATIM (2006) Biomass [PJ]	SATIM (2006) Electricity [PJ]
Food and Beverage	23.1	33.8	10	15.0
Mining	3.5	84.4	0	117.6
Textiles	3.3	Not Given		
Chemicals	1.5	110.0	0	35.7
Paper and pulp	2.9	67.9	41.2	37.4
Transport Equipment	1.1	Not Given		

[1]Boiler energy source is assumed to be predominantly fuel, although some electrode boilers are in operation.

Source 20: SATIM 2006

The food and beverage sector has a diverse range of company sizes that are more likely to utilise smaller package boilers than the large chemicals/petrochemicals and paper/pulp companies. Therefore, there is better agreement between the estimated energy consumption values between the current work and that of the SATIM model. Significant amounts of energy in mining and the chemical industries are also utilised for non-process heating.

3.2.3 Energy Sources for Target Industries

As discussed in Section 5.4, the return on investments (ROI) associated with SHIP plants is dependent on the costs of the alternative heat sources. Therefore, it is vital to understand the landscape in terms of energy carriers used for process heating in different industries. Currently there is lack of detailed data on the use of different energy carriers within South African industries. There is also significant disagreement between the industry sub-sector Energy Balances (final energy consumption) between the DoE and other models such as the SATIM model.

As part of the Solar Payback project an initial bottom up study was conducted to analyse the fuels used for process heating in different industries. Three sets of independent data sources were consulted to give an indication of the fuels utilised:

Aggregated energy audit data from National Cleaner Production Centre (NCPC)
The NCPC is a national programme established by the government to increase industrial competitiveness through energy efficiency interventions. As part of the energy audit process the energy consumed by the boiler systems of plants is recorded along with the type of fuel utilised. Energy audit data was provided by the NCPC that included the boiler fuel type and annual boiler fuel consumption. Aggregated data for a total of 107 companies spanning 5 industry sectors was provided as presented in Figure 16 to maintain company confidentiality.

Registered combustion emissions sources from the City of Cape Town (CoCT)
The Air Quality Management (AQM) department at the City of Cape Town maintains a database of different industrial combustion sources. Energy consumption per fuel type was provided by the AQM department for a total of 306 companies. Again, aggregated information was provided to maintain company confidentiality.

Industrial market research data from the company Ozone Business Consulting (O3BC)
The company Ozone Business Consulting has conducted a number of industrial market surveys to understand energy usage within different industries. Information was provided on a total of 83 companies that had been studied as part of previous research conducted up until 2009. Therefore, it should be cautioned that the data could be out of date, however, it still yields insight into industrial energy usage. This data typically covered the large energy consumers within each sector.

Figure 16 shows that in the NCPC and O3BC databases coal consumption is dominant (data on bagasse/biomass was not available). The O3BC database includes several large companies including the sugar mills with only 39 companies accounting for 16.7 PJ of energy consumption. In contrast, the NCPC database includes a number of smaller companies with 44 companies accounting for 1.4 PJ of energy. **A general trend identified is that as the energy consumption per company decreases there is a decrease in coal usage and an increase in the use of other fuels such a paraffin, HFO and natural gas.** This is likely due to logistical issues regarding coal sourcing, storage and ash disposal. The CoCT database shows the highest usage of paraffin and HFO. This is possibly due to the higher number of smaller companies as well as higher coal costs and lack of natural gas.

In the textiles sector both the NCPC and CoCT databases identify an increased use of HFO in this sector, while the O3BC identified significant use of LPG as well as coal. Data on the chemicals sector did not show good agreement between the available sources. This is likely due to the diverse nature of different chemical companies that have significantly different processes. The NCPC data found the use of LPG in the automotive industry and coal dominant in the paper and pulp industry (biomass data not available).

The data available from the NCPC database also included the total electricity consumed for a number of companies. Figure 17 shows that for the companies identified had large heating demands, fuel consumption was significantly higher than electricity consumption on average. This should not be considered representative of the industry's overall electricity consumption as there are a number of companies that could use substantial amounts of electricity but were not identified as having boilers or utilising process heating. A comparison with figures provided by IRENA indicates reasonable agreement with global averages averages as displayed in Figure 18.

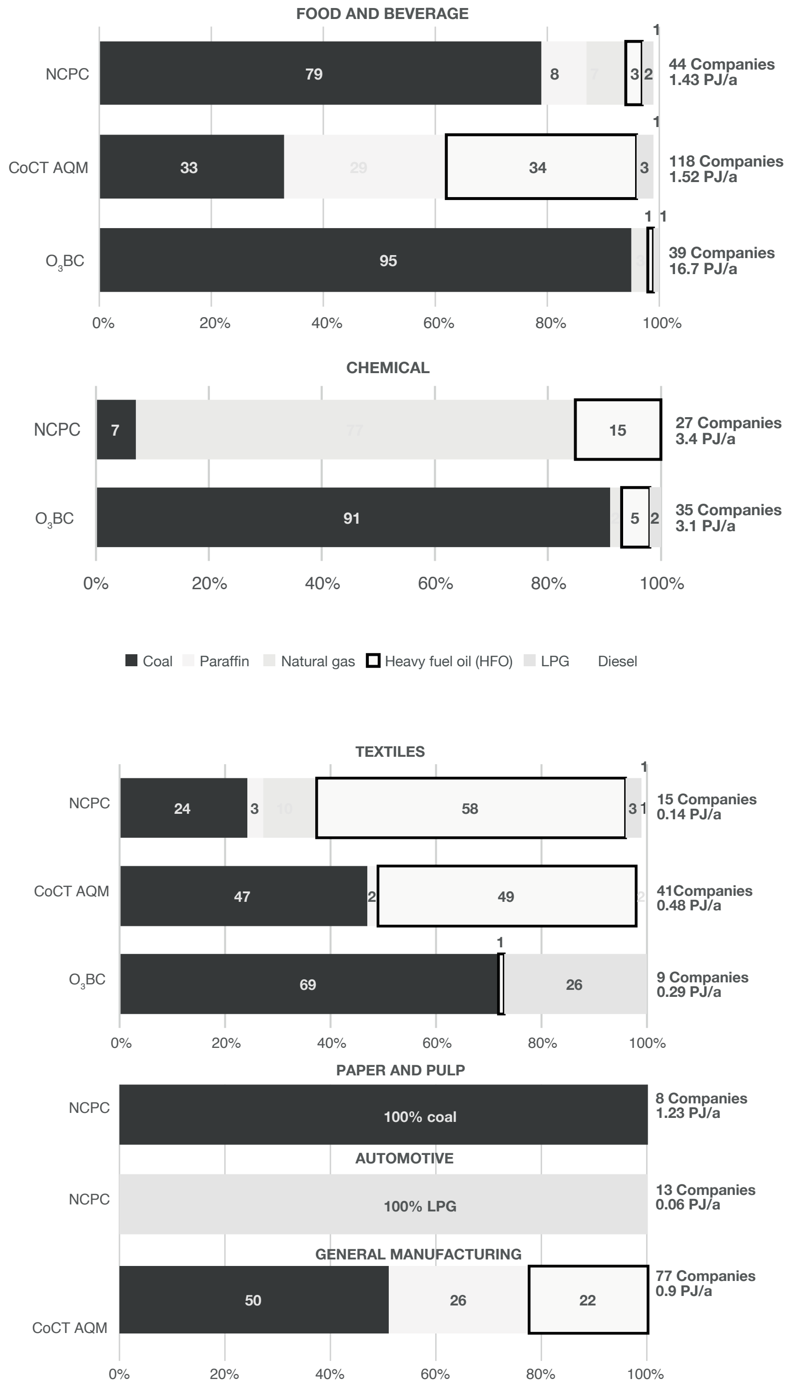


FIGURE 16: Breakdown of fuel consumption in target industries (number of companies and summed energy consumption given for each dataset)

Source 21: Sources: NCPC, CoCT AQM, O3BC

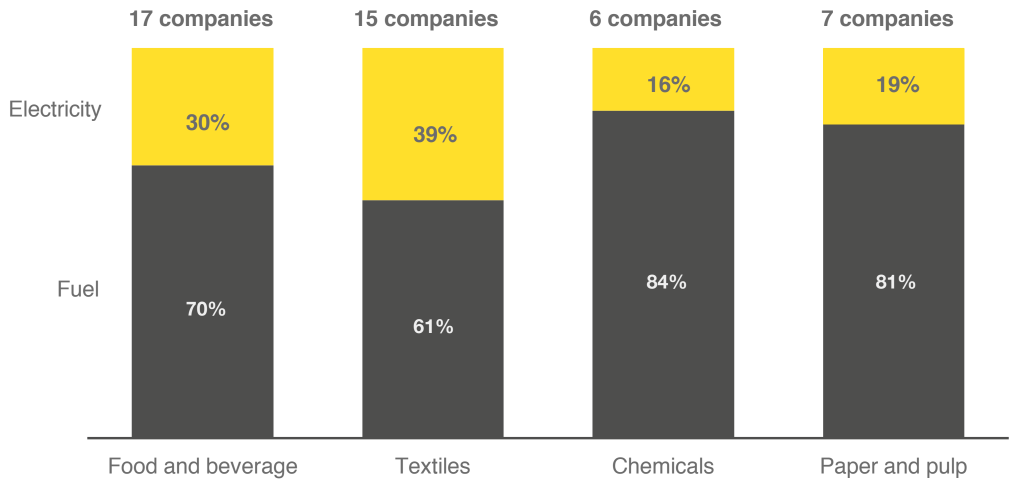


FIGURE 17: Comparison of fuel and electricity consumption in some companies from NCPC audit data

Source 22: from NCPC audit data

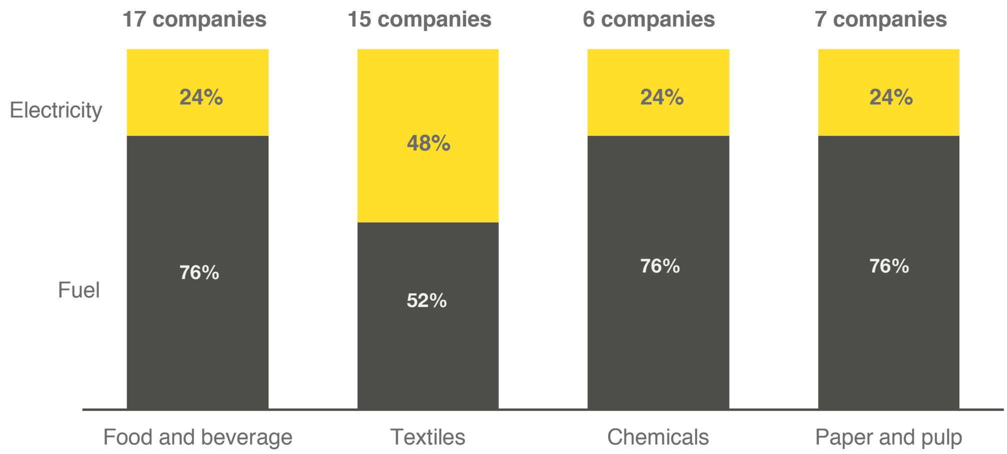


FIGURE 18: Comparison of fuel and electricity consumption in some companies

Source 23: Sagen, 2014

3.3 Target Industry Overviews

This section provides a description of the target industries, with a focus on economic output, industry structure and regional distribution. As shown in Figure 19, the three most important sub-sectors of the manufacturing sector in South Africa are the chemicals, metals, and food and beverages industries. Growth in specific manufacturing sectors is important, when considering potential industries for SHIP integration in South Africa. Food and beverage has been experiencing growth in real output over the past 15 years indicating a growing sector with improved potential for solar thermal. In contrast, real output from the textiles sector has remained flat due to increased competition from imports from Asia. The contribution to manufacturing of the Clothing, Textiles, Footwear, Leather (CTFL), and wood and paper products sectors are also significantly smaller than food and beverage, and chemicals sectors.

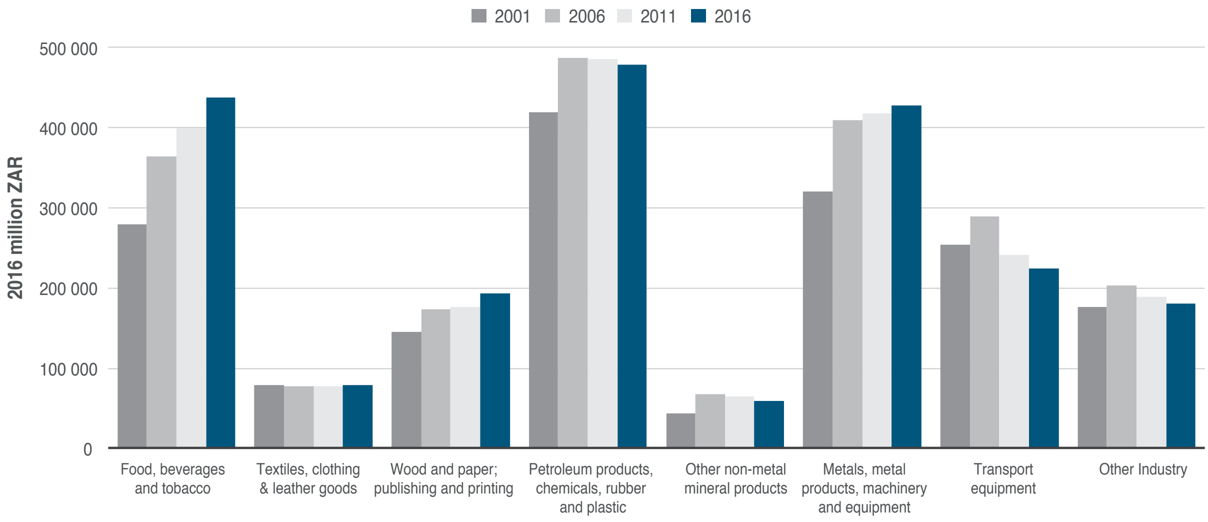


FIGURE 19: Real manufacturing output (2016 million ZAR) in South Africa

Source 24: EasyData, 2017

Regional distribution of income from the various industry sub-sectors provides a good indicator of the provinces which have a high number of active companies. Figure 20 shows that in general more than 70% of the output of the target industries is located in Gauteng, KZN and the Western Cape. Gauteng has a GHI greater than 2000 kWh/m^2/yr., but it also has the lowest competing energy costs in terms of coal and natural gas.

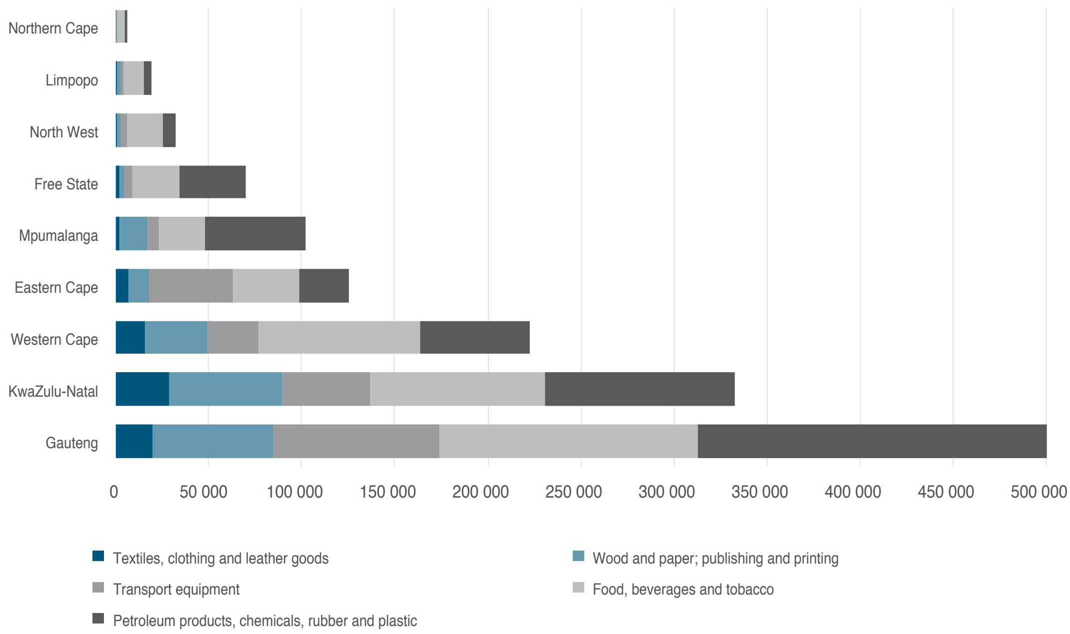


FIGURE 20: Regional breakdown of output for relevant SHIP industries (2016 million ZAR)

Source 25: EasyData, 2017

3.3.1 Food and Beverage

South Africa has a well-established food and beverage industry. The value chains in the food industry include protein (meat, poultry, and seafood), fruit and vegetables, dairy, grain, and confectionary. In general, the industry is highly concentrated with the top five firms accounting for 25.8% of total income in the sector and the top 20 companies accounting for 49.8% of the total income (Pretorius, et al., 2017). Many manufacturers in this sector operate state of the art production facilities. Typically, the sector is based in urban areas, although there are exceptions for some products like fruit juices.

According to the Statistical Business Register there are a total of 8980 companies registered under SIC 30: Food and Beverage and Tobacco (StatsSA, 2017). This database includes a number of micro companies that do not have significant manufacturing capacity. In South Africa once a company's wage bill exceeds 500k ZAR per annum it is required to pay a skills development levy to a Sector Education and Training Authority (SETA). Thus, the data provided by SETA's in each sector provides a better indication of the number of sizable companies that are active in the sector. SETA defines company sizes by the number of employees where micro (<10), small (<49), medium (49-149) and large (>149).

Table 6 shows that there is a total of 1892 companies paying skills development levies to the FoodBev SETA, with the majority of companies with less than 49 employees in size. A detailed breakdown of the data in Table 6 is presented in Appendix B. A list of companies in the O_3BC database is provided in Appendix C.

TABLE 6: Food and Beverage companies with wage bill exceeding R500k pa

Sub-sector	Small	Med	Large	Tot
Baking, cereals, confectionery and snacks	221	51	42	314
Beverage manufacturing	173	31	32	236
Dairy manufacturing	167	25	26	218
Manufacture of food preparation products	434	78	43	555
Processed fish, meat, fruit and vegetables	419	98	52	569
Total	**1414**	**283**	**195**	**1892**

Source 26: FoodBev SETA, 2011

3.3.2 Clothing, Textiles, Leather and Footwear

The value chain in the textile and clothing industry consists of number of processes from sourcing raw materials, yarn spinning, fabric weaving, dyeing, apparel sewing, trimming, labelling, packaging and delivery (Chaddha, Dhanani, Murotani, Ndiaye, & Kamukama, 2009). Despite increasing local demand, the local textile industry has been in decline over the past decade due to Asian imports. This has resulted in the closure of a number of factories.

In an effort to stabilise the industry the South African government has introduced the Clothing and Textile Competitiveness Programme (CTCP). Under the CTCP, clusters have been established, which are located in the Western Cape, KZN and Gauteng. The numbers of companies registered with the Fibre Processing and Materials SETA is shown in Table 7. Despite the current state of the sector there remain opportunities for SHIP integration with government subsidies to improve industrial competitiveness. According to WWF (2017), the textile company ACA Threads has already utilised the CTCP Upgrade Grant to help finance the installation of a SHIP system.

TABLE 7: CTFL companies with a wage bill exceeding R500k pa

Sector	Companies
Clothing	590
Textiles	199
Footwear	95
Leather	80
Total	**874**

Source 27: (FP&M SETA, 2015)

3.3.3 Chemicals

The South African chemical and petrochemical industry is the largest in Africa. The sector is diversified, consisting of 11 subsectors, producing a range of products, including liquid fuels, plastics, fertilizers, explosives, agrochemicals and pharmaceuticals (CHIETA SETA, 2016). As shown in Figure 19, the chemicals sector is a significant component of the South African economy.

Table 8 shows that there are a number of companies active in sectors that have opportunities for SHIP integration such as plastics, pharmaceuticals and fast-moving consumer goods. These industries do not need high to very high temperature processes, which are often needed in the industry and which produce abundant excess heat for lower temperature processes. The companies within the chemicals sector are primarily located within urban areas, with 45% of companies located in Gauteng (CHIETA SETA, 2016).

TABLE 8: Chemicals companies with a wage bill exceeding R500k p.a.

Sub-Sector	Companies
Base Chemicals	683
Speciality Chemicals	342
Fast Moving Consumer Goods	221
Petroleum	181
Glass	181
Pharmaceuticals	161
Surface Coatings	121
Fertilizers	80
Other	20
Explosives	9
Total	**2010**

Source 28: (CHIETA SETA, 2016)

3.3.4 Paper and Pulp

South Africa has 9 pulp mills which are owned and operated by the companies SAPPI and MONDI, who are the only producers of virgin pulp. The paper industry in the country is more diversified than the pulp market with more players and products, although it remains dominated by Sappi Limited and Mondi (Genesis Analytics, 2005). Other market players include Nampak, Kimberly-Clark and Gayatri, as well as smaller mills that utilise recycled paper as the input.

The four main categories of paper products are printing and writing, newsprint, packaging and tissue paper. According to FP&M SETA there are 100 companies in Paper and Pulp paying levies (FP&M SETA, 2015). A breakdown of the paper, pulp, chemical cellulose and tissue mills in South Africa is presented in Table 9. The mills in this sector are concentrated in KZN and Gauteng, with the mills in Gauteng relying on recycled paper.

TABLE 9: Paper, pulp, chemical cellulose and tissue mills in South Africa

Product	Mills
Paper	5
Paper board	3
Kraft	4
Newsprint	1
Pulp	2
Chemical Cellulose	2
Packaging Paper	3
Packaging Board	5
Linear Board	1
Tissue	18

Source 29: PAMSA (http://www.thepaperstory.co.za/)

3.3.5 Automotive

The automotive industry also plays an important role in the South African economy. This sector includes vehicle retail, distribution, servicing, as well as automotive parts manufacturing and vehicle manufacturing. Currently, 7 large multinational vehicle Original Equipment Manufacturers (OEMs) operate in the country, including BMW, Toyota, Mercedes Benz, Nissan, Volkswagen, Ford, and General Motors (announced will be exiting). According to merSETA (2013) there are also a number of smaller specialist medium and heavy commercial manufacturers and 400 automotive component suppliers. The Automotive Chamber of merSETA includes 256 levy paying members, of which 44% are located in Gauteng (merSETA, 2013).

3.4 Companies that Expressed Interest in Solar Payback

In the course of the Solar Payback Project, an online survey was submitted to a number of manufacturing companies. Figure 21 provides a summary of the sectors of companies that indicated an interest in the project, as well as the energy carriers that are currently used for process heating. The results show that the most responses were received from food and beverage as well as chemical companies. It is interesting to note that electricity is the dominant energy carrier that is currently used by companies indicating an interest in Solar Payback. This is likely caused by companies that are concerned about rising electricity prices and are looking for alternative lower cost heating options.

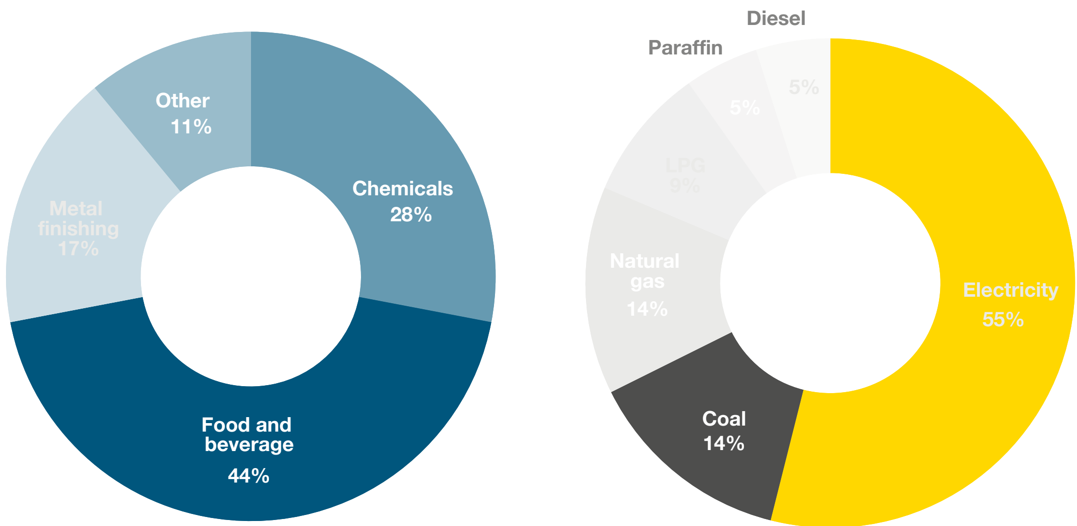


FIGURE 21: Breakdown of Responses to Solar Payback survey
a) Companies that responded to project (19 total) b) energy sources currently used for heating

3.5 The Potential of Low and Medium Temperature Applications

The data collected clearly highlights the potential of the food and beverage industry as having the highest potential for SHIP projects in South Africa. The steam demand analysis shows that approximately two thirds of the steam demand in the selected sectors is utilised in the food and beverage sector, a total of 17.3 PJ of steam, requiring 23.1 PJ input fuel energy (assuming a 75% boiler efficiency). International studies show that 55% of the heat demand in this industry is typically below 100°C, while the remaining 45% is below 400°C. Furthermore, the industry has been experiencing the largest economic growth of all the manufacturing sectors in South Africa over the past 15 years. An analysis of the industry structure shows that there are a number of companies active in the dairy, protein products, fruit and vegetables processing and beverages sectors. All of these sectors have a number of international case studies available where solar thermal has been successfully integrated to provide process heat.

A significant obstacle to the adoption of SHIP in the South African food and beverage sector is the extensive use of low-cost coal as a boiler fuel. The analysis presented in this chapter has shown that very large companies are more likely to use coal fired boilers, while smaller operations, especially in the Western Cape, with annual energy consumption in the range of 4 GWh/a are more likely to utilise alternative boiler fuels such as HFO and paraffin, due to logistics related to coal.

There remain opportunities for SHIP integration in the textiles sector with an estimated steam demand of 2.5 PJ. Although this number is subject to uncertainty due to the number of textile companies that have closed in recent years leading to a migration of boilers into other industries. Current companies in the CTFL sector have the potential to utilise government support grants and incentives to access financial support for using SHIP plants to increase industrial competitiveness. The smaller companies active in the textile sector are also more likely to utilise HFO and paraffin instead of coal.

The diverse nature of the chemicals sector in South Africa presents a challenge to developing general conclusions on the potential of SHIP for the industry. According to the steam analysis 1.1 PJ of steam is used in this sector (excluding boilers greater than 16 MW), however, this does not take into account direct process heating as well as electrical process heating, which are utilised in this sector. There are a number of companies operating in sectors like plastics and rubber products as well as pharmaceuticals where there are good opportunities for SHIP integration.

The steam demand in the Paper and Pulp sector is estimated at 2.2 PJ (excluding boilers greater than 16 MW, which are used in the large Pulp mills). Although opportunities for SHIP integration exist in this sector, there is currently only one plant in operation globally in this sector. Data from 8 companies active in this sector showed that coal was extensively used. Another disadvantage of this sector is the relatively small number of companies, with only 100 companies registered with Fibre Processing and Manufacturing (FP&M) SETA.

Automotive manufacturing plays an important role in the South African economy. An estimated 0.8 PJ of steam is utilised by companies in this sector. Energy audit data highlighted that this sector makes extensive use of LPG for process heating applications such as painting. This presents a good potential for SHIP applications, as LPG is the most expensive energy carrier in South Africa. In fact, the BMW plant Rosslyn Pretoria has already demonstrated the use of solar thermal for integration in painting. Up to 67% of the heat demand in this sector is below 100°C.

Conclusions for the Usage of SHIP in South African Target Industries

- More than 270 documented projects worldwide demonstrate that solar heat is a feasible technology for producing heat for industry applications of up to 400°C in regions with abundant sunshine.
- Most international SHIP projects are in the food, beverage and agricultural sector, a considerable share of large and very large projects have also been realised in the mining and quarrying as well as in the textile sector.
- The use of low cost of coal fired boilers, especially by larger companies is a challenge, potential exists with smaller companies which use alternative fuels paraffin, HFO with higher heating costs.
- Steam is the dominant heat transfer medium for industrial processes, even for processes with lower temperature heating demand than 100°C. According to own research, about two thirds of the steam demand is in the food and beverage industry.
- In South Africa the food and beverage industry has the highest potential for the use of SHIP projects with an estimated 17.3 PJ of energy demand in low energy demand. The industry structure is also composed of smaller units, more likely to be appropriate for solar thermal installations.
- According to available data, coal is the dominant energy source for larger companies, while smaller ones use other, more expensive sources such as oil, paraffin, natural gas, HFO, LPG.
- The automotive, textile, food and agriculture as well as the chemical sector use dominantly or partially non-coal energy sources to generate heat.
- International studies estimate that 55% of the demand in the food sector is below 100°C and the remaining 45% below 400°C, especially dairy, protein products, fruit and vegetables and beverages sectors have international shown international showcases.
- Food and beverage industries have grown in South Africa over the last 15 years, while other relevant industries have stagnated.

CHAPTER 4

PROJECT DEVELOPMENT PROCESS FOR SHIP PLANTS

4.1 Description of the Design and Planning of SHIP Plants

The design of a SHIP plant is a process that goes from a preliminary analysis to estimating the feasibility of the project and ends with the commissioning of the system. The key steps of the design and planning of a SHIP plant are listed below (*source in bibliography IEA/SHC Task 49 "Solar Heat Integration in Industrial Processes"*).

Preliminary analysis to identify the potential for a SHIP application based on basic information on the end-user's energy consumption, location and heat requirements. This analysis should already draw the existence of potential for a SHIP application (there are heat requirements, energy costs are such that the investment could likely be viable).

Detailed analysis of heat supply and heat consuming processes, as well as information on site conditions such as available space on the ground or on the facilities' roof, access to the general infrastructure e.g. water or electricity networks, vicinity to the integration point or to operation and maintenance activities, etc.

System yield simulation and economic modelling. Based on the simulation results, economics of solar systems can be calculated according to full costs of the investment and prices of the conventional fuels.

Technical and economic viability study that identifies the design and integration options of the solar system, and defines the technical and economic conditions for the investment to be viable.

System engineering and the definition of technical requirements to be considered in the tendering and commissioning stages.

Tendering and commissioning. For these three aspects the following should be guaranteed:

- an objective comparison between different supply offers;
- the suitability of the equipment and services to be supplied; and
- the quality of the installation and functionality of the system according to the planned operation.

Operation and maintenance procedures to be carried out either by an external service provider or internally by the servicing unit for the facilities.

Key aspects of the design and planning process of a SHIP plant are a comprehensive analysis of the current heat supply system, the calculation of the effective heat demand, and the solar integration, which are further explained below.

Current heat supply system

Heat supply and distribution are usually based on steam boilers. Otherwise, it can be based on other heat transfer fluids such as hot water, thermal oil or air. It could also rely on combined heat and power systems or heat pumps.

Steam boilers are the most common heat supply system in industry. They feed the different processes directly or indirectly through heat exchangers with steam. Steam-driven systems are often used even when processes occur at low temperature levels (T<100°C). They have a higher complexity due to make-up water treatment, condensate recovery, degasification (see Figure 23), and operation requirements. Steam-driven systems have a high energy density that enables smaller diameters and lower heat losses in the heat distribution network and high heat transfer rates driven by condensation that results in heat delivery at constant temperature.

(Pressurized) hot water is suitable for low temperature levels (T < 100°C - 120°C). It relies on less demanding hot water boilers but requires higher piping diameters and potentially presents higher heat losses in view of higher mass flows and lower energy density.

Thermal oil is suitable for temperature levels up to 350°C. It relies on thermal oil boilers and presents as advantages a higher operating temperature than that normally used in steam driven systems and lower pressures. The drawbacks relate to the higher cost of the heat transfer media and to the lower heat capacity compared to water, thus requiring higher mass flows, larger piping diameters and higher heat losses. Thermal oil driven systems also present specific hydraulic circuit requirements, related to safety (e.g. prevention of leakage, inflammation/explosion, toxicity) and operation (e.g. gas protection preventing thermal oil oxidation, pre-drying of hydraulic loop before filling).

Air has the lowest heat capacity compared to water or thermal oil. Air-driven systems are used only in direct supply to specific processes – drying or thermal curing chambers. Heat supply relies on hot air burners rather than on boilers.

Combined Heat and Power (CHP) or cogeneration systems with simultaneous production of electricity and heat.

Heat Pumps can upgrade low temperature waste heat to higher, process suitable temperatures by means of vapour compression (electricity driven) or absorption (thermally driven) cycles. Electrical resistances may also be used, however, normally in smaller systems.

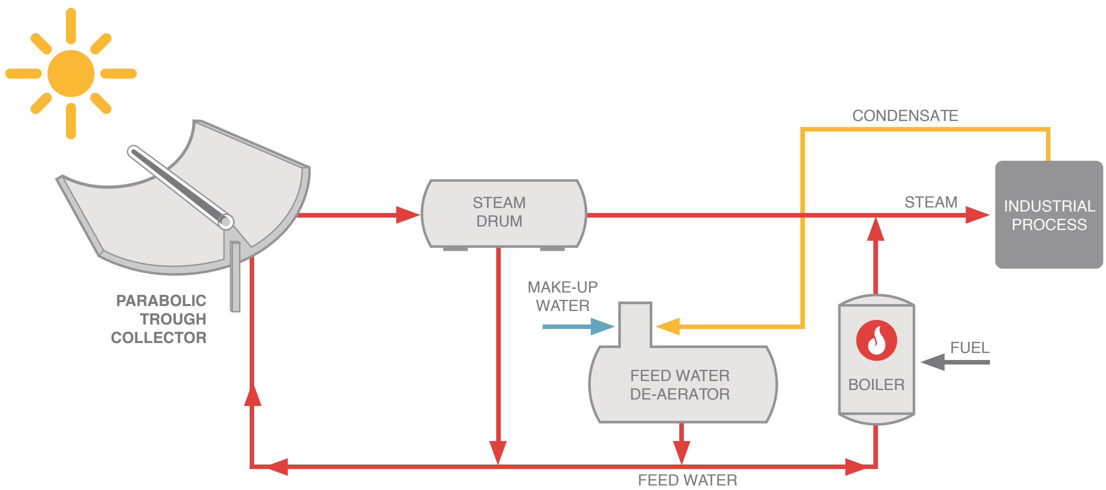


FIGURE 22: Scheme of a solar heat integration to generate steam

Source 31: IEA TASK 49

In direct solar steam generation, the water is partly evaporated in the concentrating collector and then separated from the remaining water in the steam drum. In indirect solar steam generation, the collector field heats water or thermal oil in a closed circuit to generate steam via a heat exchanger.

Regarding **energy sources**, heat supply systems might rely on the use of gaseous, liquid or solid fuels, besides electricity. The difference in start times required by gaseous/liquid fuel or solid fuel driven boilers must be mentioned, with the latter requiring longer periods and thus impacting the duration of stand-by periods. A summary of common heat conversion technologies, heat transfer fluids and energy sources is presented in Table 10.

TABLE 10: Heat conversion technologies

Conversion Technology	Fuel	Heat Transfer Fluid
Boiler	Gas, LPG, oil, coal, biomass, biogas	Steam, hot water, thermal oil
Cogeneration systems	Gas, LPG, oil, coal, biomass, biogas	Steam, hot water, thermal oil
Burner	Gas, LPG, oil, coal, biomass, biogas	Hot air
Heat Pump	Electricity	Hot water, hot air, thermal oil

Source 32: Ben-Hassine, 2015

Effective heat demand

An updated view of the energy efficiency potential and an estimation of the effective heating demand after possible adoption of energy efficiency measures, including load profiles and heat supply temperatures is the cornerstone of any optimized solar system design.

The dimensioning of the solar thermal system should be based on effective heat requirements, i.e. considering first waste heat recovery potentials both at heat supply and process levels. Often it is possible to identify heat recovery possibilities in most of the industrial sites, either through equipment inefficiencies (e.g. surface thermal losses, steam leakage) or through the identification of waste streams carrying heat which can be used directly in the process or in neighbour processes (e.g. exhaust gases, cleaning in place, naturally cooled material streams).

Solar integration

Once effective heating requirements have been analysed, it is possible to identify both the required demands and the temperature at which they occur. The latter is a paramount design parameter, as it influences heavily the suitable solar thermal technologies to consider (see Figure 11).

The integration of solar heat might occur at two different levels:

- **Supply level:** solar heat is integrated directly or indirectly at some point of the heat supply circuit. Integration might occur after a pre-heating approach, before the boiler (pre-heating make-up water, condensate of feed-water), or after a direct or indirect steam generation concept, with integration at the steam line. A supply level approach usually stands for higher integration temperatures. Integration at supply level presents the potential for higher solar fractions, yet at expense of higher operating temperatures and lower efficiency on the solar field side, potentially calling for the use of tracking solar collectors.

- **Process level:** solar heat is integrated in the process, either directly or indirectly via heat exchangers. Heat is supplied at process temperature, often lower than conventional heat supply temperature. Whereas process level integration presents the potential for lower operating temperatures at the solar field, it faces resistance by the end-users, often reluctant on direct interactions with their processes. Integration at process level requires deep knowledge on process temperature and load profile.

TABLE 11: Comparing process and supply level integration methods

Criteria	Process level	Supply level
Accuracy of process data (date needed for system design)	High	Medium
Flexibility (in case of process changes)	Low	High
Collector efficiency (efficiency decreases with temperature)	High (for lower temp. processes)	Low (except for heating of booiler makeup-water)
Solar share (solar yield/total heat demand)	Low (restricted to supplied processes)	High
Required storage size (storage increases investment costs)	Large	Small

Source 33: (Haagen, 2017)

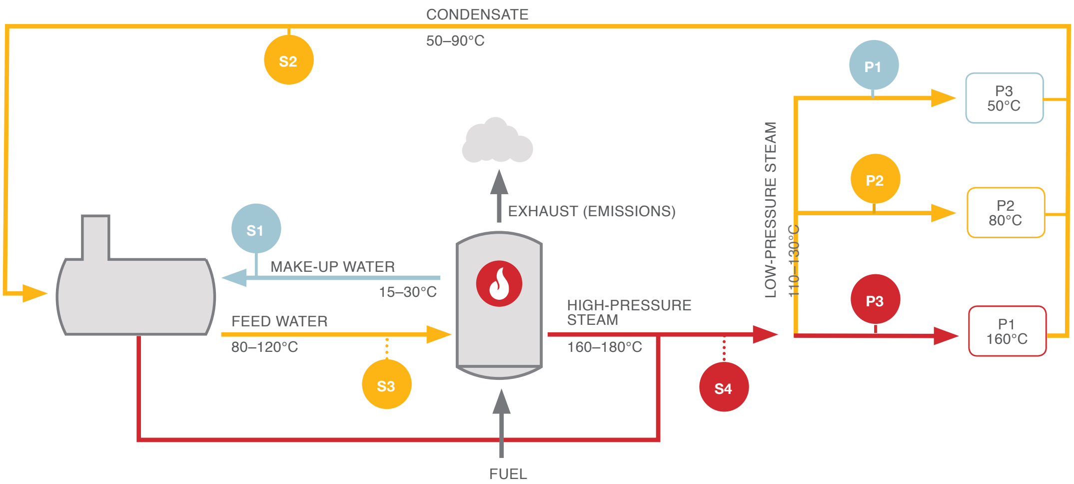


FIGURE 23: Possible solar integration points on a conventional heat supply system*

Source 34: Fraunhofer ISE

*S1, S2, S3 mark three possible integration points to different processes: P1 presenting a process temperature TP=160°C, P2 with TP =80°C and P3 with TP =50°C.

4.2 Structure of a SHIP Project in South Africa

In order to realise a SHIP project, the heat demand of an industrial user has to be covered by the appropriate solar technology. The system has to be planned and constructed when financing is secured and maintained during the time of operation.

Heat consumers have the task of understanding the characteristics of their energy demand and, in doing so, are also able to select the most efficient mix of energy carriers to cover their demand. Consumers have multiple options for energy supply including electricity, coal, natural gas, solar heat, biomass and others. Consumers are also important in terms of dissemination or adoption of new efficient technologies including those providing solar-based (low to mid-temperature range) heat. In addition to implementing technologies and understanding the demand profile, the heat consumer (as the party best-positioned to understand their operations) also leads efforts to develop the business cases for the use of alternative energy supply options such as solar heating.

Engineering, Procurement and Construction (EPC) specialists have the potential to play multiple roles. The first of these is in building the proposed technology intervention for any heat consumer while also providing the capabilities, track record, and performance guarantees that attract sufficient funding to support implementation of solar heat interventions. Although EPC contractors providing equity is more commonly seen in renewable energy power generation projects, equity can also be an offering from EPC service providers in solar heat or energy efficiency projects where revenue saving benefits are shared between EPC contractors and the heat consumers.

Commercial banks offer, or are conduits for, special loans to fund energy efficiency and other similar initiatives; this would cover equipment upgrades and other elements for a business to be more energy efficient and green-focused. In many cases funds for these products come from government agencies or international development agencies. Although the service and financing terms may differ from one bank to the next, the majority of large lenders in South Africa have a facility for "greening" existing industrial operations. Products offered may include: credit lines/facilities from development agencies, advisory services, investment rebates, loans (project and asset finance), and unsecured lending. Ultimately, such lenders also set terms for servicing the finance provided for interventions such as solar heating installation. The debt service is achieved using positive cash flows generated from increased profitability due to implementing the solar heating project.

Equity providers are often required in instances where proposed technologies do not have sufficient operational track records to attract favourable financing terms from mainstream lenders. For this reason, equity providers are often critical for the introduction of newer technologies. For this role in backing new and pioneering technologies, equity providers often offer financing that is typically more expensive (i.e. requires higher returns) than what may be sourced through concessional loans from development agencies.

Operations and Maintenance (O&M) service providers are critical for ensuring that any solar heat innovations, installations, and interventions perform to the expected level. Without the satisfactory performance of the installed solar heating equipment, it is not possible to service the financing instruments used to support any proposed industrial solar heating project. O&M service providers also fulfil the important role of transferring skills such that the heat consumer (i.e. client and entity taking up the technology) is self-reliant in operating and maintaining the equipment as so to ensure the performance of the solar heating installations.

Energy Service Companies (ESCOs) can be considered as one-stop-shop providers of energy supply and saving solutions, including design, financing, technology procurement, implementation and O&M.

For the implementation of an energy solution, clients normally agree on a longer-term contract with an ESCO. The ESCO realises the energy solution, i.e. solar heat installation, and carries the financing, design and construction, as well as performance risk. Thus, the client does not need to assume debt for new form of energy supply, freeing up capital to invest in other areas of core business. The typical contractual arrangements in the ESCO model are either shared savings or guaranteed energy savings contracts. Under a shared savings contract, the client and ESCO share the cost savings, realised by the project, based on some predetermined percentage for the duration of the contract. Once the contract ends, the client retains any further savings afterwards. In a performance-based, guaranteed energy savings contract, the ESCO guarantees a certain level of energy savings to the clients and receives a fee if the guarantee is met.

Government departments provide oversight on the development of the energy sector promoting objectives that industrial solar heating can contribute towards, such as lower greenhouse gas emissions, higher energy efficiency, and local manufacture of new technologies. The proposed Energy Efficiency standards and regulations from the Department of Energy provide good examples of how authorities can assist in shaping or accelerating deployment of solar heating technologies. Regulations under consideration include mandatory reporting of energy use and management by companies consuming energy above prescribed thresholds. Moreover, the long-term goal of such regulations envisages mandatory submission of Energy Management plans by the companies affected. Details of how industrial solar heating is used may be included in such Energy Management Plans.

4.3 Project Operation and Maintenance

Daily operation of a solar thermal system used for water heating requires little input from the user for daily operations. The system is usually installed with electronic control systems which regulate daily operation. These systems monitor temperature and system pressure and they regulate the operation of pumps. Maintenance activities on solar thermal systems are separated into daily, weekly, monthly and yearly regimes. On a daily basis, a simple check is required of the pressure, pumps, and electronics to ensure that operation is within the designed levels. Piping should also be checked daily to ensure that there are no leaks. On a weekly basis, the solar array and piping insulation cladding is to be checked for damage or accumulation of dirt. Cleaning of the solar array is to be carried out on a monthly basis and the chemical properties of the heat transfer fluid, if any, should be checked at least once each year and corrected if required (Kempf, July, 2017).

Table 12, adapted from (Aidonis, et al.), provides further details on maintenance requirements:

TABLE 12: Maintenance procedure for SHIP plants

Maintenance or periodic inspection	Frequency
Condition of collector array	Once a year
Transfer fluid testing	Twice a year (before summer and before winter)
Pressure of the primary circuit should be constant	Twice a year or more often if easy
Difference in Temperature created by the collectors (during sunny hours) should be near the design value (e.g. about 20°C)	Twice a year
Collector temperature should be almost equal to the collector array outlet	Twice a year
Primary circuit pump is off when there is no sun	Twice a year
Presence of air in the primary circuit (noise)	Once a year
Collector glass should not become dirty	Once a year
Energy meter in “good operating conditions” should show more than about 3 kWh /m^2 in one day	Twice a year or more often is easy

Source 35: Aidonis, et al.

Conclusions for the Planning Process of SHIP Plants

- Standardised processes for planning, structuring as well as running SHIP projects exist internationally and could be applied on South African industrial companies.
- The development of a SHIP plant requires a thorough analysis of the existing processes, required temperature levels as well as the economic potentials for energy efficiency and waste heat recovery.
- Integration points for SHIP can be at supply level, which provides an additional source of heat, usually steam or hot water, for running industrial processes. At process level integration of SHIP offers a very accurate provision of heat directly into already existing processes.
- The stakeholders that have to be involved are the Project Owner, the EPC and O&M contractor, the technology providers as well as the financing bodies.

CHAPTER 5

ECONOMIC PROFITABILITY OF SHIP SYSTEMS

Within the Solar Payback project, a Calculation Tool for simple pre-assessment of the technical and financial viability of SHIP systems has been developed. The goal is to facilitate decision makers in industrial companies to make a quick financial analysis of a SHIP plant for their processes. The tool gives information on solar irradiation and solar yield and can be used before local measurements or simulations.

The tool offers a comprehensive range of technical input parameters that enable the user with a preliminary evaluation once a site, conditions of operations, quantity and type of conventional fuel as well as the project life time has been selected.

Principal financial indicators of the tool include the **static and dynamic Pay Back Time, Internal Rate of Return (IRR)** and the **Net Present Value (NPV)** as well as the Levelized **Costs of Heat (LCOH)**. The results are presented in a list of input parameters as well as in form of graphs. The tool will be accessible on the website www.solar-payback.com.

The **Return on Investment (ROI)** is a performance measure to assess the effectiveness of an investment. A project should be considered for investment, if the ROI is higher than another available investment opportunity. The South Africa 15 Year Government Bond's yield rate of 9.3% could be used as benchmark.

In the context of the study, the tool was used to calculate some individual SHIP plant for fictional cases that might be suitable for South Africa. Section 5.1 explains the methodology and the applied parameters while section 5.2 presents results for the cases given.

5.1 Methodological Considerations

In order to make an appropriate selection of cases, some considerations have to be made for the selection of case studies to be used for the calculations in section 5.2. The upfront investment costs have a high impact on the economic feasibility of a SHIP project since interest rates are high in South Africa. Therefore, locally produced components like collectors and tanks should be used, also to avoid the taxes on imported goods. Flat plate collectors as well as vacuum tube collectors are the dominating solar collector types in South Africa for the larger solar thermal systems, though at least one solar thermal cooling system has been installed with concentration technology (see Chapter 2.3).

Operating temperatures are between 30 and 90°C for flat plate technologies as well as up to 140°C for vacuum tube collectors. As described in Chapter 2.2, many industrial production processes can be covered with these temperatures, such as: washing and bleaching in the textile industry, re-tanning in leather factories, pasteurising milk in dairies or cleaning surfaces in machinery production (see Figure 11). For this reason, case studies with flat plate collectors and operating temperatures of 75°C are used in Chapter 5.2 for analysing the impact of different framework conditions on the profitability of SHIP plants for the sample calculations. Steam is also an important heat carrier source but would require concentrating technologies to produce it in large quantities. This section serves to explain the usability and understanding of the tool developed in the project.

A limiting factor of many SHIP plants is the available space on the factory site for mounting the collector field. Since South African companies in the SHIP relevant sectors - food and beverage are usually small and medium sized and might be a good option as sample cases for future market exploration (see Table 7). In addition, they often use non-coal-based fuels, which will increase the competitiveness of solar thermal solutions. The active area of the collector field is set at 500 m^2 in the case study calculations. Such a flat plate collector field can be mounted on an area of 900 m^2 to avoid shading between the rows. Some projects of 100 to 1200 m^2 have been installed mostly for non-industrial purposes, thus it seems a good size to be realizable in South Africa by local engineering companies.

In the fictional case the total heat demand in the factory was set at 800 MWh_{th} annually, so that the 500 m^2 collector field reaches at least 50% solar fraction. This is, however, a rather arbitrary value, and other solar fractions are certainly also possible.

At this point, a short introduction into the methodology used in the tool shall be given. The German Fraunhofer Institute for Solar Energy (Fraunhofer ISE), one of the Solar Payback partners, has calculated the annual solar yield reached with SHIP plants for various South African cases, differing in the following parameters:

- 5 irradiation sites: Bloemfontein (2.2 MWh/m^2a), Cape Town (2.0 MWh/m^2a), Johannesburg (2.0 MWh/m^2a), Port Elizabeth (2.0 MWh/m^2a) and Durban (1.7 MWh/m^2a)[1]
- 4 collector technologies: flat plate, evacuated tube, parabolic trough, Linear Fresnel
- 5 average collector operation temperatures: 50, 75, 100, 150 or 200°C
- 3 daily production operation modes in the factory: daytime, night time, continuous.
- 2 weekly production operation modes in the factory: 5 days/week and 7 days per week
- 2 annual production operation modes in the factory: continuous or 1-month stoppage (e.g. for maintenance or holidays etc.).
- Efficiency of the conventional system varies between very low, which means 50% thermal conversion of energy, via 60% (low), 70% (moderate), 80% (high), 90% (very high) to 100% (no losses).

The user of the tool can carry out economic and financial pre-assessments based on these default yield values without running a technical simulation of the planned SHIP system. All the several thousand solar yields were calculated with a solar fraction of 50 % to make them comparable with one another. For this reason, the economic feasibility calculations in Chapter 5.2 assume a solar fraction of 50% as well.

1 The tool considers the different technology types, e.g. concentration technologies like parabolic trough collectors use direct irradiation, while non-concentration collectors like flat plate collectors can also benefit from diffuse irradiation. Depending on the site chosen, the collector yield can vary significantly. E.g. for concentration technologies it would be Bloemfontein (2.6 MWh/m^2a), Cape Town (2.3 MWh/m^2a), Johannesburg (2.2 MWh/m^2a), Port Elizabeth (2.0 MWh/m^2a) and Durban (1.5 MWh/m^2a).

TABLE 13: Description of the case study parameters	
Used collector type	Flat plate
Average operation temperature[16]	75 °C
Supplied processes	Washing, bleaching, re-tanning, pasteurising and cleaning
Estimated annual energy consumption	800 MWh_{th}/year
Active collector area (aperture area)	500 m²
Necessary space for mounting the collector field[17]	900 m²
Specific thermal storage volume	50 litres / m² collector area
Production profile in the factory	Continuous over the year
Moderate thermal conversion efficiency of existing heat supply system	70%
Net end consumer price per gross flat plate collector area including hydraulics and installation	7079 ZAR/m²*
Net end consumer prices for water storage tank (above 3 m³)	32180 ZAR/m³**

Source 36: Source: Financial Tool in Solar Payback 2018

*The specific collector price was identified by using information available at http://SHIP-Plant.info database and then adjusted according to inflation and exchange rate to 2017 values and refers to larger systems. When asking for a quotation the cost might vary.

**The specific storage tank price is set at 2,000 EUR/m³ for a tank above 3 m³, which was converted with 1 EUR = 16.09 ZAR in the tool. When asking for a specific quotation the cost might vary.

Based on the technical parameters as summarised in Table 13, the tool calculates the total investment costs of the SHIP installation. These are based on specific net collector field and storage tank prices including installation.

SPP, IRR and WACC: The language of bankers and investors

As industry professionals often do not use the same language as bankers and investors when presenting solar thermal projects, it is important to explain the most important terms and key performance indicators, or KPIs, for the economic and financial feasibility assessment of SHIP plants.

On the economic and financial side, the tool uses both static and dynamic methodologies. Static economic analysis compares only yearly averaged savings with the corresponding costs and does not consider the time value of money. Whereas dynamic methods are based on a discounted cash flow and account for the time value of money.

In economics, it is generally preferred to receive cash today rather than in the future, because it is of higher value today than it will be in some years. That´s why in dynamic methodologies the future cash flows are being converted to current values (today) by means of a discount rate or discount factor. A commonly used method for finding the appropriate discount rate is called the Weighted Average Cost of Capital, or WACC. Based on the structure of project financing, the WACC serves as the hurdle rate, that is, the minimum acceptable rate of return for prompting an investment decision.

The longer the investment period, the more the results of static and dynamic calculation methods differ. As investment for solar systems shows long lifetimes (in the range of 20 years), preferably the method of dynamic economic analysis should be applied, which fully considers the importance of the time when payments occur. Nevertheless, as static payback calculation is more common in South Africa, Chapter 5.2 uses both types of KPIs – Simple Payback

2 The higher the required temperature, the more expensive the technology has to be applied. If temperature is lower (e.g. 50 °C) the cost can be even lower. The tool calculates with different base costs. We use a base case of 100 %.

3 Here again, the collector technology defines the necessary space that would vary depending on the use of non-concentration technologies or concentration technologies. On 900 m² available space, 500 m² aperture area of flat plate or vacuum tubes could be installed or 360 m² (aperture area of parabolic trough or even 517 m² of Linear Fresnel. As mentioned in Chapter 2, the later technologies can be used for higher temperature and if direct solar irradiation is mostly available.

Period (SPP) based on static analysis and Project Internal Rate of Return (P-IRR) based on the discounted cash flow method. Both KPIs describe the profitability of the investment, but do not consider the type and costs of financing. The two KPIs can be defined as following:

- Solar Payback Period is the time required for recovering the investment in a project from the annual savings. Typically, the management in industries expect SPPs of around 3 to 5 years.
- The P-IRR represents the rate of return which an investment project is expected to generate. The investment is profitable if the P-IRR is larger than the WACC, meaning that the expected return surpassed the costs of capital.

5.2 Economic Calculations of Case Studies under Certain Frame Conditions

In this chapter the tool is used to assess the economic feasibility of the case study defined in Chapter 5.1, which is a 500 m^2 flat plate collector system supplying hot water of 75°C that could be used in a dairy, leather factory or metal processing plant. Table 14 summarises additional parameters set for this reference case. Diesel is used in the example factory with an estimated price of 1090 ZAR/MWh. The fuel prices are based on the data collected in Table 2 based on mid 2017 values.

TABLE 14: Further parameters for the basic case study calculation Case Diesel Johannesburg A	
Annual medium irradiation potential as in Johannesburg	2.0 MWh/m^2
Energy source for current heat supply system	Diesel
Average price for current energy source	1090 ZAR/MWh
Daily production profile in the factory	Daytime
Weekly production profile in the factory	Seven days a week
Average collector operation temperature	75 °C
Energy inflation rate	9.9 %
Investment / technology lifetime	20 years
Annual O&M costs	1 % of CAPEX

Source 37: Solar Payback 2018

TABLE 15: Prices of energy sources used for process heat	
Diesel	1090 ZAR /MWh
Coal	160 ZAR /MWh
LPG	1470 ZAR /MWh
Electricity	1180 ZAR /MWh
Paraffin	690 ZAR/MWh
HFO	450 ZAR / MWh

Source 38: Solar Payback 2018

Assumptions base example (Case Diesel Johannesburg A)

When Diesel is substituted in the example factory of the reference case, the investment pays off in 3.75 years according to the static payback period (6.5 years according to discounted payback calculations) and the project-IRR reaches 24.4%. Therefore - at the first glance - this SHIP application would be considered profitable, because first the payback period is below 5 years, which is generally considered to be the maximum acceptable SPP. Secondly, the WACC (definition in chapter 5.1) is lower than the P-IRR, since interest rates of loans from commercial banks are usually above 10%. The solar payback calculation tool defines a default interest rate for industrial clients in South Africa of 11.97% that derives from the 10-year government bond rate plus a fixed surcharge for the client credit margin and the liquidity spread of the financing bank. The cost of equity is considered at 16.09%, which, with a 50% financing/equity ratio, would bring the pre-tax WACC to 13.995%.

Over the 20 years of the lifetime of the 500 m^2 SHIP system would save around ZAR 32,120,053 in costs compared to a Diesel system if an energy inflation of 9.9% per annum is considered. The system costs of ZAR 3,434,975 have already been deducted from this revenue.

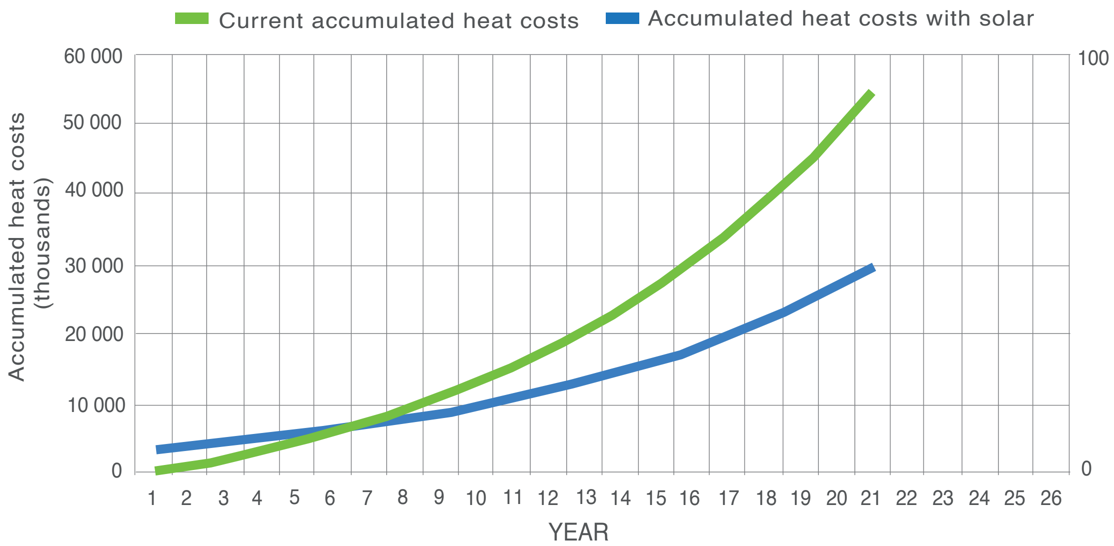


FIGURE 24: Comparison of electricity base case with conventional scenario

Source 39: Solar Payback 2018

Variation of this example: Modified use of the factory (Case Diesel Johannesburg B)

If we take the same example with Diesel as fuel but reduce the production mode of the factory from 7 to 5 days a week and 1 month of break (e.g. for maintenance or holidays). Then the simple payback would be 5.25 years (11.25 years according to discounted payback methodology) and a project IRR would be 19%. If a factory is not in operation on weekends, around one-third of the annual sunshine of the collector surface cannot be used additionally, which increases the solar heat price significantly.

Variation: Increased Boiler Efficiency (Case Diesel Johannesburg C)

The initial example (Case Diesel Johannesburg (A), continuous use for 7 days a week, daytime) above could be further modified with a highly efficient boiler with 90% thermal conversion efficiency. Then the simple payback time would be 5 years (10.25 years discounted payback) and P-IRR of 19.8%.

It can be seen that these technical modifications already have an influence on the investment decision. While for the first case (A) and the third (C) case the invest decision would be probably positive, the second case (B) might be negative. The influence should be even more important if the fuel price varies.

Variation: Energy Inflation Rate

Relevant are also the assumptions about future energy prices. Though data reveals that the average inflation for fuels has been very high in the past, this might not necessarily be the case for the future. If for example the same case (Case Diesel Johannesburg (A)) would use the average inflation rate of 4.7% p.a. for fuels (instead of 9.9%) as well, the statically payback period would be 4.5 years and the discounted one 10 years. The project IRR would be only 18.4%, thus the decision on the realisation of the project would be probably still be positive, but the project would be less attractive.

Variation: Fuel source

As mentioned in Table 15, the fuel prices vary greatly. So any fuel that would replace Diesel, which is cheaper than Diesel should decrease the economics of the case mentioned above, while more expensive fuels will increase the economics.

If for the "Case Diesel Johannesburg (A)", the fuel diesel is replaced by coal (ZAR 160 MWh), then the simple payback time would be 17.5 years and the project IRR 1.1%. Thus no economic viability would exist for this case, even though the other conditions would be favourable.

Nevertheless, the example shows that it naturally depends very much on the fuel costs and the overall framework conditions, whether the investment decision will lead to positive or acceptable outcomes or not.

Besides Diesel and coal South African companies use Liquefied Petroleum Gas (LPG), electricity, paraffin and heavy fuel oil (HFO) to cover their heat demand (see Table 15).

Table 16 shows how the type of substituted energy source impacts the economic profitability of the reference SHIP system. When LPG is used - the most expensive industrial fuel – the SHIP system pays off in only 2.75 years, and the P-IRR is at comfortable 31.2%. The savings over 20 years even add up to ZAR 44,515,385. But also, replacements of electricity and Diesel by solar thermal could be good options, since they remain below the accepted 5 years.

If the common fuels coal, paraffin or HFO are used, then the investment will not be made since the P-IRR is either much below expectation.

TABLE 16: Economics of different fuel sources as given for the base case provided in Table 13

	Reference case	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Energy source	Diesel (ZAR 1090 / MWh)	Coal (ZAR 160 / MWh)	LPG (ZAR 1470 / MWh)	Electricity (ZAR 1180)	Paraffin (ZAR 690 / MWh)	HFO (ZAR 450 / MWh)
SPP / Years	3.75	19	2.75	3.5	8	11,25
P-IRR	24.4%	1.1%	31.2%	26.1%	11.8%	7.1%
Savings over 20 years	ZAR 32,120,053	ZAR 1,784,112	ZAR 44,515,385	ZAR 35,055,745	ZAR 12,320,143	ZAR 6,840,102

Source 40: Solar Payback 2018

Variation: Higher Irradiation

The next step is to analyse the impact of a higher solar irradiation potential on the economic feasibility of the SHIP reference plant (see Table 17). Thus the system is simulated for a factory in Bloemfontein, which has ha higher irradiation of 2.2 MWh/m². Under these, very favourable conditions, the substitution of Diesel but also LPG and electricity would be even more attractive.

TABLE 17: Reference case at a site with better irradiation potential of 2.2 MWh/m² (e.g. Bloemfontein) and production at 7 days a week

	Reference case	Alternative 1	Alternative 2	Alternative 3	Alternative 4	Alternative 5
Substituted energy source	Diesel (ZR 1090 / MWh)	Coal (ZAR 160 / MWh)	LPG (ZAR 1470 / MWh)	Electricity (ZAR 1180)	Paraffin (ZAR 690 / MWh)	HFO (ZAR 450 / MWh)
P-SPP /years	3.25 years	16.5 years	2.25 years	3 years	7.25 years	10,25 years
P-IRR	26.9%	2%	34.3%	28.7%	13.3%	8.3%
Cumulated savings over 20 years	ZAR 36,522,105	ZAR 2,430,284	ZAR 50,452,096	ZAR 39,821,268	ZAR 14,270,777	ZAR 8,112,254

Source 41: Solar Payback 2018

As the two examples reveal, it seems important for planners and engineers to explain to potential industrial investors that a SHIP plant is an investment into improving the infrastructure of the factory; therefore, payback times are not really the best and only criterion. When introducing solar process heat applications to new customers, a figure with a baseline cost comparison seems to be a good door opener. Such a chart compares the heat energy costs over 20 years if the business continuous as normal and compares this with the reduced heat energy costs after the installation of a SHIP system (see Figure 24). A baseline cost comparison is also offered in the tool as part of the graphic results.

Conclusions for the Planning Process of SHIP Plants

- The Solar Payback Tool for Economic Analysis allows the calculation of Key Performance Indicators (KPIs) based on thousands of solar yield calculations for different South African SHIP case studies and pre-defined default values.
- Simple Payback Period (SPP) and Project's Internal Rate of Return (P-IRR) are used to compare the economic profitability of different technology and operational variants.
- In the reference case a 500 m² flat plate collector system supplies hot water at 75°C to a dairy, leather factory or metal processing plant for bleaching, washing, re-tanning, pasteurising and cleaning, which is a rather favourable, thus economic application.
- Substituting electricity with the SHIP reference plant is economically profitable under most frame conditions.
- Substituting Diesel, electricity or LPG with the SHIP reference plant is economically profitable under most frame conditions.
- The higher the rate of utilisation, the better the economic results become.
- A paradigm shift away from investment decision mainly on short SPP (below 5 years) towards considering the cumulated savings over the 20-year technology lifetime of the SHIP plant will increase the number of SHIP variants that will be economically profitable.

CHAPTER 6

CONCLUSIONS AND RECOMMENDATIONS

6.1 Potential for SHIP in South Africa

South Africa possesses an excellent solar resource that can be effectively used in various industrial sectors to reduce their dependence on fossil fuels. Manufacturing is concentrated in the Gauteng province where the annual average GHI exceeds 2000 $kWh/m^2/yr$. A conservative estimate of steam demand in the analysed sectors shows that a total of 26.5 PJ of steam energy utilised, equating to 35.3 PJ on input fuel energy (assuming 75% boiler efficiency).

In this work the food and beverage sector was highlighted as the best opportunity for solar thermal integration in the country, with an estimated 17.3 PJ of steam demand each year. Over the past 15 years this industry has been experiencing growth, while the output from other manufacturing sectors has been stagnating or decreasing. The food and beverage sector is also the third largest contributor in terms of manufacturing value creation in the country, behind the chemicals and metals sectors.

Despite the favourable solar potential and existence of target industries in South Africa with a significant heat demand at low and medium temperatures, there remains a significant barrier to SHIP adoption, namely the low cost of coal. With input energy costs in the order of 0.12-0.20 ZAR/kWh, many large companies have optimised their operations to utilise large coal fired boilers. Although a carbon tax has been proposed of 120 ZAR/ton CO_2e, this would only increase the input energy costs by around 0.04 ZAR/kWh.

In recent times some large companies, especially those in the food and beverage sectors, have stated that they recognise adverse effects that fossil fuels have on the environment and they are moving towards reducing their coal usage. This effort is expressed in the FTSE/JSE Responsible Investment Top 30 Index where the big companies compete against each other with their sustainable investments. These companies have made public declarations to reduce their emissions, provide annual sustainability reports that outline their progress in improving energy efficiency and decreasing emissions. In the near term, it appears that most of these companies are focussing on energy efficiency and the installation of PV systems as electricity in South Africa has the highest emissions per kWh.

A further barrier to the adoption of solar thermal systems is the current climate of uncertainty in the country, with negative business confidence indexes. Therefore, many companies are unwilling to invest in SHIP due to high initial investment costs in an uncertain business environment with high interest rates. For this reason, it is critical to examine alternative business models like ESCO models. Also, banks have to be briefed and trained as there is a huge lack of comprehensive finance models suiting for SHIP technology.

6.2 Barriers and Recommendations

This report has highlighted that many South African industries have a high potential for SHIP integration. The following recommendations are made to further develop the SHIP market in South Africa to reach its high potential.

Barriers to SHIP Development identified during the Enabling Study

- Limited number of SHIP plants operation in South Africa
- Low cost of conventional heat sources such as coal and natural gas
- No detailed data on heat demand within different South African Industries
- Lack of awareness of solar thermal technologies and how to integrate into the plant

- High interest rates and general low business confidence
- Policy uncertainty regarding when carbon tax will be introduced due to postponements of implementation
- Many companies first consider PV power systems as an alternative to SHIP due to ease of integration
- High transaction costs for project development for small scale SHIP plants for small and medium sized companies

Recommendations for SHIP Market Development in South Africa

Raising awareness of the benefits of SHIP technology amongst industry, policy makers and financial institutions

One of the key aims of the Solar Payback project is to initiate raising awareness that SHIP is a competitive clean energy source for a number of market segments and that it is a mature technology with several hundred plants operational worldwide. However, successful market development requires sustained communication with key stakeholders to convey the benefits of SHIP plants, which include:

- Attractive payback periods for target industries using petroleum-based boiler fuels
- Potential to hedge against rising energy costs and a possible future carbon tax
- Combined with energy efficiency, SHIP can increase industrial competitiveness
- Positive impact on company's sustainability profile through the reduction of CO_2 emissions

Continued communication between SHIP technology suppliers with industry is essential to identify opportunities for an increased number of demonstration plants in South Africa with attractive payback conditions that will build local industry confidence in the technology. Research institutions and universities can play a critical role in conducting sector specific SHIP feasibility studies to identify opportunities for SHIP deployment under favourable investment conditions. In particular, it is critical to maintain open communication with financial institutions regarding SHIP technology to ensure that interest rates do not include an added risk premium for SHIP plant financing.

Assisting in Financing SHIP Projects to Stimulate Market Development

In contrast to conventional heat generation systems such as fossil fuel fired boilers, SHIP projects have significant upfront investment costs. A number of companies in target SHIP sectors identified in this report are small and medium-sized enterprises without the adequate capital to develop a SHIP plant without some form of financing. The opportunity cost of capital within these companies also remains high. The financing of SHIP projects in South Africa presents a challenge with high interest rates and low business confidence. In many cases companies are looking to make investments with payback periods lower than 3 to 5 years. In order to stimulate the SHIP market, investment support mechanisms should be considered such as low interest loans, with the aim of developing a sustainable market.

Development of new Business Models for SHIP Deployment

ESCOs present an interesting mechanism to increase the uptake of SHIP plants. An ESCO is typically based on an energy performance contracting model. In cases where the end user is looking for off-balance sheet funding of a SHIP plant, the production of heat could be outsourced to a heat ESCO. Various models exist but the ESCo would typically be responsible for design, project management, funding, and receive payment through heat purchases from the end consumer. Applicable heat ESCO models for SHIP deployment in South Africa should be further investigated.

REFERENCES

Aidonis, A., Drosou, V., Mueller, T., Staudaher, L., Fernandez-llebrez, F., Oikonomou, A., & Spencer, S. (n.d.). *Procesol II Solar thermal plants in industrial processes: Design and Maintenance Guidelines.* Pikermi, Greece.

al, S. e. (2014). IRENA.

Ben-Hassine, I. e. (2015). *Guideline for solar planners, energy consultants and process engineers giving a general procedure to integrate solar heat into industrial processes by identifying and ranking suitable integration points and solar thermal syst.* Online: IEA/SHC Task 49/IV, Subtask B, Deliverable B2.

Bergh, J. (2014). *Techno-economic Impact of Advanced Coal Beneficiation using Models for Predicting Liberation Functions.* PhD Thesis, University of the Witwatersrand, Johannesburg.

BIZCO Business Consulting. (2012, September). *Eskom Approves BBE Energy's Solar Based Energy Project*. Retrieved from http://bizco.co.za/eskom-approves-bbe-energys-solar-based-energy-project/

Blackdot Energy. (2016). *SA Most Amazing Solar Thermal Installations*. Retrieved from http://www.blackdotenergy.co.za/sttp-wg3-video-project/

Chaddha, A., Dhanani, Q., Murotani, R., Ndiaye, F., & Kamukama, R. (2009). *Textiles and Apparel Cluster in South Africa.* Microeconomics of competitiveness.

CHIETA SETA. (2016). *Sector Skills Plan for the Chemicals Sector: Final Update 2017-2022.*

City Power Johannesburg. (2016). *Tariffs and charges 2016/2017.*

CSIR. (2017). *Formal comments on the Integrated Resource PLan (IRP Update Assumptions, Base Case and Observations 2016.* Pretoria.

Department of Energy. (2010). *Policy to Support the Energy Efficiency and Demand Side Management Program for the Electricity Sector through the Standard Offer Incentive Scheme (2010).* Pretoria: Department of Energy.

Department of Energy. (2011). *Integrated Resource Plan.* Pretoria.

Department of Energy. (2015). *State of Renewable Energy in South Africa.* Pretoria, South Africa: Department of Energy .

Department of Energy. (2016). *2016 South African Energy Price Statistics.* Directorate: Energy Data Collection, Management and Analysis.

Department of Energy. (2016). *Draft Integrated Energy Plan 2016.* Pretoria.

Department of Energy. (2017, 06 01). Retrieved from http://www.energy.gov.za/files/energyStats_frame.html

Department of Environmental Affairs (DEA). (2016, December 12). *Department of Environmental Affairs, Climate Change*. Retrieved from Department of Environmental Affairs: https://www.environment.gov.za/

Department of Environmental Affairs. (2011). *National climate change response white paper.* Pretoria: Department of Environmental Affairs.

Department of Environmental Affairs. (2017). *Technical Guidelines for Monitoring, Reporting and Verification of Greenhouse Gas Emissions by Industry: A companion to the South African National GHG Emissions Reporting Regulations.* TG-2016.1.

Department of Minerals and Energy. (1998). *White paper on the Energy Policy of the Republic of South Africa.* Pretoria: Department of Minerals and Energy.

Department of Minerals and Energy. (2003). *White paper on renewable energy.* Pretoria: Department of Minerals and Energy.

Department of Trade and Industry. (2013). *Programme guidelines: Production incentive programme.* Pretoria: Department of Trade and Industry.

Department of Trade and Industry. (2014). *MCEP Guidelines.* Pretoria: Department of Trade and Industry.

Department of Trade and Industry. (2015). *Black Industrialists Policy.* Pretoria: Department of Trade and Industry.

Department of Trade and Industry. (2016). *Industrial policy action plan 2016/17.* Pretoria: Department of Trade and Industry.

E3 Energy . (2017). *In the media: CBC Solar Thermal Installation*. Retrieved from https://www.e3energygroup.com/

EasyData. (2017). *EasyData by Quantec*. Retrieved from http://www.easydata.co.za

Economic Development Department of the Republic of South Africa. (2011). *Green Economy Accord.* Pretoria: Economic Development Department of the Republic of South Africa.

EIA. (2017). *Annual Energy Outlook.* U.S. Energy Information Administration.

Energy Research Centre. (2014). *SATIM Methodology v3.2.*

Environmental and Energy Study Institute. (2011). *Issue Brief: Solar Thermal Energy for Industrial Uses.*

Eskom. (2017). *Tariffs and Charges 2017/2018.*

Euroheat and Power. (2005). Ecoheatcool Work Package 1: The European Heat Market.

FoodBev SETA. (2011). *Sector skills plan for the food and beverages manufacturing sector 2011/12-2015/2016.*

FP&M SETA. (2015). *Sector Skills PLan: Update for the Financial Year 2015-2020.*

Genesis Analytics. (2005). *Forestry Industry Market Analysis Part 2.* Johannesburg.

Global Solar Water Heating Market Transformation and Strengthening Initiative. (2012). *Guide on Standardisation and Quality Assurance for Solar Thermal.*

Green Cape. (2016). *Energy services: Energy efficiency and embedded generation.* Cape Town: Green Cape.

Hertzog, H. (2012). *Component Testing for Solar Water Heating.* Sunshine Rocket Consulting. Retrieved from http://greencape.co.za/assets/Uploads/energy-efficiency/Component-testing-for-SWH-120912-1.pdf

Intergovernmental Panel on Climate Change. (2006). *IPCC guidelines for national greenhouse gas inventories.* Intergovernmental Panel on Climate Change, https://www.ipcc.ch/pdf/special-reports/sroc/Tables/t0305.pdf.

Joubert, E. C., Hess, S., & Van Niekerk, J. L. (2016). Large-scale solar water heating in South Africa: Status, barriers and recommendations. *Renewable Energy*, 809-822.

Joubert, E., Hess, S., & Van Niekerk, J. L. (2016). Large-scale solar water heating in SOuth Africa: Status, barriers and recommendations. *Renewable Energy*, 809-822.

Kempf, R. (July, 2017). Solarzone. Electronic communication.

Mekhilef, S., Saidur, R., & Safari, A. (2011). A Review on Solar Energy Use in Industries. *Renewable and Sustainable Reviews*, 15: 1777-1790.

merSETA. (2013). *Regional Sector Skills Plan: Gauteng-North West Region.* Pretoria.

National Treasury. (2013). *The Regulations in terms of section 12L of the Income Tax Act, 1962 on the Allowances for Energy Savings.* Pretoria: Department of Energy.

National Treasury. (2017). *Draft Carbon Tax Bill.*

SABS. (2017). *Solar Water Heating - Certification & Assessment*. Retrieved from https://www.sabs.co.za/Sectors-and-Services/Sectors/Solar/solar_ac.asp

SABS. (2017). *Solar Water Heating - Standards & Publications*. Retrieved from https://www.sabs.co.za/Sectors-and-Services/Sectors/Solar/solar_sp.asp

SASOL. (2012). *Sasol gas transmission tariff application for the poeriod 26 March 2014 to 30 June 2015.*

Sasol. (2017). *Sasol Gas Application for Approval of MAximum Gas Prices in Terms of Section 21(1) (p) and Approval of Distinguishing Features in Terms of Section 22(1) of the Gas Act, 2001 (Act No. 48 of 2001) for the Period 1 July to 30 September 2016.*

SA-STTRM. (2015). *The South African Solar Thermal Technology Roadmap: Direction for South Africa's solar thermal energy future.*

South African Bureau of Standards (SABS). (2011). *South African National Standard: Energy Management Systems.* Pretoria: South African Bureau of Standards (SABS).

South African Petroleum Industry Association. (2017, 07 01). *Old Fuel Prices*. Retrieved from http://www.sapia.org.za/Overview/Old-fuel-prices

StatsSA. (2017). *Personal communication with Abel Chauke.* Statistics South Africa.

Transnet. (2016, December 12). *Transnet pipelines*. Retrieved from Transnet pipelines: http://www.transnet.net/Divisions/PipeLines.aspx

WWF. (2017). *Industrial scale solar heat in South Africa: Oppertunities in agr-processing and textiles.* WWF Technical Report.

Appendix A – Common Industrial Processes for SHIP Integration

Table A1: Suitable Processes for SHIP Integration (Mekhilef, Saidur, & Safari, 2011)

	Industry	Process	Temperature Range (°C)
Food and Beverage	Meat	Washing, sterilization	60-90
		Cooking	90-100
	Dairy	Pressurization	60-80
		Pasteurization	100-120
		Drying	120-180
		Concentrates	60-80
		Boiler Feed water heating	60-90
	Tinned Food	Sterilization	110-120
		Pasteurization	60-80
		Cooking	70-90
		Bleaching	70-90
	Flours and by-products	Sterilization	60-80
	Beverages	Washing, Sterilization	60-80
		Pasteurization	60-70
Textiles		Bleaching, dyeing	60-90
		Drying, degreasing	100-130
		Dyeing	70-90
		Fixing	160-180
		Pressing	80-100
Paper		Cooking, drying	60-80
		Boiler feed water	60-90
		Bleaching	130-150
Chemicals	Chemical	Soaps	200-260
		Synthetic rubber	150-200
		Process heat	120-180
		Pre-heating water	60-90
	Plastics	Preparation	120-140
		Distillation	140-150
		Separation	200-220
		Extensions	140-160
		Drying	180-200
		Blending	120-140

Appendix B – Detailed list of Companies from FoodBev SETA

Table B1: Companies paying levies to FoodBev SETA (FoodBev SETA, 2011)

Description	Total
Baking, cereals, confectionery and snacks	314
Manufacture of breakfast foods	9
Manufacture of bakery products	239
Manufacture of cocoa, chocolate and sugar confectionery	46
Manufacture of nut food	20
Beverage manufacturing	236
Manufacture of beverages	40
Distilling, rectifying and blending of spirits, alcohol production from fermented materials and manufacture of wine	117
Manufacture of beer and other malt liquors and malt	9
Breweries except sorghum	16
Sorghum beer breweries	1
Manufacture of malt	5
Manufacture of soft drinks, production of mineral water	48
Dairy Manufacturing	218
Manufacture of dairy products	86
Processing of fresh milk	28
Manufacture of butter and cheese	8
Manufacture of ice cream and other edible ice	90
Manufacture of milk powder, condensed milk and other edible milk products	6
Manufacture of food preparation products	555
Production of lard and other edible fats	1
Manufacture of vegetable and animal oils and fats	21
Manufacture of crude oil and oil seed cake and meal	8
Manufacture of compound cooking-fats, margarine and edible oils	8
Manufacture of food preparation products	207
Manufacture of macaroni, noodles and similar farinaceous products	8
Manufacture of other food products not considered elsewhere	224
Manufacture of coffee, coffee substitutes and tea	21
Manufacture of spices, condiments, vinegar, yeast, egg, products, soups and other food products	57
Processed fish, meat, fruit and vegetables	569
Production, processing and presentation of meat, fish, fruit, vegetables, oils and fats	115
Production, processing and preservation of meat and meat products	208
Manufacture of prepared and preserved meat, including sausage	52
Processing and preserving of fish and fish products	65
Manufacture of canned, preserved and processed fish, crustaceans and similar foods	23
Processing and preserving fruit and vegetables	68
Manufacture of canned, preserved, processed and dehydrated fruit and vegetables, except soup	38
Total	**1892**

Appendix C -Ozone Business Manufacturing Database

This appendix provides a breakdown of manufacturing companies according to the Ozone Business Consulting database of manufacturing operations for the food and beverage, textiles, chemicals and automotive sectors. It should be cautioned that this data was collected up to 2009 and some companies especially those in textiles may no longer be operation. Similarly, it does capture new companies in food and beverage. This data was collected during research projects for Eskom. Therefore, regional distributions for companies were available as per the Eskom refined regions, as shown in the map below. Note energy audits were not conducted for all of the company contacts on the database.

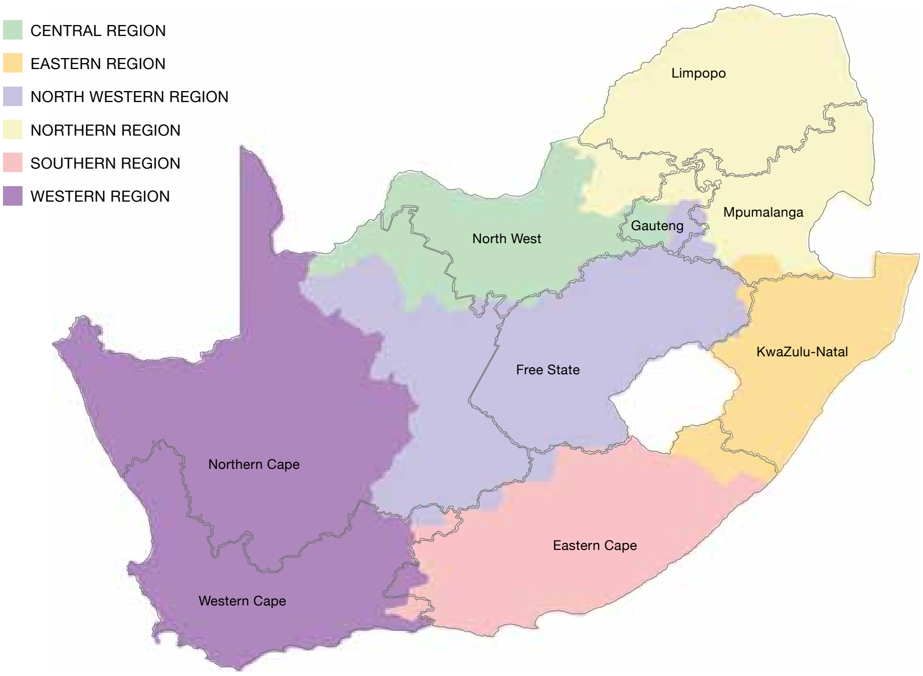


FIGURE 25: Comparison of Eskom regions with provincial boundaries

Source 42: Eskom

Table 18: Table C1: Food and Beverage Companies from O_3BC database

Sub-sector	Central	Eastern	North Western	Northern	Southern	Western	Total
Protein products	26	27	34	27	9	68	191
Beverages	13	19	15	12	7	121	187
Bakery products	32	21	23	70	7	20	173
Other food products	32	20	18	25	9	40	144
Grain products	22	14	28	37	5	17	123
Milk products	20	18	23	21	9	20	111
Fruit and veg. products	8	7	13	27	6	38	99
Processed food products	12	12	6	6	1	12	49
Dessert products	8	5	5	5	2	13	38
Fats and Oils	2	5	4	5	0	2	18
Sugar	0	14	0	2	0	0	16
Total	**175**	**162**	**169**	**237**	**55**	**351**	**1149**

Table 19: Textiles Companies from O_3BC database

	Central	Eastern	North Western	Northern	Southern	Western	Total
Clothing & Knitwear	262	468	37	62	74	474	1377
Weaving & knitting	15	37	10	7	13	34	116
Footwear	7	42	0	0	4	20	73
Fibre, Spinning & Yarn prod	5	11	0	3	6	20	45
Leather Tannery	7	4	5	9	10	7	42
Home textiles	7	2	1	3	0	13	26
Dyeing and finishing	2	8	0	2	0	10	22
Integrated mills	1	8	1	2	4	2	18
Non-woven	1	4	0	2	2	2	11
Total	**307**	**584**	**54**	**90**	**113**	**582**	**1730**

Table 20: Chemicals Companies from O_3BC database

Sub-sector	Central	Eastern	North Western	Northern	Southern	Western	Total
Plastic Products	173	160	169	81	38	156	777
Speciality Chem.	105	92	115	24	18	68	422
Rubber Products	29	25	40	20	11	31	156
Household Cleaning Chem.	46	22	22	10	14	36	150
Pharmaceuticals	52	10	21	14	5	16	118
Personal Care Chem.	26	17	15	8	3	12	81
Commodity Inorganics	13	13	14	13	0	2	55
Pure Functional Chem.	3	18	18	2	4	5	50
Inorganic Fertilizers	7	8	13	0	0	12	40
Liquid Fuels and Other	10	12	8	2	0	6	38
Commodity Organics	5	8	8	3	1	3	28
Fine Chemicals	1	2	2	2	0	2	9
Explosives	3	0	1	2	0	2	8
Primary Polymers, Rubbers	0	3	3	0	0	1	7
Organic Fertilizers	1	0	0	1	1	1	4
Total	**474**	**390**	**449**	**182**	**95**	**353**	**1943**

GLOSSARY

Agro-Processing Support Scheme (APSS)

business-as-usual (BAU)

Centre for Renewable and Sustainable Energy Studies (CRSES)

City of Cape Town (CoCT)

CO_{2e} (carbon dioxide equivalent)

Department of Energy (DOE)

Department of Environmental Affairs (DEA)

Department of Trade and Industry (DTI)

Direct normal irradiation (DNI)

Energy Information Administration (EIA)

Energy Research Centre (ERC)

Free On Board (FOB)

German Development Bank (KfW)

Global Horizontal Insolation (GHI)

Green Energy Efficiency Fund (GEEF)

greenhouse gas (GHG)

Heavy Fuel Oil (HFO)

Industrial Policy Action Plan (IPAP)

Intended Nationally Determined Contribution (INDC)

Levelized Cost of Heat (LCOH)

Liquefied Petroleum Gas (LPG)

Manufacturing Competitiveness Enhancement Programme (MCEP)

Megawatt (MW)

monitoring, reporting, and verification (MRV)

National Cleaner Production Centre (NCPC)

National Industrial Policy Framework (NIPF)

NERSA (National Energy Regulator of South Africa)

Ozone Business Consulting (O3BC)

Production Incentive Programme (PIP)

Return on investments (ROI)

Solar Heat for Industrial Processes (SHIP)

South African Rand (ZAR)

South African Revenue Service (SARS)

United Nations Framework Convention on Climate Change (UNFCCC)

United Nations Industrial Development Organization (UNIDO)

United States Dollar (USD)

Supported by:

Federal Ministry
for the Environment, Nature Conservation
and Nuclear Safety

based on a decision of the German Bundestag

AHK SUSTAINABLE ENERGY COMPETENCE CENTRE

sanedi

CSIR our future through science