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# Large-scale Rollout of Concentrating Solar Power in South Africa

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September 2009

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## ISDA Project

This paper is part of the project, International Support for Domestic Action (ISDA). Case studies from five developing countries assess the barriers and drivers of actions that shift individual sectors onto low-carbon growth paths. Five cross-cutting papers then explore how international financial mechanisms, technology cooperation, IP aspects and suitable monitoring and reporting arrangements can enhance the scale, scope and speed of their implementation. The individual reports are available at <http://climatestrategies.org/our-reports/category/43.html>.

## Acknowledgements

The authors wish to thank, without implicating, the many useful comments and assistance from workshop and survey participants. We wish to thank the LTMS team.

## Publisher

Climate Strategies 2009

For citation and reprints, please contact the publisher Climate Strategies



*Parabolic trough*



*Linear Fresnel*



*Dish Stirling*



*Central receivers*

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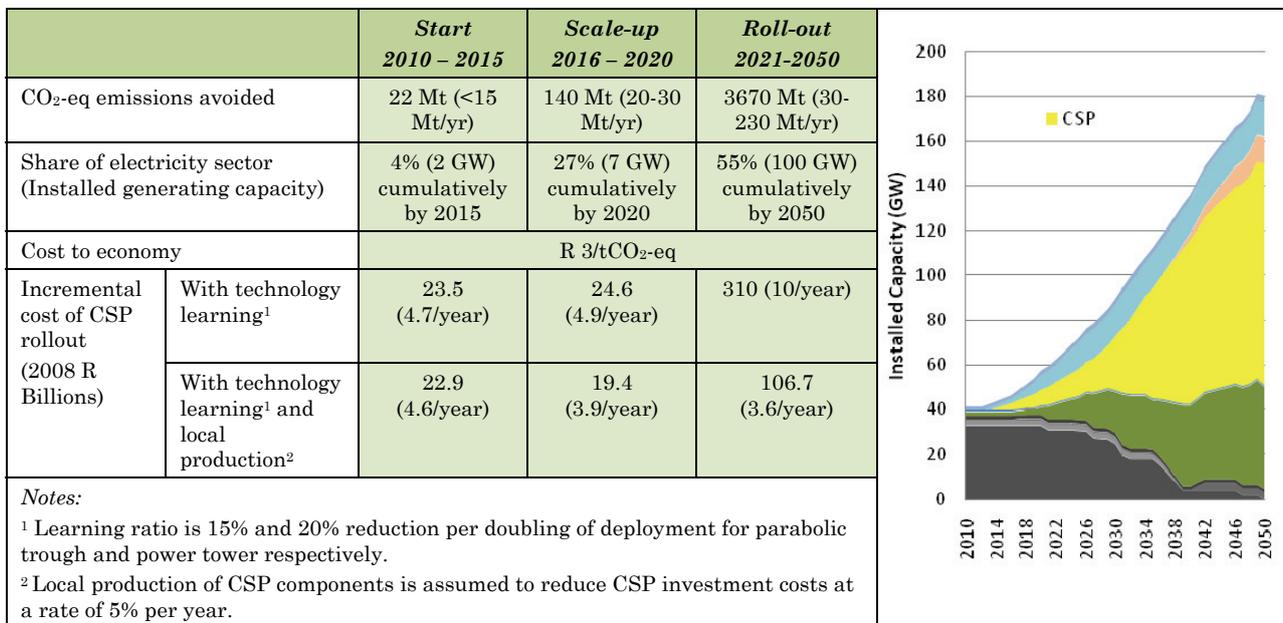
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## Executive Summary

### Abstract

As part of Climate Strategies 'International Support for Domestic Climate Policies' project this paper assesses the large-scale rollout of CSP in South Africa. Described as a Nationally Appropriate Mitigation Action (NAMA), the scale of CSP deployment is determined, and the amount of greenhouse gas emissions saved and incremental investment costs are estimated in line with the modelling outcomes of the Long-Term Mitigation Scenarios (LTMS) for South Africa (Chapter 2). Based on a stakeholder workshop held in May 2009 the drivers in support of the rollout of CSP are described, in particular the recently established Renewable Energy Feed-In Tariff (REFIT), and three major barriers relating to technology, regulation and infrastructure are highlighted (Chapter 3). The paper further assesses options of international support in light of the climate change negotiations to overcome the barriers identified (Chapter 4), and lastly, it assesses indicators that may be successful in monitoring the large-scale rollout of CSP (Chapter 5).

In this study we define the 'large-scale' rollout of CSP in line with the more optimistic 'renewables extended with learning' projection modelled in the LTMS of South Africa, as depicted in the figure below. The rollout is characterised by three phases: during the initial 'Start' phase, from 2010 to 2015, 2 GW of CSP capacity is constructed, from 2016 to 2020 the 'Scale-up' phase results in a 7 GW CSP capacity, and by the completion of the 'Rollout' phase (2021 to 2050) 100GW of CSP capacity should be established. This could result in 3,850 Mt CO<sub>2</sub>-eq saved over the period 2010-2050 and would require an incremental cost of R 4.7-10 billion per year if CSP technologies experience learning rates of 15 to 20% per year, and less (R 3.6-4.6 billion per year) if the country manages to create a local supply of CSP components.



### Needs: Drivers and Barriers

A number of technology, infrastructure, regulatory and industry barriers would have to be overcome for the country to achieve the rollout of CSP envisioned. The three main

barriers identified include a lack of capacity to innovate, whereby in the ‘Start’ phase technology would have to be imported, and more storage technology would have to be developed. Towards the ‘Scale-up’ phase South African-specific technology would have to be developed and by ‘Rollout’, technological innovations, such as water-saving technology would have to be implemented.

Barriers relating to South Africa’s low capacity to regulate are mainly linked to the recently established REFIT. There are still a number of issues that need to be resolved before private sector agents can fully engage in the CSP rollout in South Africa, in particular the question of whether REFIT will be capped and how the power purchase agreements will be administered. The Renewable Energy Purchase Office also seems to already be ‘oversubscribed’.

	<i>Start (2010-2015)</i>	<i>Scale-up (2016-2020)</i>	<i>Roll-out (2021-2050)</i>
<b>Innovate</b>	Import technology Storage technology Eskom cooperation	SA specific technology	Water-saving technology
<b>Regulate</b>	REFIT untested	REFIT expiry unknown	SAPP day-ahead market
<b>Operate</b>	Initial grid expansion	Increased grid expansion Grid-wide storage	Massive grid expansion Water-stress
<b>Manufacture</b>	Risky investment: ‘Test Plant’ – no market outlook	Lacking skills for local content	
<b>Finance</b>	Grants from Climate Change fund	Investment facilitation; NAMA crediting from Climate Change fund & loans	Equity, mezzanine, debt, insurance & carbon-based

Operational barriers feature the large-scale need for grid expansion in South Africa, to link areas that are suitable for CSP development, such as in the north-western parts of the country, to the main electricity consumer centres. South Africa is fortunate to have the skills necessary to achieve this, though the financing of it may be a major barrier. The overriding barrier noted, is the financial requirement for the rollout of CSP, with which most of the above mentioned barriers could be overcome. South Africa could greatly benefit from international financial support to alleviate the financial hurdle.

### **Options for addressing barriers**

Overcoming the innovation (technology) barriers would require support for the deployment of CSP plants that use non-commercially available technology, such as Eskom’s proposed 100MW plant. Initially the international financial support could be designed with 50% risk-sharing for the first 100 MW plant and 25% risk-sharing for four more 100MW plants, which would cost an estimated R10 billion. Later, agreements on bilateral R&D collaboration could be forged and CSP technology discoveries could be shared under the climate change technology transfer agreements. International support at these stages could be in proportion to the incremental cost, which at 50% would be just over R 2 billion annually for 2015-2020 and R 2-5 billion annually for 2021-2050.

Barriers associated with the REFIT would largely be dealt with domestically in the short-term, once the mechanism has been tested by an independent project developer and guidelines are finalised. International support to the REPA could be in the form of training 100 staff for 5 years at an annual cost of R 50 billion, and support could be directed at completing countrywide feasibility studies for CSP at a possible cost of R 240 million annually. Furthermore the international community could contribute to the estimated cost of REFIT.

The grid-expansion necessary to facilitate the large-sale rollout is predicted to be substantial. The north-west of South Africa would have to be linked to the ‘backbone’ grid of South Africa, which may be achieved through the construction of a transmission line in 2010-2015, five more in 2016-2020 and 60 thereafter till 2050. The international community could support by financing the incremental costs incurred.

	<i>Start (2010 – 2015)</i>	<i>Scale-up (2016 – 2020)</i>	<i>Roll-out (2021-2050)</i>
<b>Technology innovation - domestic</b>	First plants online by 2014 Eskom innovate ‘test plant’	R,D&D for SA specific technology	Water-saving tech
<b>Technology innovation - international</b>	R 10 billion	R 2 billion annually	R 2-5 billion annually
<b>REFIT – domestic</b>	Enhance REPA capacity Facilitate feasibility studies	REFIT support	
<b>REFIT – international</b>	R 50 million annually & R 240 million annually	Incremental cumulative cost of REFIT (R20-90 billion annually)	
<b>Grid-expansion – domestic</b>	Linking north-west to grid ‘backbone’	Five additional transmission lines	Grid focal shift to north-west
<b>Grid-expansion – international</b>	Incremental costs of grid expansion		

### Suitable indicators

A number of suitable indicators to monitor the success of achieving the large-scale rollout of CSP can be identified. Of all the stakeholder responses, the outcome measure of electricity produced from CSP plants was ranked as the most successful. ‘CSP plant licences issued’, ‘CSP plants under construction’ and ‘committed finance to CSP developments’ indicators were also ranked highly.

In addition other effectiveness measures include a process indicator measuring the cost reduction in electricity supplied from CSP – a measure that would highlight the effectiveness of the rollout programme in competing with nuclear and coal generated electricity. An input indicator assessing the reliability of the REFIT in South Africa would help overcome the barriers relating to regulation. Lastly, it was noted that a process indicator of grid-readiness would help facilitate the rollout of CSP, in that grid planning bottlenecks would be identified and overcome.

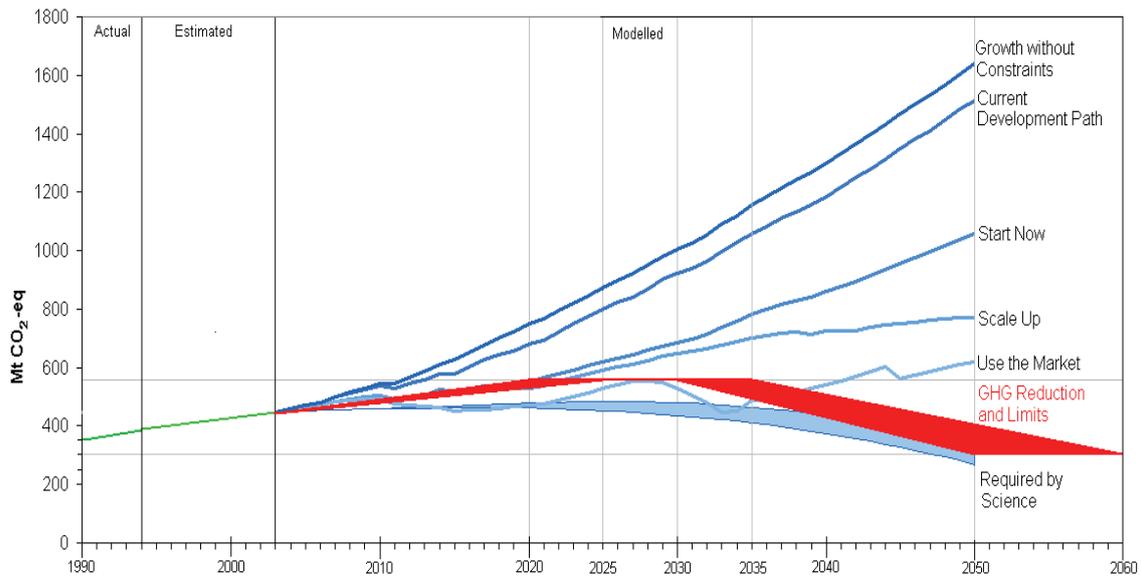
# 1. Context for South Africa's Domestic Action: Large-Scale Rollout of Concentrating Solar Power

On 26 March 2009, the National Energy Regulator of South Africa (Nersa) approved the Renewable Energy Feed-In Tariff (REFIT) Guidelines (Nersa 2009). REFIT provides Power Purchase Agreements for R2.10 per kWh to concentrating solar power (CSP) developments in South Africa, a higher rate than for other renewable energy technologies for electricity generation. Already the country has seen some climate change related financing through the Clean Development Mechanism under the Kyoto Protocol, and future (post-2012) financing could significantly scale-up the financial and technological resources potentially available to South Africa's renewable energy projects, including CSP developments.

South Africa has among some of the best solar resources in the world; the country has already committed itself to a target of 10,000GWh of renewable energy by 2013 (DME 2003). At the Department of Minerals and Energy (DME) Renewable Energy Summit in March 2009, the then Energy Minister indicated that more ambitious targets 'for the period 2013 and 2018 could be set in the range of six to nine percent and nine to fifteen percent of the current capacity respectively' (DME 2009). This may result in a renewable energy target of 14,500 – 22,000GWh for 2013 and 22,000 – 36,000GWh for 2018. By pursuing a higher renewable energy target, which would be dominated by large-scale rollout of CSP, South Africa's GHG emissions may (if other mitigation actions are also pursued) peak between 2020-2025, then stabilise for ten years, and decline in absolute terms thereafter – a target aligned with the mitigation actions required to prevent dangerous climate change (see figure 1).

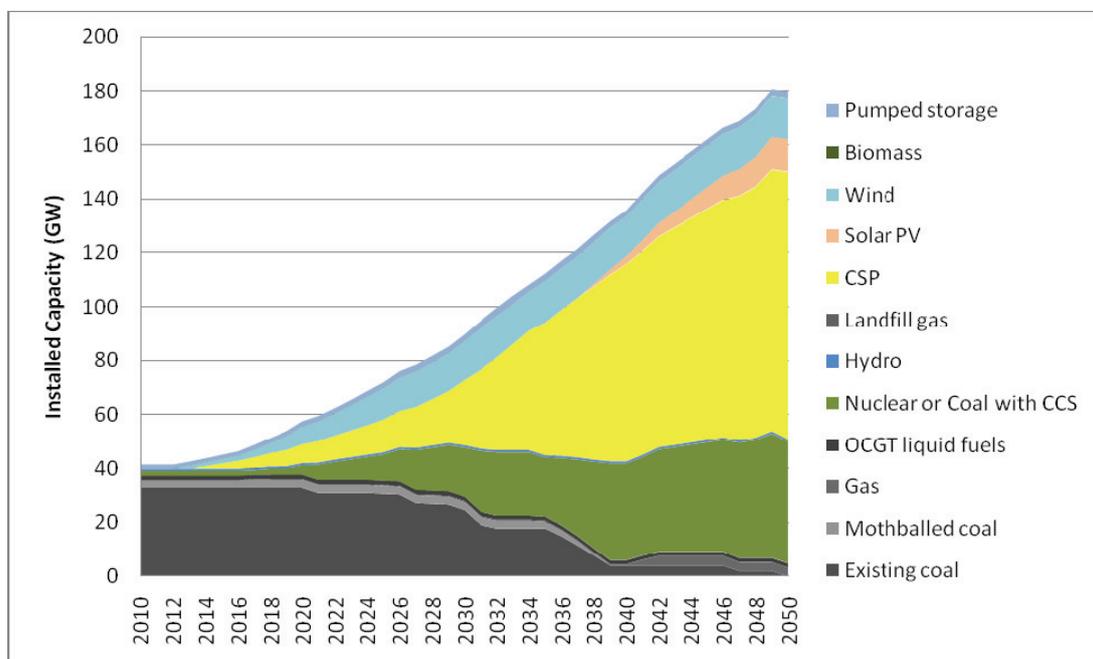
According to South Africa's Long-term Mitigation Scenarios (LTMS), one of South Africa's main carbon mitigation options lies in shifting its electricity generation away from coal (Winkler 2007). Under the 'Current Development Plans' (CDP) scenario of the LTMS, South Africa's electricity continues to be overwhelmingly generated from coal and to a lesser extent from nuclear; this scenario assumes that existing government policy is implemented, including the energy efficiency target of reducing final energy demand by 15% below projected levels by 2015 and the renewable energy target of 10,000GWh by 2013. Eskom's Integrated Strategic Energy Plan offers a similar strategy for coal and nuclear; stating that by 2026 the generation mix will be made up of less than 70% coal, approximately 25% nuclear and 2% renewables (Eskom 2008).

Alternatively, the country can choose to mitigate greenhouse gases further (GHGs) by encouraging the development of renewable electricity, nuclear power, or a combination of both. This would require a dramatic shift in the country's electricity generation plans, but could result in a near zero-carbon electricity sector by 2050, avoiding about 8,300MtCO<sub>2e</sub> (Winkler 2007). Even though this would be a substantial carbon mitigation 'wedge', in isolation it would not be enough to reverse GHG emission growth in South Africa. Other mitigation options would need to be encouraged for the country to reach the target of reaching a GHG emissions peak between 2020 – 2025; this target is expressed by the 'Use the market' and 'Reach for the goal' strategic options presented in the LTMS (see Figure 1). Only by pursuing all four strategic options indicated in Figure 1 will South Africa be able to deviate from its current development path (CDP) to achieve the GHG emission reductions necessary to meet scientific mitigation requirements.



**Figure 1.** Long Term Emission Scenarios for South Africa (Source: Scenario Building Team 2007)

Among the different long-term scenarios presented for South Africa, the ‘Start now’ option requires that 27% of electricity to be generated from nuclear and renewables by 2030. The ‘Scale up’ strategic option is more ambitious, requiring at least 50% of electricity generation (kWh) to come from renewables and the rest from nuclear or coal with carbon capture and sequestration (CCS), thereby almost making the electricity sector carbon-neutral by 2050. According to the LTMS achieving renewable electricity supply targets of at least 27% by 2030 and 50% by 2050 would require a major rollout of CSP generation capacity (see Figure 2).



**Figure 2.** Electricity generation capacity projected for South Africa to achieve near carbon-neutral electricity generation by 2050. (Source: Winkler 2007)

CSP is a major low emissions technology that is rapidly moving forward along the innovation chain from successful pilot plants, through industrial-size demonstration, to mass commercial deployment. Despite technical validation in the 1970s, existing CSP

installations by the end of 2008 barely totalled over 400MW worldwide. Although there are numerous CSP projects in the planning process, many, such as the Club of Rome's Desertec (Clean Power from Deserts, see DLR 2005), have yet to result in investor decisions; in June 2009 there were almost 10GW of projects in the pipeline worldwide, only 1.4GW of which have secured finance<sup>1</sup>. Nonetheless, policies that support incremental scale improvements, technology innovation and cost discovery could result in CSP meeting 7% of global power needs by 2030 and 25% by 2050 (Richter et al. 2009).

With this in mind this paper sets out to investigate the large-scale rollout of CSP in South Africa, building on the first phase of the 'International Support for Domestic Climate Policies' project under Climate Strategies<sup>2</sup>. Initially the paper provides a description of the large-scale rollout of CSP in South Africa, providing a quantitative assessment of GHG emissions mitigation, which CSP technologies should be considered and what this may cost. Then the paper assesses the drivers behind such an action, the barriers that need to be overcome, and the international support that may be required to overcome these barriers. In section 5, the paper develops a set of indicators that could be useful in assessing the success of South Africa's large-scale rollout of CSP.

## 1.1 The State of CSP Technology

CSP has four major technology designs, with a total of 430 MW in service and more than 8.7 GW capacity planned (Table 1).

1. *Parabolic troughs* are systems whereby special mirrors shaped as linear parabolas reflect the sun's rays toward an absorption tube suspended at the centre of the trough's arc. The concentrated sunlight heats fluid inside the tube, generally a synthetic oil up to 400°C, which then travels to a collecting unit, where it heats water and generates steam to power turbines (Environment America 2008). The troughs are typically arrayed on a north-south axis and track the sun throughout the day. The Solar Thermal Energy Generation (STEG) plants in the US demonstrate the longest track record of this technology (17 years), which continues to gain support today, with 395 MW of capacity in service and almost an additional 5 000 MW capacity in planning.
2. *Concentrating dish/Stirling engines* are shaped like a satellite dish. They focus light rays on a single area suspended above the bowl of mirrors, where temperatures up to 750°C (Greenpeace et al. 2005) heat a thermal fluid, which in turn runs a small steam or Stirling engine. Although they have in the past been considered more useful as independent, off-grid units, particularly in remote and developing areas, the recent developments announced by Stirling Energy Systems, who plan to build up to 1.75 GW of solar farms in the California desert, indicate their additional attractiveness for connection to the national grid. Unlike the other CSP technologies, Stirling engines do not need water for cooling, though water is still necessary to clean the mirrors.
3. *Central receivers/towers* use freestanding heliostats (tracking mirrors) in an array to independently track the sun and focus its rays onto a central tower. Temperatures of up to 650°C are achieved, they require less land than parabolic troughs, and because the heliostats used as reflectors are nearly flat, their manufacturing costs are relatively low. Demonstration central receiver plants have been built, beginning with a 0.5 MW test plant in 1981 in Spain and followed by others in France, Italy, Japan, Russia and the USA (Environment America 2008). The first commercial plant, an 11 MW central receiver plant developed by Abengoa Solar, went online in March 2007 to deliver power to the city of Seville in Spain. Abengoa has since built a second 22MW plant, with an additional 600MW capacity in the planning process.

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<sup>1</sup> According to the Major Economies Forum project outline *Accelerating demonstration and deployment of Concentrating Solar Power in the lead up to Copenhagen*, MEF 9 July 2009.

<sup>2</sup> ISDCP Project online at: <http://www.climatestrategies.org/our-reports/category/40.html>

4. *Linear Fresnel reflectors (LFRs)* use long rows of nearly flat, rotating mirrors to reflect light at absorbers elevated above the plane of the mirrors. Different absorbers use either a thermal transfer fluid or directly generate steam to power turbines. While not as efficient as parabolic dishes and troughs or central receivers, LFRs offer many potential cost and structural advantages. Like central receivers, their mirrors are made of standard glass in large, flat sheets, which require fewer steel supports than parabolic troughs and can be cheaply mass-produced. The mirrors' flat-shape renders them more resistant to wind damage and makes them easier to clean (Clean Energy Action 2007). LFRs' fixed absorbers do not have moving joints, which simplify fabrication and avoid the cost and maintenance challenges presented by joints in parabolic trough arrays, and the recent development of the Compact Linear Fresnel Reflector (CLFR) has removed the problem of shadows (Mills & Morrison 1997). Demonstration LFR arrays have been built in Australia, Spain and Belgium and in the US (Environment America, 2008). Originally conceived in the early 1990s by Sydney University, CLFR was first commercialised in 2004 in Australia and is now being refined and built on a large scale, with about 1500 MW of capacity in the planning.

<i>Tech-nology</i>	<i>In service capacity (MW)</i>	<i>Planned capacity (MW)</i>	<i>Total (MW)</i>	<i>Leading locations (including planned installations)</i>	<i>Companies</i>
Trough	395	4 967	5 362	US, Spain, China, Israel, Australia, Morocco, Greece, UAE, Algeria, India, Mexico, Iran	Acconia, Iberdrola, Luz (Solel), SkyFuel, Solar Millenium, Solucar
CLFR	1	1 489	1 490	US, Libya	Ausra, SkyFuel
Tower	33	579	612	Spain, US, South Africa, Egypt	BrightSource Energy, Sener
Dish	1	1 750	1 751	US	Stirling Energy Systems
<b>Total</b>	<b>430</b>	<b>8 785</b>	<b>9 215</b>		

**Table 1.** Summary of CSP Developments to 2008 (Source: Stanley et al. 2009 and Spellmann et al. 2009)

CSP technology is well along the innovation cycle, particularly for parabolic trough, which has the most deployment plants in action to date. The other major CSP technologies, CLFR and central receivers, are being advanced by companies such as Ausra, SkyFuel, BrightSource Energy and Sener. Eskom has been pursuing the development of a 100MW central receiver design CSP plant since 2001. By late 2008 a decision on the project had not been made, as Eskom was looking for partners who would be willing to contribute investment in the range of \$50-200 million. The proposed tower plant has 14 hours of storage, which would allow for 24 hour electricity generation over summer solstice.

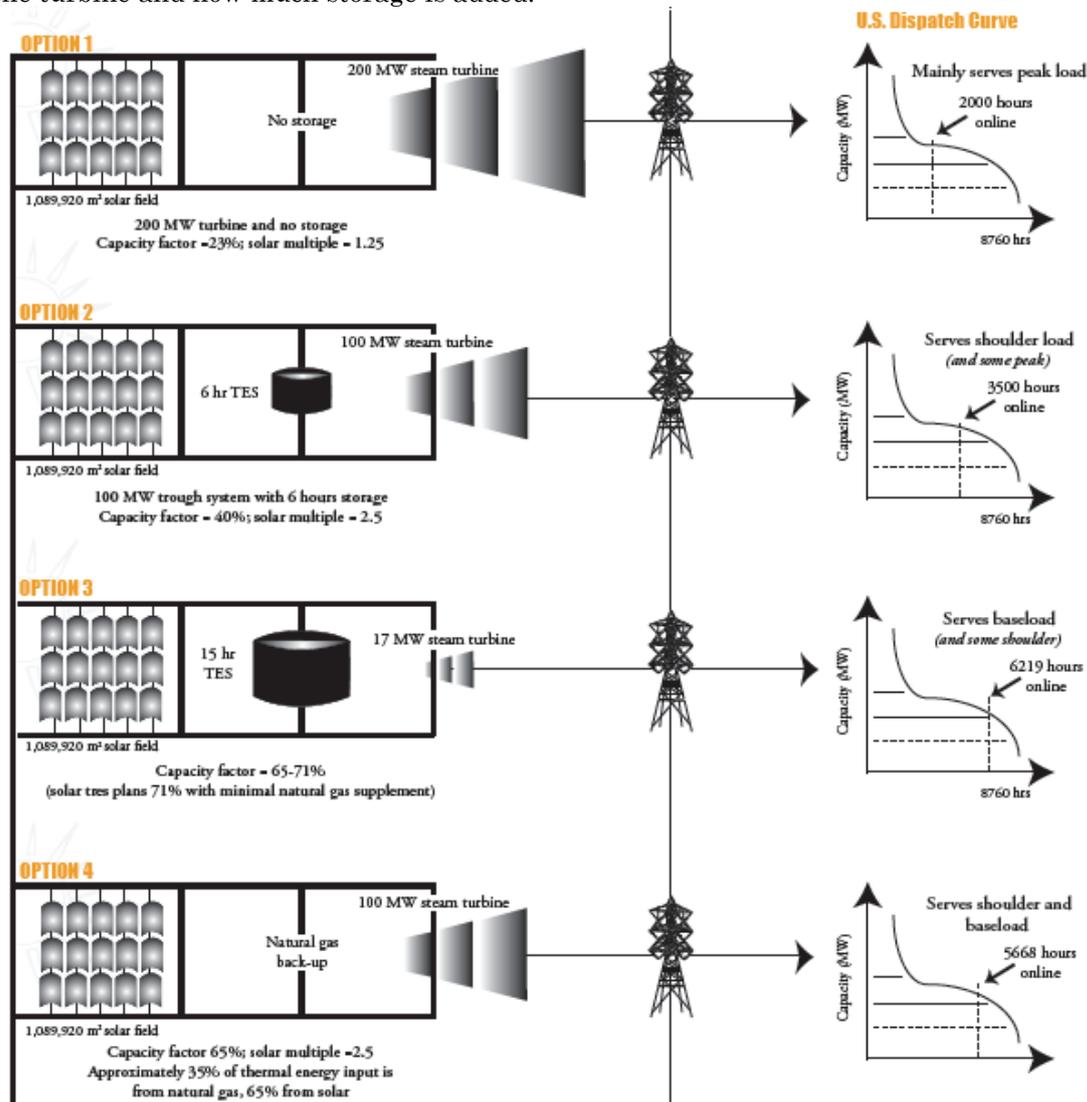
The plant is expected to require about 8,000 heliostats made up of drivers and low-iron glass that account for 40% of the investments costs, some 25,000 tonnes of salt as a heat transfer fluid, 300,000 m<sup>3</sup> of water per year and a 20m high receiver with high nickel alloy tubes, which are heated to 570°C (Van Heerden, 2009). Eskom's proposition is ambitious as the largest generation capacity for this technology, (which used a parabolic trough design rather than the central receiver design proposed by Eskom), constructed to date is only 22MW and achieved only seven hours of commercial storage capabilities.

## 1.2 CSP Designs

A number of alternative CSP plant configurations can be deployed. As shown in Figure 3, without any storage (Figure 3, Option 1), the field could supply enough energy to power a

200 MW turbine, which would operate at full capacity during the sunny hours of the day. However, with the addition of six hours of storage (Figure 6, Option 2), part of the energy from the field would be stored at any given time, so the turbine would not be as large (100 MW) but would run during more hours of the day. Option 3 (Figure 6) illustrates a tower plant with storage, such as the Solar Tres plant in Seville, Spain, which would have 15 hours of storage and a small amount of gas hybridization. With such a configuration, the plant should be able to operate all day and night in the summer. Option 4 is a solar–natural gas hybrid plant that achieves a capacity factor close to 65 percent by using natural gas for 35 percent of its energy input.

As CSP plants gain their energy from the sun they can have some reliability disadvantages similar to other renewables, though these can be minimised through the inclusion of storage or hybridisation (integration of fossil fuels as a backup generation source). These options would provide a buffer against cloudy periods, extend generation to cover peak load, and enable a CSP plant to generate power after sunset. Storage increases the plant's capacity factor and, if optimized for the size of the plant and resource base, may in some cases (e.g., around-the-clock production, as in Eskom's planned plant in summer) reduce the levelised cost of electricity. For a solar field of any given size, a fixed amount of solar energy is collected in a day, but that energy can provide electricity to the grid in a number of ways, depending on the design and configuration of the CSP plant, specifically, the size of the turbine and how much storage is added.



**Figure 3.** Different CSP plant configurations (Source: Stanley et al. 2009)

## 2. South Africa's Domestic Action

### 2.1 CSP Rollout Defined

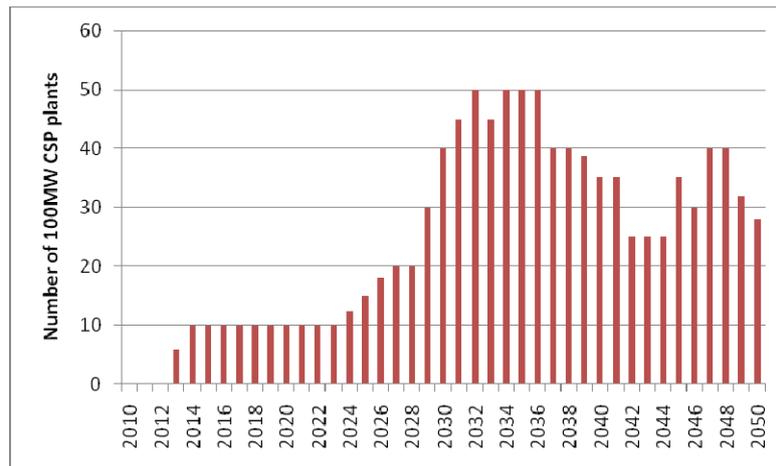
In this study we define the 'large-scale' rollout of CSP in line with the more optimistic 'renewables extended with learning'<sup>3</sup> projection modelled in the LTMS of South Africa, as depicted in Figure 2. The projection is modelled to incorporate technology learning rates and implements a driver to achieve at least 50% of electricity generation from domestic renewable sources by 2050 (Winkler 2007; Hughes et al. 2007; Winkler et al. 2009). For the large-scale rollout of CSP only parabolic trough and power towers are assessed, which are assumed to have technology learning ratios of 15% and 20% respectively (Winkler 2007; Winkler et al. 2009). According to the model output the proportion of renewable electricity generated is increasingly supplied by CSP, rising from none in 2010, to 60% by 2015, to 70% by 2020, and to about 90% after 2050 (see Figure 2). The first CSP plants would be installed in 2014, with installed generation capacity projected to increase to about 2 GW by 2015, 7 GW by 2020, and 100 GW by 2050, which equates to 4%, 27% and 55% of the total generation capacity required (see Table 2).

Due to lower electricity supply capacity from renewable sources compared to fossil-fuel based sources the South African generation capacity by 2050 would be larger under this scenario; 180GW compared to the base-case of about 110GW (Winkler 2007). According to the model outcome of the LTMS achieving the large-scale rollout of CSP would require the construction of ten 100MW CSP plants annually between 2014 and 2020, rapidly scaling this up to forty 100MW plants annually by 2030, and rolling out 100MW CSP plants in the region of 25 to 50 plants every year thereafter until 2050 (see Figure 4).

		<i>Start</i> 2010 – 2015	<i>Scale-up</i> 2016 – 2020	<i>Roll-out</i> 2021-2050
CO <sub>2</sub> -eq emissions avoided		22 Mt (<15 Mt/yr)	140 Mt (20-30 Mt/yr)	3670 Mt (30-230 Mt/yr)
Share of electricity sector (Installed generating capacity)		4% (about 2 GW) cumulatively by 2015	27% (7 GW) cumulatively by 2020	55% (100 GW) cumulatively by 2050
Cost to economy		R 3/tCO <sub>2</sub> -eq		
Incremental cost of CSP rollout (2008 R Billions)	With technology learning <sup>1</sup>	23.5 (4.7/year)	24.6 (4.9/year)	310 (10/year)
	With technology learning <sup>1</sup> and local production <sup>2</sup>	22.9 (4.6/year)	19.4 (3.9/year)	106.7 (3.6/year)
<i>Notes:</i>				
<sup>1</sup> Learning ratio is 15% and 20% reduction per doubling of deployment for parabolic trough and power tower respectively.				
<sup>2</sup> Local production of CSP components is assumed to reduce CSP investment costs at a rate of 5% per year.				

**Table 2.** Description table of a large-scale rollout of CSP in South Africa. (Values derived from LTMS, Winkler 2007)

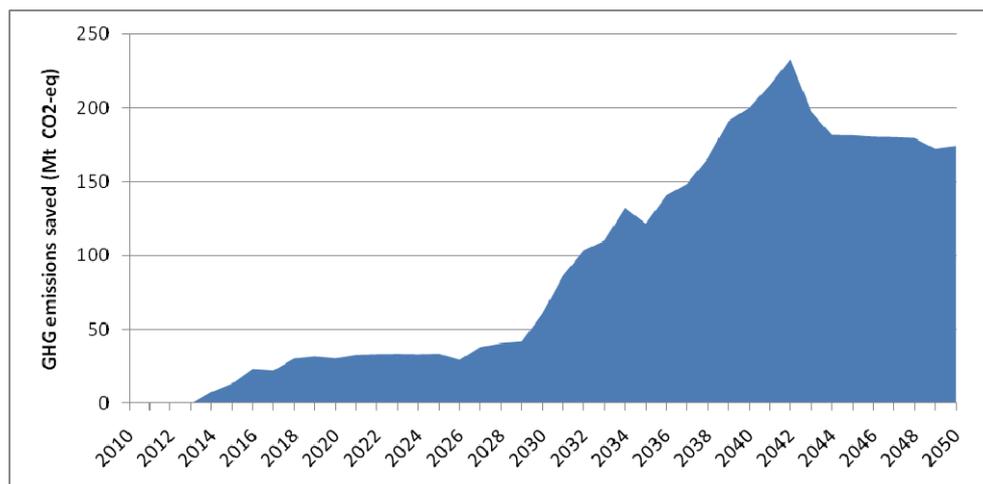
<sup>3</sup> See LTMS (Winkler 2007; Hughes et al. 2007; Winkler et al. 2009): The 'renewables extended with learning' mitigation option in the LTMS was run with technology learning included as opposed to most of the other options analyzed, where technology learning was excluded. Furthermore a



**Figure 4.** Projected number of new 100MW CSP plants needed to achieve a 50% target by 2050 (Source: Adapted from LTMS, Winkler 2007)

According to the MARKAL model used in the LTMS (Hughes et al. 2007) about 3,800 MtCO<sub>2</sub>-eq GHG emissions are expected to be saved from the large-scale rollout of CSP from 2010 to 2050<sup>4</sup>. With the construction of the first CSP plants in 2014 40 MtCO<sub>2</sub>-eq or less are mitigated every year until 2030, after which the annual emissions saved increases dramatically reaching more than 200 MtCO<sub>2</sub>-eq around 2040, and by 2050 more than 170 MtCO<sub>2</sub>-eq of GHG emissions are expected to be saved annually (Figure 5).

Such GHG savings are comparable to, although less than, the projected savings from increasing industrial energy efficiency (4,805 MtCO<sub>2</sub>-eq over the whole period). Similarly a carbon tax may achieve high emission savings, estimated at 1,804 MtCO<sub>2</sub>e for a R100/tCO<sub>2</sub>-eq and 16,361 MtCO<sub>2</sub>-eq for a R1000/ tCO<sub>2</sub>-eq (Winkler 2007). Furthermore, the carbon savings projected from the large-scale rollout of CSP under the ‘renewables extended with learning’ scenario are thought to hardly cost the South African economy at R3/ tCO<sub>2</sub>-eq (Table 2).



**Figure 5.** GHG emissions saved due to the large-scale rollout of CSP in South Africa (Source: Adapted from LTMS data. Hughes et al. 2007)

<sup>4</sup> Estimates of emissions saved from large-scale rollout of CSP are derived from LTMS (Winkler 2007; Hughes et al. 2007; Winkler et al. 2009). The difference in emissions from the ‘renewables extended with learning’ and ‘base case with learning’ was determined and the proportion of this due to the expansion of CSP was calculated based on the difference in CSP electricity output between the two scenarios.

## 2.2 Electricity Generation in South Africa

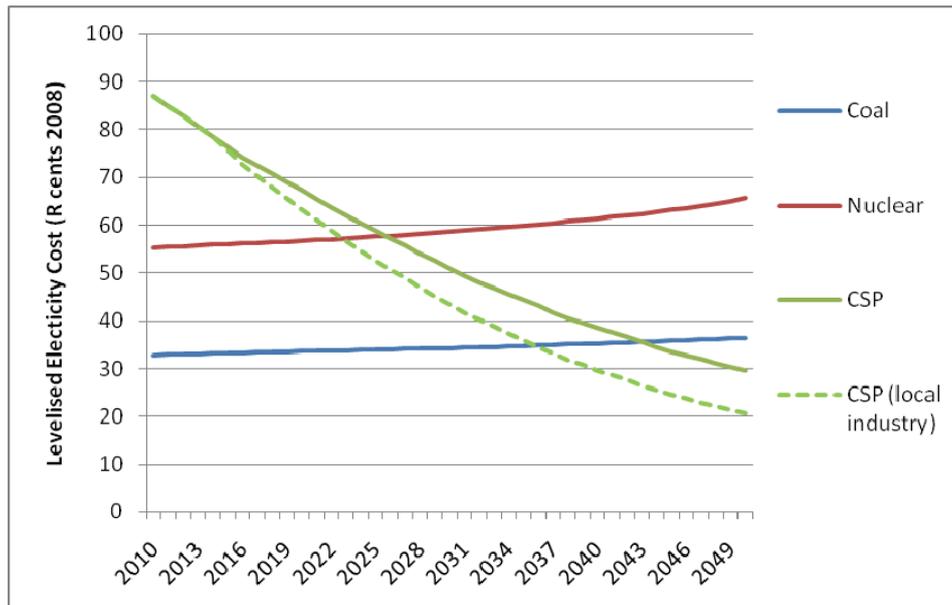
The electric power industry in South Africa is dominated by Eskom Holdings Limited, a vertically integrated company that generates, transmits and distributes electricity to internal markets, as well as purchasing and selling electricity to and from Southern African Development Community (SADC) countries. Eskom is owned by the South African government and is regulated under licences granted by the National Electricity Regulator of South Africa (Nersa). With a generating capacity of 43,037 MW Eskom generates about 95% of South Africa's electricity consumption and supplies 45% of Africa's electricity (Eskom 2008). More than 90% of its electricity comes from the burning of coal, 12,530 Mt in 2008. According to its integrated strategic electricity planning process, by 2026 less than 70% of Eskom's electricity will be generated from coal; only about 2% will be generated by renewable sources, the rest will be supplied by nuclear, hydro, pumped storage and imports (Eskom 2008). This is certainly a far cry from the 27% electricity supply from renewable by 2030 or 50% by 2050, as envisioned for the large-scale rollout of CSP.

Electricity transmission in South Africa is a monopoly owned company, operated by Eskom with around 27,000 km of high voltage lines from 132kV and above. The transmission infrastructure is vast and extends through the length and breadth of South Africa (see Figure 9). The recent upward trajectory of energy consumption and demand has put the transmission infrastructure under tremendous pressure, which necessitates a speedy review of the national transmission grid code and its application (DME 2008), especially if the projected CSP generation capacity is to be accommodated.

Internationally, the CSP industry is expected to experience major growth in the next decade, with governments around the world introducing policies to further the CSP innovation cycle. Three major policies are operating worldwide; firstly, there are mandatory purchases of renewable energy at a fixed price (known as a feed-in tariff) in Germany and Spain, and more recently also in South Africa. Secondly, renewable portfolio standards, which require a minimum share of power to come from renewables, are used in many US states. The third policy of government-sponsored competitive bidding for renewable energy concessions uses long-term contracts awarded to lowest-price projects, as in China and Ireland (Nersa 2009).

Market creation by government is thought to pull the CSP industry towards greater commercialisation and eventually drive the price of electricity from CSP low enough to make it competitive with other generation sources, in particular coal-generated electricity. CSP learning curves are thought to be anywhere in the ranges of 5-32% and 2-20% for parabolic trough technology and central receiver technology respectively (Winkler 2007; Winkler et al. 2009; see also Sargent and Lundy 2003; Solar Task Force 2006). As the technology matures on a global scale, cost reductions are thought to come from production changes (process innovations, learning effects and scaling effects), product changes (innovation, design standards and redesign) and changes in input prices (World Bank and GEF 2006).

Accordingly, the levelled cost of electricity from CSP is estimated to be competitive with the levelled cost of conventional coal by 2045 and with nuclear by 2026 (see Figure 6). If coal power plants are to be built with carbon capture and sequestration (CCS) then the levelled costs of electricity from these would increase considerably (Marquard et al. 2008). Furthermore, the levelled cost of CSP generated electricity may experience a greater learning rate due to local production of CSP components (Holm et al. 2008), estimated here at reducing the LEC further at an annual rate of 1% after the construction of the first CSP plant in 2014 (Figure 6).



**Figure 6.** Projections of the levelised costs of electricity from coal, nuclear and CSP in South Africa. (Source: adapted from Marquard et al. 2008)

### 2.3 CSP Development Costs

Although it has proven difficult to estimate the total investment cost for the large-scale rollout of CSP in South Africa, estimates can be drawn from the price-tag attached to the most recently constructed global CSP plants. Nevada Solar One, built in 2007 in the US, was the first parabolic trough to be constructed after the SEGS. It is designed with a 64MW generation capacity, no storage capabilities, and was estimated to require investment of about \$266 million. Therefore, a 100MW plant may require a R3.75 billion investment<sup>5</sup>. Andasol 1, constructed in Spain in 2009, has 50MW generation capacity with seven hours storage from molten salt, and required €300 million investment. A 100MW plant may require R7.8 billion investment<sup>6</sup>, though with such thermal storage the plant would have a far higher capacity factor. Lastly the PS10, a SRS design built in Spain in 2007, which has a generation capacity of 11MW with a 30 minute steam storage system and required an approximate investment of €43 million; for a 100MW plant investment cost may therefore be R5.1 billion.

According to the modelling undertaken for the LTMS (Winkler 2007), which incorporates technology learning rates for CSP plants, incremental costs to achieve the rollout of CSP on the scale envisioned would be R4.7 billion per year for the ‘Start’ (2010-2015) period; rising to about R4.9 billion ZAR per year for the ‘Scale Up’ (2016-2030) period; and further rising to about R10 billion ZAR per year for the ‘Rollout’ (2031-2050) period<sup>7</sup>. Therefore, the CSP rollout proportion of reaching a low carbon electricity generation target by 2050 would require an additional R23.5 billion for 2010-2015, R24.6 billion for 2016-2030 and R310 billion for 2030-2050 (see table 2). Overall the large-scale rollout of CSP in South Africa is expected to require additional financing of about R9 billion per year for the whole period, 2010-2050.

<sup>5</sup> Exchange rate assumed at R 8 = US\$ 1

<sup>6</sup> Exchange rate assumed at R 13 = Euro 1

<sup>7</sup> Estimates of incremental investment cost for the large-scale rollout of CSP are derived from LTMS (Winkler 2007; Hughes et al. 2007; Winkler et al. 2009). The difference in investment costs from the ‘renewables extended with learning’ and ‘base case with learning’ was determined and the proportion of this due to the expansion of CSP was calculated based on the difference in CSP generation capacity constructed between the two scenarios.

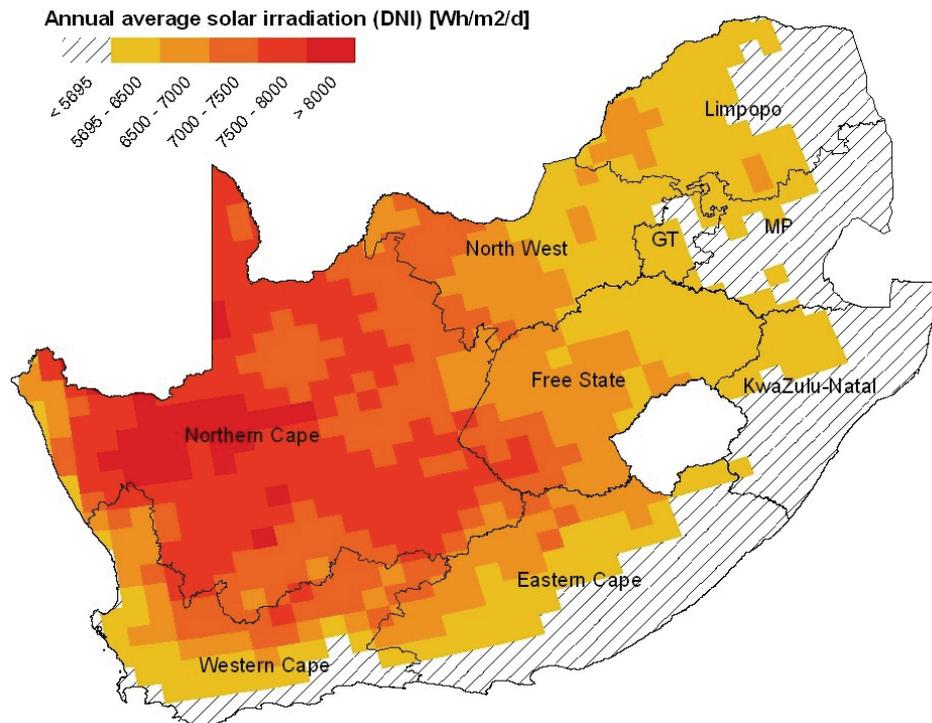
However, CSP technologies may experience higher technology learning rates if a local CSP component supply industry is developed. This would result in reduced upfront investment costs for CSP plant construction, which in turn may reduce the levelised cost of electricity generated from the CSP plants, as represented in Figure 6. If investment cost reductions of 5% per year can be achieved due to local production, in addition to global technology learning for CSP, then incremental costs for the large-scale rollout of CSP is estimated at R3.7 billion per year for the whole period (2010-2050). The 'Start' phase, 2010-2015, would require additional financing of R22,9 billion; 'Scale Up', 2016-2020 would require R19.4 billion; and the 'Rollout' phase, 2021-2050, would require notably less additional financing, namely R107 billion at R3.6 billion additional per year (see Table 2).

Following this review of South African mitigation action, the next sections of the paper assess the drivers and barriers the rollout of CSP faces, discusses possible international support mechanisms that could be employed to overcome the three main barriers, and reviews some of the indicators that may be used to monitor the progress towards achieving the large-scale rollout of CSP in South Africa. The next sections are based on the outcomes of a stakeholder workshop, held in Cape Town on 22 March 2009, which 46 participants from government, industry, NGOs and research institutions attended. The discussions on the day revolved around three broad themes, the technological, infrastructure and industrial requirements for the large-scale rollout of CSP. The outcome of a survey (see Appendix 1), which was completed by 21 workshop participants, is also used in the following assessment. The survey was designed to assess stakeholder's perception of the REFIT, their understanding of what international support is necessary for large-scale CSP deployment, their sentiment towards different indicators and whether these would be successful in measuring the progress of technology and mitigations actions.

### 3. Requirements Needed to Achieve the Large-scale Rollout of CSP

#### 3.1 Drivers of the Rollout

South Africa is fortunate to have much renewable energy potential, in particular it has a high solar potential (**Error! Reference source not found.**) with annual direct normal irradiation (DNI) reaching over 2500 kWh/m<sup>2</sup> (DME, 2003). Such DNI values are comparable to other high solar irradiation centres, such as north Africa and the southwest of the US (2600 kWh/m<sup>2</sup> annually). Upington, with more than 7000 Wh/m<sup>2</sup> daily average DNI, is thought to receive more than cities in California, Nevada and New Mexico in the US, as well as sun-soaked countries such as Jordan, Morocco, Crete, India and Spain (Eskom, 2007). In **Error! Reference source not found.**, hatched areas are comparable with solar irradiation values of Spain (< 5695 Wh/m<sup>2</sup>/d). Much of the land with high DNI (> 7000 WH/m<sup>2</sup>/d) is also flat (slope < 1%), and does not contain threatened vegetation. As such, of the appropriate land that is within 20km of transmission (> 220 kV lines), it is estimated that 550 GW of CSP generation capacity could potentially be installed. This would equate to 3.3-5.4 times the electricity requirement forecast for South Africa for the year 2025 (Nersa, 2007).



**Figure 7.** Overview of South Africa annual direct normal irradiation (Wh/m<sup>2</sup>/d) (Source: Fluri 2009)

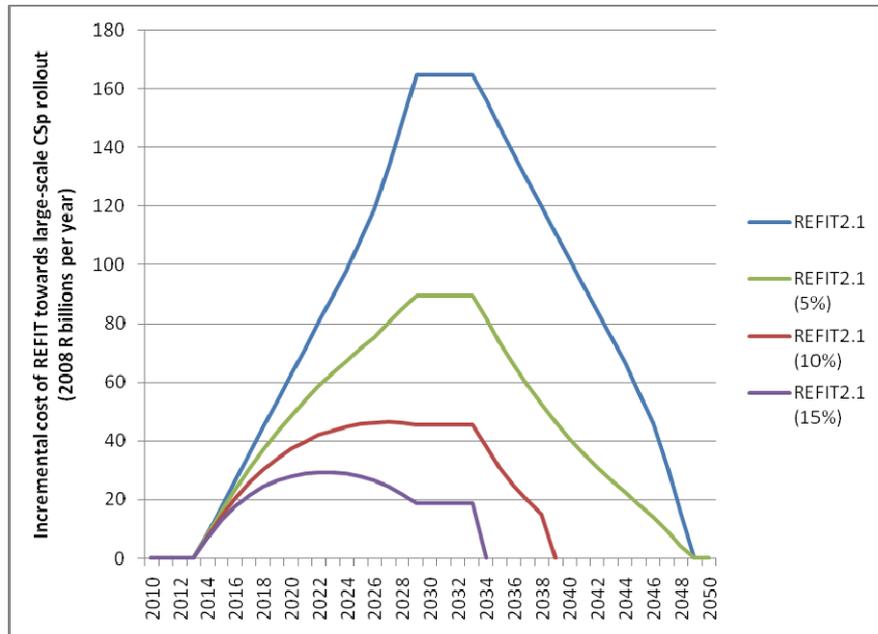
A major driver for interest in the large-scale rollout of CSP in South Africa has been the establishment of the renewable energy feed-in tariff (REFIT) by Nersa. The REFIT guidelines stipulate that a power purchase agreement of R2.10 per kWh for CSP developments, based on a parabolic trough technology with 6 hours of storage, is assured for the next 20 years – a higher rate than for other renewable energy technologies for electricity generation (Nersa, 2009). Of the 21 workshop participants surveyed, the majority indicated some positive sentiment for the REFIT with about 50% noting that it is ‘very’ sufficient, 30% marking ‘somewhat’ and about 20% marking ‘overwhelmingly so’, to scale-up CSP in South Africa. Nersa is presently deciding on feed-in tariff rates for CSP tower design and for CSP parabolic trough designs without storage (Nersa, 2009b).

According to Nersa the REFIT will be reviewed every year for the first five-year period of implementation and every three years thereafter. The resulting tariffs will apply only to new projects. The Renewable Energy Power Purchase Agency (REPA) is being housed in Eskom’s Single Buyer Office and they will be responsible for the monitoring and verification of RE projects. The Medium Term Power Purchase Program (MTPPP) standard Power Purchase Agreement (PPA) will be used as a basis for the REFIT standard PPA and Nersa will facilitate the adoption of the agreement for REFIT purposes. Lastly, additional costs of purchasing power under REFIT, beyond the avoided costs, will be passed on to all Eskom consumers under existing ‘pass-through’ arrangements which are currently in place for IPPs (Nersa, 2009).

Assuming REPA would support the large-scale rollout of CSP until 2030, by when the levelled cost of electricity would certainly be competitive with nuclear if not even coal (see Figure 6), and assuming the price of generating conventional electricity in South Africa rises by 20% annually for the next 3 years and 2% thereafter from the present levelled cost of R 0.20/kWh<sup>8</sup>, then the incremental annual cost of REFIT (at a rate of R 2.10/kWh) in

<sup>8</sup> The levelled cost of electricity generation in South Africa was estimated at 60% of the present average customer price paid for electricity (R 0.33/kWh after the 31% rise for the year 2009/2010, see Nersa 2009c). The value of R 0.20/kWh was cross-referenced with the estimated levelled cost of electricity as determined by Marquard et al. (2008).

support of the rollout of CSP would rise annually to peak around R 165 billion around 2030. If however Nersa decides to reduce the tariff paid for CSP by a rate of 5% less per year from R2.10 in 2014 after the first CSP plants are constructed, then the annual incremental cost of the large-scale rollout of CSP would not reach a cost above R 90 billion per year. Similarly, at a tariff reduction rate of 10% annually then the incremental costs would peak at R 46 billion around 2025 and at 15%, in line with the estimated learning rate for CSP, the annual cost of REFIT would peak around R 30 billion in 2020 (see Figure 8).



**Figure 8.** Estimated annual costs of REFIT, reduced by 5%, 10% and 15% after the first CSP plants are built in 2014, in support of the large-scale rollout of CSP.

During the workshop it was further noted that the future benefits of a large-scale CSP rollout programme are strong drivers for this action. In particular the growth of a solar industry development programme could lead to large-scale job creation and possible foreign earnings through the export of the technology, especially if South Africa were to become a market leader in the less-developed central receiver and LFRs technologies. It was further noted that South Africa's well-established auto industry could possibly evolve to supply the CSP industry ('from Hummers to heliostats!). If 5.9 jobs are expected for each MW of CSP generation capacity constructed (Agama Energy 2003) then the large-scale rollout of CSP may result in creating over 600,000 jobs.

It seems that it would be in South Africa's best interest to take a two-track approach to the CSP technology available. On one hand, it makes immediate sense to construct the most commercially viable technology, namely parabolic trough power plants, as these have already reached a cumulative global deployment of almost 600 MW. The second angle to pursuing CSP technology is aimed at establishing market competitiveness globally through investing in CSP technologies that the South African industry base can more easily adapt to. Central receivers and Linear Fresnel systems belong to this track, because they do not require the specialised parabolic mirror systems of the parabolic trough systems. Eskom, for one, seems to be pushing the second technology development approach as they are developing a 100MW central receiver system with a custom heliostat design to be produced locally.

### 3.2 Barriers to Achieving the Rollout

During the discussions at the CSP stakeholder workshop a number of issues facing the large-scale rollout of CSP in South Africa were raised. These can broadly be grouped into technological (innovate), infrastructure (operate), industry-related (manufacture) and legal/regulatory (regulate) issues (see Table 3). The lack of financial support, however, seemed to be the largest barrier to the large-scale rollout of CSP in South Africa.

	<i>Start 2010 – 2015</i>	<i>Scale-up 2016 – 2020</i>	<i>Roll-out 2021-2050</i>
<b>Innovate</b>	Import technology Thermal storage tech Eskom cooperation	SA specific technology	Water-saving tech
<b>Adopt / manufacture</b>	Risky investment: 'Test Plant' branding – no market outlook	Lacking skills for local content	
<b>Operate / maintain</b>	Initial grid expansion	Massive grid expansion Lacking skills	Grid-wide storage Water-stress
<b>Regulate</b>	REFIT untested	REFIT expiry unknown	SAPP day-ahead market
<b>Finance</b>	Venture capital & grants from CC fund (eg World Bank Clean Technology Fund)	Investment facilitation; NAMA crediting from Climate Change fund & loans	Equity, mezzanine, debt, insurance & carbon-based
<b>Stakeholder interest</b>	REFIT established	Growing Solar Industry Development Program	Future jobs and exports
<b>Stakeholder concerns</b>	REFIT untested	Eskom as electricity distributor	EIA – water

**Table 3.** Main barriers facing the large-scale rollout of CSP in South Africa

Of those who completed the workshop survey, more than 70% considered financial support as the most necessary form of international support, due to the lack of financing, especially under the current global economic climate. This is largely the result of the high investment costs for CSP developments. Technology, institutional capacity, and policy support could be driven by financial support. It seems that the initial technical and engineering requirements are quite well understood. However, CSP developers are only able to prepare feasibility studies and further research, in order to develop CSP technologies to suit the South African context, with financial support. Financial support could aid capacity building in the Single Buyer Office of Eskom, thereby ironing out any bottlenecks that may appear in the REFIT process, as well as supporting infrastructure development, such as major grid expansion into the Northern Cape.

#### *Technology barriers*

Since South Africa has only installed one 25kW solar dish with a Stirling engine to date, at the Development Bank of Southern Africa premises, the country lacks experience with CSP technology. To start large-scale rollout of CSP, therefore, the country would have to invest in importing the required technology, in particular parabolic trough technologies. Thermal storage technology, such as molten salt storage, would also have to be acquired. Importing such technology may prove costly and hence could be a barrier to the large-scale rollout of CSP.

The other CSP technologies identified are largely commercially unproven (Table 2), especially at the scale required for the scale of CSP rollout envisioned, which is certainly a hurdle that needs to be overcome. In particular, novel thermal storage solutions and

smaller-scale applications of CSP for off-grid communities or rooftops are required. As South Africa lacks natural gas resources, coal would also have to be investigated for country-specific CSP designs as a suitable backup fuel. These technological barriers could be overcome through a large solar R&D programme.

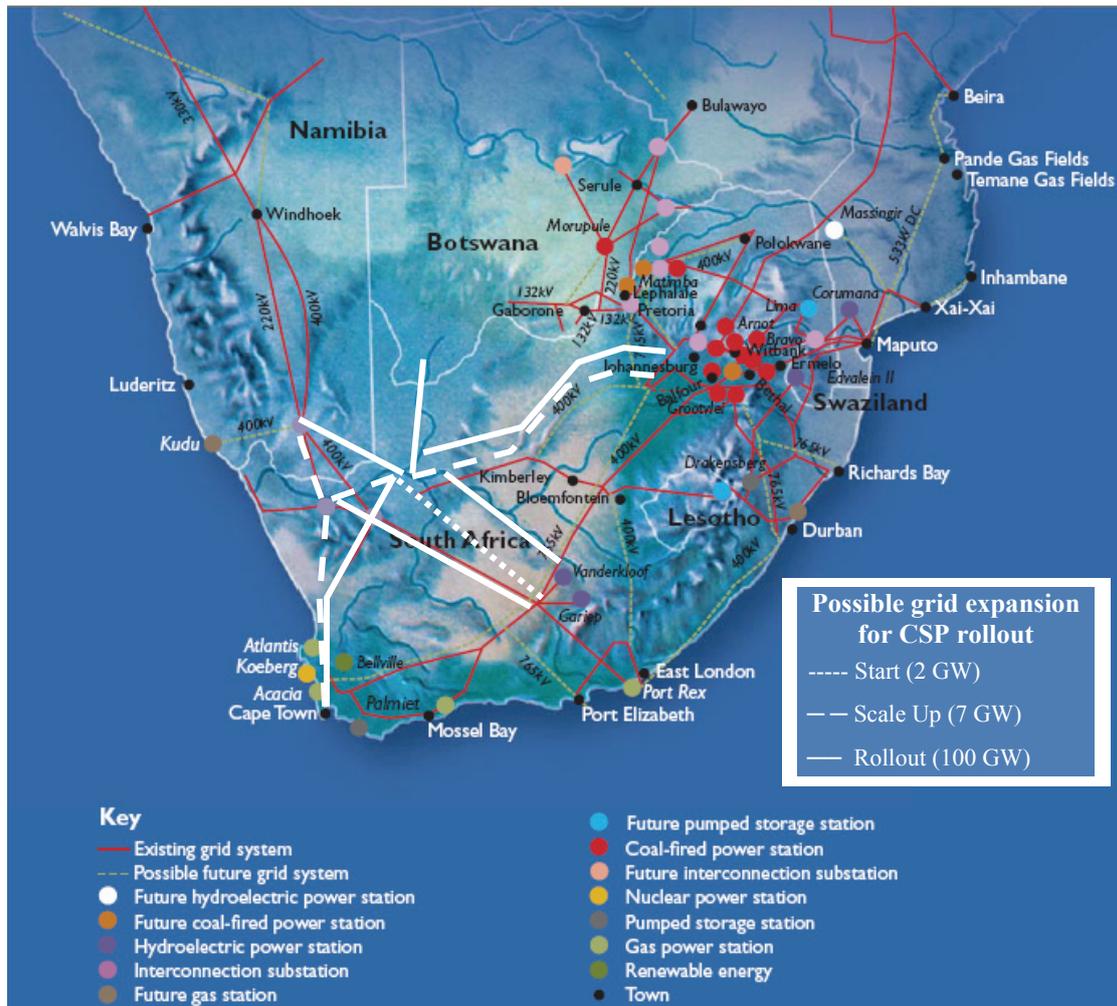
Initially, water requirements for the large-scale rollout of CSP were not deemed to be a major barrier. However, once the programme is scaled up and rolling CSP plants out, with 10 to 40 plants of 100MW being constructed annually (Figure 3), water is certainly thought to become a major barrier. If Eskom's 100MW plant is projected to require 300,000 m<sup>3</sup> of water per year for cooling and cleaning the mirrors (Van Heerden 2009) and the lower Orange River – the main water supply to the Northern Cape – is thought to have 150 million m<sup>3</sup> annually available for development (DWAF, 2004), then little more than 50GW CSP capacity can be constructed in this region. In the long-term this is probably the biggest issue facing the rollout of CSP in South Africa.

Nonetheless, the water requirements for the CSP rollout programme may be offset by reduced water use in the declining coal-based electricity generation. According to Sparks (2006) the present electricity generation system degrades ground water quality by coal mining activities, uses excessive amounts of water for cooling and undervalues the true opportunity cost of water as paid by Eskom. The upper Orange River, although not ideally situated to support CSP developments, may support a greater expansion of CSP growth, with 900 million m<sup>3</sup> of water available for development annually (DWAF 2004).

Climate change is also expected to bring dryer conditions to most of Southern Africa, where a 10% reduction in rainfall for South Africa can result in major (30-40%) reductions in river flow (de Wit et al. 2006). Today western South Africa is experiencing its biggest drought in over 100 years with water shortages in 2004 leading to almost no water discharge from the Orange River dams (de Wit et al. 2006). Unless water-saving technologies are further researched and developed, and water is redirected from coal-based electricity generation, the large-scale rollout of CSP in South Africa is probably unachievable.

#### *Infrastructure barriers*

The major infrastructure barrier for CSP plants is grid connectivity, which may become the main reason for not reaching a large-scale rollout of CSP, as stipulated by the 50% target by 2050. Although the initial integration of CSP plants in the Start phase of the rollout is not seen to be too much of an issue, by the Scale up phase grid expansion may be in the order of what California envisions to reach a 33% renewable portfolio standard by 2020. Towards the Rollout phase further infrastructure expansion may be necessary as the concentration of South Africa's grid may have shifted from the coal mining areas in Mpumalanga and Gauteng to the north-west of the country. Figure 9 shows Eskom's power plants and their proposed future grid systems, overlaid by the possible grid expansion necessary for the large-scale rollout of CSP.



**Figure 9.** South Africa's electricity grid showing Eskom's power plants and their proposed future grid systems (Source: adapted from Eskom 2008)

A transmission planning study, probably commissioned by the new Energy Department, needs to be completed. The study should encourage the completion of Eskom's expansion plans aimed to support customer loads in the Southern Cape, West Coast, Peninsula and Namaqualand. Although the study should be based around existing structures, it should focus beyond Eskom's direct transmission expansion needs to incorporate those of the IPPs, in particular the CSP developers. Specifically the grid expansion into the northern parts of the Northern Cape, where the most suitable CSP land has been identified, would have to be incorporated in the transmission planning study. It is hoped that such a study would also result in updated distribution codes by building on existing regulatory structures.

Furthermore, South Africa should also investigate alternative storage options at a national grid level, such as through the promotion of electric vehicles or more pump-storage schemes. At the stakeholder workshop discussions it was suggested that such storage capabilities should be considered for funding through the REFIT. A number of the CSP developers in attendance at the workshop also questioned who should shoulder the costs of the necessary grid expansion into the north-western parts of South Africa and beyond into Namibia and Botswana with the aim of expanding the Southern African Power Pool.

### *Regulatory Barriers*

At the workshop, while discussing CSP storage technologies, a major barrier to large-scale CSP rollout in South Africa was identified, namely the question of whether the present renewable energy targets set by the government, such as the present 10,000MWh by 2013, would constitute a 'cap' to the deployment of renewables. Along these lines there also seemed to be some confusion about the Department of Minerals and Energy's statement, prior to the announcement of the REFIT that renewable energy projects have to go through a bidding process to gain the power purchase agreements. The update to the Electricity Regulation Act 2006 clearly states that 'the system operator shall be responsible for selecting the preferred IPP under the REFIT Programme' (DOE 2009). It is therefore questionable whether the bidding process can be married with the REFIT, and until the issue is cleared it will constitute an administrative barrier preventing immediate CSP developments in South Africa.

Furthermore, although the Single Buyer Office is obliged to buy electricity generated from renewable sources under the REFIT, the rollout of CSP could be prevented by non-tariff gate-keeping criteria, such as proximity, capacity and stability criteria that have been set out in the New Generation Regulations (DOE 2009). Already the Single Buyer Office is 'oversubscribed' with projects<sup>9</sup>, and the first renewable energy project approvals are only expected by February 2011; if not solved, this would prove to be a barrier to achieving the multiple 100MW CSP plant deployment envisioned.

The REFIT is also not clear on whether a minimum of six hours of storage for any CSP development in South Africa is prescribed. Since there is little commercially proven storage technology available, such a requirement may discourage potential CSP investors in South Africa; who may perceive investing in unproven storage technology too risky, or who were only interested in a bankable CSP project without storage and would therefore end up investing elsewhere. It was thereby proposed that Nersa addresses this issue with more clarity and considers establishing an alternative feed-in tariff for CSP without storage, or with less storage, so as to accommodate all CSP developers. It is also recommended that the REFIT is expanded to incorporate off-grid power generation from renewable energy sources, such as a CSP with back-up fuel supply.

Another possible barrier to CSP deployment is the bureaucratic Environmental Impact Assessment (EIA) process (see Fakir and Nicol 2008). As seen by Eskom's CSP development plans, which started in 2001, but took them a number of years to complete the EIA. This is may become more of a barrier in the later stages of large-scale rollout of CSP, when water availability becomes scarce.

Lastly there is a notion that Eskom needs to support the large-scale CSP rollout programme; firstly by breaking its monopoly control of the power generating industry, and secondly by sharing more CSP specific information, such as solar radiation maps. Furthermore, housing the Single Buyers Office for renewable electricity in Eskom may represent a conflict of interest and thereby diminish the potential contribution independent power producers could bring to the large-scale rollout of CSP.

### *Industry barriers*

South Africa's industry is noted as a possible major driver of CSP development, since the presence of a large automotive industry would yield itself well to supplying CSP components such as steel, glass and reflective coating. In addition South Africa's construction sector is well established to manage large-scale projects. For many industries in South Africa, which are currently struggling under the global economic downturn, developing a solar industry may be a great growth opportunity. Nonetheless, the discussions at the workshop indicated that the major barrier was the high risk involved in

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<sup>9</sup> according to Yousuf Haffejee, who heads the REPA., speaking at the Democracy Foundation REACT workshop, 17 June 2009

investing in developing the CSP-supply industry. It was noted that a few pilot CSP plants would have to be deployed in the short-term, which would test the REFIT and indicate a commitment from South Africa towards developing the solar industry. In particular Nersa or government should highlight what CSP deployment they aim to support with the REFIT, so as to generate market confidence.

There seems to be an educational and perception barrier, in that CSP rollout in South Africa has not yet been perceived as anything more than 'a pilot', which may have to do with Eskom's position over their 'test plant'. To redirect the national perception and support the large-scale rollout of CSP, Eskom could brand their development as 'building an industry' – the Solar Industry Development Programme. A national planning framework, possibly led by the Department of Trade and Industry, would have to be established to encourage the industry by coordinating with other government departments and interested industrial sectors. Holm et al. (2008) similarly identify 'the most important constraint is not money, men, machines, materials or management, but the motivation, the inspired political will' for the deployment of renewable energy in South Africa.

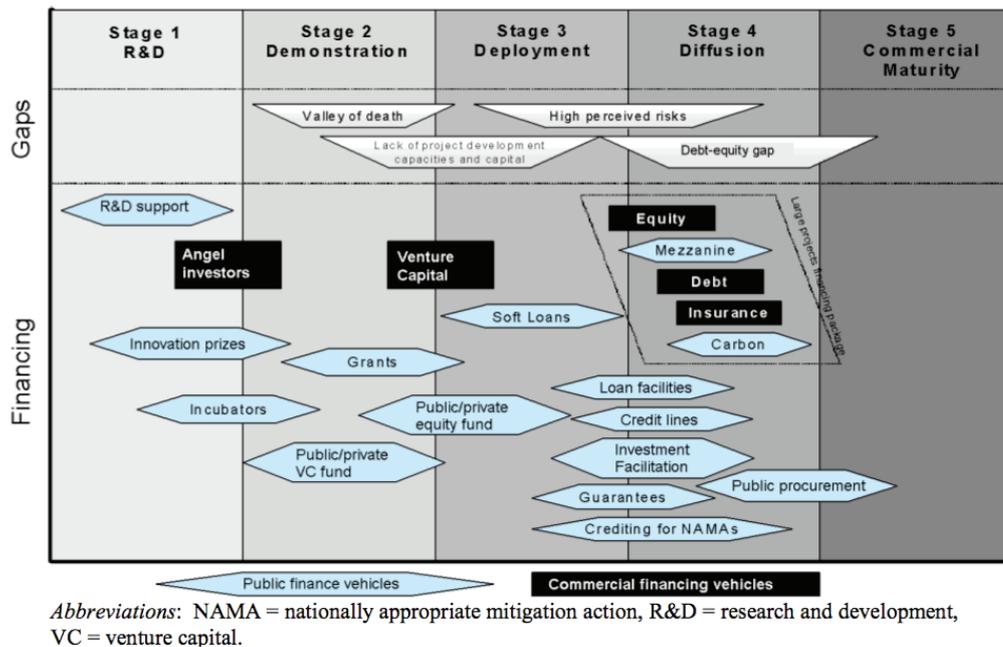
Government should initiate a public-private partnership and thereby invite CSP developers to establish test facilities. Small towns or regional electrification may be a way of getting the CSP rollout to take root. The CSP stakeholders in attendance at the workshop made reference to similar experience gained from the World Bank's support for South Africa's rapid bus transport system, where initial investment steps had to be completed domestically before international support could be lobbied. According to Esrthlife and Oxfam (2009) overcoming the omnipresence of Eskom and its preference for fossil fuels is largely considered to be the most compelling obstacle to developing a renewable energy market in South Africa.

#### 4. Addressing Barriers in the Light of International Support

International financial support is deemed the most vital component of a strategy to achieve the large-scale rollout of CSP. Financing can come in many forms and at many stages along the maturity progression of a technology (see Figure 10). For the Start phase of CSP rollout in South Africa (2010-2015) financing could come from commercial investors. The current global economic climate presents difficulties for CSP developers in accessing finance, even with the REFIT in place; therefore, additional public finance vehicles would have to be rallied. These would include R&D support and grants from a climate change fund, such as the World Bank Clean Technology Fund.

Further down the CSP deployment chain for South Africa, during the Scale up time-frame from 2015 to 2020, funding could be classified as crediting for a Nationally Appropriate Mitigation Action in the form of a soft loan or as guarantees. In the Rollout phase, from 2030-2050, the CSP technology would probably be close to commercial maturity, and private funding sources, such as debt and insurance, would play a larger role. Further public funding would also be necessary, however, especially to achieve the scale of deployment envisioned. This funding could be in the form of loan facilities, guarantees and possibly carbon-based funding. Newer CSP technologies at this stage would also require Research and Development (R&D) support and demonstration grants.

South Africa to date has received some notable international assistance for clean energy investments. There may be greater participation of donors and multilateral agencies than participation of private funds (IISD 2009), though this is hoped to change with increasing interest in South Africa's REFIT. The Global Environmental Fund is supporting the Renewable Energy Market Transformation Project (REMIT); UNDP has been directly involved in sector-specific projects, most notably the South African Wind Energy Programme that originated with the Darling National Demonstration Wind Farm in 2000; and the Renewable Energy and Energy Efficiency Partnership, USAID and NORAD have also been active in providing funds (IISD 2009).

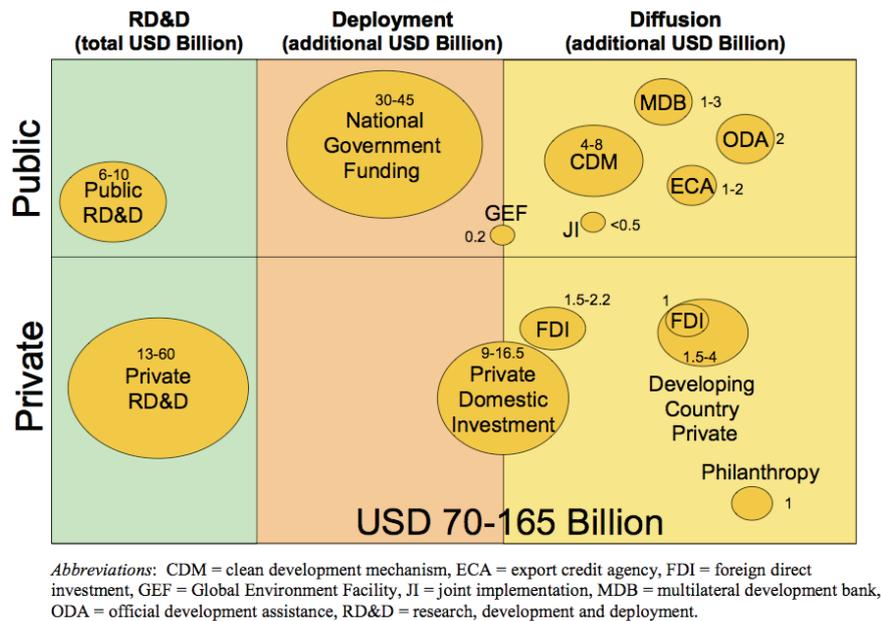


**Figure 10.** Financing mechanisms for climate change mitigation technologies (Source: EGTT 2009)

Globally, in terms of total capital costs required to prevent dangerous climate change, the International Energy Agency (IEA 2008) reports investment requirements in the diffusion phase of up to \$1,100 billion annually, as an average over the years 2010–2050. For diffusion in developing countries, \$660 billion per year would be required based on an investment share of 60% for developing countries and 40% for developed countries, as estimated by the IEA. The IEA also estimates that \$100–200 billion per year is required globally in early deployment costs, 60% of which would be required in developing countries. Furthermore, developed countries are thought to have to at least double public Research, Development and Demonstration (RD&D) for low-carbon technologies by 2015 and quadruple it by 2020. This would deliver an estimated additional \$10–30 billion per annum to push through key technologies, including CSP (Climate Group 2009). The Major Economies Forum could kick-start this process by agreeing to a global demonstration project for CSP technology.

By contrast, total financing resources currently available for technology research, development, demonstration, and transfer of mitigation technologies is only in the region of \$70–165 billion per year, according to the Expert Group on Technology Transfer under the UNFCCC (see Figure 11). Therefore, to support the mitigation technologies necessary to prevent climate change, additional financing of \$332–835 billion would be required by 2030 (EGTT 2009) and more than double that by 2050. According to the Climate Group (2009) CSP requires a total investment of \$590 billion for 2005–2050 to reach a 630 GW capacity globally. If South Africa were to complete its large-scale rollout of CSP, reaching 100 GW capacity by 2050, the country would require total finances of almost \$100 billion (R800 billion). Only R 4-10 billion annually of such financing is deemed incremental.

For South Africa to entice private investors for CSP projects technology and policy risks will have to be overcome. The basic options of international financial support would include grants towards the incremental costs and credit guaranties and loans to reduce the financing costs. The following section estimates what kind of international support may be required for South Africa to overcome the barriers faced by its CSP rollout programme.



**Figure 11.** Estimates of current financing for mitigation technologies (Source: EGTT 2009)

#### 4.1 Barrier: RD&D (Technology and Innovate)

A number of possible technological barriers were identified that need to be overcome to reach the large-scale rollout of CSP projected for South Africa. These include researching and developing CSP technologies that could gain from South Africa's present industry-base, which are aimed at encouraging domestic CSP component production, CSP technologies that allow for greater storage abilities and technologies that result in less water use, such as dry cooling or using ocean water for cooling.

Although the international community is already supporting South Africa through funding for the Renewable Energy Market Transformation Programme (REMIT), further CSP research and development, as well as diffusion, needs to take place. The REMT Project supports Renewable Energy Power Generation and Solar Water Heater initiatives through a help desk by offering pre-investment finance and an opportunity to leverage off established investment networks. REMT further supports the Department and other relevant government agencies with technical assistance and capacity building in policy development, regulatory framework, financing mechanisms and resource assessment. The Global Environmental Fund is contributing US\$ 6 million to REMIT from 2009 for four years. International support aimed at deploying CSP test plants, thereby proving commercial viability of different technologies and reducing costs, could certainly aid South Africa's large-scale rollout of CSP.

The scale of RD&D may be comparable to that invested in the Pebble Bed Modular Reactor, which over the years is estimated to cost R14.6 billion (Thomas 2006). Initially the international financial support could be designed with 50% risk-sharing for the first 100 MW plant and 25% risk-sharing for four more 100MW plants, which would cost an estimated cost of R10 billion. Later, agreements on bilateral R&D collaboration could be forged and CSP technology discoveries should be shared under the climate change technology transfer agreements.

In the later phases, after 2015, RD&D support could be necessary for alternative CSP components and designs that have not been tested as yet. Furthermore, if the South African government were to put a cap on the amount of CSP deployed, through limiting the REMIT, additional financing would be required to support the CSP rollout to the level envisioned, namely 7GW by 2020 and 100GW by 2050. This may be in proportion of the incremental cost, which at 50% would be just over R 2 billion annually for 2015-2020 and R 2-5 billion

annually for 2021-2050, depending on the level of technology learning and local production, and hence cost reductions experienced for CSP plants. International support directed at the RD&D of CSP would hopefully drive the learning process for the technology and establish a market demand for local CSP components.

## **4.2 Barrier: REFIT (Regulate)**

A number of suggestions are being discussed as the REFIT in South Africa is legally and structurally developed. Firstly, it seems best for the REFIT not to be ‘capped’ by a government-imposed domestic renewable electricity supply target, in order to encourage as much flexibility as possible for the market. South Africa presently finds itself in the situation of only having achieved 5% of the 10,000 GWh renewable energy target, six years after the target was established with four years until completion (Holm et al. 2006). Maximum flexibility should be encouraged towards achieving a larger-scale growth in the generation capacity of renewables, in particular for CSP. Given that the Single Buyer Office is already ‘oversubscribed’ with project proposals, ironing this out with international support may be necessary for achieving the CSP rollout presented in this paper. For example, this could take the form of support for 100 staff members for five years at R50 million per year, totalling R250 million for the five years.

Although it is suggested that Eskom should support the grander vision of developing a CSP industry, in line with the projected rollout presented by this paper, allowing them to house REPA would discourage Independent Power Producers (IPPs) from investing in South Africa. Therefore, the REPA under Single Buyer Office should become independent. It is suggested that IPPs are incorporated in South Africa’s integrated energy planning process, which could result in higher renewable energy targets, thereby creating a viable framework for IPPs to further the large-scale rollout of CSP in South Africa. The new generation regulations, which are about to be released by Nersa, should not entail stringent non-tariff gate-keeping criteria so as to allow for maximum CSP development.

To ease out the potential bureaucratic IEA for CSP plants, especially on the scale required, it is suggested these gain preferential treatment and only require ‘basic assessments’. Furthermore, it is suggested that ideas suitable for CSP plants should be identified in a planning process that would involve municipalities and other interest groups. Such countrywide feasibility studies could benefit from international support, where CSP research groups are established and financially supported. Such activities may cost R 240 million per year, if we take the US Department of Energy’s Solar Energy Technologies Program (US DoE 2008) as a yardstick<sup>10</sup>.

Furthermore, international support could be directed at aiding South Africa in funding the estimated incremental cost of REFIT for the large-scale rollout of CSP (Figure 8). These could range R 20 – 90 billion annually, depending on the rate of tariff reduction Nersa plans to impose.

## **4.3 Barrier: Grid-expansion (Infrastructure)**

As mentioned earlier the ‘invisible barrier’ is the need for a large-scale grid-expansion into the sunnier northwestern part of South Africa. The Transmission Planning Study should stipulate the scale of expansion necessary, and indicate what the government commits itself to. International financial support would certainly be useful in driving South Africa’s grid development to support the large-scale rollout of CSP.

For the first few GW of CSP capacity under the Start phase of the rollout, the most efficient transmission option would probably be to construct a 765kV line from Upington to the Hydra station at De Aar, reinforcing the backbone of the grid and allowing power to be

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<sup>10</sup> see the Solar Energy Technologies Program Budget.  
<http://www1.eere.energy.gov/solar/budget.html>

distributed anywhere in the country (Figure 9). For a distance of 400 km such a line with substations could cost about R5 billion.

For the Scale Up phase, transmission lines would have to be constructed between the Western Cape, the West Coast, Namibia and Grauteng. Such an undertaking may be comparable to what California envisions as necessary to reach a 20% or 33% renewable portfolio standard by 2010 and 2020 respectively. They estimate that four new transmission lines are required by 2010 and seven more by 2020, at a cost of \$4 billion and \$12 billion respectively to achieve their expanded generation of 75TWh from renewables by 2020 (CPUC 2009). With just under 40TWh of electricity expected to come from CSP plants by 2020 South Africa may have to expand its grid by half that of California, at an estimated cost of R 60 billion<sup>11</sup>.

The Rollout phase of CSP deployment in South Africa would require further grid expansion, shifting much of the grid concentration from the coal-mining areas to the north-west of the country. If by 2050 CSP generates approximately 460TWh of electricity and the transmission development required is in line with the expansion of CSP generated electricity, then the equivalent of 60 more transmission lines would have to be constructed between 2021 and 2050, at a potential cost of R700-800 billion. The total cost of such an expansion may be reduced if the distances that need to be covered are deemed great enough to make investments in direct current transmission lines. The international community could support such a grid development programme by, for example, covering its incremental cost relative to a baseline grid development based on a business as usual scenario.

The three barriers discussed above – technology R&D, REFIT support and grid-expansion support – can to a large extent be overcome with international financial support, and once these have been managed it is believed that the industry-related (manufacturing) barriers would solve themselves. The risk in investments towards a CSP-support industry would be reduced if the REFIT is proven functional in achieving ambitious renewable energy targets, if newer South Africa-specific technologies prove viable, and if the grid-expansion required for connecting CSP is developed on the scale estimated.

## 5. Suitable Indicators to Manage Implementation of Large-scale CSP Rollout

### 5.1 Indicators Assessed

To assess the progress of large-scale CSP rollout a number of process indicators were suggested in the questionnaire distributed at the stakeholder workshop. Potential process indicators were chosen in line with major yardsticks along the CSP project development process.

Early process measures, aimed at the amount of interest in South Africa for CSP developers, include the percentage of CSP developers globally that are either engaged in South Africa or have set up an office there. Data for such indicators would be relatively easy to compile through questionnaires to CSP developers. Further along the CSP deployment process, water and land rights for CSP plants would have to be acquired. The amount of land and water rights acquired could be established from the completed EIAs for CSP proposals.

Other process indicators identified, which that would give an estimation of the large-scale rollout of CSP in South Africa, could include the amount of finances committed to CSP, the number of CSP plants under construction, or the number of CSP plant licences issued by REPA. Data for committed finance and plants under construction could probably be identified from annual and sustainability reports of CSP developers in South Africa,

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<sup>11</sup> Exchange rate assumed at R 8 = US\$ 1

whereas licences issued would be registered with REPA, who facilitate the PPAs for CSP and other renewable electricity generation projects.

A more direct indicator, aimed at monitoring the CSP contribution to the South African electricity supply, would be the amount of electricity generated (kWh) per year, a measure that would be monitored by Nersa and reported by all the CSP developers actively generating electricity in South Africa. Lastly, the percentage of CSP in the national electricity supply planning process was deemed to be a useful progress indicator, as this gave an indication of the South African government's stand with regard to the large-scale rollout of CSP.

## 5.2 Indicator Usefulness

Of all the stakeholder responses, the outcome measure of 'electricity produced' from CSP plants was ranked as the most successful (see Figure 12 below). This outcome indicator could measure the CSP share of the electricity sector more accurately than the installed capacity (GW) measure that was used to define South Africa's large-scale rollout of CSP (Table 1). The amount of electricity generated would also indirectly measure the GHG emissions saved, thereby influencing the 'GHG mitigated' outcome indicator. The usefulness of the 'electricity produced' measure could be enhanced if it were linked to the specific CSP technology, and if it assessed the cost-effectiveness of the CSP technologies, which may be presented with the price of the electricity generated.

'CSP plant licences issued', 'CSP plants under construction' and 'committed finance to CSP developments' indicators were all ranked by the stakeholders as being successful measures of the large-scale rollout of CSP in South Africa. These input indicators are thought to be useful early measures of how much progress has been made towards the output indicators mentioned above, and thereby provide some indication of the commitment to the large-scale rollout of CSP in South Africa.

<i>Intermediate progress indicator</i>	<i>Not at all</i>	<i>Not successful</i>	<i>Somewhat</i>	<i>Successful</i>	<i>Very successful</i>
GHG mitigated			←→		
Electricity produced from CSP Plants (kWh)				←→	
CSP plant licences issued			←→		
CSP plants under construction			←→		
Committed finance to CSP developments			←→		
% of CSP in national planning process	←→				
Amount of land and water rights committed to CSP development	←→				
% of CSP developers engaged in South Africa		←→			
% of CSP developers with offices in South Africa	←→				

**Figure 12.** Range indicating success of different intermediate indicators for the large-scale rollout of CSP in South Africa

The 'percentage of CSP in the national planning process', the 'amount of land and water rights committed to CSP development' and the 'percentage of CSP developers with offices in

South Africa' were deemed to be less successful process indicators. This is probably due to the fact that none of these indicate real progress towards achieving a low carbon electricity supply in South Africa, but rather indicate the amount of interest in CSP developments in South Africa. Most of the respondents thought that such process indicators should be reported annually, or more frequently.

In addition to the indicators presented above a number of measures were highlighted as being useful in assessing the effectiveness of the large-scale rollout of CSP in South Africa. In particular, a process indicator measuring the cost reduction in electricity supplied from CSP would highlight the effectiveness of the rollout program in competing with nuclear and coal generated electricity. An input indicator assessing the reliability of the REFIT in South Africa would certainly help overcome the barriers relating to regulation, as highlighted in this paper. Lastly, it was noted that a process indicator of grid-readiness would help facilitate the rollout of CSP, in that grid planning bottlenecks would be identified and overcome.

## 6. Conclusion

South Africa has excellent solar resources and, with the recent establishment of the REFIT, has become an interesting investment destination for CSP developers. According to the country's Long Term Mitigation Scenarios, one of South Africa's main carbon mitigation options lies in shifting its electricity generation away from coal (Winkler 2007); for example towards CSP.

The large-scale rollout of CSP in South Africa is characterised by three phases: during the initial Start phase, from 2010 to 2015, 2 GW of CSP capacity is constructed, from 2016 to 2020 the Scale up phase results in a 7 GW CSP capacity, and by the completion of the Rollout phase (2021 to 2050) 100GW of CSP capacity should be established. This could result in 3,850 Mt CO<sub>2</sub>-eq saved over the period 2010-2050 and would require an incremental cost of R4.7-10 billion per year if CSP technologies experience learning rates of 15 to 20% per year, and less (R3.6-4.6 billion per year) if the country manages to create a local supply of CSP components.

A number of technology, infrastructure, regulatory and industry barriers would have to be overcome for the country to achieve the rollout of CSP envisioned. International financial support is thought to be the most useful means of facilitating the rollout. Support for technology research, development and deployment could be in the order of 10 billion Rand for the first phase, R1 billion annually for 2015-2020 and R1-2.5 billion annually for 2021-2050, depending on the level of technology learning. Specifically, cost-reduction, storage and water-saving technologies would have to be progressed.

Regulatory barriers, relating to the Renewable Energy Feed-In Tariff, could be overcome with support aimed at developing the Renewable Energy Power Purchase Agency's ability to manage Power Purchase Agreements on the scale required to achieve the large-scale rollout of CSP. This could, for example, take the form of support for 100 staff members for five years at R50 million per year, totalling R250 million for the five years. Furthermore country-wide feasibility studies for CSP would have to be undertaken and support to IPPs would have to be cultivated through a Solar Energy Technologies Programme that may cost 240 million Rand per year for CSP.

Grid expansion would have to take place on a large scale to facilitate the rollout. Initially the first CSP plants would have to be integrated (2010-2015), then allowance for greater transmission from the northwest of the country would have to be achieved (2016-2020), and finally that region could become a new distribution centre (2021-2050). Such an undertaking could gain from international financial support, which at 50% of the expansion cost would be R400 billion.

Achieving the large-scale rollout of CSP would require strong domestic commitment as well as international support. Process indicators can be used to assess the success of the rollout. The best output indicator identified would be to monitor the amount of electricity generated

by CSP plants on an annual basis; although input indicators, such as the amount of committed finance to CSP developments or CSP plants under construction, would also be useful.

The large-scale rollout of CSP in South Africa, as described in this paper, can be seen as an example of a Nationally Appropriate Mitigation Action (NAMA) and should be further explored in the context of the UNFCCC climate change negotiations aimed at a post-2012 agreement.

## References

- Agama Energy 2003. Employment Potential of Renewable Energy in South Africa. Agama Energy, Sustainable Solutions and Earthlife Africa. Prepared for Sustainable Energy and Climate Change Partnership. [http://recep-sa.org/wirec/index2.php?option=com\\_docman&task=doc\\_view&gid=3&Itemid=15](http://recep-sa.org/wirec/index2.php?option=com_docman&task=doc_view&gid=3&Itemid=15)
- Clean Energy Action 2007. *Concentrated Linear Fresnel Reflectors: The Next Generation of Concentrating Solar Power*. Clean Energy Action fact sheet. <http://www.trec-uk.org.uk/images/CLFR.pdf>
- Climate Group 2009. *Breaking the Climate Deadlock: Technology for a Low-Carbon Future*. The Office of Tony Blair. [http://www.theclimategroup.org/assets/resources/Technology for a low carbon future report.pdf](http://www.theclimategroup.org/assets/resources/Technology%20for%20a%20low%20carbon%20future%20report.pdf)
- CPUC 2009. 33% Renewables Portfolio Standard – Implementation Analysis: Preliminary Results. California Public Utilities Commission, San Francisco. <http://www.cpuc.ca.gov/NR/rdonlyres/1865C207-FEB5-43CF-99EB-A212B78467F6/0/33PercentRPSImplementationAnalysisInterimReport.pdf>
- De Wit et al. 2006. Changes in Surface Water Supply Across Africa with Predicted Climate Change *Science* 311, 1917 (2006); DOI: 10.1126/science.1119929
- Spellmann et al. 2009. *The CSP Industry: An Awakening Giant*. Global Markets Research, Companies, 19 March 2009. Deutsche Bank. <http://gm.db.com/IndependentReserach>
- DLR 2005. *European Concentrated Solar Thermal Road-Mapping (ECOSTAR)*. Pitz-Paal, R., Dersch, J. and B. Milow (eds). EU-funded study SES6-CT-2003-502578, December 2003–February 2005. Deutsches Zentrum für Luft- und Raumfahrt e.V. DLR, Stuttgart. [http://ec.europa.eu/energy/res/publications/doc/2007\\_concertrating\\_solar\\_power\\_en.pdf](http://ec.europa.eu/energy/res/publications/doc/2007_concertrating_solar_power_en.pdf)
- DME 2003. *White Paper on the Renewable Energy of the Republic of South Africa*. Department of Minerals and Energy, Pretoria. [www.dme.gov.za/pdfs/energy/cabeere/cabeere\\_page4\\_2004.pdf](http://www.dme.gov.za/pdfs/energy/cabeere/cabeere_page4_2004.pdf)
- DME 2008. *Energy Security Master Plan – Electricity: 2007-2025*. Department of Minerals and Energy, Pretoria. [http://www.dme.gov.za/pdfs/energy/energy\\_sec\\_master\\_plan.pdf](http://www.dme.gov.za/pdfs/energy/energy_sec_master_plan.pdf)
- DME 2009. *Speech by Ms Buyelwa Sonjica, MP, Minister of Minerals and Energy at the Renewable Energy Summit*. Swan Lake Conference Centre, Centurion, Gauteng, 19 March 2009. <http://www.dme.gov.za/pdfs/speeches/2009%20RENEWABLE%20ENERGY%20SPEECH.pdf>
- DOE 2009. *Electricity Regulation Act 2006: Electricity Regulation on New Generation Capacity*. Government Notice, No. R 721, 5<sup>th</sup> August 2009. Department of Energy, South Africa.
- DWAF 2004. *National Water Resource Strategy, First Edition*. Department: Water Affairs and Forestry, Republic of South Africa. <http://www.dwaf.gov.za/Documents/Policies/NWRS/Default.htm>
- Earthlife Africa and Oxfam 2009. *Climate Change, Development and Energy Problems in South Africa: Another World is Possible*. Sustainable Energy and Climate Change Partnership, a project by Earthlife Africa, Johannesburg., First Published online by Earthlife Africa and Oxfam International, February 2009.
- EGTT 2009. *Recommendations on future financing options for enhancing the development, deployment, diffusion and transfer of technologies under the convention*. UNFCCC, Expert Group on Technology Transfer, FCCC/SB/2009/2

- Environment America 2008. *On the rise: Solar Thermal Power and the fight against global warming*. B. Del Chiaro, S. Payne and T. Dutzik (eds). Environment America Research and Policy Center, Spring 2008.
- Eskom, 2008. *Together, rising to the challenge. Annual Report 2008*. Available at [http://financialresults.co.za/eskom\\_ar2008/ar\\_2008/downloads/eskom\\_ar2008.pdf](http://financialresults.co.za/eskom_ar2008/ar_2008/downloads/eskom_ar2008.pdf)
- Fakir and Nicol 2008. *Obstacles and Barriers to Renewable Energy in South Africa*. The national Environmental Advisory Forum, Department of Environmental Affairs and Tourism, South Africa.  
[http://www.environment.gov.za/Branches/COO/neaf\\_2005/Documents/Obstacles%20&%20barriers%20to%20renewable%20energy%20in%20SA.pdf](http://www.environment.gov.za/Branches/COO/neaf_2005/Documents/Obstacles%20&%20barriers%20to%20renewable%20energy%20in%20SA.pdf)
- Fluri 2008. *Preliminary results on the potential of concentrating solar power in South Africa*. Unpublished research, University of Stellenbosch Department of Mechanical and Mechatronic Engineering, Stellenbosch.
- Holm et al. 2008. *Renewable Energy Briefing Paper: Potential of Renewable Energy to contribute to National Electricity Emergency Response and Sustainable Development*. Scoping the impact of renewable energy in South Africa, Version 8 (18Jul 08).  
<http://www.earthlife.org.za/wordpress/wp-content/uploads/2008/12/rebriefingpaperfinal5aug08.pdf>
- Hughes et al. 2007. *Energy Modeling: A modeling input into the Long Term Mitigation Scenarios process*. LTMS Input Report 1, Energy Research Centre, Cape Town, October 2007. [http://www.erc.uct.ac.za/Research/publications/07Hughesetal-LTMSEnergy\\_Modeling.pdf](http://www.erc.uct.ac.za/Research/publications/07Hughesetal-LTMSEnergy_Modeling.pdf)
- IEA [International Energy Agency]. 2008. *Energy Technology perspectives: Scenarios and Strategies to 2050*. OECD/IEA, Paris.
- Marquard et al. 2008. *Costing a 2020 target of 15% renewable electricity for South Africa*. Energy Research Centre, University of Cape Town.  
[http://www.erc.uct.ac.za/Research/publications/08-Marquardetal-costing\\_a\\_2020\\_target.pdf](http://www.erc.uct.ac.za/Research/publications/08-Marquardetal-costing_a_2020_target.pdf)
- Mills, D. R. and G. L. Morrison, 1997. *Advanced Fresnel Reflector Powerplants: Performance and Generating Costs*. Proceedings of Solar 1997, Australian and New Zealand Solar Energy Society, 1997, 2.53.
- Nersa, 2007. *Updated NIRP3: national Demand Forecast. Jan 2007*. National Energy Regulator of South Africa, Pretoria.  
<http://www.nersa.org.za/UploadedFiles/ElectricityDocuments/Updated%20NIRP3%20demand%20forecast.pdf>
- Nersa 2009a. *South Africa Renewable Energy Feed-In Tariff (REFIT): Regulatory Guidelines 26 March 2009*. National Energy Regulator of South Africa, Pretoria.  
<http://www.nersa.org.za/UploadedFiles/ElectricityDocuments/REFIT%20Guidelines.pdf>
- Nersa 2009b. *Renewable Energy Feed-In Tariff – Phase 2. NERSA Consultation Paper, July 2009*. National Energy Regulator of South Africa, Pretoria.  
<http://www.nersa.org.za/documents/consultation/REFIT%20Phase%20II%20150709.pdf>
- Nersa 2009c. *Nersa's decision on Eskom's application for an interim price increase*. Media Statement, 25 June 2009. National Energy Regulator of South Africa, Pretoria.  
<http://www.nersa.org.za/UploadedFiles/News/Final%20media%20statement-%20NERSA%20decision%20on%20Eskom's%20application%20for%20an%20interim%20price%20increase%2025%20June%202009%20MN.pdf>
- Richter et al. 2009. *Concentrating Solar Power – Global Outlook 09: Why Renewable Energy is Hot*. Greenpeace International, SolarPACES, ESTELA.  
<http://www.greenpeace.org/raw/content/international/press/reports/concentrating-solar-power-2009.pdf>

- Sargent and Lundy 2003. *Assessment of Parabolic Trough and Power Tower Solar Technology Cost and Performance Forecasts*. NREL Subcontracted Report. Sargent and Lundy LLC Consulting Group, Chicago. <http://www.nrel.gov/csp/pdfs/34440.pdf>
- Solar Task Force 2006. *Clean and Diversified Energy Initiative*. Western Governors' Association. <http://www.westgov.org/wga/initiatives/cdeac/Solar-full.pdf>
- Scenario Building Team 2007. *Long Term Mitigation Scenarios: Scenario Document*. Department of Environmental Affairs and Tourism, Pretoria, October 2007. [http://www.erc.uct.ac.za/Research/publications/07Scenario\\_team-LTMS\\_Scenarios.pdf](http://www.erc.uct.ac.za/Research/publications/07Scenario_team-LTMS_Scenarios.pdf)
- Sparks 2006. *Energy and the Environment*. In Winkler (ed.) *Energy Policies for Sustainable Development in South Africa: Options for the Future*, pub. By Energy Research Centre, University of Cape Town.
- Stanley et al. 2009. *Juice from Concentrate: Reducing Emissions with Concentrating Solar Thermal Power*. World Resource Institute and Goldman Sachs Centre for Environmental Markets. [http://pdf.wri.org/juice\\_from\\_concentrate.pdf](http://pdf.wri.org/juice_from_concentrate.pdf)
- Thomas 2006. *The economic risk to electricity consumers of the Pebble Bed Modular Reactor*. Public Service International Research Unit, University of Greenwich, London. <http://www.psiru.org/reports/2006-01-E-PBMR-NER.pdf>
- US DoE 2008. *Solar Energy Technologies Program: Multi-Year Program Plan 2008-2012*, April 15 2008. UD Department of Energy, Energy Efficiency and Renewable Energy. [http://www1.eere.energy.gov/solar/pdfs/solar\\_program\\_mypp\\_2008-2012.pdf](http://www1.eere.energy.gov/solar/pdfs/solar_program_mypp_2008-2012.pdf)
- Van Heerden 2009. *South African National Energy Association Monthly Lecture*. 20 May 2009. [http://www.sanea.org.za/siteworkspace/SANEA%20Monthly%20Lecture%20-%2019%20May%202009%20\(Dr%20Louis%20van%20Heerden\).pdf](http://www.sanea.org.za/siteworkspace/SANEA%20Monthly%20Lecture%20-%2019%20May%202009%20(Dr%20Louis%20van%20Heerden).pdf)
- Winkler (ed) 2007. *Long Term Mitigation Scenarios: Technical Report*. Prepared by the Energy Research Centre for Department of Environment Affairs and Tourism, Pretoria, October 2007. <http://www.erc.uct.ac.za/Research/publications/07-Winkler-LTMS-Technical%20Report.pdf>
- Winkler, H., et al. 2009. *Technology learning for renewable energy: Implications for South Africa's long-term mitigation scenarios*. *Energy Policy* (2009), doi:10.1016/j.enpol.2009.06.062
- World Bank and GEF 2006. *Assessment of the World Bank/GEF Strategy for the Market Development of Concentrating Solar Thermal Power*. A World Bank Group Global Environment Facility Publication, Washington. <http://siteresources.worldbank.org/GLOBALENVIRONMENTFACILITYGEFOPERATIONS/Resources/Publications-Presentations/SolarThermal.pdf>