DFID Department for International Development

CONCENTRATING SOLAR POWER IN AFRICA

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Report prepared by:

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The TI-UP Resource Centre

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List of Acronyms

AC	Alternating Current
CIEMAT	Research Centre for Energy, Environment and Technology
CLFR	Compact Linear Fresnel Reflector
CPV	Concentrating Photovoltaics
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSP	Concentrating Solar Power
DC	Direct Current
DLR	German Aerospace Centre
DNI	Direct Normal Irradiance
DPT	Distributed Power Tower
EREC	European Renewable Energy Council
GEF	Global Environment Facility
HCE	Heat Collector Elements
HTF	Heat Transfer Fluid
HVDC	High Voltage Direct Current
ISCC	Integrated Solar Combined Cycle
ISCCS	Integrated Solar Combined Cycle System
LEC	Levelised Energy Cost
NEAL	New Energy Algeria Limited
NERSA	National Energy Regulator of South Africa
NREA	New and Renewable Energy Authority
NREL	National Renewable Energy Laboratory
PCM	Phase Change Material
PV	Photovoltaics
SEGS	Solar Energy Generating Systems
TES	Thermal Energy Storage
USDOE	United States Department of Energy

1 PROJECT BRIEF

IT Power has been contracted by WSPimc, under the TI-UP Helpdesk, to produce a report on Concentrating Solar Power (CSP) technologies to confirm or otherwise whether CSP is an option for Africa.

This reports covers the key CSP technologies, concentrating photovoltaics, solar parabolic troughs, linear Fresnel collectors, solar power tower, dish Stirling engines, updraft towers and the integration into conventional power plants. This report describes the key technologies, their current status and current and planned installations in Sections 2 and 3. Indicative capital and levelised energy costs for CSP plants are given in Section 4, it should be noted that a present there are few commercial CSP operating and this makes providing accurate costs difficult. In Section 5 the potential for using CSP in Africa is discussed, including incentive measures to encourage the development of CSP plants in this region.

2 KEY TECHNOLOGIES

2.1 Concentrating Photovoltaics

2.1.1 Description

Concentrating Photovoltaics (CPV) uses lenses or mirrors to concentrate sunlight onto high-efficiency solar cells. Various technology lines have been developed, with concentration factors ranging from 2 to 1000. Usually the technologies are classified into two groups: low concentrating PV (factor 2-25) and high concentrating PV (also called HCPV). CPV systems use 2-axes trackers which have been well tested through use in non-concentrating PV plants for many years. For CPV the trackers had to been enhanced, as exact positioning is essential for this concentrating technology. The output of the PV modules is direct current (DC) electricity which is converted to alternating current (AC) using inverters before feeding into the public electricity grid.

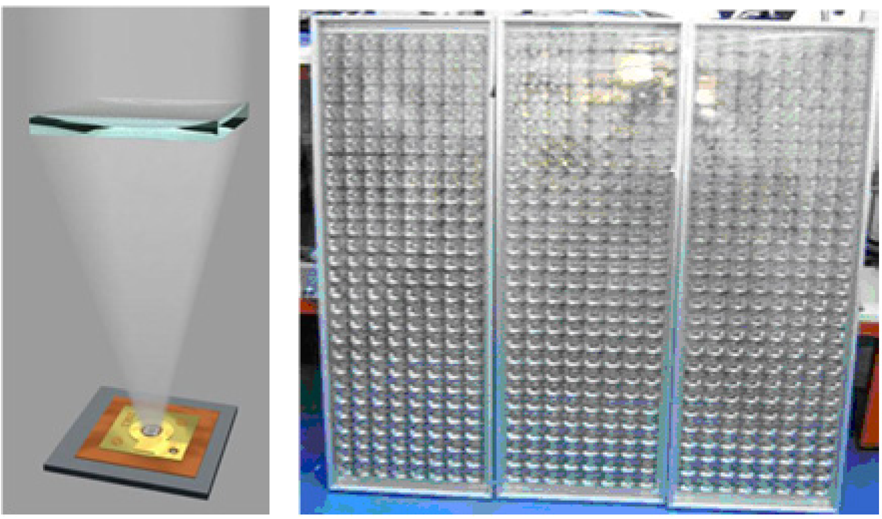

Figure 1: FLATCON technology principle and a CPV module (Sources: Concentrix, Isofotón)

2.1.2 Current Status

CPV plants are currently in the late demonstration phase. The first commercial plants are under project development. Due to the high solar concentration CPV is designed to keep the PV cells in a desired operating temperature range. An issue for early demonstration plants has been condensation in the modules.

Figure 2: CPV plant in Spain (Photo: Concentrix)

2.1.3 Operation and Maintenance

Modules should be cleaned regularly as concentrating PV plants are more sensitive about clean surfaces then conventional PV. Cables, modules and connections have to be checked on a regular basis. Inverters are the most sensitive parts of a PV installation. The power electronics, the cooling fans or the controller unit may fail at some stage during the plants lifetime. Atmospheric discharges (e.g. lightning) form a hazard on modules and the inverters. Therefore from time to time parts have to be exchanged. Good monitoring of the plant and its performance is essential to avoid longer lasting yield losses. O&M requirements are largely identical with tracked non-concentrating PV plants. To the knowledge of IT Power no special procedures have yet been developed for large CPV plants. Experience will soon be gained when large plants will be fully commissioned and operated on a day to day basis.

2.2 Solar Parabolic Trough Collector

2.2.1 Description

A solar parabolic trough collector uses U-shaped reflective troughs to concentrate sunlight onto a receiver tube positioned along the focal point of the trough. This tube contains a working fluid, usually oil or water, which can reach temperatures of up to 400°C. The receiver tube is sometimes encased in glass to reduce heat loss. The heated working fluid may be used for medium temperature space or process heat, or to operate a steam turbine for power or electricity generation. Parabolic troughs often use single-axis or dual-axis tracking, although they can also be stationary.

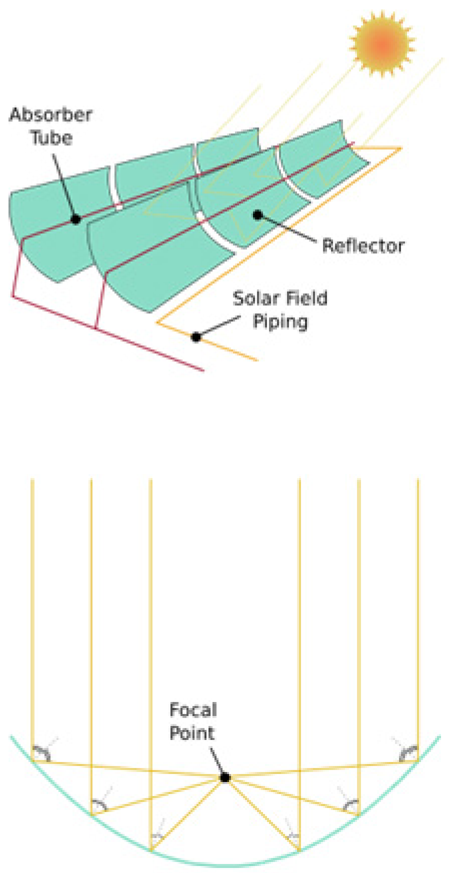

Figure 3: Principles of solar parabolic trough collector (Source: Andrew Buck)

2.2.2 Current Status

Solar parabolic trough plants are a mature technology and are usually seen as the most economic solar plant option among those tested until now. Solar Energy Generating Systems (SEGS) in California, USA have been in operation for over two decades using parabolic trough technology. SEGS consists of nine plants with a total capacity of 354MW. The turbines at this plant can be additionally run using natural gas to provide power at night. Other plants in operation include Nevada Solar One a 64 MW plant in the USA and Andasol 1 a 50MW plant in Spain.

Figure 4: SEGS IV in California, USA (Photo: NREL)

2.2.3 Operation and Maintenance

Professional and thorough maintenance is an important requirement to maintain the value of the investment and achieve high availability of the plant to capitalise on the solar resource. Long time experience has been gained during the O&M of the SEGS-plants in the USA. One of the key O&M costs is the replacement of broken mirrors due to wind load. Regular cleaning of the parabolic mirrors is an important part of the O&M tasks. The mirrors can be cleaned in different ways, currently a method using hot water steam is preferred (Figure 5)

Figure 5: Cleaning trough with water steam (Photo: NREL)

According to Bockamp S et al. (2003) recent O&M costs at the existing Californian plants have come down to an estimated US$0.025/kWh from US$0.04/kWh at the beginning. The major part of O&M costs are heat collection elements (HCE) replacement costs according, an estimate for the replacement rate of these absorber tubes is 5 % of the initial HCE investment of 490 USD/kW resulting in annual expenditures of 25 USD/kW (Sargent & Lundy (2003)). These HCE are only 1 % of the initial investment for a plant without storage. As many studies point out, that O&M costs increase only slightly, when the plant size is increased. That means the energy specific O&M expenditures decrease with power plant size and increased operating hours.

2.3 Linear Fresnel Collector

2.3.1 Description

This technology works on a similar principle to a parabolic trough. Almost flat, reflective stripes are use to form a Fresnel-shaped reflector to concentrate the solar insolation into a stationary absorber tube (steel tube with selective coating). The absorber is mounted into a secondary stage reflector. The reflector redirects misled rays onto the absorber tube. It has an opaque top and a glass pane on the bottom to avoid heat losses. In the absorber tube water is heated to raise steam, reaching temperatures around 500 °C. The steam drives a conventional steam turbine to produce electricity via a generator.

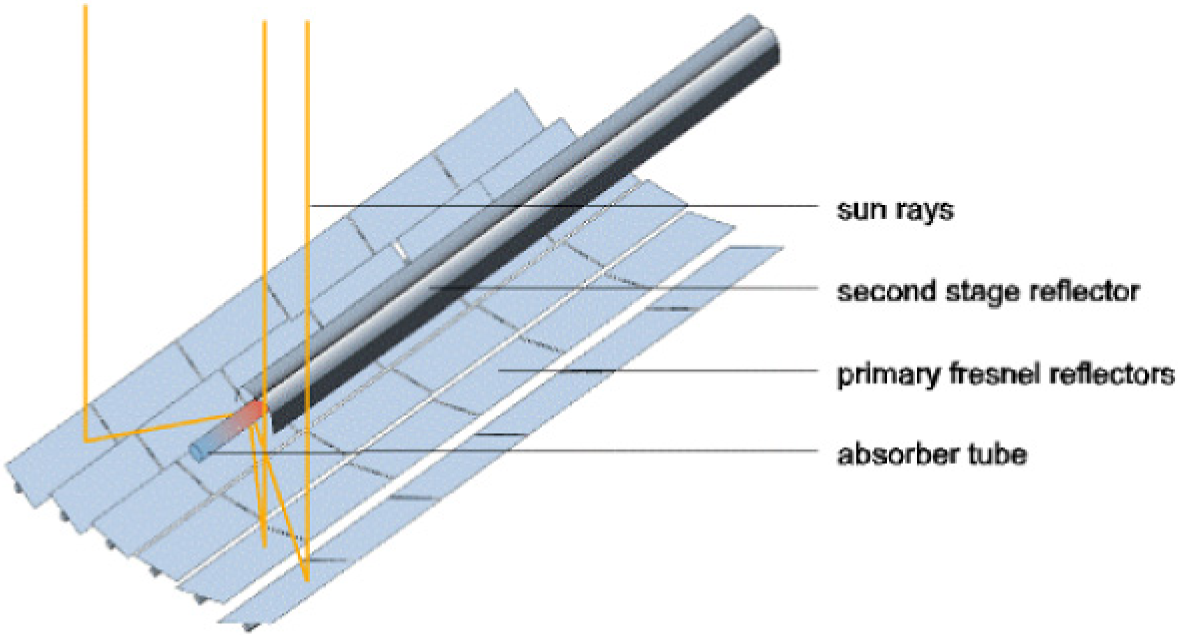

Figure 6: Principle of a linear Fresnel solar collector

Figure 7: Linear Fresnel solar collector module - demonstration plant

The advantages of the Linear Fresnel Collector in comparison to common solar parabolic trough plants are:

1. Inexpensive, almost flat mirrors
2. No vacuum technology and no metal glass sealing for absorber
3. Single, fixed absorber tube
4. Near planarity of the solar collector
5. Direct steam generation
6. Many simple and robust components, which can be manufactured locally
7. No spacing between rows is required (Only absorber casts shadow, not the mirrors)
8. Reduced maintenance costs (Mirrors have small wind load)

2.3.2 Current Status

Fresnel collectors are a more recent development than parabolic troughs, and are still in the demonstration phase. A 5MW plant was opened in 2008 in California, and a 75 MW plant is planned for Florida. A plant using Compact Linear Fresnel Reflector technology (CLFR) will be used in a 177 MW plant under construction in San Luis Obispo County, USA. Several commercial Fresnel type projects are currently under development (e.g. in Spain and Dubai).

As an alternative to the solar stand-alone option, the integration of a Linear Fresnel solar collector field into a conventional plant has been suggested (ISCC). The advantage of this application is, that no storage for continuous supply is needed, control mechanisms are cheaper and simpler and the high efficiency of large power blocks can be utilised. As a result, costs are lower and the solar resource can be used more efficiently. A 0.38MW solar add-on for a conventional plant in Liddell, Australia is currently in the test and demonstration phase. Section 2.7 includes further discussion on the integration of solar into conventional power plants.

2.3.3 Operation and Maintenance

It is expected, that the replacement costs for broken mirrors are lower than those for solar trough plants, as the Fresnel technology has less wind load. Therefore O&M costs are usually assumed to be 2% of the initial investment this leads to specific O&M costs of US$0.024 - US$0.031/kWh (Bockamp S et al. (2003)). Detailed studies often assume a 3 week maintenance break in the course of the calendar year to be taken in the month when the solar energy is at its lowest.

2.4 Solar Power Tower

2.4.1 Description

Solar Power Tower Plants consist of a field of mirrors with a tower in the centre; on top of the tower is an integrated receiver. These mirrors track the sun and are known as heliostats. In the receiver the solar insolation concentrated by hundreds of mirrors heats up a heat transfer fluid (HTF), air, oil or molten salt have been used as the HTF. Heat exchangers couple the (HTF) to steam, which can drive a conventional steam turbine.

The total power of Power Tower Plants is limited due to the limitation in the number of sun-tracked mirrors (heliostats), positioned close enough to the tower to have good tracking performance. One approach is the Distributed Power Tower (DPT) technology, where outlying towers heat steam to 350 °C and a central tower superheats the steam to 550 °C to directly drive a large turbine. The typical efficiency of a Power Tower Plant is assumed to be around 16%.

Figure 8: CESA II at Plataforma Solar de Almería, Spain

2.4.2 Current Status

Solar power towers have been around for over two decades but are not in widespread use. Demonstration plants for the power tower technology were built in the 1980s in Italy, Spain, Israel, Japan, France and the USA. In Spain and the USA they have been used continuously to further develop methods and materials, with several more towers of 20 – 100MW planned in both countries. A three tower system with two 100MW and one 200MW towers is currently being reviewed for operation in California, and South Africa is currently reviewing the feasibility of a 100MW plant.

Figure 9: Heliostat at LUZ II (Photo: Luz II plant, Israel)

2.4.3 Operation and Maintenance

The material and service costs within O&M for Solar Tres is estimated to be between US$0.6 and 0.7 million per year (Sargent & Lundy (2003)). In total a Solar Tres plant in the USA would require annual O&M expenditures between US$2.5 and 3 million per year. This accounts to between 3.2% and 3.9% of the plant investment sum. The estimation is based on the staff number of 25 staff for combined cycle power blocks with a nominal power of 120MW plus 0.03 staff per 1000m² of heliostat surface considering 100m² heliostats.

2.5 Dish Stirling

2.5.1 Description

Dish-Stirling systems use parabolic mirrors to highly concentrate sunlight. The mirrors continuously track the sun, reflecting the incoming solar rays onto its focal point. The solar heat exchanger located at the concentrator focal point absorbs the concentrated solar radiation, heating the heat transfer medium. A Stirling engine then uses this heat to directly produce electricity.

Dish-Stirling systems typically have a capacity of 10 to 50 kW per unit, but can be installed in large groups.

Figure 10: Dish Stirling, Plataforma Solar de Almeria in Spain (Photo: Sandia National Laboratories)

2.5.2 Current Status

Dish Stirling systems are a well established technology, the first systems were developed in the 1970s. Many demonstrations and research plants have been installed in Spain and USA. Two commercial scale plants are planned for California, Solar One consisting of 20,000 dishes with an initial capacity of 500MW and Solar Two consisting of 12,000 dishes with an initial capacity of 300MW.

2.5.3 Operation and Maintenance

Professional and thorough maintenance is an important requirement to maintain the value of the investment and achieve high availability of the plant to capitalise the solar resource. Regular cleaning of the parabolic mirrors is an important part of O&M for this system. There are currently no cost data available for the O&M of commercial Dish Stirling plants due to the lack of commercial plants in operation.

2.6 Updraft Tower

2.6.1 Description

A Solar Updraft Tower is a large-scale solar thermal power plant (30 – 200 MW). In a Solar Updraft Tower air is heated under a large transparent collector roof. Due to the different densities of warm air inside the collector and ambient cold air, the air inside flows to the centre of the collector roof, and ascends through an updraft chimney in the middle, driving turbines that generate electricity.

Figure 11: Prototype Updraft Tower, Manzanares, Spain

2.6.2 Current Status

Updraft towers have been proven to work in principle; however there are no plants currently in operation

In 1982 a small-scale experimental model of a solar updraft power plant was built in Manzanares, Spain. The chimney had a height of 195 metres and a diameter of 10 metres with a collection area (greenhouse) of 46,000 m^2 (about 11 acres, or 244 m diameter) obtaining a maximum power output of about 50kW. This pilot power plant operated for approximately eight years.

There is a proposal to construct a solar updraft tower in Ciudad Real, Spain entitled Ciudad Real Torre Solar, with an expected output of 450 MW of electricity. If built, it would be the first of its kind in the European Union and would stand 750 metres tall covering an area of 350 hectares. This is currently at the pre-feasibility stage, but it is unclear whether they have any financial backing. EnviroMission is currently carrying out a final feasibility study to build a solar updraft tower power generating station known as Solar Tower Buronga at a location near Buronga, New South Wales. In Botswana the Ministry of Science and Technology designed and built a small-scale solar updraft chimney system for research. This chimney ran from 7 October until 22 November 2005. In mid 2008 the Namibian government approved a proposal for the construction of a 400 MW solar updraft chimney called the Greentower. The tower is planned to be 1.5 km tall and 280 m in diameter, and the base will consist of a 37 km^2 greenhouse in which cash crops can be grown.

2.7 Integration into Conventional Power Plants

As an alternative to the solar stand-alone option, the integration of a CSP into a conventional power plant has been suggested. The advantages of this application are:

1. No storage for continuous supply is needed (over night or cloudy periods)
2. Control mechanisms are cheaper and simpler
3. The high efficiency of large power blocks with large turbines and high temperatures can be utilised.
4. The power block can be operated near nominal power (high efficiency range), even in times of lower solar resource availability.
5. Little extra costs for integrating solar share.

As a result, costs are lower and the solar resource can be used more efficiently. In fact the cost estimations are so promising that conventional power plants are expected to be commonly offered with a solar share in 10 years time.

One disadvantage is that the optimal solar share, where the solar resource is used in the most efficient and economically most attractive way, is very small (1 – 10 %) and the emissions originating from the conventional part are only slightly reduced. Nevertheless the concepts can save fuel, emissions and costs as well as support the market introduction and dissemination of solar thermal plants.

The mains options for integrating solar power plants into conventional plants are:

1. Solar live steam in hybrid Rankine plants - solar superheated steam in hybrid operation mode (typically 75 % solar share)
2. Solar gas turbine combined cycle - Solar Power Towers in hybrid operation with gas burning chamber (any solar share)
3. Integrated Solar Combined Cycle System (ISCCS) - steam and gas turbine: solar field feeding the steam turbine together with heat recovery steam generator, which uses the exhaust gas of the gas turbine (solar share optimum 5 - 10%, if storage is used based on rated power of 50 MW solar, 200 MW conventional)
4. Solar feed water preheating - solar plant preheating the feed-water in conventional Rankine plants (solar share typically 1 %)
5. Solar plants with co-firing option - solar heat is backed up or increased by co-firing with conventional energy sources (any solar share)

2.8 Heat Storage

A solar power plants' generation schedule is directly dependant on the current solar resource, therefore a storage system is needed in order to ensure uninterrupted electricity production. In some cases storage systems are designed large enough to provide energy throughout the night or at least for the evening demand of settlements. In solar stand-alone systems the implementation of a properly dimensioned storage system can reduce the Levelised Electricity Cost by increasing the generated energy over the plants' life time. It also allows operation at high turbine efficiency factors over a long period and avoids loss of potential energy generation when the solar resource reaches peak values. A major advantage of solar thermal power plants integration into conventional power plants' cycle pre-heating is that there is always the possibility to co-fire the cycle with conventional fuels. Hence the investment for a storage system can be saved in that particular design.

There are two systems that can be used to mechanically store energy using potential energy:

1. Air pressure storage systems – these systems can store up to 600MWh, but have a comparatively low efficiency of 42%.
2. Pumped storage systems – these are used in pumped storage electricity plants, where water is pumped into an elevated reservoir and drives hydro-turbines when needed. These systems have an efficiency of approximately 80% and can store up to 8000MWh.

Unfortunately both systems require an appropriate natural setting to be applicable. The alternative hydrogen systems are still expensive, have low life expectancies and low conversion efficiencies.

Therefore Thermal Energy Storages (TES) are usually the most feasible and appropriate, if the energy is already available in the form of heat and is exploitable in the form of heat (e.g. solar thermal power plants).

The following systems can be considered for implementation:

1. Two-Tank Indirect System
2. Two-Tank Heat Storage with Direct Molten Salt Heat Transfer Fluid (HTF)
3. Single Tank Thermocline System with Direct Molten Salt HTF
4. Thermal Energy Storage Media piped by standard HTF

A storage system has to be designed individually to fit the heat exchangers with the storage and to fit it to the capacity of the turbine under operation in the solar thermal power plant. Temperature levels on both sides (input and output) have to be suitable for the selected storage technology.

2.8.1 Two-Tank Indirect System

A tank with cold fluid and another with hot fluid form the storage system in this configuration. In the indirect system heat exchangers are used, because the storage fluid is different from the Heat Transfer Fluid (HTF) used in the solar thermal power plant, as for a Direct Oil Storage System the storage would have to withstand high pressures and require unjustifiable high investments.

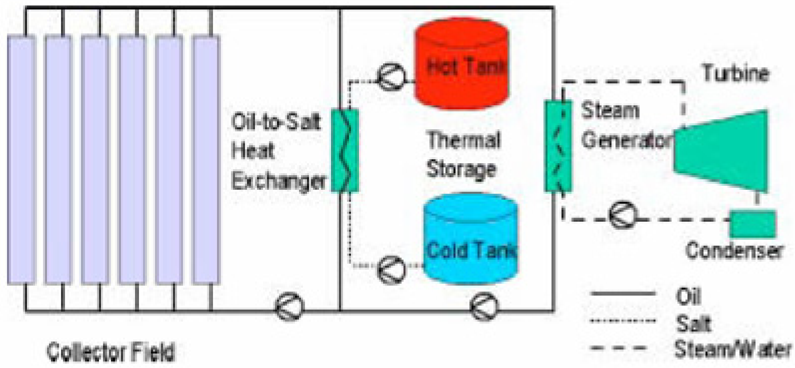

Figure 12: Two-Tank Indirect Storage System (Source: NREL)

Molten salt serves as storage medium. Carbon steel tanks with insulation (e.g. calcium silicate block insulation) are used to store the energy. The efficiency of the plant decreases slightly with such a storage system from 37.9% to between 34.7% and 37.5% according to an US study (NREL 2006) (footnote). The storage costs were assessed to be in the range of US$25 to 34/kWh$_{th}$ of storage capacity. I.e. a 4 hour storage for a 50 MW$_{el}$ plant would have expected costs of 4 h * 50 MW / (35/100) US$30 /kWh = US$17 million. Likewise a 12 hour storage capacity would have estimated costs of US$53 million.

2.8.2 Two-Tank Heat Storage with Direct Molten Salt Heat Transfer Fluid

In the Two-Tank Heat Storage System the losses caused by using heat exchangers are avoided by using molten salt directly in the solar field as the Heat Transfer Fluid (HTF).

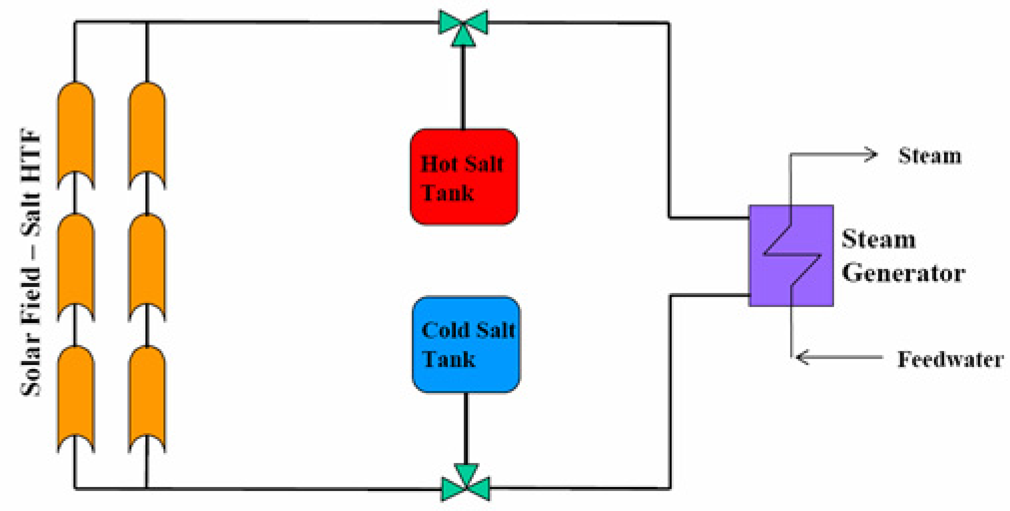

Figure 13: Two-Tank Direct Molten Salt Storage System (Source: NREL)

To keep the salt molten, a minimum temperature of approximately 220°C has to be kept. The feasibility of such a system has been demonstrated, but for commercial plants the minimum temperature condition seems too critical and too demanding. Salt mixtures allowing a lower minimum temperature are under development.

2.8.3 Single-Tank Thermocline Storage System with Direct Molten Salt

The fluid is kept in a single tank with the temperature ranging from hot to cold where the area between is called thermocline. The storage capacity is dependent on tank size and the operating temperature range. The tank is partially filled with another, less expensive non-liquid storage medium, which makes this technological solution economically interesting. The operation challenge is to keep the thermocline zone in the tank at any time. This system works with Molten Salt as used in Section 2.8.2 to avoid pressurised storage technology.

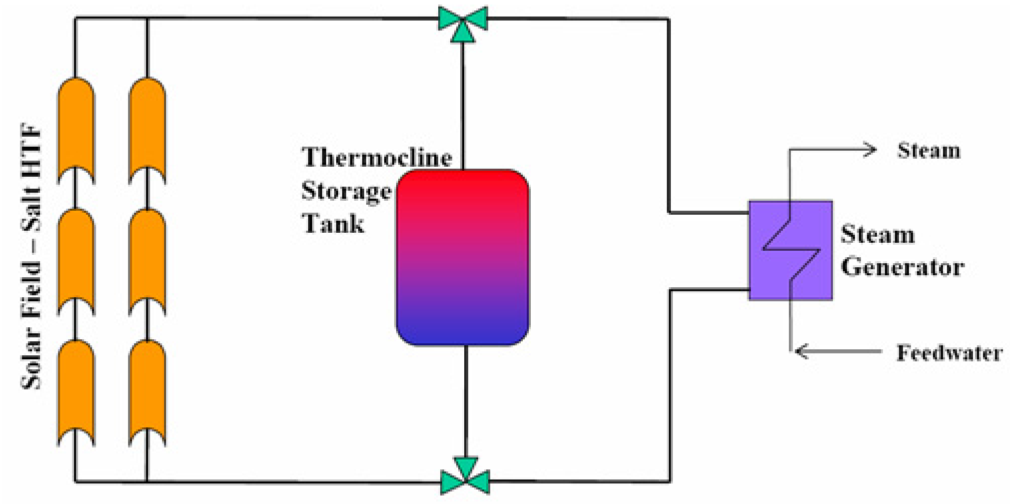

Figure 14: Single-Tank Thermocline Storage System with Direct Molten Salt (Source: NREL)

2.8.4 Thermal Energy Storages with Storage Media

Solid Storage Media

Another technology builds on solid storage media to store the thermal energy. Investigated media include concrete and castable ceramics forming storage blocks which are filled around pipes conducting the Heat Transfer Fluid (HTF) i.e. the storage is literally built around the heat exchanging tubes. The concrete storage option is cheaper and easier to handle. The degradation rate is found to be low. An advantage of this type of storage is that they can be distributed and embedded under the surface below the solar field.

Phase Change Materials

Phase Change Materials (PCM) can serve as a very cost efficient storage media. However until now the different technological options that have been researched are not considered commercially applicable yet.

3 CURRENT AND PLANNED INSTALLATIONS

3.1 Operational

Name	Location	Technology	Capacity (MWe)
Solar Energy Generating Systems (SEGS I – IX)	Mojave Desert California, USA	Parabolic trough	354
Nevada Solar One	Las Vegas, Nevada, USA	Parabolic trough	64
Andasol 1	Granada, Spain	Parabolic trough	50
Saguaro	Arizona, USA	Parabolic trough	1
Kimberlina Solar Thermal Energy Plant	Bakersfield, California, USA	Fresnel collector	5
Liddell Power Station Stage 1	New South Wales, Australia	Fresnel collector to supply steam to power station	5
PS10 solar power tower	Seville, Spain	Solar power tower	11
Umuwa	South Australia	Concentrating PV	0.22
Yuendumu	Northern Territories, Australia	Concentrating PV	0.24
Lajamanu	Northern Territories, Australia	Concentrating PV	0.29
Hermannsburg	Northern Territories, Australia	Concentrating PV	0.19

3.2 Under Construction

Name	Location	Technology	Capacity (MWe)
Solúcar Platform	Andalucia, Spain	Solar power tower, parabolic trough, PV and Stirling engine	300
Martin Next Generation Solar Energy Center	Florida, USA	Parabolic trough	75
Alvarado 1	Badajoz, Spain	Parabolic trough	50
Palma del Rio II	Cordoba, Spain	Parabolic trough	50
Majadas de Tiétar	Cáceres	Parabolic trough	50
Solnova 1	Spain	Parabolic trough	50
Solnova 3	Spain	Parabolic trough	50
Energia Solar De Puertollano	Spain	Parabolic trough	50
SA Solar Plant	Spain	Parabolic trough	50
Extresol 1	Spain	Parabolic trough	50
	Egypt	Parabolic trough with heat storage	20
Andasol 3 solar power station	Granada, Spain	Parabolic trough with heat storage	50
Hassi R'mel	Algeria	Parabolic trough providing steam input for gas powered plant	30

Kuraymat Plant	Egypt	Parabolic trough providing steam input for gas powered plant	20
Beni Mathar Plant	Morocco	Parabolic trough to supply steam for hybrid power plant	20
Yzad Solar Thermal Plant	Yazd, Iran	Parabolic trough to supply steam for hybrid power plant	67
Liddell Power Station Stage 2	New South Wales, Australia	Fresnel collector to supply steam to power station	35
PS20 solar power tower	Seville, Spain	Solar power tower	20
Solar Tres Power Tower	Spain	Solar power tower with heat storage	17
Mildura	Victoria, Australia	Concentrated PV	154
SolFocus	Spain	Concentrated PV	3
Keahole Solar Power	Hawaii	MicroCSP parabolic trough	1

3.3 Announced

Name	Location	Technology	Capacity (MWe)
Mojave Solar Park	California, USA	Parabolic trough	553
Solanan	Arizona	Parabolic trough	280
Solana	Arizona, USA	Parabolic trough	280
Beacon Solar Energy Project	California, USA	Parabolic trough	250
Harper Lake Energy Park	California, USA	Parabolic trough	250
Ramat Negev	Israel	Parabolic trough	250
Unknown	California, USA	Parabolic trough	245
Carrizo Energy Solar Farm	California, USA	Parabolic trough	177
Unknown	Jordan	Parabolic trough	150
Shams	Madinat Zayad, United Arab Emirates	Parabolic trough	100
Theseus	Greece	Parabolic trough	52
Extremasol 2	Spain	Parabolic trough	50
Murciasol 1	Spain	Parabolic trough	50
Murciasol 2	Spain	Parabolic trough	50
Helios 1	Ciudad Real, Spain	Parabolic trough	50
Helios 2	Ciudad Real, Spain	Parabolic trough	50
Bethel 1	California, USA	Parabolic trough	50
Bethel 2	California, USA	Parabolic trough	50
Victorville 2	California, USA	Parabolic trough	50
Majadas de Tiétar	Cáceres, Spain	Parabolic trough	50
Alvarado	Badajoz, Spain	Parabolic trough	50
Ecija 1	Andalucia, Spain	Parabolic trough	50
Ecija 2	Andalucia, Spain	Parabolic trough	50
Solnova 2	Spain	Parabolic trough	50

Solnova 4	Spain	Parabolic trough	50
Manchasol 1	Ciudad Real, Spain	Parabolic trough	50
Manchasol 2	Ciudad Real, Spain	Parabolic trough	50
Agua Prieta II	Sonora, Mexico	Parabolic trough	25
Almaden	Florida, USA	Fresnel reflector	20
Gotasol	Gotarrendura, Spain	Fresnel reflector	10
Ivanpah Solar Electricity Generating System	California, USA	Solar power tower	400
Upington	South Africa	Solar power tower	100
eSolar 1	California, USA	Solar power tower	84
eSolar 2	California, USA	Solar power tower	66
Almaden	Albacete, Spain	Solar power tower	20
Cloncurry Solar Power Project	Cloncurry, Australia	Solar power tower	10
Solar One	California, USA	Stirling engine	850
Solar Two	California, USA	Stirling engine	750
Solar Mission Project	Australia	Solar updraft chimney	200

4 COST ESTIMATES

Cost estimates have been published over the 30 years of research by Spain, Germany and the USA and experience with the O&M of the SEGS plants in the USA. The commercial market has only begun developing over the past few years. The experienced competitors with experience try to achieve a return of research investment and gain a good market share before newcomers enter into the market. Installation and development costs are therefore only roughly published in news releases and promotional presentations. With the existing attractive feed-in tariffs the manufacturers and project developers do not give out costing figures as they are considered highly commercially highly sensitive. Another aspect is that costs can differ widely with land conditions, legal frameworks and local resources. Some developers even prefer the potential customer to state a desired LEC and a concrete installation site and then make an offer or not. At present there are very few CSP plants under construction in Africa therefore cost estimates are based upon news releases available from plants in Europe, Australia and the USA. Not all of these plants are considered to be in the range of full commercial viability yet. Costs are expected to decrease and become more reliable as projects will lose the pioneer character. Operation and maintenance experiences and methods are currently further evaluated at the first few commercial plants, which are mostly built by a consortium including the manufacturer. Changes in technologies, methods and costing are likely to happen in the near future. Current cost experiences for O&M are also considered commercially highly sensitive information and therefore not given out. Updraft tower have not been under construction since for decades and will therefore not be covered in this section.

In most regions where CSP is currently deployed the cost of electricity generation through CSP is higher when compared with the cost of electricity generation through traditional technologies. However, with large scale implementation and advances in technology the cost of generation through CSP is expected to fall. According to a report by the Electric Power Research Institute (2006) once the global deployment of CSP will reach 4GW, the cost of generating electricity could be as low as US$0.08/kWh (nominal 2015 dollars) or nearly US$0.05/kWh (real 2005 dollars). A report by the European Renewable Energy Council (EREC) and Greenpeace (2007) suggests that electricity produced from CSP plants will be cheaper than that from coal power plants by 2030.

The costs of CSP can be assessed using initial capital costs, operation and maintenance cost, financing cost, or Levelised Energy Cost (LEC) per generated energy unit. The most reliable data for maximum generation costs may be drawn from countries like Spain, where commercial plants are operated harnessing a feed-in tariff. The simple sensible assumption is that this feed-in tariff exceeds the costs (LEC). In a The next step the comparison of would be to compare the Direct Normal Irradiance (DNI) resource with sites in Spain can to determine an achievable LEC in alternative for sites in Africa. However for actual project development influences because of local costs and conditions in Africa and changing costs for power plant components (e.g. turbine) will have to be considered.

4.1 Initial Capital Costs

A report for CSP Today (2008) provides estimates for the initial capital costs for parabolic troughs in the USA from 2007 to 2015 for expected sizes of plants to be installed in these years, as shown below in Table 1. A decrease in cost per MW from US$4.9 million to US$3.2 million is expected from 2007 to 2015.

Table 1: Initial Capital Costs in 2005 dollars (million US$)

Parameter	2007 100MW	2009 100MW	2011 150MW	2015 200MW
Site Work and Infrastructure	2.5	2.4	2.6	2.7
Solar Field	230.9	105.1	243.1	268.4
HTF System	10.0	9.9	11.9	13.5
Thermal Energy Storage	58.0	57.9	71.3	89.4
Power Block	38.8	38.8	49.0	56.8
Balance of Plant	22.5	22.5	28.4	33.0
Contingency	30.7	28.2	33.7	37.7
Total Direct Costs	**393.3**	**354.8**	**439.9**	**510.6**
Indirects	101.1	92.8	113.5	129.7
Total Installed Cost	**494.4**	**457.6**	**553.4**	**631.4**
Cost per MW	4.9	4.6	3.7	3.2

Table 2 compiled by DESERTEC-UK (2008) shows the announced capital costs for several operating and planned CSP plants around the world. This shows parabolic trough costs in the region of US$4.2 million per MW to US$8.1 million per MW these are higher than estimates produced by CSP Today. For hybrid ISCC plants the costs detailed are US$0.8 million per MW and US$1.3 million per MW. For solar power towers capital costs are US$4.2 million per MW and US$5.4 million per MW according to DESERTEC-UK.

Table 2: Initial Capital Costs in 2007 dollars (million US$)

Name	Technology	Cost	Capacity (MWe)	US$/MW
Nevada Solar One	Parabolic trough	266	64	4.2
Andasol-2, Granada	Parabolic trough	351	50	7.0
Andasol, Granada	Parabolic trough	332	50	6.6
Extremadura province, Spain	Parabolic trough	809	100	8.1
Sacyr-Vallehermoso project, Spain	Parabolic trough	890	150	5.9
Beni Mathar, Morocco	Parabolic trough in hybrid power plant	632	470	1.3
Victorville 2, California	Parabolic trough in hybrid power plant	450	563	0.8
Seville (complete project, inc. PS10)	Solar power tower	1,618	300	5.4
PS10, Seville	Solar power tower	47	11	4.3

News releases about the costs of the first Andasol plant ranged between €300 and 450 million EUR. These figures are much higher than the US$332 million USD found in Table 2. It is recommended to handle costing figures with caution.

A report by the World Bank (1999) states that the installed capital costs of near-term trough plants are expected to be in the range of €2.4 million – 3.5 million (US$3.2 million – 4.6 million) per MW for 30-200MW purely solar plants, and about €1.1 million (US$1.4 million) per MW for 130MW hybrid ISCC with 30MW equivalent solar capacity

4.2 Levelised Energy Cost

The LEC is highly dependent on local resources, construction costs, accessibility, shipping, local staff costs, etc. The duration over which LECs are calculated also vary from study to study and this makes direct comparison from different reports difficult.

The report by the World Bank (1999) mentioned above estimates total power generation costs between €0.07 – 0.10/kWh (US$0.09 – 0.13) for purely solar plants and less than €0.07/kWh (US$0.09) for hybrid ISCC plants. Another study carried out for the National Renewable Energy Laboratory (NREL) and the United States Department of Energy (USDOE) by Sargent and Lundy (2005) looked at the costs of various CSP technologies. It is not stated what boundary conditions have been used for the calculation of the LECs e.g. whether transformer and land development are included, and comparison with figures from other reports can therefore not be made. For Trough Technologies (parabolic and Fresnel) Sargent and Lundy estimate that the LEC would drop to US$0.065/kWh by 2020 from US$0.11/kWh, expressed in year 2005 US dollars. This drop in cost is due to technical improvements, economies of scale, volume production and development of a thermal storage system. For Solar Tower plants they estimated that the LEC should drop to approximately $0.057/kWh, expressed in year 2005 US dollars. There is more uncertainty surrounding the cost estimates for this type of technology due to the lack of commercial scale Solar Tower plants that have been built by 2005. Calculations of other CSP technologies LEC were not carried out in this report.

A report by Black and Veach (2006) gives a LEC in 2005 dollars of US$0.157 in 2007 reducing to US$0.103 in 2015 for parabolic trough CSP. These results are of a similar magnitude to those from the Sargent and Lundy report, although as the boundary conditions are not known a direct comparison can not be made. Black and Veach also made a comparison of LEC of CSP using gas to generate electricity, as the same methodology was used for all the calculations this allows comparison of the cost of CSP against gas. For gas generation they calculated LEC for 2007 was between US$0.119 for a simple cycle turbine and US$0.168 for a combined cycle turbine.

Figure 15 shows a table produced by the California Energy Commission (2007) for different generation systems for different developers: merchant, independently owned utilities, and municipal utilities. This shows the CSP is already cost competitive with simple cycle electricity generation, but has one of the higher LECs of the technologies considered.

In-Service Year =2007 (Nominal 2007$)	Size	Merchant		IOU		Muni	
	MW	$/kW-Yr	$/MWh	$/kW-Yr	$/MWh	$/kW-Yr	$/MWh
Conventional Combined Cycle (CC)	500	514.56	101.35	476.31	93.97	443.68	87.79
Conventional CC - Duct Fired	550	521.49	102.72	482.14	95.12	448.59	88.77
Advanced Combined Cycle	800	485.30	95.59	447.16	88.22	413.91	81.90
Conventional Simple Cycle	100	250.81	586.36	196.68	460.01	133.90	313.42
Small Simple Cycle	50	270.85	633.21	213.36	499.02	147.98	346.37
Advanced Simple Cycle	200	205.06	479.40	160.83	376.17	106.18	248.52
Integrated Gasification Combined Cycle (IGCC)	575	678.11	131.66	492.79	95.68	384.74	74.70
Advanced Nuclear	1000	728.50	99.86	538.03	73.75	488.88	67.01
Biomass - AD Dairy	0.25	937.69	145.65	723.65	112.41	636.95	98.94
Biomass - AD Food	2	323.64	50.27	80.72	12.54	-51.00	-7.92
Biomass Combustion - Fluidized Bed Boiler	25	915.59	125.49	793.72	108.78	855.28	117.22
Biomass Combustion - Stoker Boiler	25	854.32	117.09	745.23	102.14	814.95	111.69
Biomass - IGCC	21.25	929.64	127.41	781.13	107.06	771.37	105.72
Biomass - LFG	2	370.07	54.49	294.14	43.66	317.72	47.86
Biomass - WWTP	0.5	458.23	87.35	361.82	70.59	296.38	60.36
Fuel Cell - Molten Carbonate	2	933.83	120.84	774.10	100.17	672.03	86.96
Fuel Cell - Proton Exchange	0.03	1289.91	166.91	1026.94	132.89	858.56	111.10
Fuel Cell - Solid Oxide	0.25	776.26	100.45	615.21	79.61	531.28	68.75
Geothermal - Binary	50	573.15	91.82	400.34	66.10	384.60	67.18
Geothermal - Dual Flash	50	542.03	88.67	383.07	64.58	375.70	67.01
Hydro - In Conduit	1	256.67	63.36	183.90	46.09	185.71	48.01
Hydro - Small Scale	10	700.93	171.03	480.62	119.06	338.23	86.43
Ocean - Wave	0.75	1440.72	1201.48	1006.79	846.40	716.79	611.59
Solar - Concentrating PV	15	495.96	271.96	334.48	185.55	204.88	116.23
Solar - Parabolic Trough	63.5	671.03	294.54	497.90	219.23	349.47	154.86
Solar - PV	1	1117.12	608.42	723.14	396.30	461.81	256.29
Solar - Stirling Dish	15	1121.75	544.27	859.49	417.02	643.25	312.10
Wind - Class 5	50	289.10	99.03	195.24	66.88	177.44	60.78

Source: Energy Commission

Figure 15: LECs for different generation systems

According to the LECs from the reports above CSP is already cost competitive with small simple cycle gas turbines, and has the potential to be cost competitive within 10 to 25 years with other conventional and low-cost renewable technologies. Although the economic attractiveness strongly depends on fuel prices and local resources.

4.3 Main Cost Influences

A feasibility study carried out by IT Power investigating the use of CSP plants looked at the cost of different types of plants over the lifetime of the plant. For all types of plant the major life-cycle cost was the operation and maintenance of the plant, accounting for 40 to 60% of the expenditure for the plant over the expected time of operation. A fraction of this cost was related to the salaries of the staff. In the assumed scenarios the financing and the investment costs represented similar shares.

4.4 Main Cost Reduction Potential

Future cost reductions in CSP plants are expected to be through technological improvements, development of more robust components, development of lower-cost materials, fast-installable components, locally producible components, scale-up of individual plant capacity, increasing deployment rates, competitive pressures, new heat storage systems and advancements in operation and maintenance methods. Some manufacturers are already exploring new approaches which give-up a few percentages of the high energy efficiency achieved in research-oriented plants in order to focus on economic efficiency.

4.5 Financing Mechanisms

The financing mechanisms usually applied for the implementation of CSP projects are similar to those for other energy generation projects. Additionally they may count with governmental grants, cheap loans, loan guarantees or other project facilitating support.

As an example for the three projects Ivanpah 1, 2, 3 totalling 400MW of CSP in California, USA, a consortium has been built, consisting of main partners:

- Morgan Stanley (equity partner)
- BrightSourceEnergy (project developer and equity partner)

Other manufacturers like Schott are expected to sell components for this project. The project will be commercially viable under a Power Purchase Agreement with Pacific Gas and Electric, California. A loan guarantee from Department of Energy, USA, ensures a low risk interest supplement.

Other examples in Kuraymat, Egypt and El Fresnal, Mexico count with grants from the GEF. In the first case EPC contracts have been tendered and foreign investment is the main external financing source. In Mexico the national utility will own and operate the plant.

5 CSP IN AFRICA

5.1 Solar Resource

Technically Africa has a potential that far exceeds local demand and even world demand. Concentrating solar technologies offer good prospects for further development and cost reductions in the region. Developing countries in Northern Africa could potentially attract significant foreign investment due to an opportunity to export the surplus electricity produced from CSP through ultra high voltage direct current (HVDC) grid connections to European countries. To assess the potential for CSP the share of diffuse irradiation and the constantly changing inception angle have to be taken into account. In regions with high humidity this can lead to low potential for CSP, even though the global solar irradiation is high and the potential for non-concentrating PV is high.

According to the DLR (German Aerospace Centre) the technical potential is measured based on a threshold Direct Normal Irradiance (DNI) of 1800 kWh/m^2/year which is considered to be the minimum required for the successful deployment of CSP. DLR classifies irradiations above 2000 kWh/m^2/year as economically promising. Figure 16 shows the DNI in kWh/m^2/day for Africa.

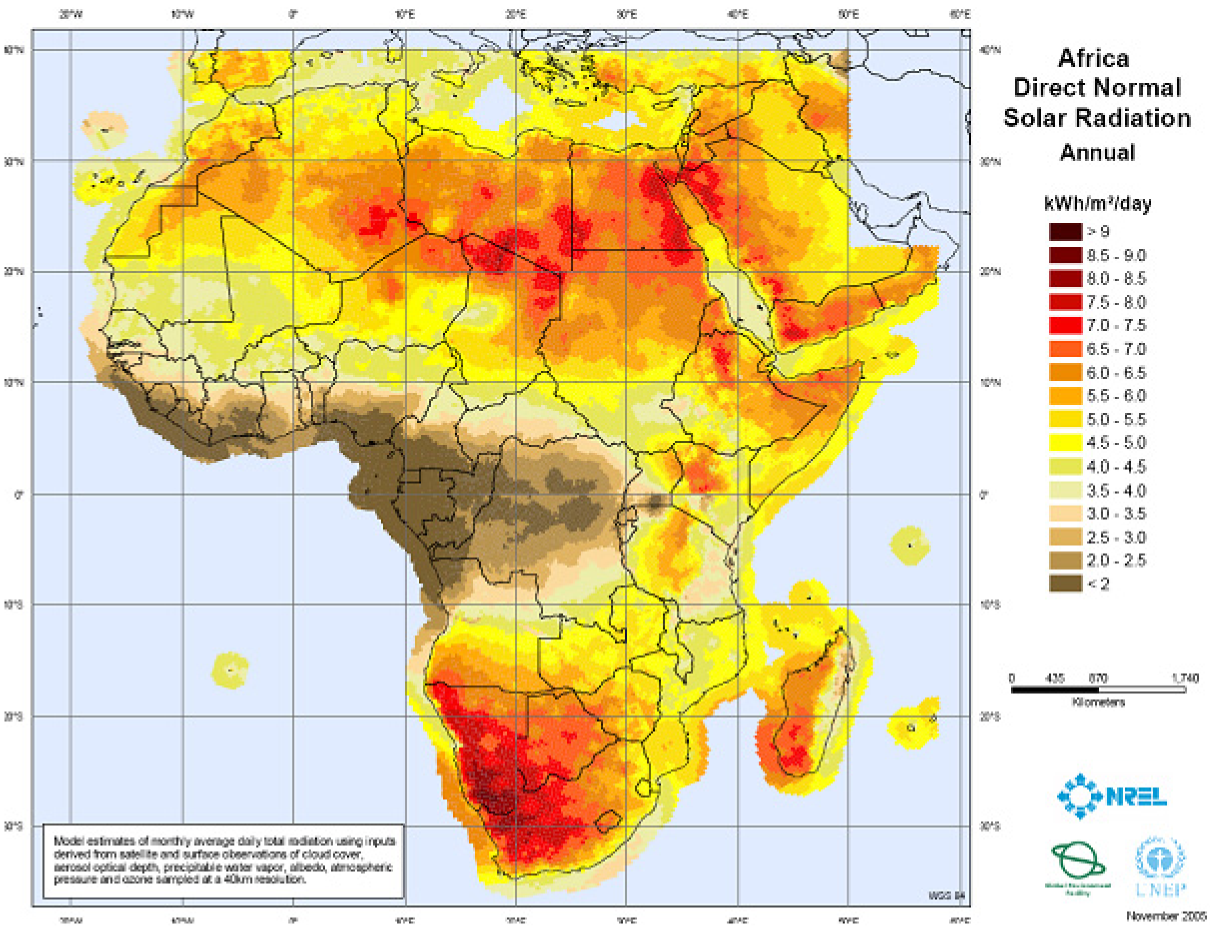

Figure 16: Direct Normal Irradiance in Africa (Source: NREL (2005))

2000kWh/m^2/year is equivalent to 5.5kWh/m^2/day; the following countries have favourable solar irradiation according to Figure 16:

1. Morocco
2. Algeria
3. Tunisia
4. Libya
5. Egypt
6. Niger
7. Chad
8. Sudan
9. Ethiopia
10. Somalia
11. Kenya
12. Uganda
13. Tanzania
14. Zimbabwe
15. Zambia
16. Angola
17. Namibia
18. Botswana
19. South Africa
20. Mozambique
21. Mauritania
22. Madagascar
23. Swaziland
24. Lesotho

Namibia, South Africa, Egypt and Libya show particularly high potential for CSP projects.

The discussion of the potential CSP for Africa has been split into two parts the Mediterranean Region (Morocco, Algeria, Tunisia, Libya and Egypt) and the Rest of Africa

5.1.1 Mediterranean Region

This region of Africa has high solar irradiance levels which provide a vast potential for CSP. One of the major drivers for CSP in this region is the potential to export to Europe as suggested by DESERTEC (2009). This paper suggests a renewable electricity supergrid network across Europe, North Africa and the Middle East using solar, wind, biomass, hydro and geothermal technologies and high voltage direct current (HVDC) transmission lines to reduce transmission losses. The solar plants (PV and CSP) are planned to be located mainly in Northern Africa. Figure 17 shows a map of the proposed supergrid.

Figure 17: Supergrid concept (Source: DESERTEC)

The demand for electricity in Northern African countries is expected to increase due to rising populations; additionally this population growth is going to put pressure on the declining water resources resulting in the need to construct desalination plants. Desalination plants are energy intensive and CSP offers an important opportunity in this region to produce the energy required to supply these (solar heat driven desalination) and other energy demands without using fossil fuel plants. The renewable auto-generation of electricity will be important to avoid dependence or restrictions from rising fossil fuel prices and shrinking resources. For those countries with own fossil fuel resources it will enable to not have to consume their precious resources on their own, but rather selling them on the market. CSP plants are currently planned in Algeria, Egypt and Morocco. Tunisia and Libya have yet to announce any plans to construct CSP plants.

Algeria

Algeria has set up a national programme for the promotion of renewable energy sources in the frame of its Sustainable Energy Development Plan for 2020. Algeria, as the first non-OECD country, published a feed-in law in March 2004 with elevated tariffs for renewable power production, including solar thermal power for both hybrid solar-gas operation of steam cycles, as well as integrated solar, gas combined-cycle plants. There are currently no government subsidies available for renewable technologies.

A 140MW ISCCS plant with 30MW of solar output is currently under construction. Algeria's renewable energy agency New Energy Algeria Limited (NEAL) has also planned three solar thermal hybrid plants to be launched at Naâma in 2010, Meghaïer in 2012 and Hassi R'Mel in 2015. Each plant will have a total combined capacity of 400 MW out of which 75MW is from solar.

Egypt

Egypt has formed a New and Renewable Energy Authority (NREA) that is responsible for the promotion of renewable energy sources. There are currently no feed-in tariffs or government subsidies available for renewable technologies. However, a 150 MW ISCCS plant in which 20

MW would be from solar using parabolic troughs is currently under construction in Egypt, supported by the government through low gas prices and an attractive electricity purchase price. The plant is expected to be operational by the end of 2009.

Morocco

A new national utility owned 230 MW plant ISCCS with a solar capacity of 30 MW is under construction using funding from the Global Environment Facility (GEF). There are currently no feed-in tariffs or government subsidies available for renewable technologies.

5.1.2 Rest of Africa

The demand for electricity in African countries is expected to increase due to rising populations; CSP offers an important opportunity in this region to meet the rising energy demands without using fossil fuels and reduce dependence on their increasing prices.

Throughout Africa there has been a strong market in off-grid conventional PV systems, and more recently larger on-grid PV systems have been installed. The viability of concentrating solar technologies has been proven by solar ovens and solar cookers. But there are currently no CSP plants operating in Africa, although Botswana briefly tested a pilot solar updraft chimney in 2005 and Namibia is planning to construct one. A solar power tower is currently being considered in South Africa and the National Energy Regulator of South Africa (NERSA) has recently announced their feed-in tariff guidelines. There are currently no other plans for CSP plants nor are there any feed-in tariffs or government subsidies available for renewable technologies in the other countries covered in this section.

Several countries have set targets for electricity generation from renewable sources. South Africa has set a target of 10TWh of renewables by 2013, about 4% of demand, Kenya has set targets for almost 400MW from wind and biomass by 2020 and Uganda called for increases in use of renewables from 4% to 61% of total electricity demand by 2017. Rwanda has also targeted 90% of its electricity to be renewable by 2012.

South Africa

The South African national electricity utility Eskom has decided to pursue molten-salt solar power tower technology within its programme on bulk renewable electricity, aiming for a series of 100 MW commercial solar tower array. A feasibility study for a 100MW pilot project in Upington has been carried out, and a decision on whether to begin construction is expected soon.

Eskom studied both parabolic trough and central receiver technology to determine which is the cheaper of the two and weighing up risks. The national utility is also looking at manufacturing the key components through local suppliers and is gathering estimates from local glass and steel manufacturers. Ultimately, a decision will be made on a variety of factors, including cost, and which plant can be constructed with the largest local content.

5.2 Suitable CSP Technologies for Africa

Parabolic troughs are the main option for the deployment of CSP in Africa. Parabolic troughs are the most proven and mature of the technologies, and are already in use in several plants across Europe and the USA. Developing countries usually believe and trust in the technological options which are developed and deployed in the very industrialised countries. Even if another technological option or approach would be more suitable for local and regional conditions, the role model function of the industrialised countries would probably be decisive. Within the next 3 years solar power tower technology is expected to improve, and several commercial plants will be in operation making this technology a viable option for future plants in Africa. Another competitor technology currently in the piloting phase are Linear Fresnel plants, offering a prospect for a low-cost technology. In the mid-term solar updraft towers can be the most attractive options for simple technology, lowest costs and high scalability. Regarding scalability Dish Stirling offers small distributed generation units suitable for farms or supplemental supply at business sites.

The quickest method to implement CSP in this region is through ISCCS with parabolic troughs. ISCSS are cheaper to construct than stand alone solar plants, and generate electricity at a lower price. The integrated solar share can be operated at highest efficiency of all plants and is already cost effective in many locations, as significant direct fuel savings can be achieved. Construction of ISCCS plants will start to reduce the price of CSP due to volume production.

The conventional section of the power plant can be brought online rapidly to meet the increasing electricity demand in the region (considering later solar pre-heating), with the solar section being brought online at a later date. This double stage implementation will enable countries to develop technical capabilities, manufacturing facilities and train people to install, operate and maintain CSP plants at a slower pace and still increase the electricity generation capacity.

5.3 Practical Considerations

One of the benefits of CSP plants is that they can be located in the desert and uncultivated lands where previously there may have been few opportunities or alternative land usages. Commercial activity in such areas will benefit local communities directly with the creation of new jobs and indirectly with the increase in local services required to support new jobs created. According to a survey by ESTELA (2008) every 100 MW installed will provide 400 full-time equivalent manufacturing jobs, 600 contracting and installation jobs and 30 annual jobs in O&M.

When considering a location for a CSP plants the following criteria should be considered in the site-selection process:

1. Access to transport infrastructure - Required for the delivery of equipment, supplies, components, staff etc.
2. Access to water – CSP plants require access to water for steam generation, cooling and cleaning of mirrors. A 280MW CSP plant can expect to consume 2.3 – 2.6 million m^3 of water per year (Avery, 2007). This may compete will local requirements for water, particularly in desert areas. Solar desalination is an integrated solution for this conflict.
3. Solar resource – Above 2000kWh/m^2/year to be economically viable as a rule of thumb
4. Land area – A typical CSP plant requires between 20,000 to 40,000m^2 of land per MW of installed capacity. The large land area also leads to concerns about the possible impact of CSP plants on local flora and fauna, particularly the potential destruction of clean and unused desert lands. CPV is very modular and does not need a single large land area. The option for plant expansion on the same site should also be considered when looking for a suitable site.
5. Land costs – Due to the large land areas required the land costs can be a significant part of the capital costs.
6. Grid infrastructure - One of the key barriers to the construction CSP plants in Africa is the lack of suitable and robust power transmission lines and distribution

networks; investment is needed by governments in their power infrastructure. This would not only enable the use of the electricity generated by the own country, but also the export between adjacent countries.

7. Ambient conditions - Maritime conditions might increase costs due to corrosion protection, this is particularly relevant if the CSP plant is to be used for desalination.
8. Low pollution and seldom sandstorms – This includes the necessity to protect the plant from dust and sand raised by traffic or industrial activities nearby. Pollution and dust in the atmosphere can reduce the insolation that reaches the collectors. Additionally frequent sandstorms increase the frequency of cleaning required and strong winds can lead to a higher mirror breakage rate.
9. Terrain - Trough collectors require a very flat terrain to allow the absorber tube to be horizontal, and other collectors also require relatively flat terrain. Due to this requirement for flat land, CSP plants may compete with agricultural activities and may affect local communities.

5.4 Incentive Measures

Incentive measures are vital to facilitate technological development in energy generation using CSP. This would allow CSP to be competitive with other energy generation technologies that operate on fossil fuels and facilitate its deployment in the mass market.

A clear, low risk market in CSP is required to interest project developers in investing in this technology. Market creation policies embedded in national law providing a stable and long term investment environment with relatively low risks offer an attractive prospect to potential developers.

Targets for Renewable Electricity

An increasing number of countries have established targets for renewable energy. These targets have been shown to be most effective if they are based on a percentage of a nation's total electricity consumption. In 2001 the European Union adopted a Directive on Electricity Production from Renewable Energy Sources which established national targets for each Member State, although at present these are not legally binding.

In the USA, Renewable Portfolio Standards have been established to gradually increase the contribution of renewable power in some of its states, the target percentage of renewable power and year by which this should be achieved vary from state to state. As a result of these targets Nevada and Arizona are both negotiating long term power purchase contracts for solar thermal power plants.

Power Purchase Agreements with National Utilities

In countries with a monopoly in electricity generation and distribution the governmental influence could be used to set up Power Purchase Agreements between the national utility and project developers. This may also include contracts for cheaper primary energy prices for integrated power plants (e.g. for gas).

Energy Legislation

Legislation might require a minimum CSP share in the preheating of every new conventional power plant project. Within the next 5 to 10 years this is expected to be a standard component for conventional fuel power plants when being ordered. Regional development can be assisted by requiring this energy efficient option.

A certain share of energy generation from renewables for developments of settlements and industrial development zones could be required.

Feed-in Tariffs

Feed-in tariffs set a fixed tariff rate or premium is allocated to particular renewable technologies. These tariffs reflect the relative costs of the renewable technology compared to the price for conventional power generation. Utility companies are then obliged to buy all the renewable power produced at the specific rate. A national feed-in tariff is seen as an effective way to aid growth for renewable energy markets.

Feed-in tariffs for CSP technologies have been established in France, Germany, Greece, Israel, Italy, India, Portugal and Spain. Table 3 shows the CSP feed-in tariffs for these countries.

Table 3: CSP Feed-in Tariffs

	Capacity	Tariff	Duration Years	Inflation Adjusted	Restrictions	Hybrid Eligible
Algeria	ISCCS	100-200%	Lifetime	Yes		
France		€0.30/kWh	20+	Yes	Max 12MW	No
Germany		€0.46/kWh	Lifetime	No		No
Greece		€0.23-0.27/kWh	10+	No		Yes
Israel	>20MW	US$0.16/kWh	20+	Yes		Max 30%
Italy		€0.30 – 0.36/kWh	25	Yes		Yes
India	<10MW	INR 13	20	Yes	Max 10MW	Unknown
Portugal	>10MW	€0.16/kWh	15	No		No
Spain	<50MW	€0.27/kWh	25+	Yes	Max 50MW	Max 15%

In Africa, Uganda has feed-in tariffs for hydro and cogeneration plants, but does not specify any tariff for other forms of generation. South Africa has recently announced their feed-in tariff guidelines, and the UK is also preparing their feed-in tariff legislation.

In Spain the feed-in tariff triggered the CSP market after many years of research and development without commercial deployment. An increasing number of CSP plants are being constructed and planned, the tables in Section 3 show Spain as a leader in numbers of CSP plants being implemented.

Financial Incentives

CSP projects are eligible for carbon credits under the clean development mechanism (CDM), this can help with the initial capital costs of the project, making this technology a more attractive investment opportunity. Finance may also be available from the Global Environment Facility, World Bank and development banks to support the implementation of CSP technologies.

In the USA CSP plant are eligible for subsidies and tax incentives from the government reducing the capital costs of the plants. Specialised solar power components might be freed from customs duty.

Research

Steady investment in R&D for improving technology and efficiency is required to reduce the cost for producing electricity from CSP, and improve the practical viability of setting up large scale CSP plants. Under the 7th Framework Programme (FP7) the EU is anticipated to invest approximately €50 billion is solar research, on top of the €25 billion already contributed to the development of CSP technologies under the 5th and 6th Framework Programmes.

5.5 Development of a CSP Project

For implementation the following steps are recommended:

1. Assessment of regional solar resource
2. Assessment of grid conditions and technical feasibility in the target region
3. Assessment of legal, environmental and economic conditions of target region
4. Assessment of working skills and technological development level
5. Technology selection
6. Market review
7. Assessment of manufacturers and developers
8. Assessment of technology (visit existing plants, review operation documentation)
9. Full feasibility study
10. Request a full detailed offer
11. Arrange financing scheme
12. Place order as soon as possible (especially for turbine)

The technical implementation duration of solar thermal plants in recent years has been determined by the delivery time of the turbine. From other North-African projects the experience can be drawn that it is essential to include sufficient contingency in the financing scheme to meet unforeseen expenditures, characteristic to young technologies.

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APPENDIX A: LIST OF CSP ORGANISATIONS

A.1 MANUFACTURERS AND PROJECT DEVELOPERS

Listed below is a selection of CSP technology manufacturers, this list is not exhaustive.

- Abengoa, Spain - www.abengoa.es
- Acciona, Spain - www.acciona.es
- Ausra, USA - www.ausra.com
- Bright Source Energy, Israel - www.brightsourceenergy.com
- Cool Earth Solar, USA – www.coolearthsolar.com
- Ecosystem Solar Electric, USA - www.esecorp.org
- eSolar, USA - www.esolar.com
- Energy Innovations, USA - www.energyinnovations.com
- Entech Solar, USA - www.entechsolar.com
- Flagsol, Germany - www.flagsol.com
- Flabeg, Germany - www.flabeg.com
- Green Volts, USA - www.greenvolts.com
- HD Solar, UK - www.heliodynamics.com
- Iberdrola, Spain - www.iberdrola.es
- Infinia, USA - www.infiniacorp.com
- Prism Solar Technologies, USA - www.prismsolar.com
- Schott, Germany - www.schott.com
- Sener Aeronáutica, Spain - www.sener.es
- Silicon Valley Solar, USA - www.sv-solar.com
- SK Energy, Germany - www.sk-energy.de
- SkyFuel, USA - www.skyfuel.com
- Solar Millennium, Germany - www.solarmillennium.com
- Solar Reserve, USA - www.solar-reserve.com
- Solar Power Group, Germany - www.spg-gmbh.com
- Solar System,Australia - www.solarsystems.com.au
- Solel, Israel - www.solel.com
- Sopogy, USA - www.sopogy.com
- Stirling Energy Systems, USA - www.stirlingenergy.com
- Stellaris, USA - www.stellaris-corp.com
- Sustainable Heat & Power Europe GmbH, Germany - www.shp-europe.com
- Torresol Energy, Spain - www.torresolenergy.com
- Wizard Power, Australia - www.wizardpower.com.au

A.2 RESEARCH ORGANISATIONS

- Commonwealth Scientific and Industrial Research Organisation (CSIRO), Australia- http://www.csiro.au/science/Solarenergy.html
- Electric Power Research Institute, USA - www.epri.com
- Fraunhofer Institute for Solar Energy, Germany – www.ise.fhg.de
- German Aerospace Centre (DLR), Germany - www.dlr.de
- Instituto de Concentración Fotovoltaica, Spain - www.isfoc.es
- Plataforma Solar de Almeria, Spain - www.psa.es
- PSE AG, Germany – www.pse.de
- National Renewable Energy Laboratory, USA - www.nrel.gov/csp/
- Research Centre for Energy, Environment and Technology (CIEMAT), Spain - www.ciemat.es
- Sandia National Laboratory, USA - www.sandia.gov/solar/

A.2 ORGANISATIONS

- CSP Today, UK – www.csptoday.com
- European Renewable Energy Agency – www.eurec.be
- Solar Paces - www.solarpaces.org
- US Department of Energy (USDOE), USA – www.energy.gov