Technology Innovations:
Solar Grid-based (CSP)

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Introduction

Concentrated Solar Power (CSP) also known, as Solar Thermal Electricity (STE) is capable of providing dispatchable, baseload (round the clock) and peaking solar thermal electricity. Despite its unique capabilities, there are a number of myths about CSP that need to be debunked. This paper addresses the seven myths below. The paper also presents a way forward for debate and discussion on how the Southern African Development Community (SADC) could position itself as a regional hub for the development and deployment of CSP power stations, in turn contributing to industrialisation, social and economic transformation in the SADC region.

- Myth 1 – CSP like wind and solar PV is an intermittent technology and is not dispatchable
- Myth 2 – CSP unlike gas is not capable of providing peaking power
- Myth 3 – CSP unlike conventional power stations is not capable of providing round the clock baseload power
- Myth 4 – CSP is too expensive and it will always be so
- Myth 5 - CSP does not provide much localisation for industrialisation and it may be better for countries starting a CSP programme later (after 2020 or so…)
- Myth 6 – CSP deployment is expensive and inefficient for most economies Myth 7 – CSP does not contribute much to the environment as it uses water and endangers birds

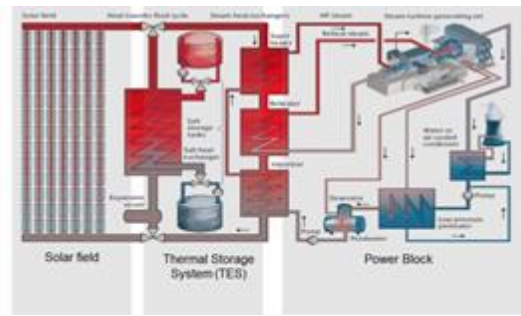

Figure 1: CSP Technology – main features

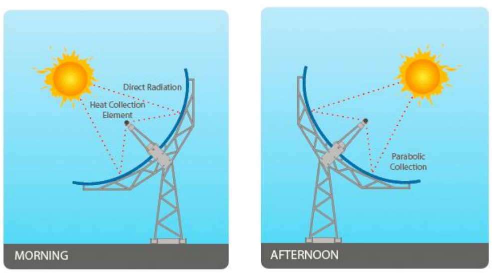

Figure 2: Solar Thermal Collectors (Parabolic Trough Technology)

How it works?

CSP power stations convert raw, free and non-polluting solar energy into dispatchable, non-intermittent renewable energy electricity. CSP power stations like conventional power stations (coal, gas, nuclear) use a steam turbine to generate electricity; the only difference between conventional power stations and CSP power stations is the fuel source they use.

The main features of a CSP Power Station are: a solar field that is based on mobile parabolic collectors or heliostats; a steam cycle; and a thermal energy storage system with molten salts.

The source of fuel for CSP power stations is the sun: at sunrise with the collectors orientated towards the east, the collectors start working. They harness the sun's energy and transmit it to a receiver where a thermal fluid carries the energy to a steam cycle. The generated steam turns a turbine located in the power block, generating electricity.

Once the turbine has reached its maximum mechanical thermal capacity all the surplus thermal energy collected in the solar field is sent to the thermal storage system. As sunset approaches and the amount of energy collected in the solar field starts to fall, the thermal storage system inverts its cycle and releases the stored energy (steam) to the power block by heating the thermal fluid.[1]

Addressing the myths

Myth 1 – CSP like wind and solar PV is an intermittent technology and is not dispatchable

Dispatchable generation refers to sources of electricity that can be dispatched at the request of the grid or system operator. These are generating plants that can be turned on or off, or can adjust their power output on demand. Thermal Energy Storage (TES) allows CSP power stations to deliver electricity on demand without additional cost, even after sunset. CSP is grid-friendly; it does not cause grid instability. This is not only due to TES but also because of the use of conventional turbine technology to generate electricity.[2] Its "grid friendliness" is the most distinct feature of CSP power stations compared to other renewable energies and allows for integration into the grid of more intermittent renewable sources (wind and PV) without jeopardising grid stability. This specific feature of dispatchability of CSP power stations raises the overall value of the electricity produced by CSP power stations.

Myth 2 – CSP unlike gas is not capable of providing peaking power

Peak matching power stations are employed to match the highest demand during the day. Demand typically peaks for power grids at a relatively predictable time, depending on culture, weather and geographic location. South Africa's four new CSP power stations currently under construction; Xina, Karoshoek Solar One/Ilanga CSP1, Kathu and Redstone all have thermal storage systems that are designed to meet South Africa's daily evening peak demand which occurs between 4:30 pm and 9:30 pm. These four projects which have a combined capacity of 400MW once complete will play an essential role by providing five hours of firm peak demand electricity every day of the year at tariffs lower than the OCGT's that run on diesel and are currently used by South Africa's energy utility Eskom to provide peaking electricity.[3]

Myth 3 – CSP unlike conventional power stations is not capable of providing round the clock baseload power

Figure 3: Gemasolar 20MW CSP Tower

Baseload refers to power stations that are always on and are generally the biggest generation units. Typically this term refers to coal and nuclear power stations. Sometimes reservoir based hydroelectric power sources are also included if they have large enough reservoirs or have proven reliability. These power sources are used generally to meet most of the demand in an electrical system. These sources are always on unless they are down for maintenance, repair or refuelling (as in the case of nuclear). CSP power stations with a right-sized thermal storage system can provide baseload solar thermal electricity. The 20MW Spanish Gemasolar CSP power station (Figure 3) is a living example of a CSP power station that is

[1] It is also possible that at some times during the day the turbine is not run and more heat is stored – for example to cover peak demand in winter time, when the available energy is more limited. This is for example how the 250 MW CSP plant "Solana" is operated in winter in Arizona, USA where the turbine runs for both the morning and evening peaks.

[2] Even without storage CSP has both thermal and spinning inertias.

[3] This situation explains the "Multiplier" (x2.7) between base and peak remuneration level of these plants which has been introduced within the Renewable Energy Independent Power Producers Procurement Programme (REIPPPP).

providing electricity 24/7. The TES system at Gemasolar has 15 hours of storage, allowing Gemasolar to provide electricity around the clock.

The 50MW Bokpoort CSP power station currently under construction in South Africa has a Thermal Energy Storage System with a capacity of 9 hours and will be able to provide electricity around the clock (baseload) as shown in the illustration below. CSP power stations with thermal storage have the potential to provide baseload power. This is the first solar technology to have the baseload capability.

Myth 4 - CSP is too expensive and it will always be so

The cost of solar thermal electricity has not seen the same rapid cost cuts as photovoltaics over the last few years. One reason for this is the much longer lead time for projects that have a unit size in dozens of megawatts as opposed to PV which has greatly benefitted from its scalability. Moreover much of the CSP technology is mature so the learning curve is not as steep as with PV. Recent technology improvements have brought the cost of solar thermal electricity for new plants down into the range of 16 to 20 US cents per kWh, thus shielding against fossil fuel price volatility and risks. Such costs are not excessive when compared with the costs of peaking plants run on diesel fuels or—depending on the location – natural gas, as demonstrated by South Africa. Furthermore, there is still ample room for technology improvements and cost reductions in the solar field, receiver, heat storage parts and how they constitute collectively an inclusive solar plant with the more classical turbine and balance of plant.

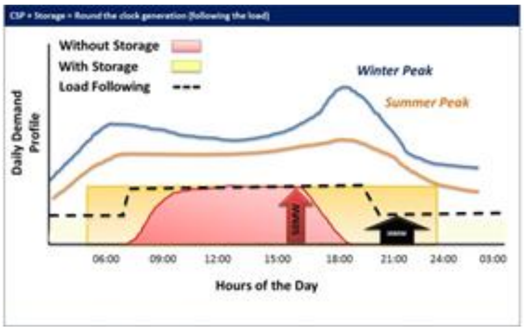

Figure 4: Load following profile of 50MW Bokpoort CSP

The result will be that cost optimisation (also in manufacturing components), economies of scale after deployment of larger power stations (i.e 100-250 MW) are expected to reduce the costs below 10 c€/kWh before 2020. This means by 2020 solar thermal electricity will be competitive against new coal and gas-fired power stations. What is crucial to bring the costs for CSP downwards further to give these plants a Power Purchase Agreement (PPA) of 30 to 35 years, similar to that of the coal baseload IPP program being introduced by the South African Department of Energy.

Myth 5 - CSP does not provide much localisation for industrialization and it may be better for countries starting a CSP program later (after 2020 or so…)

There is an erroneous perception by some policy-makers that it would be better to wait until CSP becomes competitive before considering deploying CSP power stations in their own countries. A support programme for CSP will provide immediate positive returns to the economy of any given country in terms of GDP increase, employment and taxes right from the starting up of the construction phase, whilst the first premiums will be paid some years later. ESTELA has performed simulations for different countries, which show that the returns to the economy will be always greater than the corresponding premiums. The "golden era" also has to be taken into consideration. This is when project finance funding has been paid off and costs are only those related to the operation and maintenance of the plant. The local content delivered during the construction of the CSP power stations will increase with time and with a CSP bidding program that has certainty. Therefore an ambitious country can reach a point where the CSP power stations can be deployed without any further country support. Those countries that started their renewable energy support program earlier will be in a position for reaping further benefits by building CSP power stations with a local content close to 80%. Others may start later their CSP programme with the majority of the supplies coming from abroad. Additionally such countries with an ambitious CSP program will no doubt enjoy an additional "first mover advantage" in their region and become an exporter to neighbouring countries.

Myth 6 – CSP deployment is expensive and inefficient for the economy of the countries

Investments in CSP power stations bring high macro-economic benefits to those countries in a leadership position. Due to its high local economic content, the CSP industry contributed to the national GDP, during both construction and the operation of the CSP power stations. In terms of direct job creation, the CSP industry has created jobs in manufacturing, engineering and construction throughout the world. This is anticipated to continue as the global CSP market is set to reach up to €130 billion per year, according to the IEA technology roadmap for CSP. Based on IEA's estimates, €39-57 billion will be invested on average every year between 2015 and 2030, creating 275,000 to 520,000 jobs worldwide. The jobs will cover a wide spectrum of direct activities related to:

- Engineering, development and financing
- Manufacturing of components; reflectors, receivers, etc
- Construction, civil, installation and commissioning works
- Operation and Maintenance (O&M)

In addition to such direct activities, the CSP industry will also create numerous indirect jobs: research, training, transport, information and communication (ICT) activities, general maintenance services, etc.

In Spain each 50MW CSP power station with thermal storage installed is equivalent to 2,250 job years that span from the design phase until completion of construction. During operation, each 50MW CSP power station needs around 50 employees for the operation and maintenance, that is 1 job per MW and at present there is no other technology that can compete with CSP on direct jobs created during the O&M phase. A report from the National Renewable Energy Laboratory (NERL, USA) estimates that investing in a 100 MW CSP generates 4,000 (direct and indirect) job years plus 94 permanent jobs and USD628 million in economic output – compared to 330 job/years plus 13 permanent jobs and USD47 million economic output for an identical investment in natural gas-fuelled power station. CSP investment creates more than 10 times more employment (and social wealth) per MW than the same investments in fossil fuel power generation.

In South Africa, a 100 MW CSP power station will have a 1,000 workers during the construction phase, an economic output of around R10 billion and close to 100 permanent staff during the operationally phase of the power station.

Myth 7 – CSP does not contribute much to the environment as it uses much water and endangers birds

CSP power stations use the sun as their fuel source, there are no CO_2 emissions that are generated and the technology is ideal for addressing the global climate change challenge. CSP power stations have a low water footprint, as they require less water per hectare in comparison to agricultural activities. The South African CSP projects—apart from the Bokpoort CSP—all use dry cooling technology, which uses 90% less water compared to wet cooling technology. There has been some misleading reports in the USA about bird deaths associated with CSP power stations, especially the story about a new solar power project in California killing up to 28,000 birds per year by reflected sunlight, which is based on a number of uncertain assumptions. The impact of CSP power stations or other renewable energy resources in power generation on bird deaths has been largely overstated. For example, every year cats kill between 1.4 and 3.7 billion birds, windows nearly 1 billion, cars some 60 million, the mining and the burning of coal nearly 8 million. If killing birds had to be avoided at all costs, then windows, pet cats and roads should all be prohibited, as commented by the IEA's recent study.

Potential CSP Regional Development and Industrialisation in Southern Africa

With only 4GW of CSP installed globally, the CSP technology is relatively young compared to other energy technologies and has a strong potential for further innovation, cost reduction and localisation.

The CSP Industry has experienced robust growth since 2009, this growth has been concentrated in Spain and the United States, but has begun to be seen in many other countries. Market prices which have been slow to diminish finally seem to be falling. With 2,304 MW of cumulative CSP capacity, Spain leads the world in the deployment of CSP power stations.

Southern Africa has one of the world's best solar resources; the Direct Normal Irradition (DNI) of most Southern African countries is higher than that of the world leading country, Spain. South Africa, is leading the way in the development and deployment of utility scale CSP power stations in the Southern Africa Development Community (SADC). To date 600MW of CSP projects have been approved by the Department of Energy (DOE) under its flagship program; the Renewable Energy Independent Power Producer Program (REIPPPPP).

Given the need to develop the SADC economy and to migrate to a low carbon future, the deployment of CSP power stations can play a key role in the re-industrialisation of the SADC economy and to position the region as a market leader in the manufacturing of CSP components both for the regional and international markets. To unlock this opportunity will require the regional governments to demonstrate the same type of leadership that the regional countries displayed as the frontline states that were fighting for the liberation and freedom for South Africa. That common vision allowed Southern African leaders to work together and to remain focused on the main goal. With a population of around 230 million people, a grid that is already connected Southern Africa as a region could lead the way in the deployment of CSP power stations which will bring much needed regional industrial development, job creation, social and economic transformation.

Kaxu: South Africa's first CSP power station with 2.5 hours of storage

Challenge Questions

1. Since CSP power stations have the ability to provide dispatchable, peaking and baseload solar power. What measures need to be put in place for SADC to become the global hub for the deployment and manufacturing of CSP components for the regional and international markets?
2. For CSP power stations to become more competitive from a tariff standpoint what type of procurement framework needs to be put in place to drive down the costs of CSP?
3. Would an airbus model of industrialisation and manufacturing of CSP components in SADC region where different countries manufacture certain components be a sound framework for the uptake of CSP across the region?

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