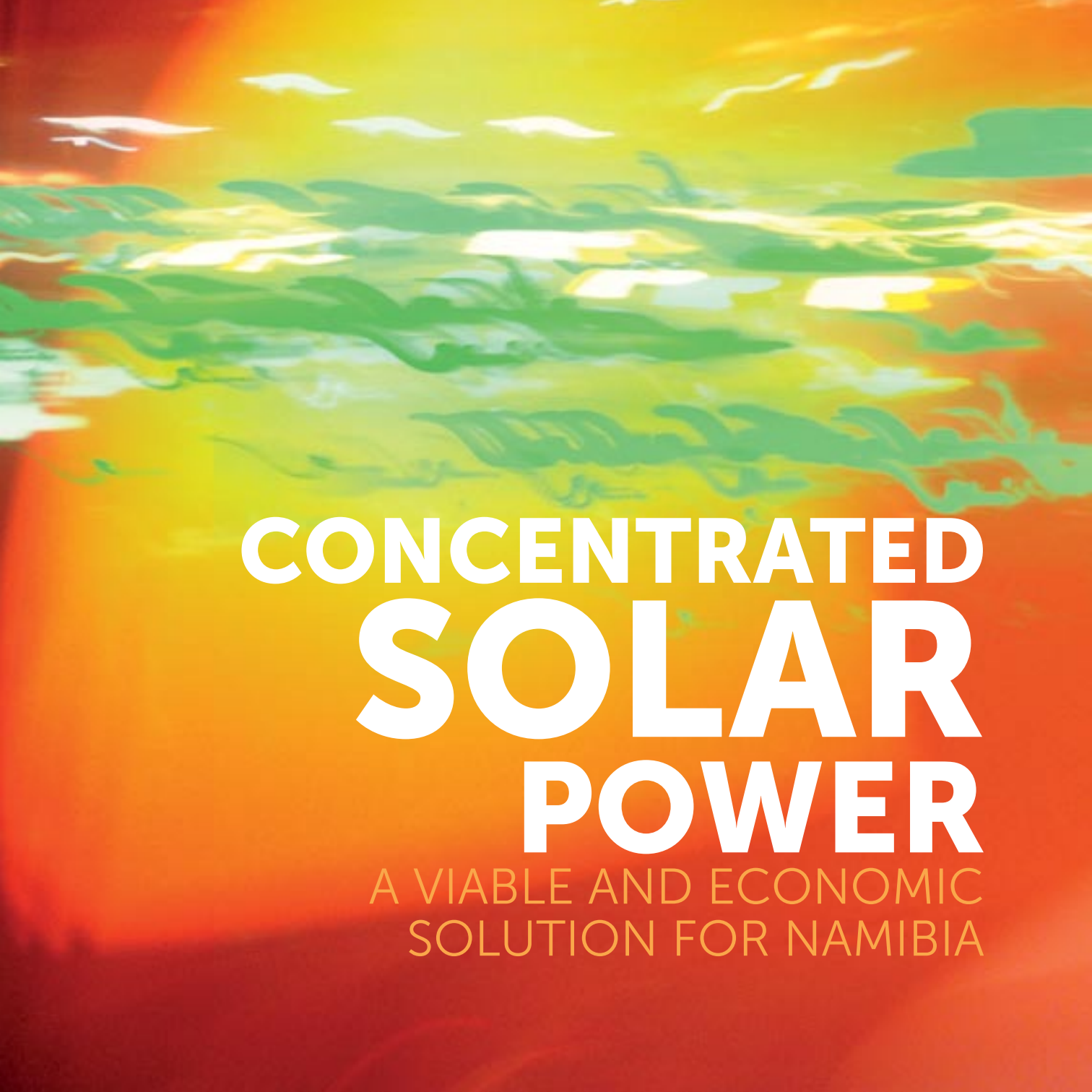

CONCENTRATED
SOLAR
POWER
A VIABLE AND ECONOMIC
SOLUTION FOR NAMIBIA

CONCENTRATED SOLAR POWER

A VIABLE AND ECONOMIC SOLUTION FOR NAMIBIA

Namibia has one of the best solar resources in the world and is currently not fully exploiting it

CSP is a mature and proven technology that can help us to produce cheap and clean energy reducing imports and creating jobs and wealth for our country

The Renewable Energy and Energy Efficiency Institute (REEEI) at the Polytechnic of Namibia, under the sponsorship of the Ministry of Mines and Energy and the Energy and Environment Partnership with Southern and East Africa (EEP S&EA), has undertaken a pre-feasibility study for Concentrated Solar Power (CSP) development in Namibia.

The results of this study highlight four very important messages:

> Firstly, Namibia has one of the best solar resources in the world and is currently not exploiting it. Namibia's solar potential, unlike most locations in the world, is much stronger on Direct Normal Irradiation (DNI) which makes it highly suitable for CSP development. This extraordinary resource involves more than 33,000 km^2 of suitable sites for CSP with a theoretical potential of more than 250,000 MWe.

> Secondly, CSP is not about science fiction or James Bond movies. Hundreds of MW have been deployed, currently producing electricity around the world, and many plants are still under construction and in planning. The commercial CSP technologies work on the principal of a conventional thermoelectric power plant but use solar energy as fuel. This allows CSP technology to be hybridized with conventional fuels such as gas or biomass or, for example, to be integrated into conventional coal-fired power plants. Moreover, it is possible to implement a thermal energy storage system to extend the hour of operation in hours of absent solar radiation and to thus increase the plant's cost effectiveness.

Due to the fact that Namibia's peak electricity consumption is in the evenings, it is essential that thermal energy storage is used.

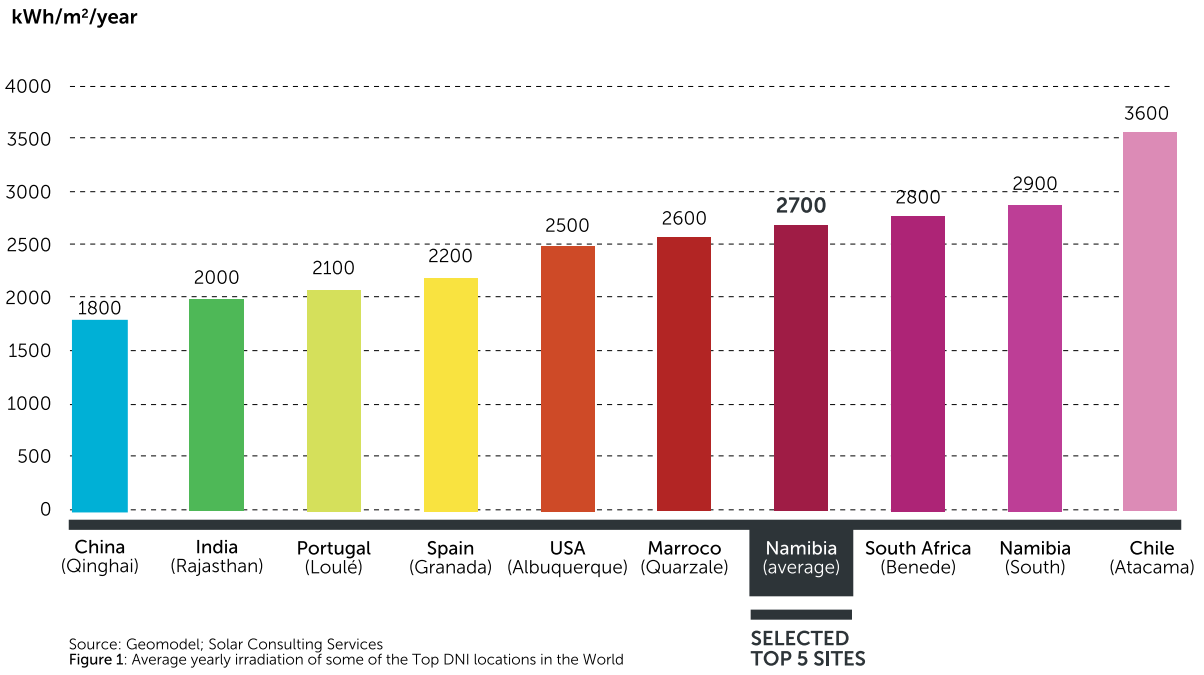
> Thirdly, the coming energy gap and the long lead time for realizing the best medium term power generation alternatives for Namibia offer the country the opportunity to take advantage of CSP in a cost competitive manner, even with coal or natural gas. And, as the investment capacity of the energy sector will be of critical importance in the near future, given the challenges ahead, CSP can unlock available development funding for renewable energies in Africa – which Namibia can and should benefit from.

> Finally, the most promising CSP technologies have reached a mature and commercial status and can be used to produce cheap and clean power, to reduce electricity imports, and create jobs and wealth for the country. Namibia can source up to 40% of the investment cost from within the country and create more than 1,000 jobs.

Given the above, Concentrated Solar Power is not only a viable and economic solution for Namibia, it is the best short term power generation alternative to respond to Namibia's energy challenges.

Kudakwashe (Kuda) Ndhlukula,
Head of the Renewable Energy and Energy Efficiency Institute of Namibia

Namibia has one of the best solar resources in the world



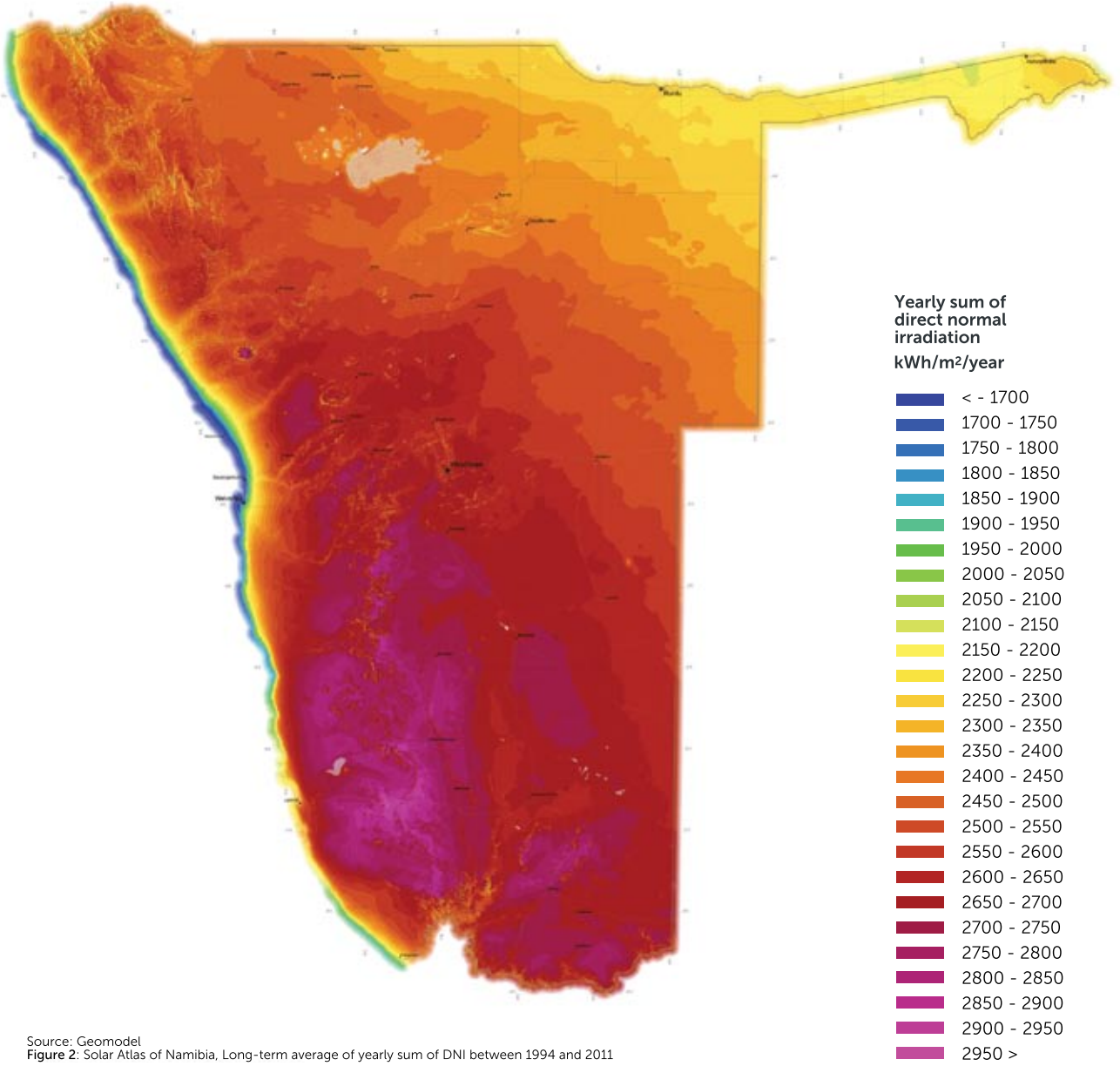
Source: Geomodel; Solar Consulting Services
Figure 1: Average yearly irradiation of some of the Top DNI locations in the World

Namibia has one of the best solar resources in the World, characterized by exceptionally high values of DNI, which makes Namibia one of the most suitable places in the world to develop CSP plants.

Global irradiation may be described by 3 components: direct, diffuse and reflected irradiation, with reflected irradiation playing an insignificant role. Concentrating solar technology requires solar irradiation to impinge on the mirrors in near parallel rays such that they can be reflected – this is only the case for direct normal irradiation. DNI is the irradiation impinging per unit area measured on a flat surface positioned perpendicular to the direction of the beam of light from the instantaneous position of the sun in the sky. Diffuse irradiation takes no part in CSP as the rays have no particular direction, meaning that they cannot be reflected in a certain direction and thus cannot be concentrated.

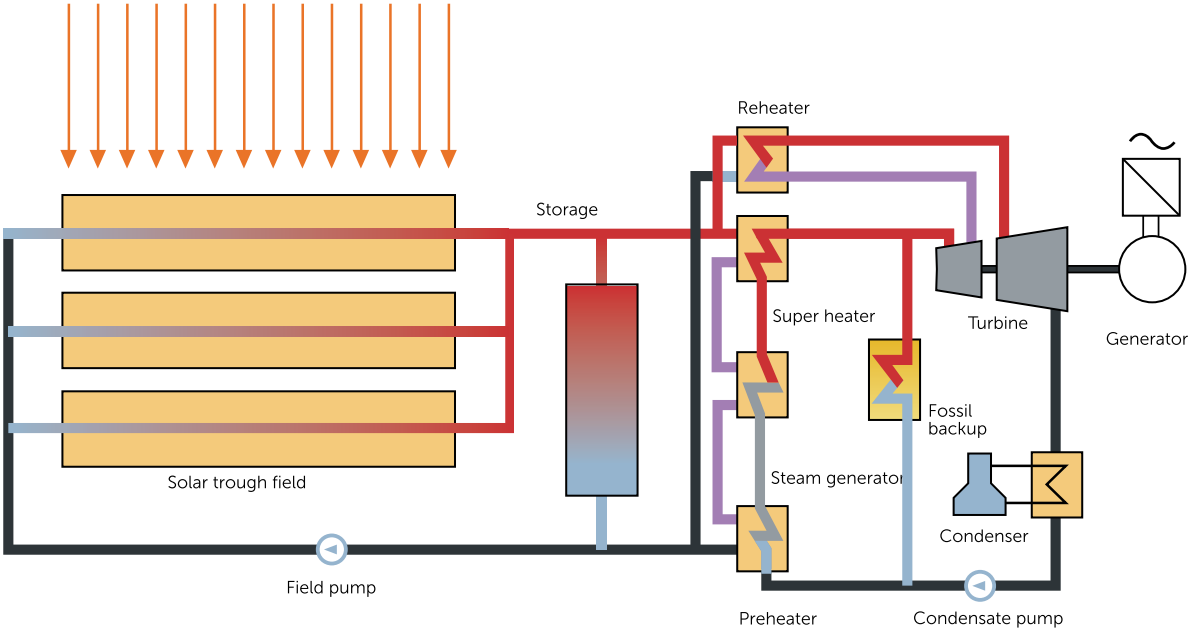
The advantage for Namibia is that it has DNI values ranking top worldwide and that there is a low aerosol impact in these favoured and potential locations for building a CSP plant compared with other potential locations in the world. Note that, in clear sky situations, aerosols are the primary factor determining the extinction of DNI.

This combination gives Namibia one of the best solar resources in the World.



Source: Geomodel
Figure 2: Solar Atlas of Namibia, Long-term average of yearly sum of DNI between 1994 and 2011

CSP is a mature technology that can take advantage of Namibia's exceptional solar resource



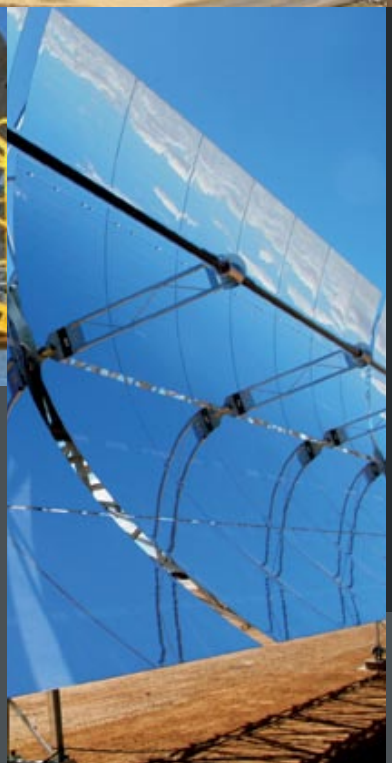
Source: (adapted):©Renewable Energies ISBN:978-989-96529-0-3
Figure 3: Sketch of a CSP trough power plant

CSP power plants transform thermal radiation energy into heat by means of using a large array of sun-tracking mirrors which reflect and focus the irradiation onto a smaller image area, the receiver. Generally, there are four CSP technologies available for harnessing solar radiation: power towers, parabolic trough power plants, linear Fresnel collectors and dish Stirling systems. With exception of the dish Stirling system, all CSP technologies work on the principle of thermoelectric power plants. The primary use of a CSP plant is the generation of electricity.

CSP systems are highly flexible for integration with conventional power plants and for blending the thermal output with fossil fuel, biomass and even geothermal resources. Basically, all technologies that use heat can be combined with solar thermal: natural gas; biomass; coal – combination with coal is usually called augmentation.

From the existing CSP technologies, most operational experience could be obtained with the parabolic trough technology and therefore it is the most mature one. Furthermore, the fact that for parabolic trough plants the boiler is an entirely separate component facilitates hybridization.

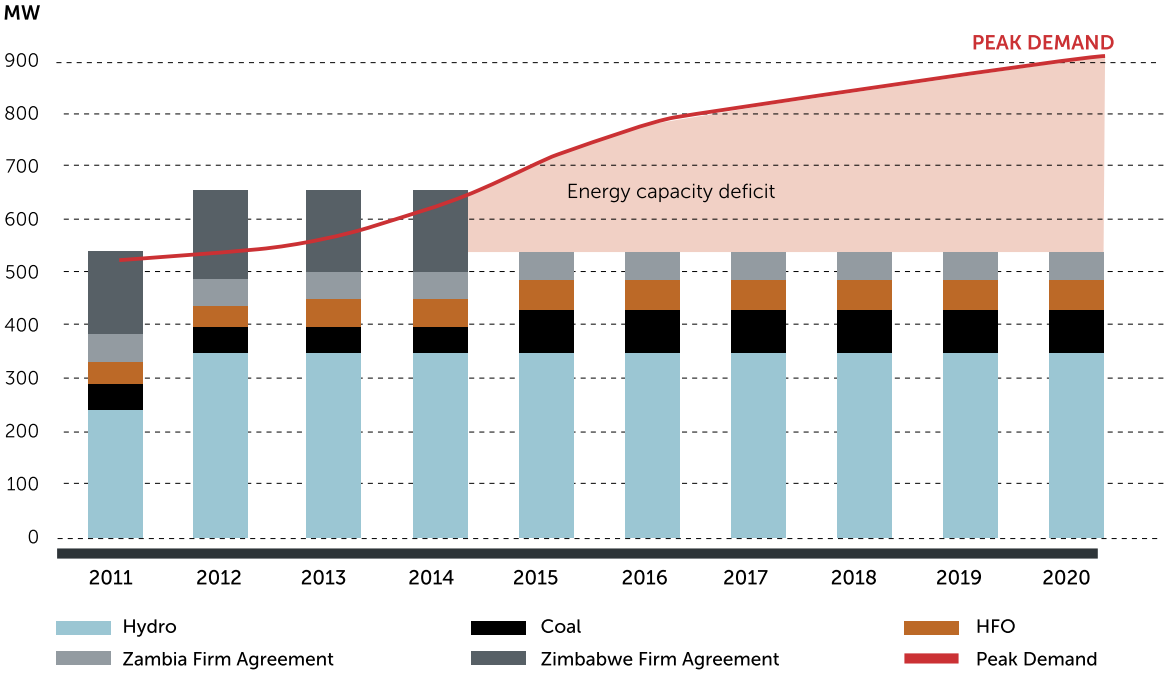
The SEGS (Solar Electricity Generating System) power plants in California were the first commercial CSP plants in the world. These power plants were built between 1981 and 1990 and have a total installed electric capacity of 354 MW . They are still in operation today, demonstrating the reliability and durability of this technology.



CSP trough is the most experimented CSP technology with several advantages:

> Response to short-term fluctuations of solar irradiation
> Easy combination with combustion fuels (hybridization)
> Easy and cost effective implementation of thermal storage
> Usability for other purposes than electricity generation (e.g. solar cooling, process heat, seawater desalination)

Namibia needs to increase the supply of electricity, particularly at peak time



Source: Hatch Planning Parameters and Generation Options Draft Report – April, 30 2012; Gesto analysis
Figure 4: Namibia energy peak demand and capacity forecast

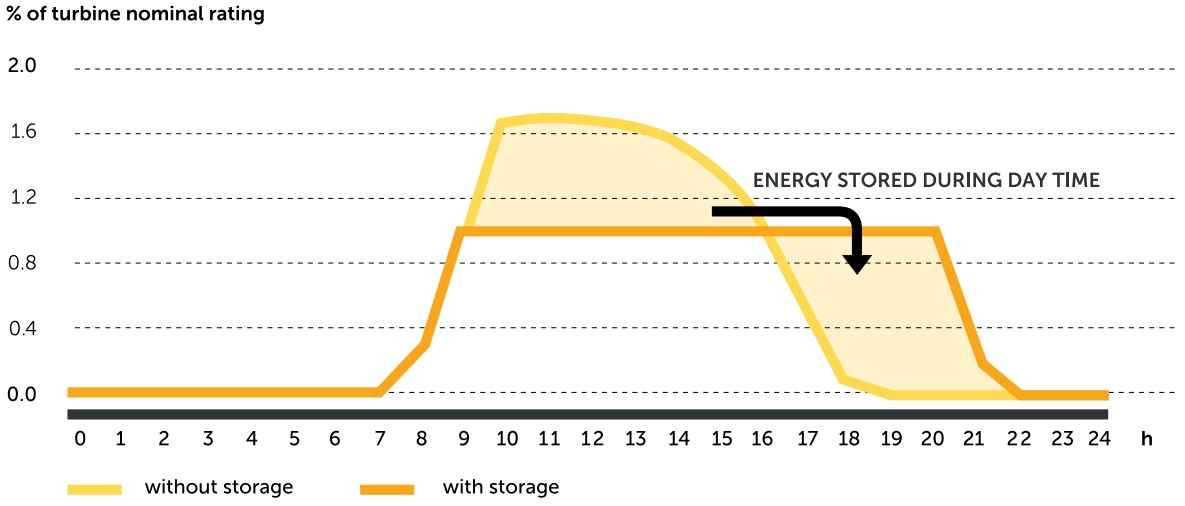
Namibia has been a net importer of electricity for many years and nowadays imports up to 70% of its electricity consumption from neighboring countries. However, the strong increase in energy consumption in the Southern African Development Community (SADC) region will imply a reduction of available electrical power for imports during mid-peak and peak periods.

With the end of the Zimbabwe power supply agreement, Namibia faces a major drop in capacity availability from 2015 onwards, which, compounded with peak demand growth, will lead to a large capacity deficit.

Furthermore, once Ruacana hydro power station will account for approximately 70% of Namibia's electricity generation capacity, the lack of water availability during dry season will further increase the electricity supply deficit.

Without short term investments in power generation, and only considering the peak and mid-peak periods, Namibia may be confronted with an energy shortage of 1,932 TWh between 2013 and 2016 alone.

CSP plants can store solar energy during the day and produce at night peak time



Source: SunBD
Figure 5: Example operation of a CSP plant

The advantage of CSP technology compared to other renewable energy technologies is the possibility of storing energy. State-of-the-art technology allows storage of up to 15 hours, which has been proven with the Gemasolar solar tower in Spain.
Furthermore, CSP plants, which work on the principle of a steam Rankine cycle and generate electric power using a coupled steam turbine and generator, require the thermal power supplied by the solar field, the thermal capacity of the thermal energy storage and the turbine capacity to be matched well in order for the plants to be operated at nominal power for a defined period of time in accordance with the plant design. With round-the-clock operation becoming possible, that is, as CSP plants can store solar energy during the day and produce at night peak time, a CSP plant has the potential to be used as a peaking plant or even as a base load power plant.

CSP based solar energy can be less expensive than fossil fuel alternatives

	Heavy Fuel Oil (HFO)	Rental Diesel	**Solar CSP**	**Solar PV/Wind & Backup diesel**
Minimum Lead Time	1.5 years	6 months	2 years	PV & Diesel: 1 year Existing wind: 1 year Other Wind: 2 years*
Investment (N$/MW)	~$10M to $15M	~0	~$40M	~$16-18M (PV or Wind) ~$2-4M (Diesel) Total: ~$20M
Operating Cost (Fuel + O&M - N$/MWh)	~$1,200	~$3,300 (based on Tanzania contracts with Aggreko and Symbion)	~$250-$400	~$150–200 (PV) or ~$100–150 (Wind) or ~$2800 (Diesel)
Total Cost (N$/MWh)	~$1,750 (@40% utilization & US $120/Brentt)	~$3,300	~$1,450 (Devpt. Banks) ~$1,770 (IPP)	PV&diesel: $1,730 (IPP) Wind&diesel: $1,720 – 2,125 (IPP)**

* Wind parks already with 1 year wind measurements and environmental impact assessment can be built in 1 year
** Tariff for wind calculated considering that 40% of the energy will be sold at off-peak hours at $350/MWh throughout the period for 2,500 and 3,000 hours net equivalent generation

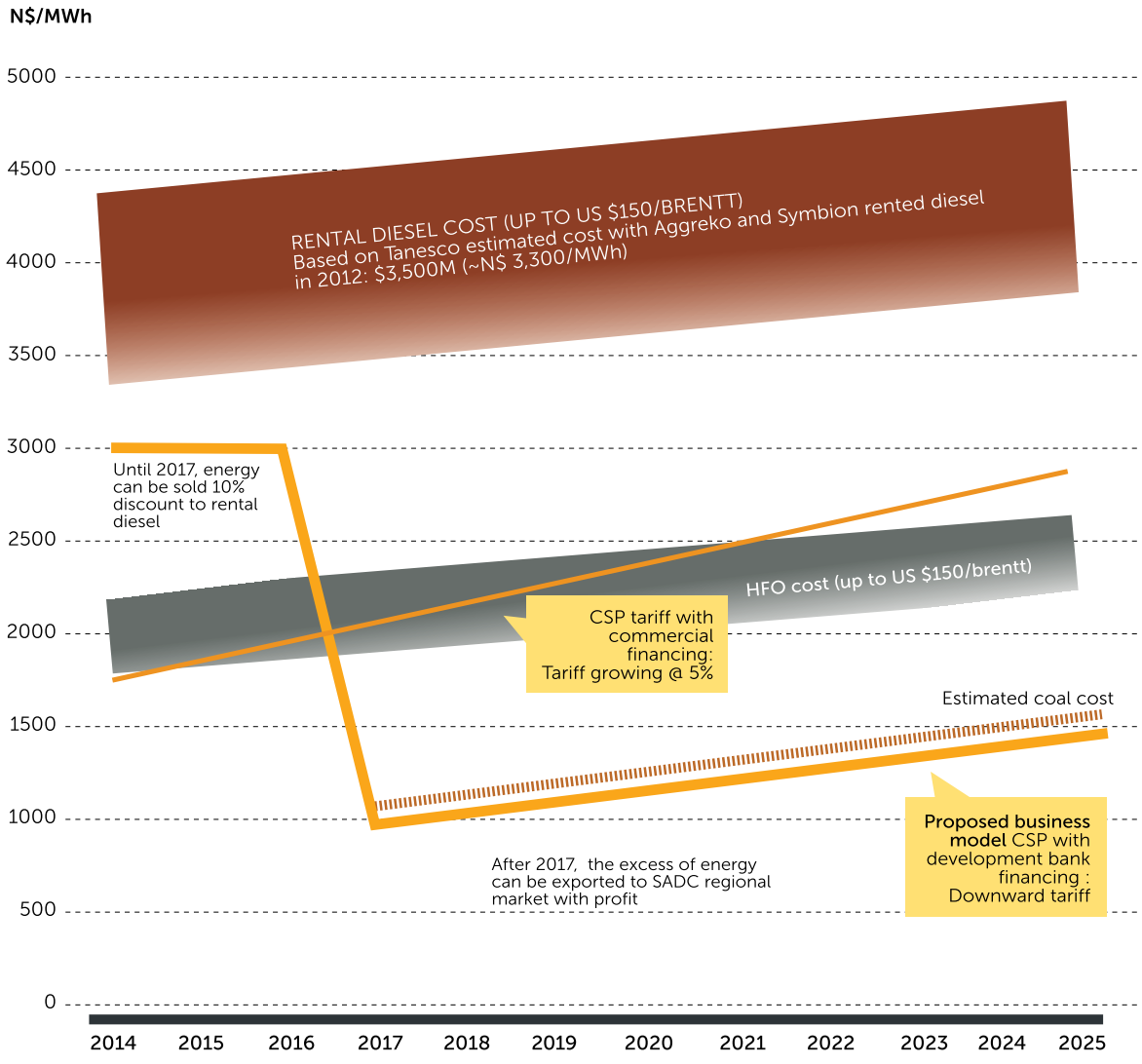
Notes: An initial 5 year tax exemption and a 34% tax rate, for the remaining period, was considered. Yearly rent and insurance costs as well as production degradation are reflected in the total cost's value. Inflation of 5%. Average project IRR of 15% and 11% in case of commercial and development financing, respectively.
Source: HFO: Hatch Planning Parameters and Generation Options Draft Report – April, 30 2012; CSP: SUNBD; Solar PV&Wind/diesel: South Africa refit results; Gesto analysis

Figure 6: Short term electric generation alternatives

Given Namibia's needs for electricity in the coming years and the strong energy consumption growth in SADC region, without short term investments in power generation, Namibia most probably will have to meet its energy gap with the very expensive option of rental diesel.

If we consider that 75% of the 1,932 TWh of estimated Namibian energy gap would be met using rental diesel, this would represent a total cost of N$ 6,377 million for Namibia. Hence, if Namibia invests in CSP and uses part of the named costs to reduce the initial investment in a CSP plant instead of importing diesel, this would reduce the investment and the required cost for the remaining period (see graph example on the right for downward tariff). CSP would become cost competitive even with coal.

Integrating wind power and solar PV projects with backup diesel generators may also be an interesting and economic alternative that Namibia may explore together with CSP. Clearly, investing in CSP will always be more cost effective than rental diesel and if we consider the development of CSP projects with available development bank financing, CSP becomes the most economic short to medium term technology alternative.



Source: Hatch Planning Parameters and Generation Options Draft Report – April, 30 2012; Gesto analysis
Figure 7: Required feed-in-tariff by technology

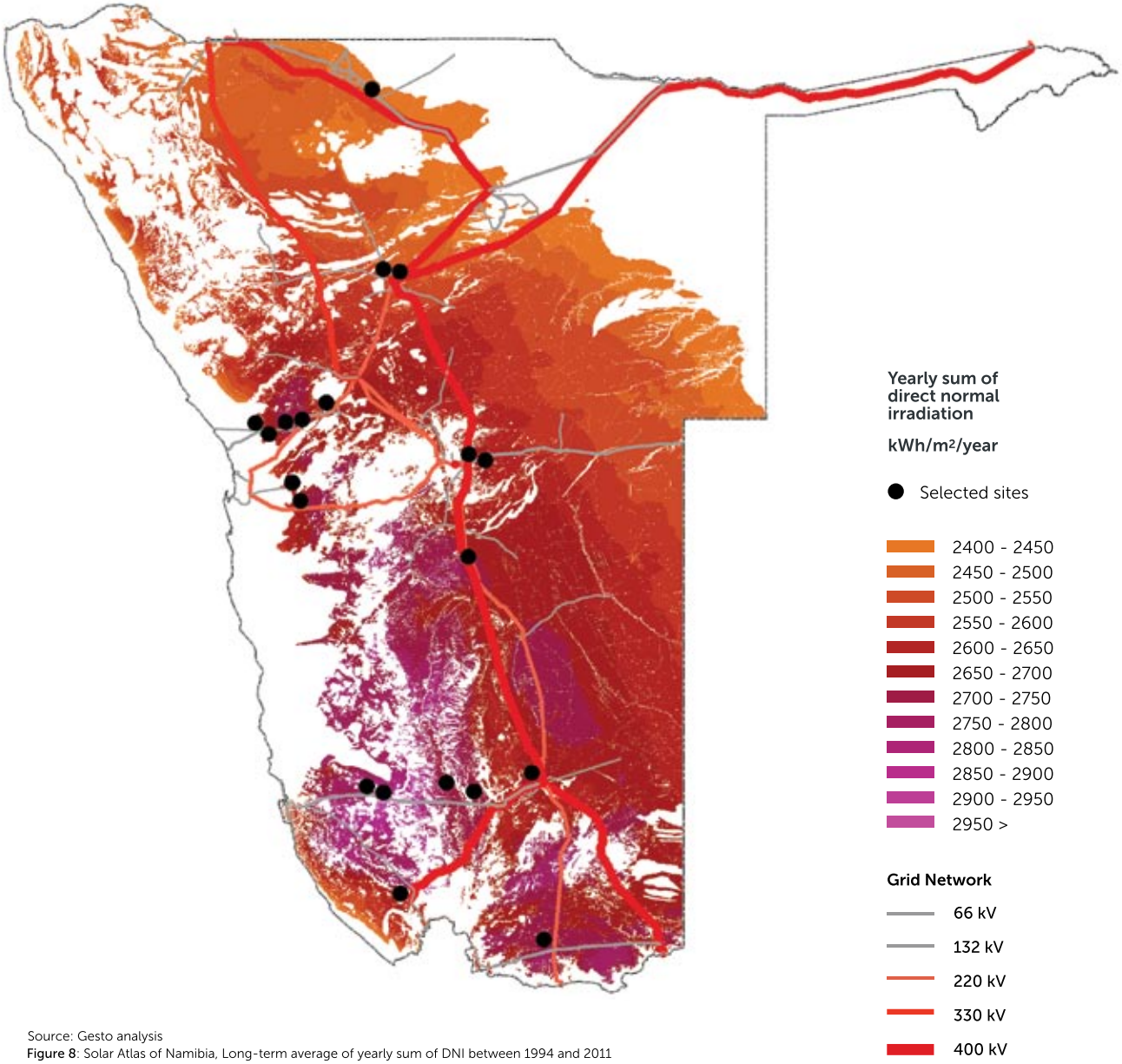
Namibia has more than 33,000 km² of potential sites for CSP development and more than 250,000 MWe of projects

In the pre-feasibility study for the development of a CSP power plant in Namibia several points had to be investigated. In the first phase, all the Namibian territory was analyzed, using a multi--criteria analysis methodology, to identify the most suitable locations for developing CSP projects. The solar resource was crossed with economical, feasibility and environmental criteria, such as terrain slope, soil type, distance to grid with sufficient connection capacity, air temperature, water availability, road distance and protected areas. The potential for alternative business models taking into account synergies of CSP with other technologies, namely, desalination, mines, wind generation, augmentation with coal and hybridization with gas or biomass, was considered and valued.

This methodology, based on geographic information systems (GIS), identified more than 33,000 km² of potential sites for CSP development, which theoretically is equivalent to a capacity of more than 250,000 MWe.

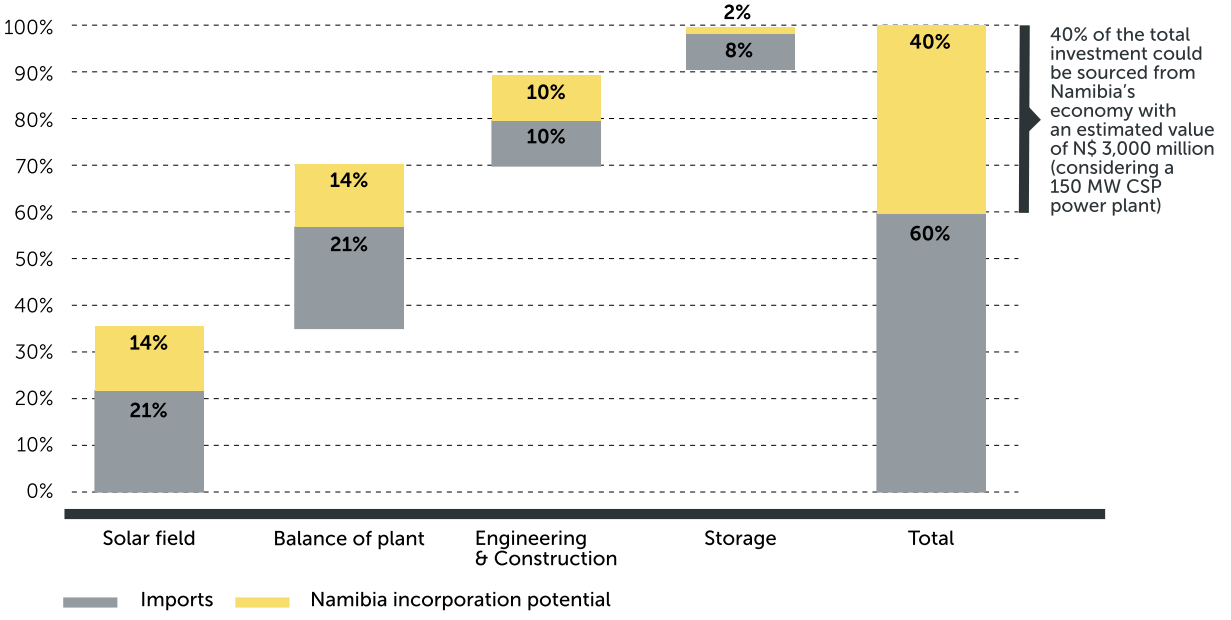
In a second phase, the 20 most suitable locations were prioritized according to CSP potential and were visited by CSP and environmental experts. A preliminary environmental and feasibility analysis was conducted during the site visits to select the most promising sites to develop CSP power plants in Namibia.

The environmental analysis considered different criteria: land use, cultural and socio-economic values, landscape and fauna and flora values. Despite the fact that about 46% of the territory is protected area, 3 of the best 5 projects received the best environmental classification in the performed study. CSP can be developed in Namibia with minimal impact on the environment.



Source: Gesto analysis
Figure 8: Solar Atlas of Namibia, Long-term average of yearly sum of DNI between 1994 and 2011

ADVANTAGES OF CSP FOR NAMIBIA



Source: Solar-Institut Jülich; SunBD
Figure 9: CSP Namibia incorporation potential

Namibia's world class solar resource and short term energy deficit outlook make CSP the most competitive short term energy alternative for Namibia

> Namibia has the second best DNI solar radiation in the world, just after Chile.

> Great solar resource and short deployment time (compared to coal, hydro or natural gas plants) allows CSP investment to be quickly repaid if used instead of short term diesel alternatives. Low operating costs allow CSP to become cost competitive even with coal in the medium term.

CSP development in Namibia can have access to development funding for renewable energies in Africa and a CSP program could enhance Namibia's international visibility and credibility

> Significantly decreasing the cost of debt and increasing the required tenors, which results in lower tariffs.

> Increasing access to available financing (this is important due to the high investment requirements until 2017).

CSP is a proven technology with more than 1 GW of plant capacity already installed:

> Spain has >750 MW and the USA >440 MW installed electric power.

> Energy storage already tested and deployed in many projects around the world.

CSP can guarantee dispatchable peak power, even for the night peak time, and does not need to produce electric power at off-peak periods when the value of energy in the region is very low

> Dispatchability can be guaranteed through storage or hybridization with biomass.

A bet on CSP allows the production of cheap and clean energy reducing imports and promoting a national cluster that creates jobs and wealth

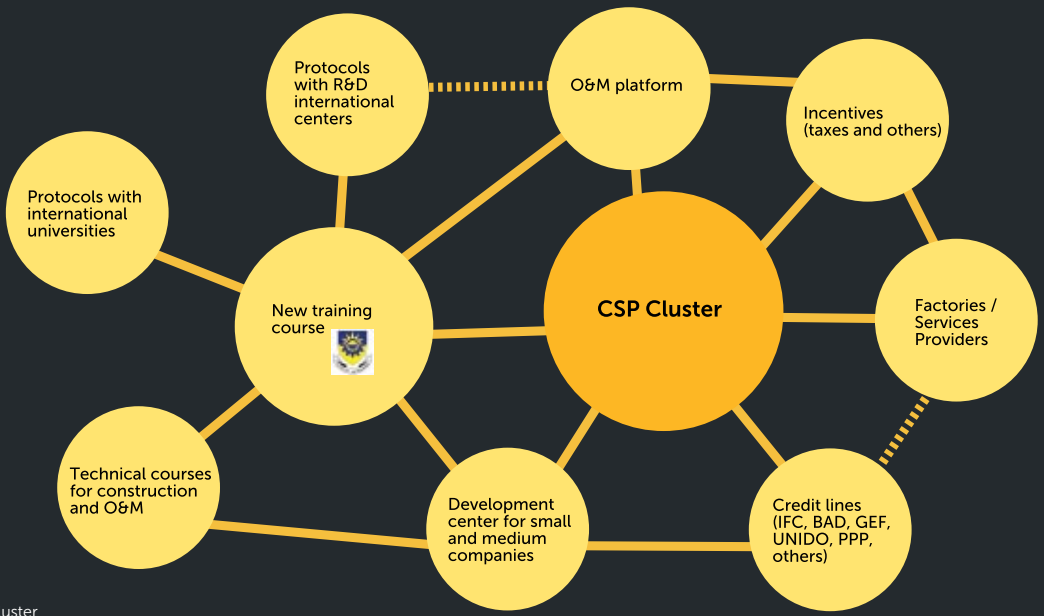


figure 10: Namibia CSP Cluster

The creation of a CSP cluster could maximize CSP's advantages for Namibia with a positive impact on the economy and education sectors:

Up to 40% of the investment in a CSP plant could be sourced from Namibia's economy

> Increasing demand and business volume for existing companies in Namibia (e.g. construction, metallic structures, glass, ...).

> For example, in case of a 150 MW CSP power plant, a total demand of N$ 3,000 million would take place in the next years.

CSP has a strong potential for local job creation

> This may be significantly increased if biomass hybridization is used.

> A 150 MW CSP power plant could lead to more than 100 O&M permanent jobs and 1,700 jobs during the construction phase.

A CSP technology transfer program could enhance the renewable competences of Namibian research and education institutions

> The development of a CSP strategy in Namibia will create new needs within the labor market. These new needs will require the creation of new competences in education, from technological courses for construction and O&M to power plant engineering.

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