ISEC 2024 – 3rd International Sustainable Energy Conference
Solar Thermal and Energy Efficiency for Sub-Saharan Africa's Industry and Commerce
https://doi.org/10.52825/isec.v1i.1145

Published: 19 Apr. 2024

An Outlook on the Adoption of Renewable Energy Solutions at South African Beverage Manufacturers

Francois Rozon[1], Craig McGregor[1], and Michael Owen[1]

[1] Stellenbosch University, South Africa

*Correspondence: Francois Rozon, frozon@sun.ac.za

Abstract. To decarbonise industry, which accounts for half of the total energy demand, renewable and sustainable energy solutions must be embraced. Not only to meet electricity requirements but, more importantly, to substitute fossil fuels used to generate process heat. This research assesses the cost-benefits of renewable and sustainable energy solutions for the South African beverage sector, representing an estimated 3020 GWh in annual energy demand, and provides a framework for the broader adoption of these technologies. For South African beverage producers, the study concludes that investments in photovoltaic and battery energy storage systems will continue to take priority, given the favourable 17–21 % Year-1 return on capital. However, given spatial and capital constraints, the judicious planning of solar thermal energy system requirements is advocated, to address the in-situ nature of process heat generation.

Keywords: Industry, Renewable energy solutions, South African beverages, Cost-benefit analyses

1. Introduction

As the world's energy demand continues to grow, the adoption of renewable energy needs to accelerate dramatically to mitigate carbon emissions from burning fossil fuels [1], [2]. In the last decade, measurable progress has been achieved in generating electricity from solar and wind energy, notably from solar photovoltaic (PV) systems, with global generation capacity accelerating ahead of other technologies [3]. In addition to policy and incentive support, the sustained cost reductions have contributed to this growth. On a global average, the levelised cost of energy (LCOE) from onshore wind and utility-scale PV installations, at US$0.04/kWh and US$0.06/kWh, respectively, is now lower than that of new fossil fuel power plants [3] and forecasted to reach less than US$0.03/kWh by 2030 (in 2020 real terms) [4].

While wind and PV technologies have gained notoriety, investments in solar thermal energy technologies have waned since 2015. Grow rates in concentrating solar power have decreased from 30 % to 6 % per annum [3]. Similarly, growth in solar heat generation has reduced from 12 % down to 3 % between 2015 and 2020, and while global installed capacity compared to PV or onshore wind in 2015, in 2021 the reported 522 GWth is at least a third less, with approximately 100 GWth coming from large heating systems (> 350 kWth) [5], [6], and a mere 1 GWth in capacity for industrial processes plant solar heating systems [5].

The industrial sector is the largest energy user globally and in South Africa, consuming approximately half of all energy demand [7], [8]. While electricity is important, fossil fuels burned on-site to generate thermal energy represent two-thirds of industrial energy requirements [7], [9]. For temperatures below 200 °C, steam is the most common thermal energy transfer medium for process heating. In South Africa, the beverage's energy consumption was estimated to be 3020 GWh per annum, 62 % of which is from steam boiler generated process heat [10]. The sector is of particular interest given that it is primarily consolidated and owned by international shareholders who have announced audacious reductions in carbon emissions. However, companies have been slow to reduce their carbon footprint to date.

To accelerate the adoption of renewable and sustainable energy solutions, a three-stage evolutionary framework has been proposed [10]. The three stages and associated priorities are presented in Figure 1. While efficiency measures are an essential building block, in the first phase, the focus of this work is on Stage 2 interventions and the techno-economic analyses of renewable and sustainable energy investment options.

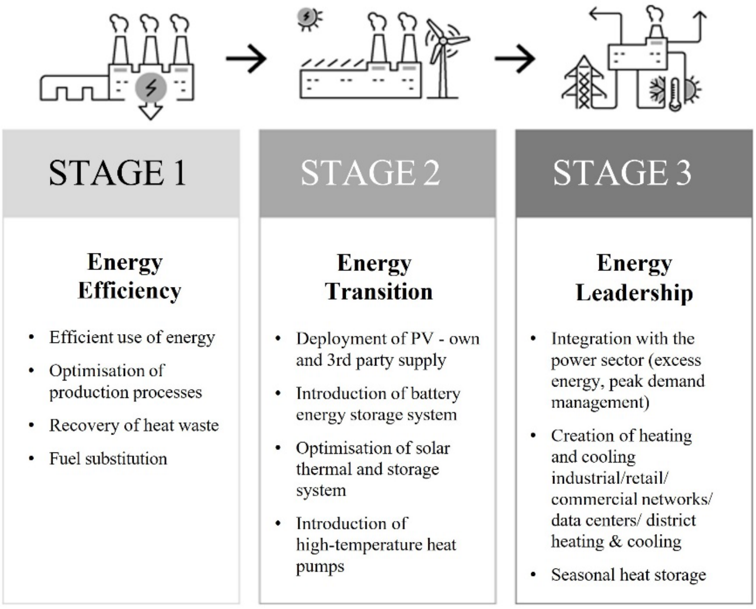

Figure 1. *Proposed three-stage holistic approach to reducing energy usage and fossil fuels by steam users [10]*

The South African government recently removed the 100 MW licensing cap imposed for electricity generation. As a result, large scale PV installations have been deployed throughout the country. The national electricity network operator, Eskom, estimated that solar PV “rooftop” capacity reached 5 GW_{peak} at the end of 2023, a doubling in capacity since 2022, and a significant increase to the reported 0.5–0.7 GW_{peak} reported at the end of 2020 [11]. Non-licensed PV installations now make up nearly as much electricity generating capacity as the 6.2 GW installed under the Renewable Energy Independent Power Producer licensing scheme [12], [13].

These conference proceedings present the cost benefit analyses and insights for renewable and sustainable energy investment options for the South African beverage sectors. The assessments used a novel capacity and cost forecasting approach for renewable energy solutions to assess immediate and future financial returns. Pragmatic “Year-1” return on capital and space metrics are presented for PV, Battery Energy Storage Systems (BESS), solar thermal parabolic trough collector systems, and high temperature heat pumps. The cost of electricity is compared to the electricity tariffs that prevailed in 2020 and an estimate for 2030 while the levelised cost of heat (LCOH) is compared to the variable cost of fossil fuel solutions from 2017 to 2023, a period of high price volatility. Detailed model simulations for solar thermal energy systems were used to validate findings and develop more significant insights into the competitiveness of the technologies against cheap South African coal [14]. The proceedings conclude that investments will focus on PV and BESS over the next decade, given the superior returns, improving economics and lower technology risks. However, these proceedings also argue that considerations should be given to solar thermal energy systems and heat pumps, specifically when considering expansion plans or site optimisation plans.

2. Method and materials

Business have largely adopted cost-benefit analyses when making investment decisions with the main investment criterion being the value to be created by calculating the net present value for investment options [15]. Positive net present value is achieved when project returns exceed the weighted average cost of capital [16]. This research uses a pragmatic cost-benefit approach to compare “Year-1” return on investment and space. 2020 actual capital costs and energy prices as well as 2030 estimates are used to provide current and future scenarios. Insights are then summarised in a decision tree. While these insights were derived from the energy usage and operational constraints prevailing at South African beverage facilities, the decision set should allow industrial user to prioritise renewable energy solution options.

2.1 South Africa beverage sector energy usage and carbon emissions

As part of a PhD dissertation, Rozon *et al.* have estimated the energy usage for different types of beverages across South Africa, which is summarised in Table 1 [10]. For this study, the energy requirement and operating parameters from a typical ready-to-drink packaging hall were used, which represent an important and replicable component of the energy footprint at beverage facilities. The typical annual energy demand profiles for such facilities can be found in a prior study on the techno-economic benefits of solar thermal energy systems [14].

Table 1. *2019 Estimated energy usage and carbon emissions from South African beverages [10]*

	Energy usage (GWh/annum)			**CO_{2e} emissions** (tonnes)		
	Electricity	**Heat**	**Total**	**Electricity**	**Heat**	**Total**
NARTD	**400**	**275**	**675**	**424 000**	**125 000**	**549 000**
Sparkling soft drinks	200	70	270	212 000	32 000	244 000
Juices and juice drinks	40	40	80	42 000	18 000	60 000
Packaged water	20	5	25	21 000	2 000	23 000
Value added dairy	30	70	100	32 000	32 000	64 000
Others	120	80	200	127 000	36 000	163 000
Alcoholic beverages	**730**	**1615**	**2 345**	**774 000**	**732 000**	**1 506 000**
Beer	450	910	1 360	477 000	412 000	889 000
Cider	40	110	150	42 000	50 000	92 000
Wine	60	60	120	64 000	27 000	91 000
Spirits	180	535	715	191 000	243 000	434 000
Total RSA Beverages	**1140**	**1880**	**3 020**	**1 208 000**	**852 000**	**2 060 000**

Note: Estimates are derived from publicly available information from several sources, including corporate sustainability and financial reports, industry reports, brewer/spirit/wine association manuals and bandwidth studies on energy use in the food and beverage sector. Outside-in energy usage estimates were validated with industry participants in interviews and site visits, and should be representative within a 5-10 % margin of error.

The carbon emissions associated with the South African beverage sector have been estimated at two million tonnes of CO_{2e}, representing 0.4-0.5 % of the South Africa’s carbon emissions [17]. While the thermal energy requirement represent much of the energy consumed, the high emissions associated with the coal power dependent national electricity grid, means that over one million tonnes of CO_2 emissions could be dramatically reduced through energy efficiency measures and electricity generation from renewable sources. Of the 850 thousand tonnes of CO_2 emissions associate with process heat and steam boilers, potentially a third to half of these could be avoided.

2.2 Renewable and Sustainable energy solution capex and levelised costs

The benchmark cost of renewable and sustainable energy solutions presented in Table 2 are derived from literature and have been validated for the province of Gauteng (Johannesburg) in South Africa using Polysun modelling [14], [18]. PV and BESS capital costs and LCOE are readily available for South Africa [19], [20]. The capital costs and LCOH for solar thermal energy systems are derived from international benchmarks [3], [8]. The LCOH of high-temperature heat pumps required to meet steam requirements is derived using typical European capital costs [21] and the representative industrial Megaflex South Arican electricity variable tariff for 2020 [22]. The variable cost of electricity is based on a 66–132kVA direct connection to the national grid with energy usage averaged for a 24-hour, 7-day operation including ancillary service charges [22]. The 2030 electricity tariff estimates build in above-inflation annual increases at 4 % in US$ real terms. Technology capital cost, LCOE and LCOH forecasts are obtained by applying a consistent methodology of best-fit quadratic regression on capacity and applying technological learning rates as done by Rozon *et al.* [4]. Real 2020 United States Dollar (US$) values are used to express cost outlooks. The cost-benefit analyses for steam systems assume the substitution of coal, given that it is the predominant source of thermal energy used to fire steam boilers, with representative costs, reflecting recent prices obtained from the IndexMundi data portal [23].

***Table 2**. 2020 and 2030 capex, LCOE and LCOH estimates (2020 US$)*

2020 US$ values	Photovoltaics		Solar thermal (PTC)		High Temp Heat Pumps	
	Capex (US$/$kW_p$)	LCOE (US$/MWh)	Capex (US$/$kW_{th}$)	LCOH (US$/$MWh_{th}$)	Capex (US$/kW)	LCOH (US$/$MWh_{th}$)
2020 Global average	883	57	500	40	500	48
2020 South Africa		46	750	65		
2030 –South Africa	490	26	563	50	375	65

Note: 2020 PV global average capex and LCOE from IRENA [3]; 2020 PV RSA LCOE from REIPPP Window 5 [13]; 2020 solar thermal large industrial systems from IRENA [24]; 2020 solar thermal Gauteng estimates from previous solar thermal techno-economic study [14]; 2020 heat pump LCOE using electricity at US$0.08/kWh [21]; 2030 PV Capex and LCOE forecast using $3.1\,(t-t_0)^2 - 32.2\,(t-t_0) + 54$ regression to project global generation capacity with t_0 being year 2000 and a learning rate of 34 % on costs [4]; 2030 solar thermal capex and LCOH reductions assume an aggressive scenario derived from the 2000-2015 global capacity regression of $1.76\,(t-t_0)^2 - 0.4\,(t-t_0) + 66$ where t_0 is set at 2005 and a technology learning rate of 20 % [10]; 2030 heat pump capex assume similar capacity growth and learning rates as for solar thermal energy, however the LCOH is negatively impacted by above inflation electricity tariff increases with annual increases of 4 % in US$ terms.

3. Results

Given space constraints, only a portion of the electricity requirements of industrial companies are being met by embedded installations. However, the opportunity to “wheel” electricity across the South African power transmission network has opened up the option for industrial companies to secure third-party offtake agreements with independent Power Producers and the possibility to invest in offsite electricity generation. Furthermore, the high costs of operating diesel generators and the negative effect on carbon emissions are pushing companies to consider battery energy storage systems. BESS have the added benefit for direct Eskom customers to avoid the weekday five-hour-a-day peak tariff premium windows, particularly punitive during the June to August winter months in South Africa when the cost of electricity more than doubles [22]. For South African beverage producers, the study concludes that investments in photovoltaic and battery energy storage systems will continue to take priority, given the lower perceived risks and the 17–21 % Year-1 return on capital as presented in Table 3.

Table 3. *Comparative Year-1 return on capital*

	Capex	**Year-1 cost avoided**	**Year-1 cost avoided**	**Year-1 return on capex**
	(US$)	(US$/m^2)	(US$/kW)	(%)
2020				
PV vs electricity std tariffs	883 per kW_p	33	152	17%
Solar thermal energy vs coal @ US$165/t	460 per m^2	24	40	5%
Solar thermal energy vs coal @ US$300/t	460 per m^2	45	73	10%
Heat Pump vs coal @ US$300/t	500 per kW_{th}	n/a	20	4%
BESS only vs peak tariffs + diesel gen	430 per kWh	n/a	111 per kWh	26%
2030 (2020 US$ real term)				
PV vs electricity std tariffs	490 per kW_p	49	223	46%
Solar thermal energy vs coal @ US$300/t	345 per m^2	47	73	14%
Heat Pump vs coal @ US$300/t	375 per kW_{th}	n/a	neg	neg
BESS only vs peak tariffs	250 per kWh	n/a	107 per kWh	43%

Note: PV collector production of 5.29 kWh/kW_p a day for a 670 W_{peak} 3.1 m^2 module [20]; Capex values are for large projects >1 MW [3] including setup costs and forecasts [4]; 2020 Electricity based on Eskom Megaflex variable tariffs @ ZAR16.50/US$ [22] and increasing at 3 % above inflation (or from currency devaluation); Heat pump LCOH of US$45/MWh is the lowest cost based on 24/7 operation as modelled by Saini et al. [21]; 2030 Heat Pump Capex benefit offset by higher electricity tariffs increasing at 3 % above inflation; 2020 BESS benefit based on 1240 h of peak tariff avoidance and 1000 h of diesel generator avoidance with the oil price at US$70/barrel; 2030 BESS benefit based on 1240 h peak tariff avoidance and no rolling blackouts.

While returns from solar thermal energy systems were acceptable against liquid fossil fuels, Year-1 return against coal were found to be low single digit, even at coal costs of US$165/tonne. The 2019 Solar Payback initiative made similar conclusions against coal. The study however underlined that solar thermal energy technology projects delivered positive net present values against diesel (at US$0.80/l), gas (at US$1.28/kg), and electricity (at US$0.08/kWh) with an estimated internal rate of returns of more than 20 % and payback periods of 3–5 years [2]. Since 2017, the cost of liquid fossil fuel has increased in real terms further improving these returns. Nonetheless, few projects have gone ahead. Given spatial and capital constraints, the judicious planning of solar thermal energy system requirements is advocated to address the in-situ nature of process heat generation.

For high-temperature heat pumps, the availability of low-cost power (<US$0.07/kWh) and high utilisation rates are essential for projects to be viable [21]. However, given South African

electricity average tariffs now in excess of US$0.10/kWh, high temperature heat pumps, using power from the national grid, would only make financial sense during off-peak tariffs periods (weekday nights and weekends) when the cost of electricity is around US$0.08/kWh. These market dynamics will further incentivise South Arican companies to invest in large scale PV installations.

4. Discussion

The insights developed in this study have been synthesised into a decision tree presented in Figure 2. This decision tree frames a set of boundary conditions to guide investment decisions through Stage 2 technology adoption. While the focus of this work was on the South African beverage sector, the logic is relevant to other sectors making use of steam for production or manufacturing processes in geographies with high solar irradiation and the availability of low-cost fossil fuels. Stage 2 investment decisions n renewable and sustainable energy solutions should consider the following questions.

- How intensive is the carbon emissions from the national or regional power grid?
- Can electricity be sustainably sourced for less than US$0.07/kWh, making high-temperature heat pumps an attractive investment?
- Is sufficient space and capital available to deploy PV and solar thermal collectors?

The introduction of renewable and sustainable energy solutions into the plant utility services will inevitably increase the level of complexity of energy systems [25]. Furthermore, with coal having resettled at well below US$200/tonne, motivations other than purely financial will need to guide companies, namely, to meet carbon emission reduction commitments and to avoid carbon taxes, regulations or trade restrictions. For example, the International Energy Agency's net zero emission scenario calls for a ban on new fossil fuel boilers from 2025 onwards [26]. Against this background, investments in solar thermal energy systems and high-temperature heat pumps would be driven by the following questions.

- Are solar thermal energy and heat pump technologies required to meet carbon emission commitments?
- Is thermal energy demand maintained throughout the year, ensuring optimal investment returns?
- Is the current cost of heat high, namely from electro-boilers or from burning liquid fossil fuels?
- Are there opportunities to optimise processes to operate a lower temperature, thereby improving returns from solar thermal energy and high-temperature heat pump projects?

5. Conclusions

This research demonstrates that specific sectors of the South African industry can reduce carbon emissions through continued energy efficiency initiatives and improving value-creating investments in renewable electricity generation and storage. Regarding solar thermal energy systems and high-temperature heat pumps, policy and fiscal support will be necessary to develop local capabilities and for large-scale installations to be commissioned in the short- to medium-term. These conclusions are particularly relevant to the beverage sector, which operates coal-fired steam boilers and is primarily owned by international shareholders who have made bold carbon emission reduction commitments.

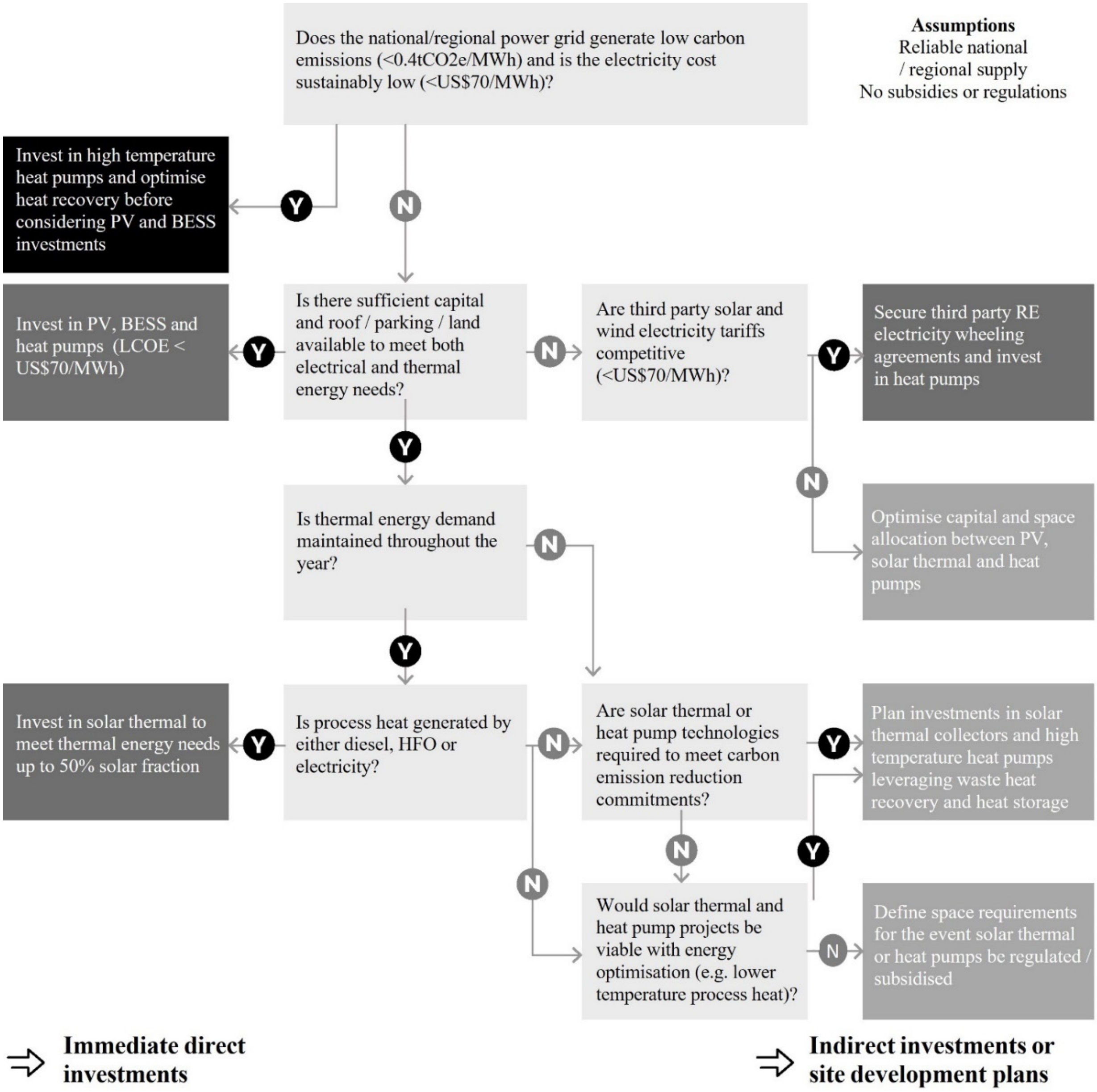

Figure 2. *Decision tree and investment priorities in renewable and sustainable energy solutions [10]*

Data Availability Statement:

Analyses data available on request.

Author Contributions:

Conceptualization, F.R.; Methodology, F.R.; Validation, F.R.; Formal analysis, F.R.; Writing—original draft preparation, F.R.; Writing—review and editing, C.M. and M.O.; Supervision, C.M. and M.O. All authors have read and agreed to the published version of the manuscript.

Conflicts of Interest: The authors declare no conflict of interest.

Funding: This research received no specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

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