A PRE-FEASIBILITY STUDY OF A CONCENTRATING SOLAR POWER SYSTEM TO OFFSET ELECTRICITY CONSUMPTION AT THE SPIER ESTATE

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Abstract

The Spier Estate – a wine estate in the Western Cape Province of South Africa – is engaged in a transition towards operating according to the principles of sustainable development. Besides changes in social and other environmental aspects, the company has set itself the goal to be carbon neutral by 2017. To this end, Spier is considering the on-site generation of electricity from renewable energy sources. This study was initiated to explore the technical and economic feasibility of a concentrating solar power plant for this purpose on the estate.

The investigation was carried out to identify the most appropriate solar thermal energy technology and the dimensions of a system that fulfils the carbon-offset requirements of the estate. In particular, potential to offset the annual electricity consumption of the currently 5 570 MWh needed at Spier was investigated using a concentrating solar power (CSP) system. Due to rising utility-provided electricity prices and the expected initial higher cost of the generated power, it was assumed that implemented efficiency measures would lead to a reduction in demand of 50% by 2017. Sufficient suitable land was identified to allow electricity production exceeding today's demand.

The outcome of this study was the recommendation of a linear Fresnel collector field without additional heat storage and a saturated steam Rankine cycle power block with evaporative wet cooling. This decision was based on the combination of the system's minimal impact on the sensitive environment and the high potential for local development. A simulation model was written to evaluate the plant performance, dimension and cost. The analysis followed a literature review of prototype system behaviour and system simulations. The direct normal irradiation (DNI) data that was used was based on calibrated satellite data. The result of the study was a levelised cost of electricity (LCOE) of R2.74[1] per kWh, which is cost competitive to the power provided by diesel generators but more expensive than current and predicted near-future utility rates. The system contains a 1.8 ha aperture area and a 2.0 MWe power block. Operating the plant as a research facility would provide significant potential for LCOE reduction with R2.01 per kWh or less (favourable funding conditions would allow for LCOE of R1.49 per kWh) appearing feasible. These results are cost competitive in comparison to a photovoltaic (PV) solution. Depending on tariff development, Eskom rates are predicted to reach a similar level between 2017 (the time of commissioning) and the year 2025. The downside of this plan is that the plant would not solely serve the purpose of electricity offsetting for Spier which may result in a reduced amount of generated electricity.

Further studies are proposed to refine the full potential of cost reduction by local development and manufacturing as well as external funding. This includes identification of suitable technology vendors for plant construction. An EIA is required to be triggered at an early stage to compensate for its long preparation.

Keywords: CSP, Concentrating Solar Power, Linear Fresnel, Sustainable Development, Spier Estate

[1] All conversion rates are calculated with R7.3 per $ and R9.5 per €. R = South African Rand (ZAR)

1. Introduction and background

The Spier Estate (hereafter referred to as Spier) is a wine estate located in the Cape Winelands region of the Western Cape Province of South Africa (see **Fig. 1**). It is actively engaged in transforming its enterprise into a company operating under the principles of sustainable development. The company's vision is to "make a real difference to society and the planet" (Spier, 2008). This statement indicates that, besides seeking a more equal and just society, Spier is committed to changing the way in which it consumes natural resources, as a source and as a sink. In this context, the short-term, self-imposed targets comprise, amongst others, plans for more environmental friendly farming, zero waste water production and a carbon neutral footprint by 2017 (Spier 2008). With more than 60% of Spier's carbon emissions caused by electricity consumption, renewable power generation provides the biggest lever towards the proposed target. The total CO_2 emissions in the business year 2007-08 was 6 055 tonnes (Spier, 2008).

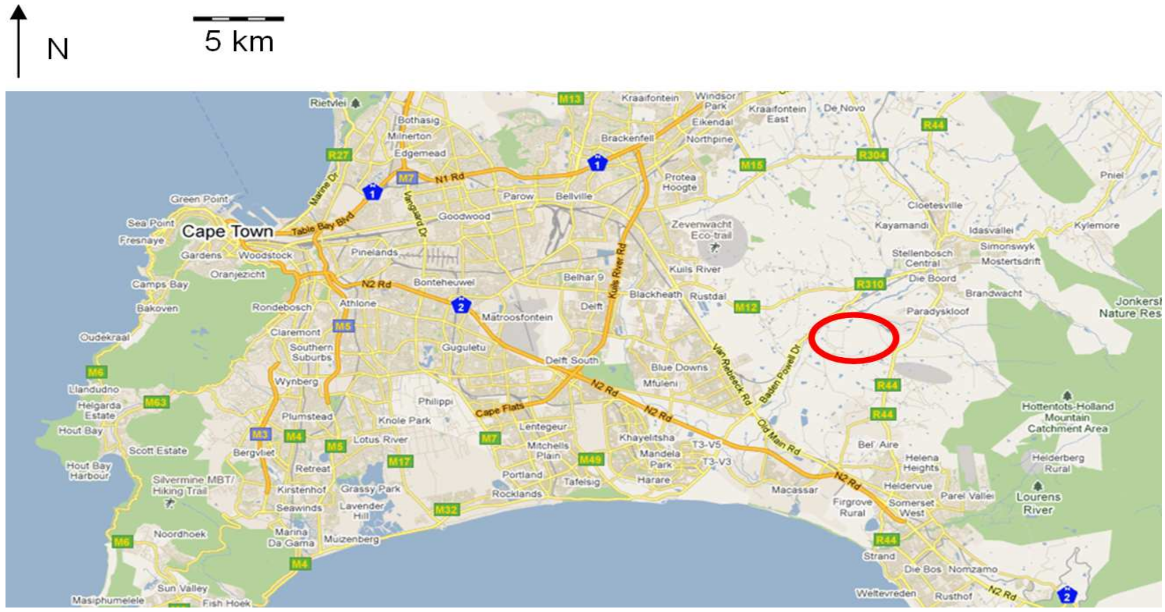

Fig. 1: Location of Spier (Google Maps, 2010)

Currently the electricity consumed by Spier is provided by South Africa's public utility Eskom, which generates more than 90% of its energy from coal. To offset its share of emissions caused by electricity, Spier is committed to generating its own electricity by means of renewable energies.

The target of this study was to identify a suitable CSP system tailored for the Spier context and evaluate the cost of construction and operation. The technologies need to conform to Spier's ethos of sustainability and South Africa's industrial environment. A CSP plant at Spier would not only represent the first operating solar thermal power plant in South Africa, but one with ideal public exposure. Spier is situated between Stellenbosch and Cape Town (two towns well known for their universities, wineries, and sought after climate) and is popular among tourists. Furthermore, due to Spier's proximity to parliament in Cape Town and Cape Town International Airport, it is easily accessible to national and international political representatives. For these reasons, a CSP plant at Spier would have high strategic and representative value.

The work in this paper was based on several underlying assumptions. Firstly, it was assumed that the City of Cape Town would buy excess electricity in times of peak production and sell back grid electricity at times of higher demand (thus working as an electricity storage system for the CSP plant at Spier). This procedure was assumed with equal prices for selling and buying. It is difficult to predict how electricity demand will behave between the time of this study and 2017; however, rapidly increasing Eskom rates for the following years are likely to boost the trend towards energy efficiency. Because Spier has not yet developed a roadmap toward their target to achieve zero emissions, there was no strategy in place to determine the extent energy efficiency measures will be deployed to reduce the need for energy production. It was agreed for this study that offsetting half of the current electricity consumption would be a sufficient target.

1.1. Electricity demand

The total electricity demand of Spier averaged at 5 570 MWh over the previous five years. This figure includes the resort, hotel, winery and farming activities. With the above mentioned assumption of 50% efficiency increase, an electricity demand of 2 785 MWh per year is expected for 2017.

1.2. General resource assessment

The Spier farm was investigated using GIS satellite data. A generated GIS map (**Fig. 2**) shows the slope over the farm and indicates grid power lines, farm roads as well as other structures (mostly houses, factory buildings and schools). The larger orange blocks are Spier's vineyards. The centre of the farm provides two areas at suitable low slope for line focusing CSP plants (parabolic trough and linear Fresnel), marked as area A and B with each measuring above 2 ha at less than 1% slope. Water access points are marked by red circles and can provide a combined capacity of up to 129 m^3/h. The Eskom grid power lines are marked in dark blue. Eskom not only allows the connection of a renewable energy production plant via a main transmission system substation or a distribution substation, it also permits a generation plant to be directly looped into an existing transmission line (ESKOM, 2010). As shown in **Fig. 2**, the suitable locations are in proximity to transmission lines. By 2012 the Eskom grid will be able to support 4 100 MW of additionally supplied electricity in the Western Cape (ESKOM, 2010). Although the National Energy Regulator of South Africa (NERSA) allows grid connection for IPPs outside the REFIT program (NERSA, 2008), the technology needs to be designed to fulfil the Distribution Code, the SA Grid Code and possibly additional codes (ESKOM, 2011).

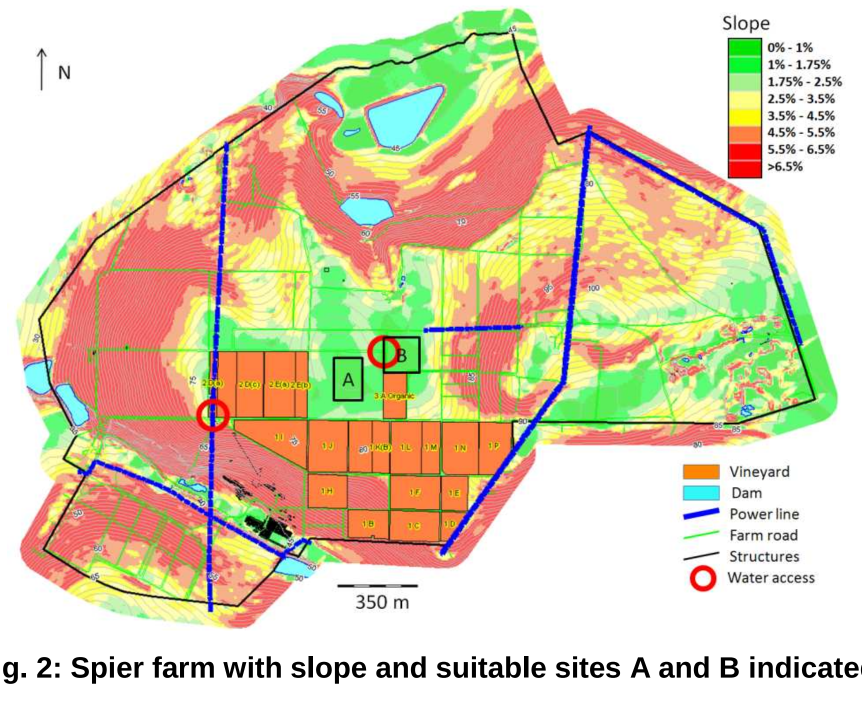

Fig. 2: Spier farm with slope and suitable sites A and B indicated

1.3. Solar resource assessment

For the analysis of the DNI, five year satellite data was used, calibrated by data gained from a ground measurement station at the University of Stellenbosch. The average annual DNI on site was calculated with 2 347.7 kWh/m^2. The calibrated hourly data of the five years was used to create a year composed of individual month, representing the average month values as closely as possible.

2. Objective

The objective of this study was to supply Spier with a pre-feasibility study on its vision to offset its electricity production by operation of a CSP plant. Part of this work was to identify and provide the following:

- Appropriate technology
- Proposed power plant configuration
- Capital cost for plant installation
- Levelised cost of electricity
- Appropriate site for the power plant
- Environmental effect
- Recommendation on the way forward

The other stimulating effects of possibly the first operating CSP plant in South Africa on marketing and sales of the Spier Estate are not discussed in this report.

3. Methodology

As a basis for research on a solar thermal power plant for the estate, an initial investigation was completed on Spier’s electricity consumption and its past development. Additionally, interviews with Spier employees were used to understand the company’s targets, approach and work done to date. The resources at the Spier farm were analysed by different satellite based tools. A solar map was developed and insolation data of the previous years investigated. Based on GIS data, the land resource was evaluated.

The selection of a suitable technology was done mainly based on a literature review of technology. A power plant simulation model was developed to extract the best sizing of the power block and the collector field. This model was written on an approach using theory and simulation results from the literature and was built on hourly steady state calculations. The simulation was verified by comparison to simulation results on a linear Fresnel prototype system as no operational experiences were available. The cost results were then analysed and, based on the findings, opportunities for cost reduction are discussed.

4. Technology identification

As stated above, development at Spier endeavours to follow the principle of sustainability. This noted effort leads to important criteria when it comes to the selection of an appropriate solar thermal power plant technology. Besides the economic matters of capital cost, LCOE and operation and maintenance (O&M) cost selection is based on:

- Potential for local development in South Africa
- Technology maturity for project realisation by 2017
- Minimal risk of soil contamination of valuable farmland
- Minimal risk of fire and explosion
- Low system complexity

The expected power plant capacity was estimated with, depending on the capacity factor, 0.9 MW to 2.9 MW.

4.1. Collector identification

In order to identify an appropriate concentrator – satisfying the above criteria – the technologies systems of parabolic dish, central receiver, parabolic trough and linear Fresnel were reviewed. The result of the review was the proposition of a linear Fresnel collector.

Parabolic dishes equipped with Stirling motors were ruled out as the 9 kW to 25 kW systems only become cost effective at large manufacturing quantity of thousands of systems (Kaltschmitt, 2007), which cannot be foreseen for the near future, with recent large scale projects being aborted (Tessera Solar, 2011; Business Wire, 2010). Central receiver systems are a more mature, and at small scale cost effective, technology. However, a power plant in the given dimensions would require a receiver tower height of approximately 35 m to 45 m (note: the 100 kW Aora-Solar system already features a tower of 30 m), which makes the technology infeasible for an application in a visually sensitive environment such as the Western Cape's Winelands.

The parabolic trough collector represents the most mature system with 354 MW installed only in the SEGS plants in California (Nixon, Dey & Davies, 2010). Parabolic trough plants have also been operated at small scale in the MW range in combination with an organic Rankine cycle (ORC) (Sinai, Fisher, 2008). To date however, the collectors are restricted to operation with synthetic oils as heat transfer fluid (HTF). HTFs are typically biphenyl/diphenyl oxide blends with an operating temperature restriction of below 400℃ and a flash point of 117℃ (DOW, 2001). A synthetic oil as HTF is not desired in case of leakage on the farm, and furthermore, the material properties provide a risk of fire. The same applies to the mentioned lower temperature ORC technology which is operated at a HTF temperature of 300℃ (NREL, 2010). The lower temperature allows for utilisation of mineral oils which also feature a lower flash point at 193℃ (Tecsia Lubricants, 2010). Another downside of the parabolic trough is the requirement of flat land as the removal of high quality farm soil is not reconcilable with the approach of sustainable development at the estate.

The other line focusing technology of linear Fresnel bypasses those matters. The technology can tolerate slopes of up to 1.75% (Nixon, Dey & Davies, 2010) and is, due to a static receiver pipe, predestined for direct steam generation (DSG) which reduces environmental risks in case of leakage. The current prototype linear Fresnel plants and the plants under construction are based on DSG (NREL, 2010; Küsgen, Küser, 2009; Häberle et al., 2002). Furthermore the technical simplicity of linear Fresnel allows high local value gain (Ford, 2008). To enhance the sustainability of this renewable energy source, linear Fresnel allows dual land usability by elevating the mirrors above the ground (Häberle et al., 2002; Scoccini, 2010) which is unique to the linear Fresnel collector due to reduced wind load on the smaller mirrors (Brost, 2010). While annual solar-to-electric efficiencies of linear Fresnel plants are estimated with 10.4% (Lerchenmüller et al., 2004) to 11.3% (Häberle et al., 2002), the sustainability aspect is further supported by it being the most efficient technology in terms of land usage.

4.2. Thermodynamic cycle

To date, four thermodynamic cycles found application in CSP (prototype) systems. Due to their working principles, the Stirling cycle and the solar Brayton cycle are not feasible in combination with a linear Fresnel collector. Owing to its functioning, the Stirling engine is not feasible in the required scale, with a 330 kW engine as the biggest reported machine (von Wedel, 2011) and high efficiencies only achieved in combination with high temperatures. The same reason rules out the solar Brayton cycle –otherwise appealing due to its requirement of no cooling water – which requires a high concentration ratio in order to efficiently achieve the required temperatures of above 1 000℃ (EC, 2005).

The remaining popular and mature cycle is the Rankine cycle (RC) with its derivatives of superheated steam RC, saturated steam RC and the ORC. The ORC can reach reasonable efficiency at low HTF temperatures (Prabhu, 2006) but the required refrigerants as working fluid (WF) are explosive and have high global warming potential (GWP) (Unitor, 2008). Further development of the ORC technology for solar thermal electricity generation seems to have stopped in commercial on-grid applications, as the small scale gives diseconomies of production for manufacturers and the high installation costs lead to a high LCOE (Orosz, 2010).

The RC with superheated steam finds application in common power plants such as parabolic trough CSP and fossil fuel coal fired power stations. In CSP applications, usually a specific part of the collector field is dedicated to steam superheating. Typical parabolic trough plants reach a steam temperature of 370℃, leading to a power block efficiency of 38% (Eck, Hennecke, 2007). Provision of a consistent superheated steam quality increases the complexity of the collector setup and requires sophisticated configuration.

The more simplified solution is the saturated steam RC which can operate at lower temperatures of 200℃ to 300℃ with efficiencies of up to 33% achieved (Mills, 2004). With utilising saturated steam, the additional superheating section of the collector becomes obsolete. A steam separator is installed prior to the turbine and in between turbine stages to maintain steam quality and turbine protection (Eck, Zarza, 2006). Typical operating conditions of saturated steam CSP plants are 250℃ to 300℃ steam temperature at 35 bar to 45 bar pressure (NREL, 2010).

The Rankine cycle with superheated steam also requires high temperatures and steam pressures which lead to higher design requirements and a complicated system configurations. The linear Fresnel system developers, Ausra and Novatec Biosol, decided to design their first prototype installations for saturated steam Rankine cycle operation. The lower system temperature and pressure of saturated steam technologies allow less complex solar field configuration and reduced risks. Therefore, the saturated steam RC is seen as a suitable combination for a linear Fresnel collector at Spier. The target of international developers is to superheated steam conditions with improved system understanding and maturity (Price 2010, Stancich, 2010).

5. System configuration

Mertins (2009) compares a simple power plant layout with a more sophisticated version. In the simple layout, the entire field is used to heat the water and generate superheated steam in the same absorber tube. The complex scheme describes a complicated system with a separated superheater stage and five reheater sections in an attempt to increase efficiency. While the more complex system offers higher solar-thermal efficiency, it does not result in considerably lower LCOE as the bottom line is less than one percent lower cost (Mertins, 2009). One has to keep in mind that a solar power plant at Spier is intended to be a newly developed plant, so unexpected errors and higher downtime than with a mature commercial plant could occur. Possibly opening the facility towards research by institutions such as Universities would lead to further downtime due to experiments. The significantly higher capital cost of the complex plant could easily lead to higher LCOE when production targets are not reached. Also, a less costly power plant would reduce investor risk. In conclusion, the simple plant layout is proposed for the Spier application.

5.1. Cooling

South Africa is a water scarce country and insufficient water is available for direct once through cooling. The water consumption for an evaporative wet cooling system – the next efficient and economically viable system – was calculated as following with T_H being the steam temperature and T_C the condenser temperature

$$\dot{V}_{water} = 2.0 \frac{l}{kWh} \cdot \frac{550°C - T_C}{T_H - T_C}$$

with 2.0 l/kWh being the reference cooling water consumption for a RC power plant operating at 550℃ steam temperature (IEA, 2010). R esults for a typical saturated steam plant with 270℃ steam temperature are 4.5 l/kWh, o r 8 978 l per hour at peak load, a quantity that can be supplied by the farm irrigation pipelines. The annual water requirement is about 12.5 million litres which represents less than 4% of Spier's total water usage. If required, this amount can be further reduced by dry cooling.

5.2. Receiver configuration

The receiver was proposed to be a single-tube system with secondary reflector. The single-tube receiver is a less complicated solution than one with multiple pipes and allows for simplified controls. It also has the potential to yield 10% more energy than the multi-tube system (Morin et al., 2006). The wide distribution of incoming beams is partially captured by the large pipe, while the passing beams are reflected by a secondary compound parabolic concentrator (CPC).

5.3. Thermal storage

Thermal storage is not envisaged for the CSP plant at Spier. The mature systems, such as molten salt storage, require high operational temperatures to avoid freezing and are only cost effective in large scale applications leading to significant increase in capital cost (Herrmann, Kelly & Price, 2004). The saturated steam system serves as small scale storage in terms of thermal inertia, and a large steam separator can allow for several minutes of continued production in case of clouds (Eck, Zarza, 2006). This form of small scale storage was seen to be suitable for a first plant in South Africa as it allows for reduced system complexity.

6. Power plant simulation

A power plant simulation was developed based on static hourly computation steps. The simulation configuration is comparable to the approach described for the DLR's greenius software (Quaschning et al., s.a.). Required feed in data includes a year of hourly DNI and hourly air temperature data, as well as the plant coordinates. The system then computes the sidereal time (Stine, Geyer, 2001) in order to compute the current position of the sun and the actual usable DNI after cosine losses.

6.1. Reflector efficiency

The position of the sun is further used to compute the reflector efficiency based on incidence angle modifiers (IAM) for longitudinal (IAM_l) and transversal (IAM_t) sun angles as follows

$$\eta(\theta_t, \theta_l) = IAM_t(\theta_t) \cdot IAM_l(\theta_l) \cdot \eta(\theta = 0)$$

With $\eta(\theta = 0)$ representing the optical system efficiency with the sun in zenith. The IAM behaviour is illustrated in Fig. 3.

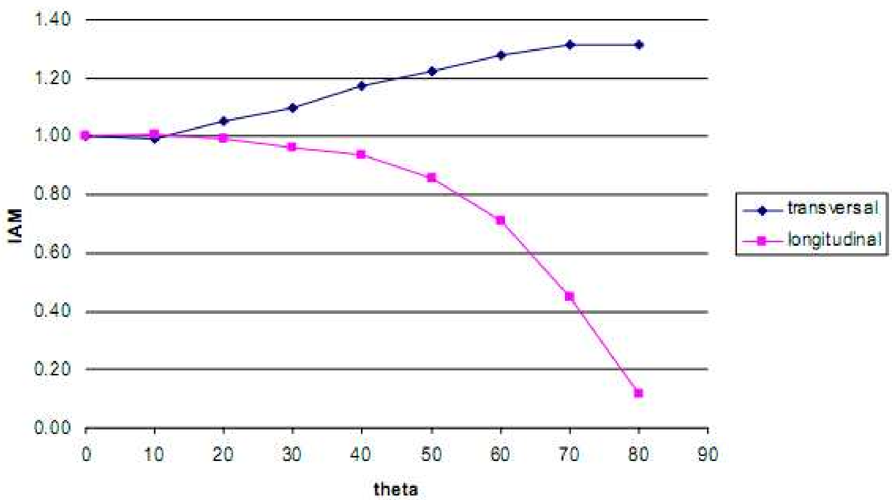

Fig. 3: Dependence of IAM of incidence angle theta of the sun beams (Häberle et al., 2002)

6.2. Receiver model

The receiver efficiency model is based on Häberle et al. (2002) description of the Solarmundo prototype. The efficiency is calculated as

$$\eta(T_{absorber}) = \eta_0 - u \cdot \frac{T_{absorber} - T_{ambient}}{E_{beam}}$$

where E_{beam} is the DNI in W/m², η_0 the optical efficiency of 61% and u the temperature dependent heat loss coefficient as calculated in equation (4) (Häberle et al., 2002).

$$u = 3.8 \cdot 10^{-4} \cdot (T_{absorber} - T_{ambient})$$

The resultant solar thermal efficiency is plotted in **Fig. 4**.

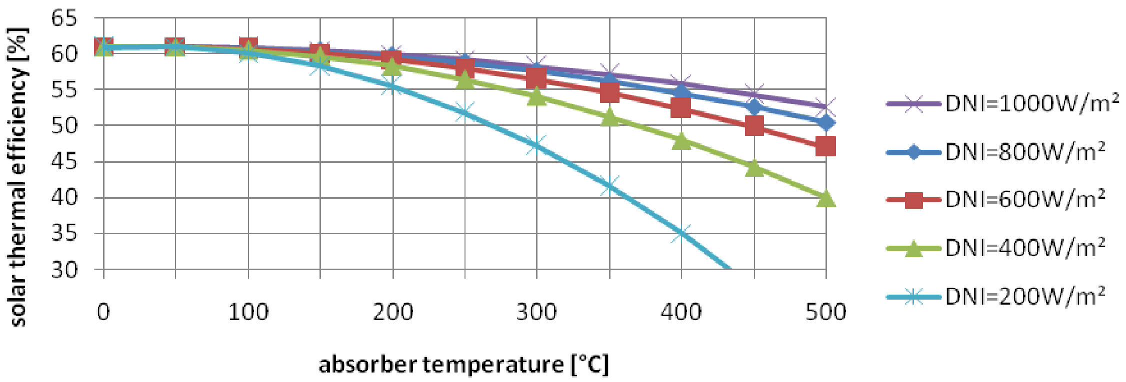

Fig. 4: Collector efficiency curve for vertical insolation

The collector is modelled as a single element. The non-linearity of the absorber efficiency suggests an investigation of the absorber pipe in segments for better accuracy. For the scope of this work, it is sufficient to see the pipe as one element at intermediate temperatures. The effect of more accurate non-linear behaviour is mostly linked to part load stages with low DNI. The effect is negligible for saturated steam application with an outlet temperature of 270℃ (Selig, 2009).

6.3. Power block model

The power block model represents the behaviour of the steam turbine. The efficiency of the turbine was based on the theoretical Chambadal-Novikov efficiency,

$$\eta_{CN} = 1 - \sqrt{\frac{T_L}{T_H}}$$

which is a modified Carnot-efficiency in order to cater for irreversibility of a real instead of ideal process. This approach is selected because no specific turbine was selected at this stage of the project. As the output of a solar thermal power plant is dependent on intermittent insolation, a sufficient steam supply to operate the steam turbine at the design point cannot be guaranteed. For that reason, the part load behaviour of a saturated steam Rankine cycle is discussed and implemented into the simulation. The part load behaviour is a simplified model, based on Eck and Zarza (2006) and Mertins (2009) as shown in **Fig. 5**.

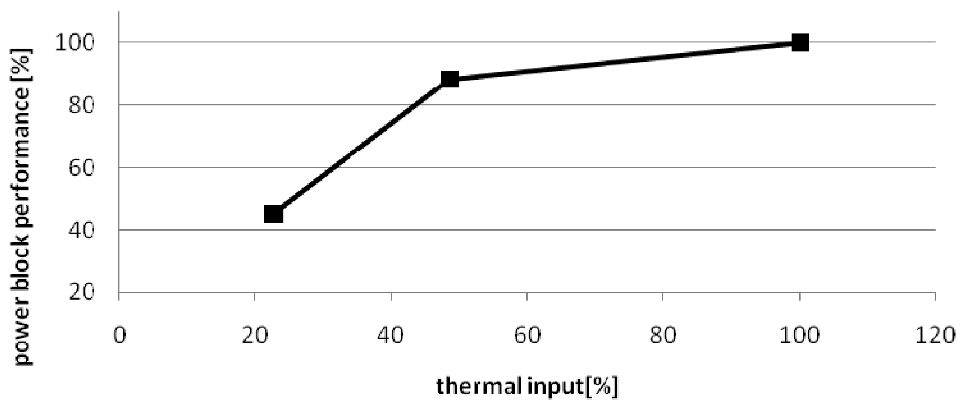

Fig. 5: Power block performance over thermal input

The turbine shut down is programmed with 30% of thermal as a typical value used in the literature (Häberle et al., 2002; Eck, Hennecke, 2007; Eck, Zarza, 2006; Mertins 2009).

6.4. Further assumptions

The simulation is supplied with further assumptions on generator efficiency of 96% (Eck, Zarza, 2006), run up phase of the plant of 1 h, parasitic losses of 9% (Pitz-Paal, 2007) and piping losses as calculated on physical background, described in Mills (1995).

6.5. Economic modelling

The benchmark for electricity producing technologies is the LCOE. This number provides a basis for comparison of technologies by giving costs per kWh of produced electricity. The LCOE is calculated as following the NREL guideline (Short, Packey & Holt, 1995)

$$LCOE = \frac{CRF \cdot k_{invest} + k_{O\&M} + k_{fuel}}{E_{net}}$$

with the capital recovery factor (*CRF*) calculated as

$$CRF = \frac{k_d \cdot (1 + k_d)^n}{(1 + k_d)^n - 1} + k_{insurance}$$

with k_{invest} as the total investment of the plant in ZAR, $k_{O\&M}$ the annual operation and maintenance cost in percent of direct investment and k_{fuel} the annual fuel cost in ZAR, which is zero in case of a solar only plant. E_{net} is the annual net electricity output in kWh and k_d the debt interest rate. The LCOE can be calculated with n representing depreciation period in years (hence the planned lifetime of the power plant) and $k_{insurance}$ the annual insurance rate in percent of direct investment. Included were capital costs for the power block, R3 990 per kW for simple once through saturated steam plant (Eck, Zarza, 2006), and for the collector, R1 140 per m², which was estimated for developing countries (Lerchenmüller et al., 2004).

6.6. Simulation verification

The simulation was tested on the data available (NREL, 2010; Selig, 2009) for the PE1 1.4 MW linear Fresnel prototype in Spain. The deviation between the above model and the data given in the sources was 2.2%. This indicated that the analysis was acceptable for a pre-feasibility investigation.

7. Results & discussion

7.1. Plant dimensions

The resulting proposed power plant dimensions are based on providing the lowest LCOE for the saturated steam linear Fresnel system operating at 270℃ steam temperature. The optimum point has been calculated with R2.01 per kWh at a plant lifetime of 25 years (8% debt interest rate, 1% insurance rate, R330 per kW O&M cost (based on (Häberle et al., 2002)). The setup requires a collector field of 17 828 m² and a power block of 2.0 MW capacity. The resulting annual net solar to electric efficiency was calculated with 6.7%[2]. The capital cost was computed with R68.4 million (LCOE of R2.74 per kWh) for a newly developed turnkey system (first plant). Assuming a research based approach with additional prototyping stage, the costs of the solar field were multiplied by a factor of two to account for the fact that the system is not a “third plant” but a first plant/prototype requiring additional effort in system production, understanding and debugging leading to capital cost of R50.3 million and LCOE of R2.01 per kWh.

With an assumed collector width of 24 m, the total field length is 743 m leaving a variety of opportunities to construct the plant, as shown in **Fig. 6**. As it can be seen, sufficient land is available at usable slopes.

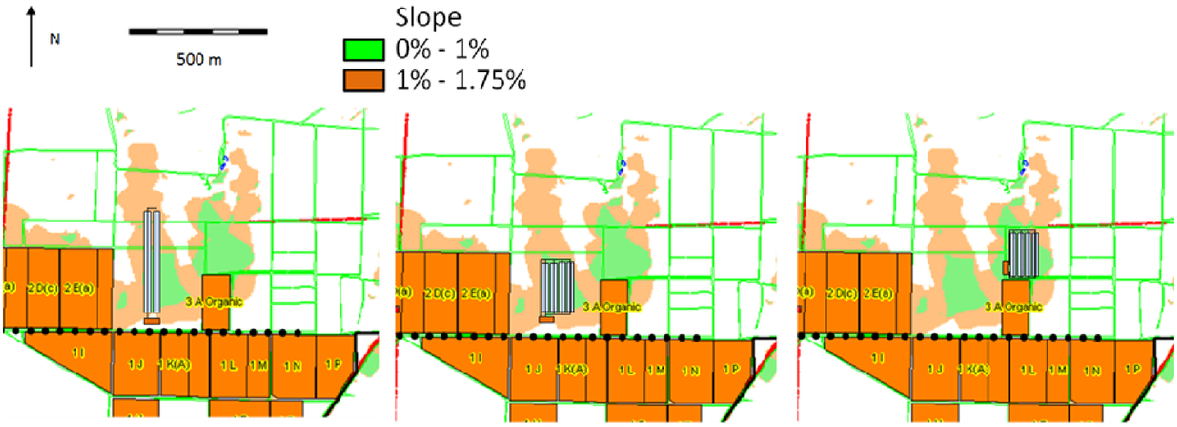

Fig. 6: Possible linear Fresnel plant setup with two lines (left) and four lines (middle and right)

7.2. Cost analysis

The sensitivity of the LCOE is shown in **Fig. 7**. A good research loan of 4% interest rate can potentially lead LCOE to drop below R1.5 per kWh. For comparison in 2010 Spier paid an average rate of R0.43 per kWh for utility provided electricity. However, the current increase in Eskom rates is radical with about 25% per year which Eskom assumed to get permitted until 2015 (Reuters, 2010). Further tariff increase with inflation rate until the year of plant commissioning in 2017 leads to a minimal utility tariff of R1.29 per kWh with higher rates possible. An ongoing increase of utility rates by 25% would lead to equal LCOE to Eskom rate at the year of commissioning in 2017.

The potential for cost reduction was investigated by a sensitivity analysis as illustrated in **Fig. 7**. It can be seen that capital cost and interest rates present the highest levers for cost reduction. Due to the high distance to the winery and the hotel facilities (including

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[2] $\eta = \frac{P_{year}}{\Sigma DNI \cdot A}$ where P_{year} is the annual electricity production and A the collector aperture area.

crossings of farm roads and rivers), cogeneration was not seen as a feasible alternative to reduce cost.

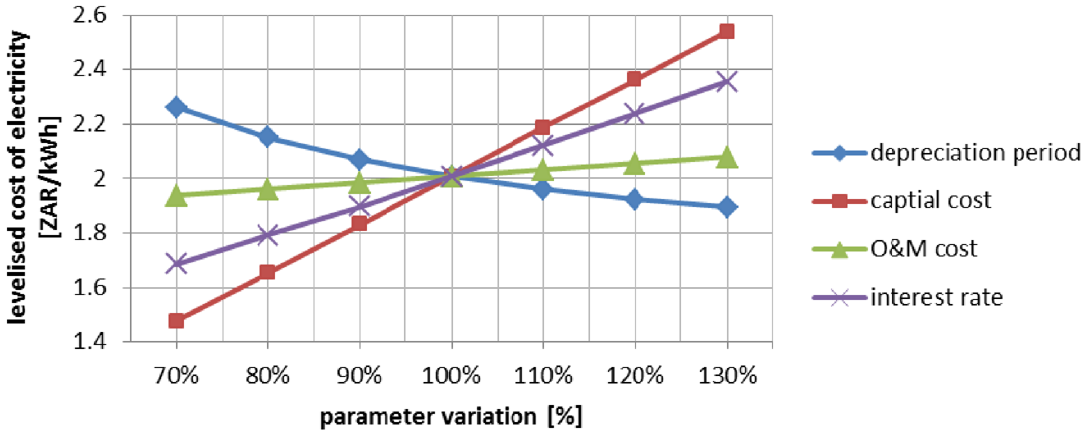

Fig. 7: Sensitivity analysis on proposed power plant

Conclusion and further work

A system fitting the requirements of a plant operating in a sustainable environment on a farm was found using the direct steam generating linear Fresnel technology. Due to the possibility of dual land usage underneath the mirrors for farming, the technology could further strengthen the sustainable approach at Spier. The site offers sufficient land for the collector field and insolation of strength superior to CSP locations in Spain. Water supply was also found to be sufficiently available.

The LCOE was identified with R2.01 per kWh. This is higher, by almost a factor of five, than the current R0.43 per kWh. Nevertheless, the reach of grid parity by 2017, the year of scheduled commissioning, is possible due to radically increasing utility rates. LCOE reduction would be achieved by allowing the university to utilise the plant for research purposes. With R49 million, the capital costs involved would be high, but national and international funds and grants for research facilities could provide potential for a cost drop. The effect of a low interest rate of 4% would lead to LCOE reduction to R1.49 per kWh. Additional research could be done on the land usage underneath the mirror field for higher attractiveness of the project. The plant sizing on cost estimation was based on a simulation model built on physics and literature results. Its applicability was verified with a single validation point – a prototype plant in Spain. Further development of the model is possible and would aid higher accuracy and allow more detailed plant sizing.

The Spier location offers a unique environment for a demonstration plant with its high public exposure and close access to Cape Town. This attractive location could further increase access ability to funding. A basic CSP plant as proposed for Spier would provide good potential as a first research station for institutions on their way to develop sophisticated utility scale projects. However, it is important to understand the dimensions and the environmental impact, especially visual, of the plant. An evaluation would be needed if such a prominent structure would fit into the Spier philosophy. An investigation on construction regulation and procedures also would be required to identify risks of project refusal.

The findings suggest that a CSP plant at Spier will be economically feasible and will be capable of meeting the company's targets of carbon offsetting. It is recommended that the solution should be further pursued, including a detailed study of alternatives. The proposed way forward is a full scale feasibility study, including investigation of the domestic manufacturing industry and a detailed electricity demand prediction at Spier. The proposed linear Fresnel technology is economically competitive to an alternative PV solution. The linear Fresnel system is estimated with R24 500 per kW installed, while PV is predicted with R25 000 to R30 000 per kW for large scale applications. A CRSES developed PV tool predicts R1.99 per kWh (financed under the same conditions as the CSP plant as described in Section 5).

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