



# Dispatchable Solar Energy 24/7 – The Case of Bokpoort CSP plant in South Africa

**Nandu Bhula**

Deputy Managing Director (Southern  
Africa)

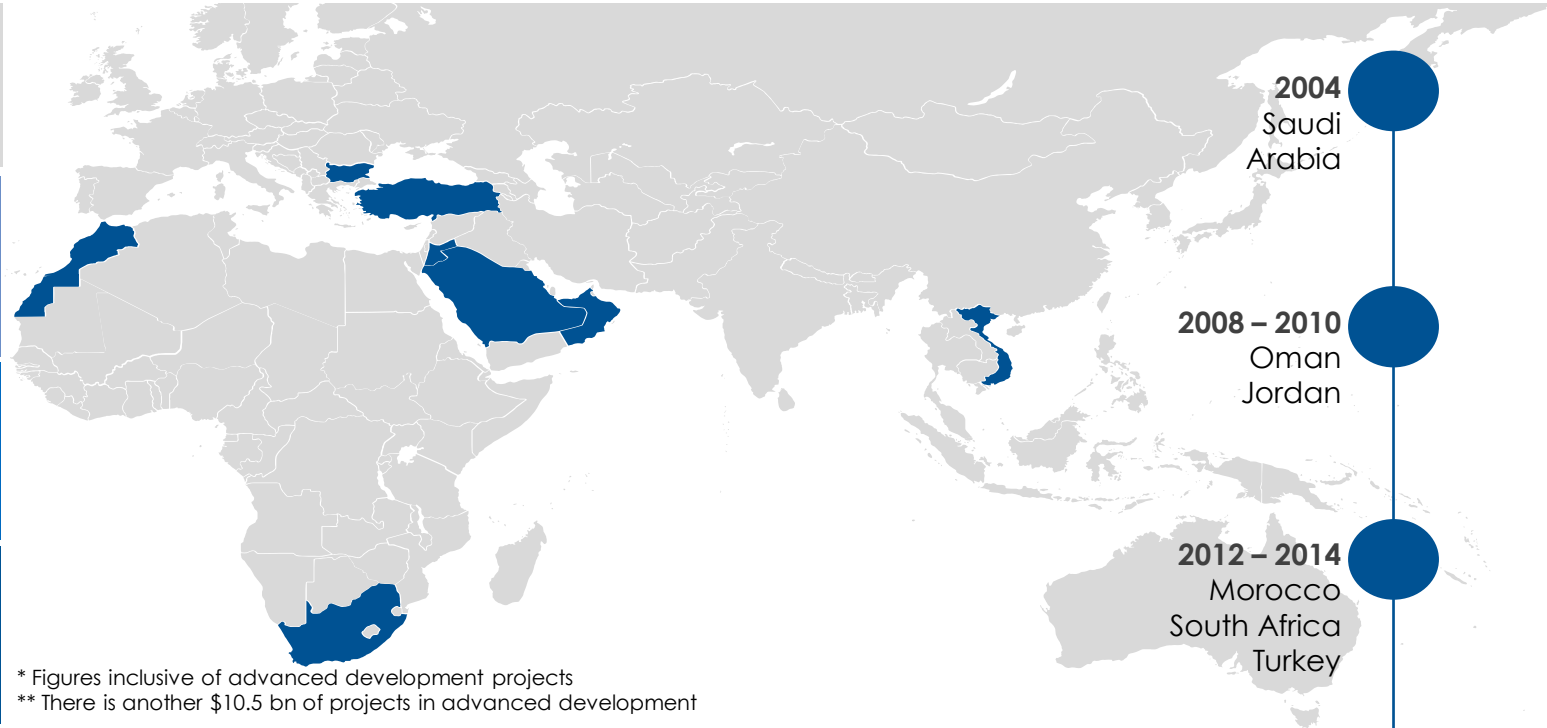
**ACWA POWER**  
كوا باور

## We develop power and desalination water plants

In over a decade we have become the second largest power & water developer in the GCC region, and a name to contend with internationally.

We have achieved this by **developing**, **investing** in and **operating** a world-class portfolio...

<b>58</b> Assets* 	<b>37.7+</b> GW Power* 	<b>5.8</b> Mm <sup>3</sup> per day Desalinated Water* 
<b>12</b> Countries 	<b>\$59+ bn</b> USD of Assets Under Management** \$	<b>21.5%</b> Portfolio in Renewable Energy based on Share of project cost 
<b>3,500+</b> Employees 	<b>30+</b> Nationalities 	<b>~60%</b> Local Employment in projects 



### DEVELOP

We win bids as lead developer, by partnering with the best and focusing on cost leadership.

### INVEST

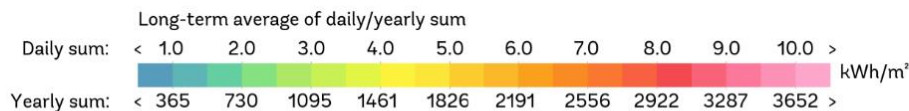
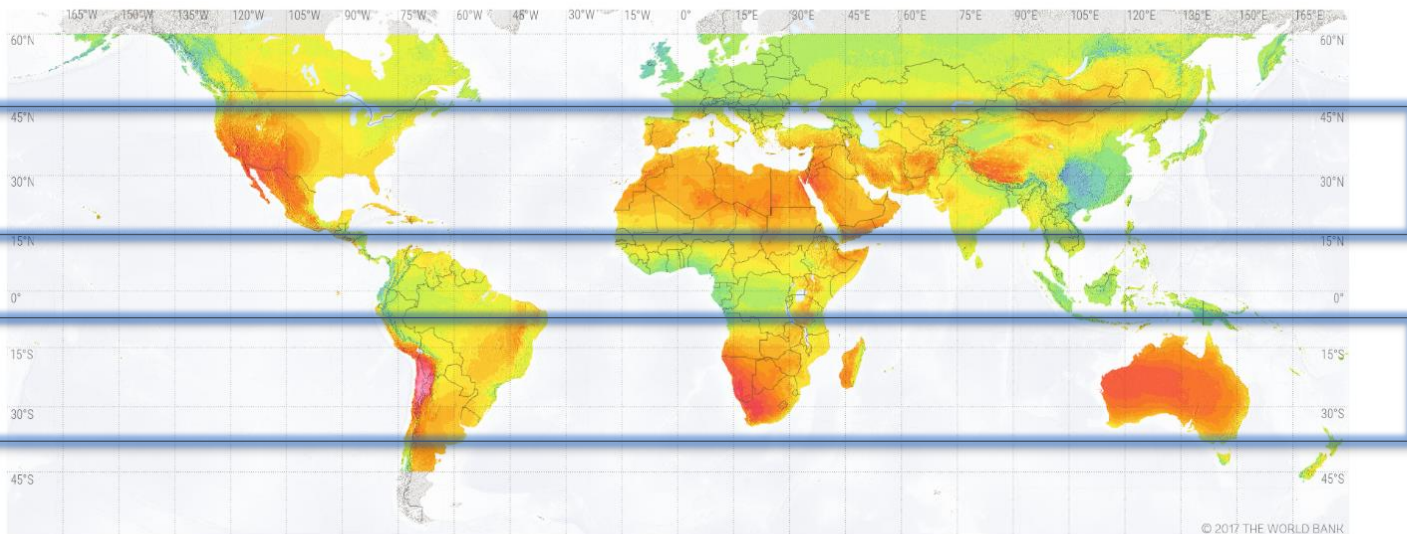
While taking significant, long-term stakes in all our plants

### OPERATE

We operate and maintain our plants to the highest global standards

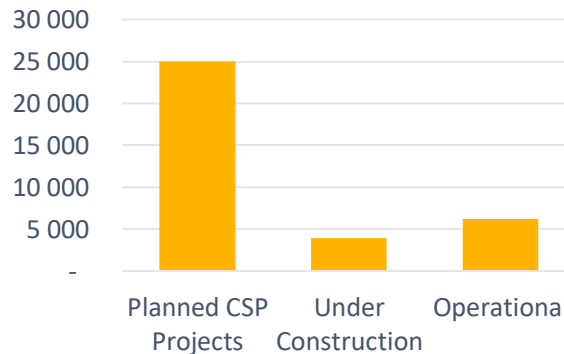
# CSP – Status across the Globe

## SOLAR RESOURCE MAP DIRECT NORMAL IRRADIATION

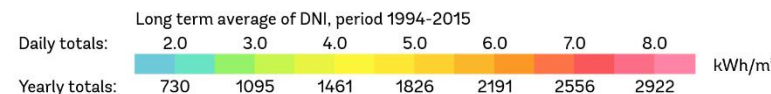
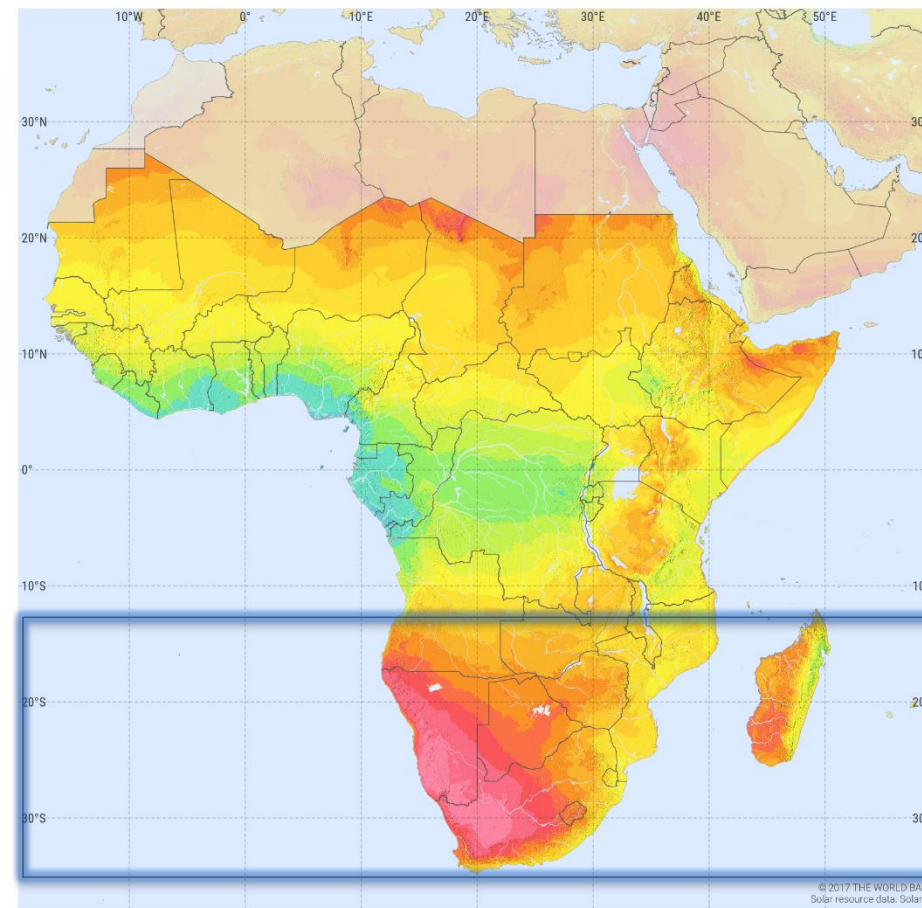


This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit <http://globalsolaratlas.info>.

- CSP technology implemented in 23 countries across the globe
- Over 6,000MW in operation
- Over 3,500MW in construction
- Almost 25,000MW planned or in development stages

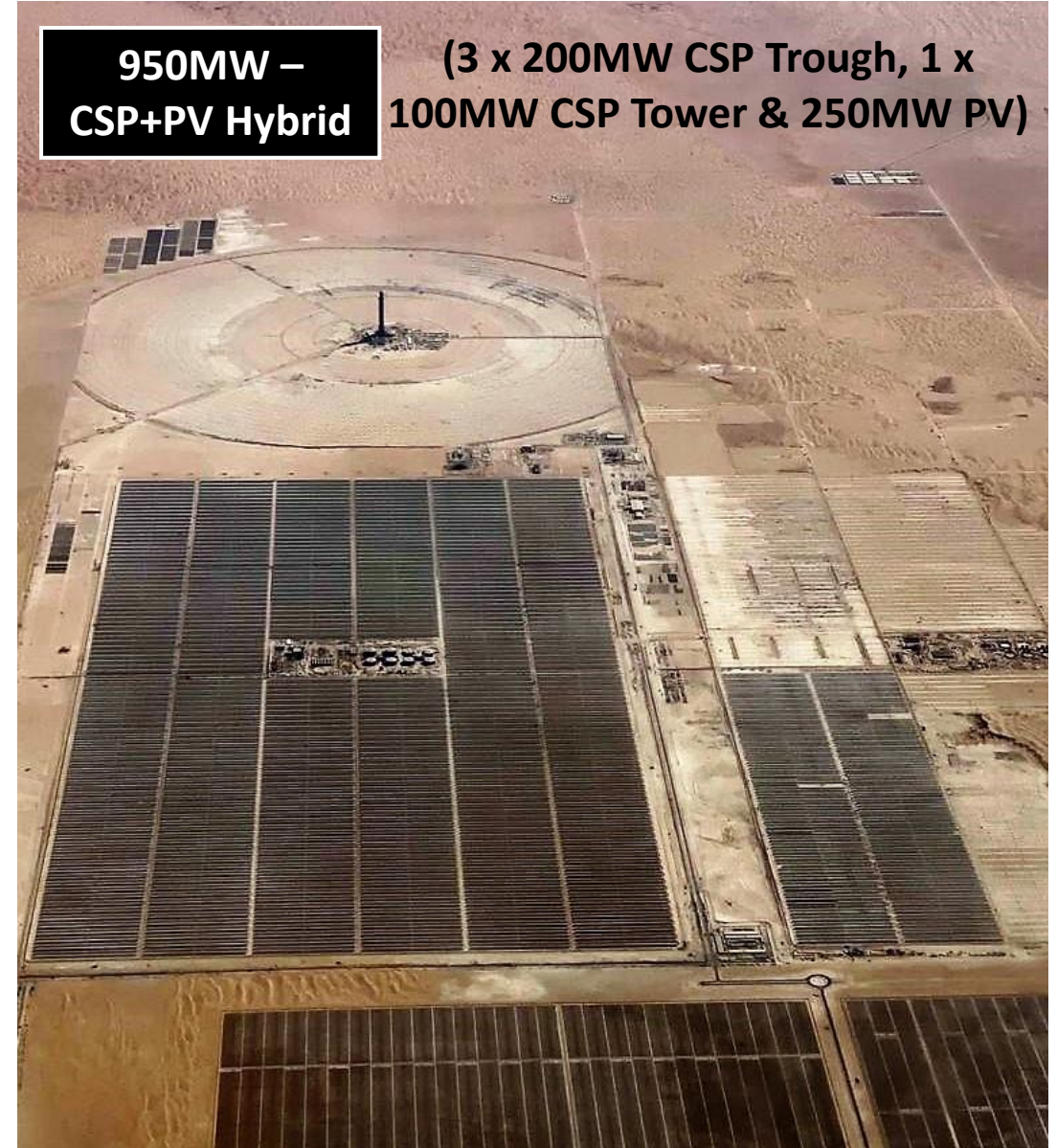
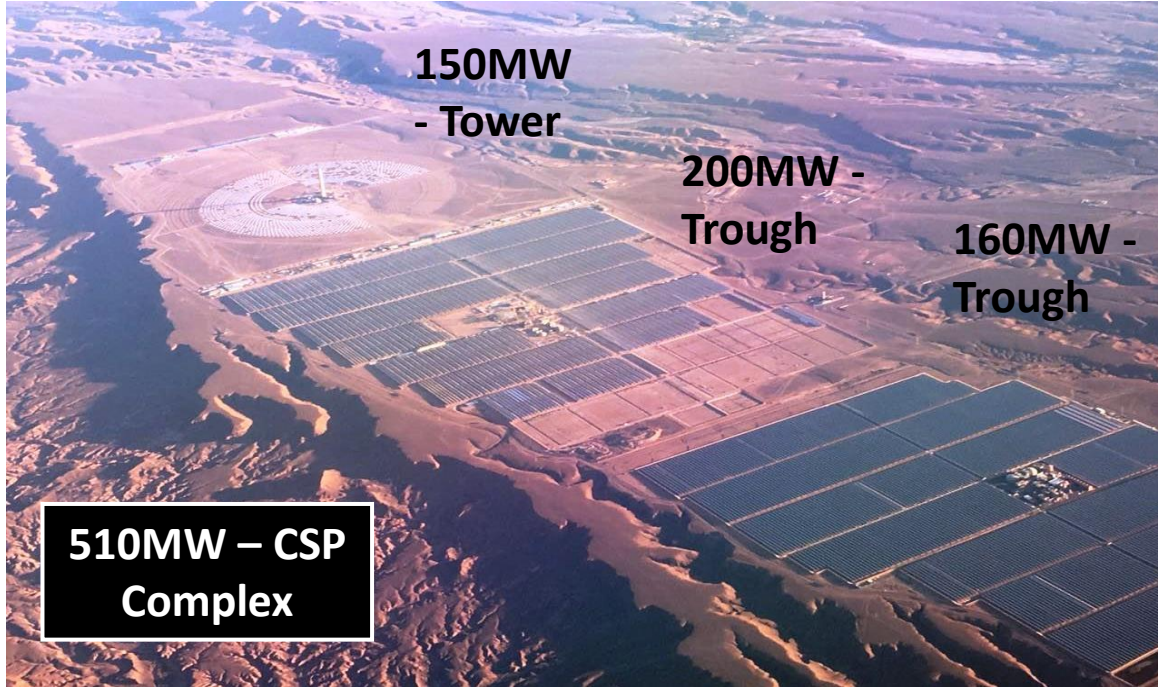


## SOLAR RESOURCE MAP DIRECT NORMAL IRRADIATION SUB-SAHARAN AFRICA



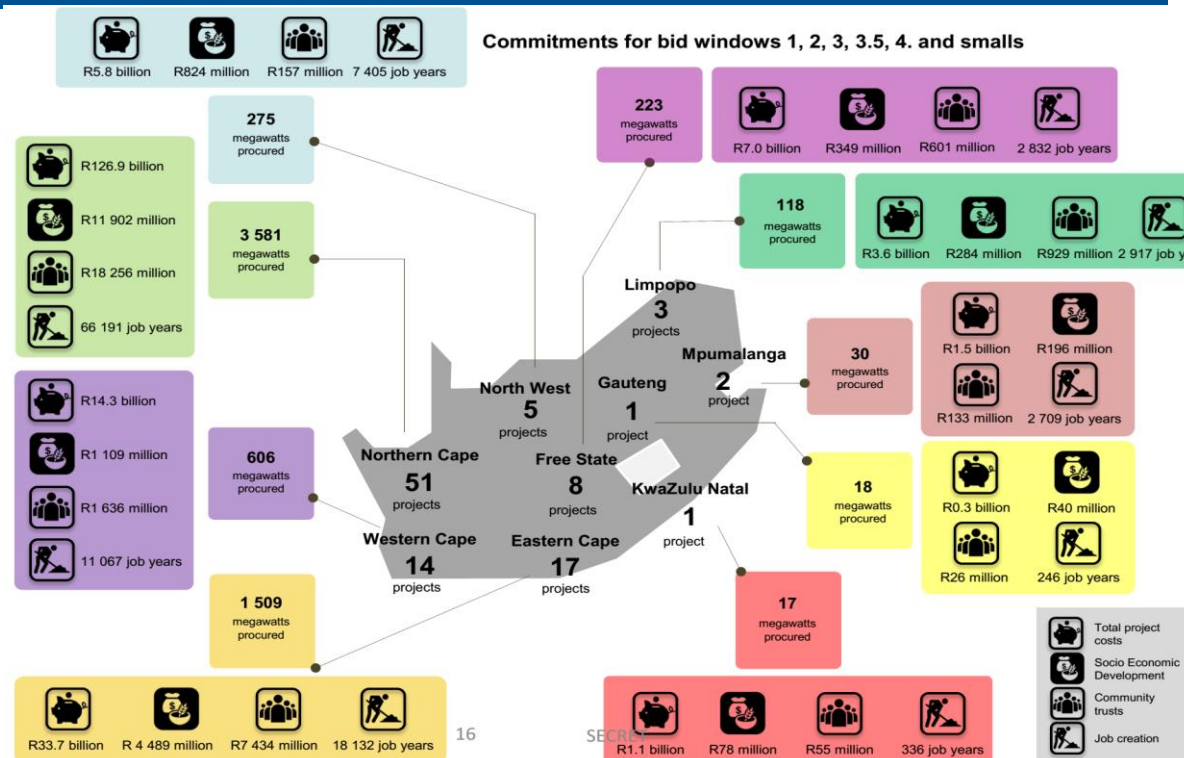
This map is published by the World Bank Group, funded by ESMAP, and prepared by Solargis. For more information and terms of use, please visit <http://globalsolaratlas.info>.

# ACWA Power CSP's in MENA Region



# South African Renewable Energy IPP Program (REIPPP)

- Started in 2011, the REIPPP is widely recognized as one of the **most successful renewable energy procurement** models in the world.
- Over **5 progressive rounds** of competitive bidding, procuring more than **6,300 MW** of renewable energy capacity across **92 projects**
- Significant progress made to Tariff reduction, investments and job creation**
- 600 MW of CSP Capacity has been procured.
- ACWA Power developed and built the **50 MW Bokpoort CSP** project in Round 2 and is about to start construction on the **100 MW Redstone CSP** project from Round 3.5



	BW 1		BW 2		BW 3		BW 3.5		BW 4		Total	
Technology	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects	Capacity (MW)	No. of projects
Wind	649	8	559	7	787	7	0	0	1,362	12	3,357	34
Solar PV	627	18	417	9	435	6	0	0	813	12	2,292	45
CSP	150	2	50	1	200	2	200	2	0	0	600	7
Landfill gas	0	0	0	0	18	1	0	0	0	0	18	1
Biomass	0	0	0	0	17	1	0	0	25	1	42	2
Small hydro	0	0	14	2	0	0	0	0	5	1	19	3
<b>Total</b>	<b>1,426</b>	<b>28</b>	<b>1,040</b>	<b>19</b>	<b>1,457</b>	<b>17</b>	<b>200</b>	<b>2</b>	<b>2,205</b>	<b>26</b>	<b>6,328</b>	<b>92</b>

# CSP – Review of CSP's in South Africa

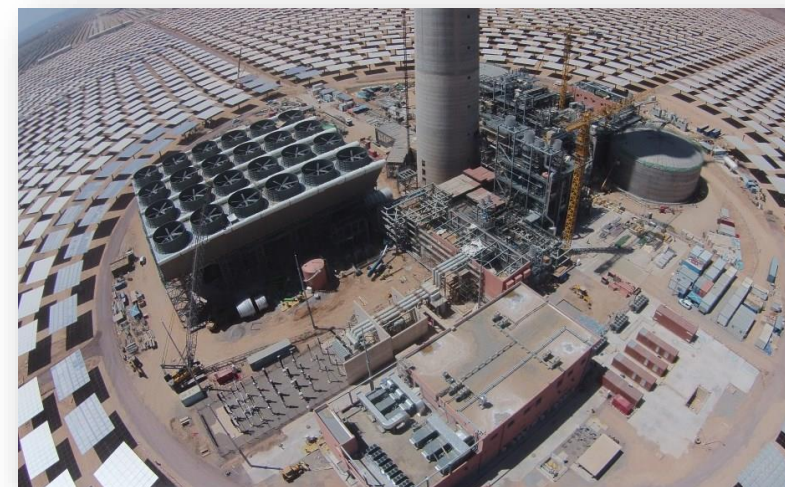
Project Name:	KaXu Solar One	Khi Solar One	Bokpoort	Xina Solar One	Ilanga I	Kathu Solar Park	Redstone
Country:	South Africa	South Africa	South Africa	South Africa	South Africa	South Africa	South Africa
Location:	Poffader	Upington	Grobliershoop	Pofadder	Upington	Kathu	Postmasburg
Technology:	Parabolic trough	Power tower	Parabolic trough	Parabolic trough	Parabolic trough	Parabolic trough	Power tower
Turbine Net Capacity:	100	50	50	100	100	100	100
Status:	Operational	Operational	Operational	Under construction	Under construction	Under construction	Financial Closure
Start Year:	2015	2016	2016	2017	2019	2019	2023
Thermal Storage	2-tank indirect	HP Steam Vessels	2-tank indirect	2-tank indirect	2-tank indirect	2-tank indirect	2-tank direct
Storage Capacity:	2.5 hours	2.5 hours	9.3 hours	5 hours	4.5 hours	4.5 hours	12 hours
Thermal Storage Description:	Molten salts	Saturated steam	Molten salts	Molten salt	Molten salt	Molten salt	Molten salt
Additional Grid Contribution	Peaking	Peaking	Base/Load Following	Peaking /Load Following	Peaking /Load Following	Peaking /Load Following	Base Load



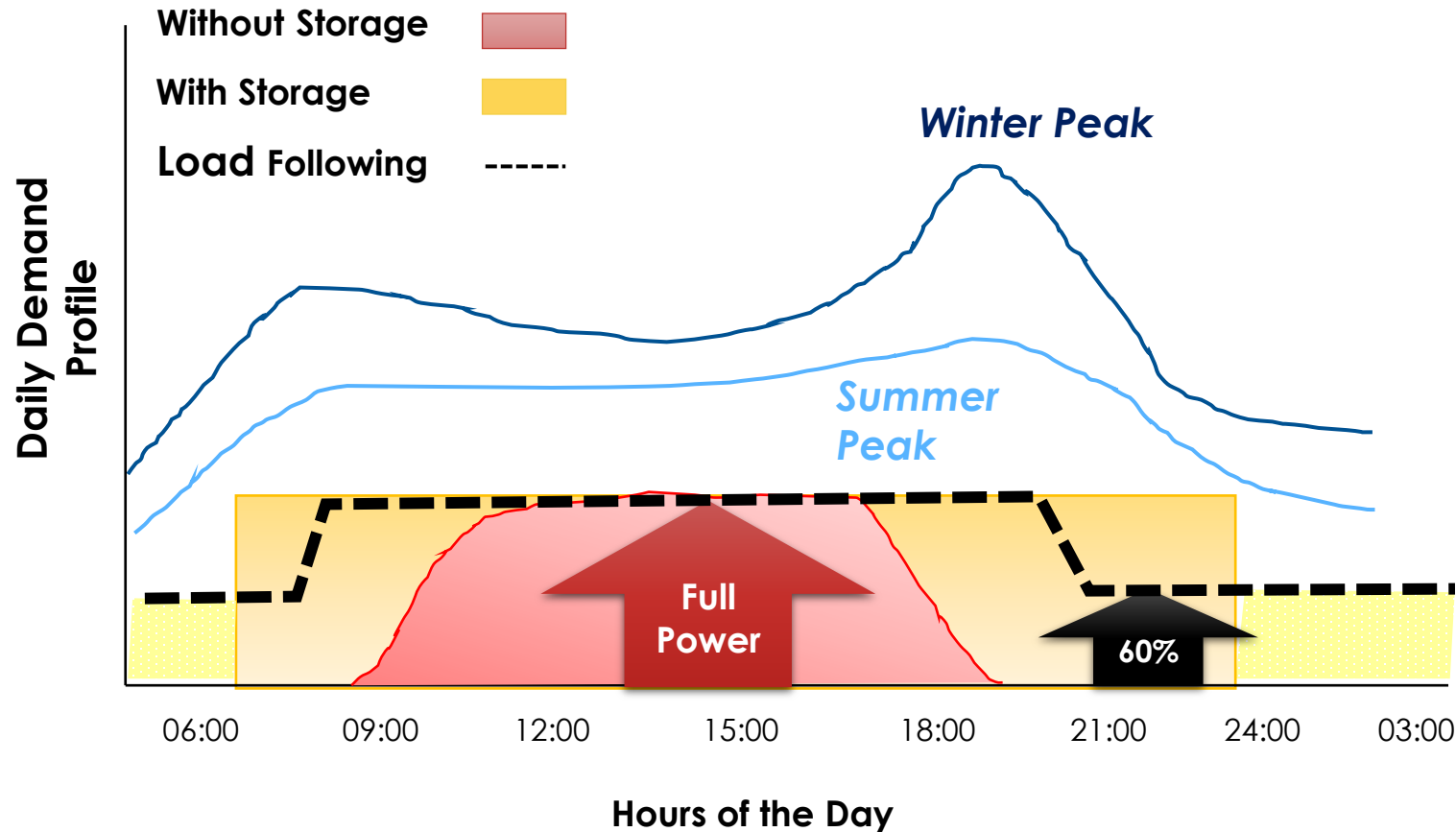
- 50 MW Parabolic trough
  - 180 loops
  - 658 000 m<sup>2</sup> of reflective surface
- Dowtherm A as HTF
  - 293 °C – 393 °C
- 9.3h Thermal Storage
- Wet cooling
  - Cooling Tower
  - Counter flow, induced draft CT (3 cells)



- 100 MW Power Tower
  - ~12k – 20k heliostats
  - 1.13 million m<sup>2</sup> of reflective surface
- Molten Salt as HTF
  - ~298 °C – 565 °C
- 12h Thermal Storage
- Dry cooling
  - ACC
  - ~ 5 x 4 cell configuration



# The Case for CSP with Storage for South Africa – design basis



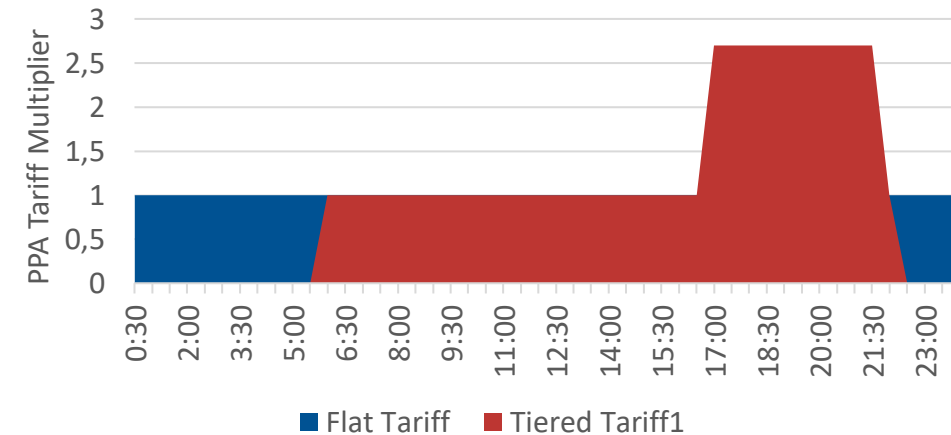
**Note: Not to Scale for Illustration Purposes only**

**CSP + Storage (adequate) = Load Following/Base Load (depending on size)**

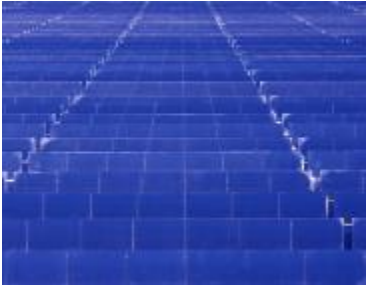
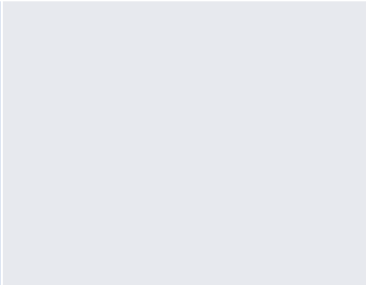
## Key Considerations:

- Solar Resource – DNI
- Grid Connectivity
- Demand Profiles
- PPA requirements – flat vs tiered tariff
- Solar Field Optimization – Winter vs Summer
- Adequacy of Storage
- Tx requirements/Grid support
- Future Possibility of Hybridization

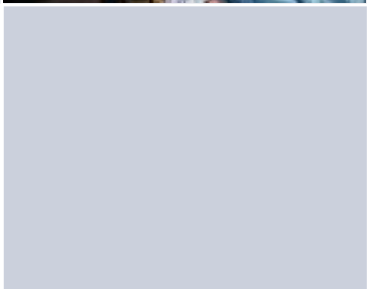
## PPA Tariff Structures REIPPPP





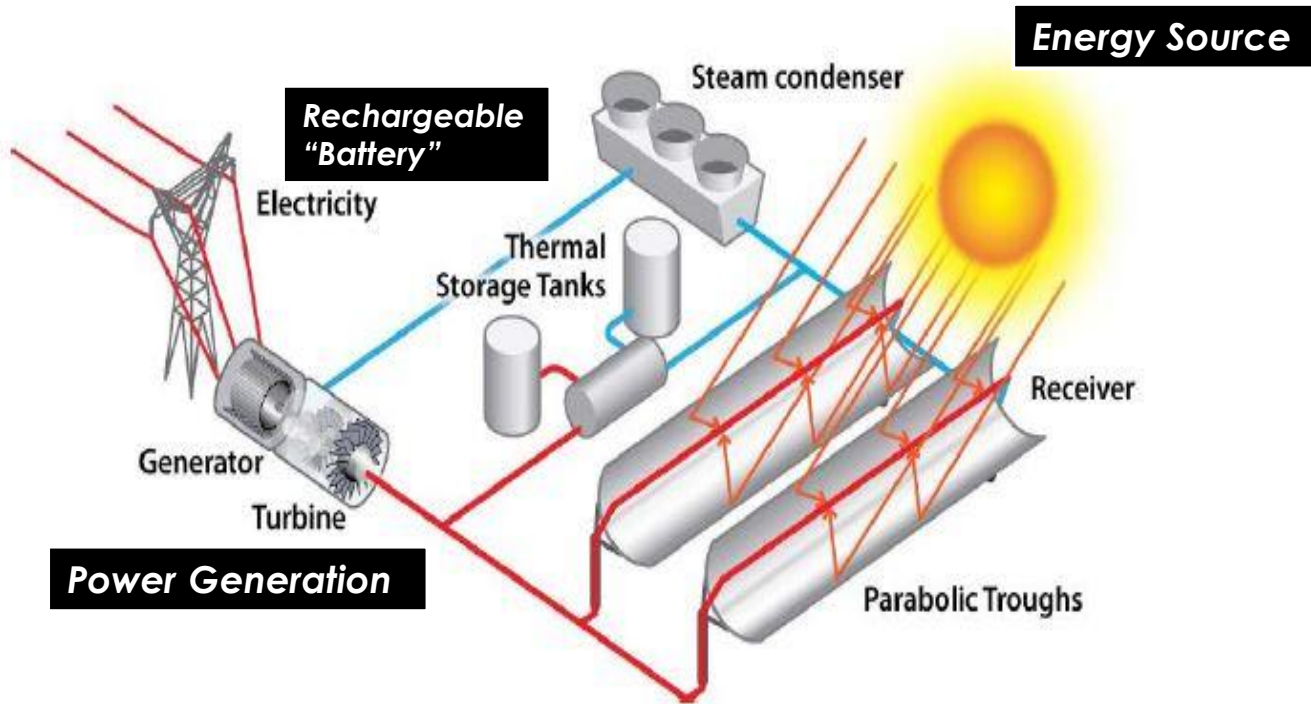


# Dispatchable Solar Energy 24/7 – The Case of Bokpoort CSP plant in South Africa



**Christo Spammer**  
CEO - Bokpoort CSP





- Bokpoort CSP: 50 MW Parabolic Trough CSP Plant
- Thermal Storage = 9.3 hours at 50 MW (Largest in Africa)

## CSP Parabolic Trough

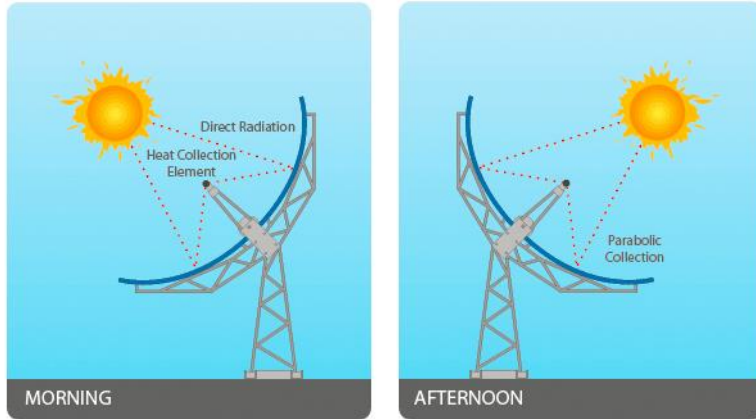
- Proven development and operational track record
- Employs single axis trackers
- "off-the-shelf" designs and systems available
- Higher energy losses/aux requirements in comparison to tower due to extensive solar field piping
- Local content opportunities high
- Lower Uncertainty – mature with 30-month delivery



- Financial Close and NTP – 25<sup>th</sup> June 2013
- 1<sup>st</sup> Synchronisation – 13<sup>th</sup> November 2015
- Early Operating Date – 6<sup>th</sup> February 2016
- COD – 19<sup>th</sup> March 2016

## Solar Field

- Eight Solar Fields - 180 Loops
  - 48 Solar Collector Elements per Loop
  - 8,640 SCEs Installed
- Flabeg Glass Mirrors
  - 241,920 Mirrors
  - 658,000 m<sup>2</sup> of reflective surface
- SENER Trough Technology
- Schott Heat Collector Elements (25,920)
- HTF – Dow Chemical (2,640 tons)

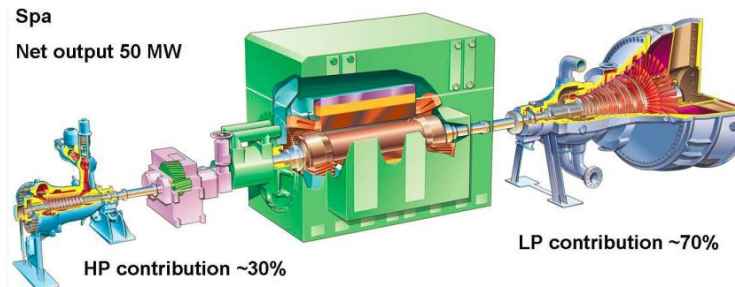


## Thermal Energy Storage

- 38,100 Tons of Salt (Potassium and Sodium Nitrate) – **9.3 hrs at MCR**
- Two Tanks – Hot & Cold
  - 40 m Diameter
  - 14 m Height
- Bank Solar Energy during the day and release it at night or as needed

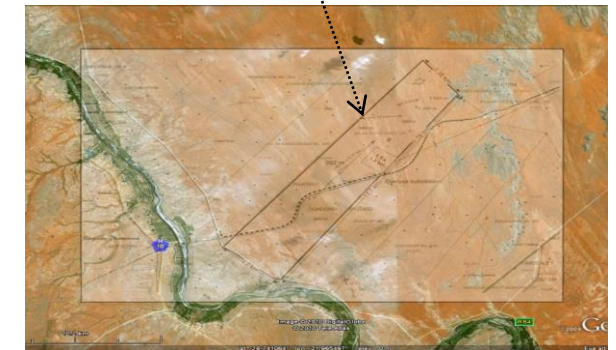
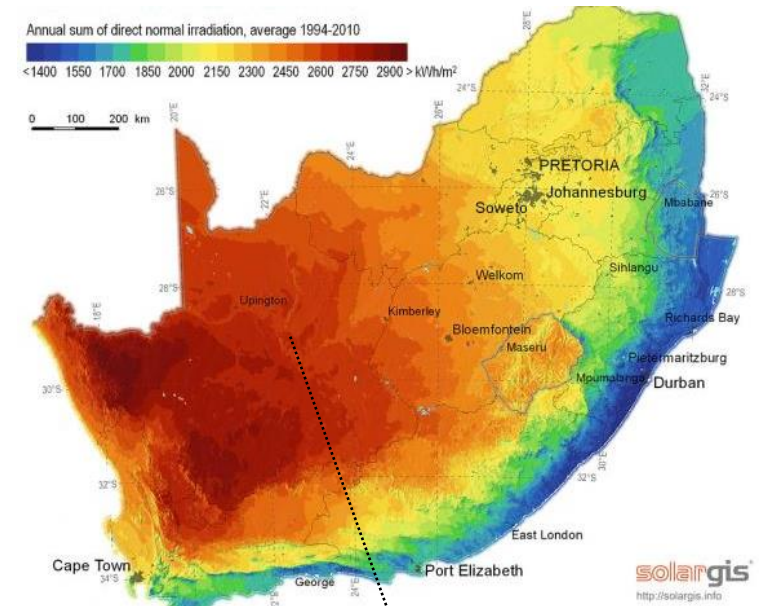
## Steam Generation

- Two Trains of Steam Generation
  - Steam Supply 103.6 bar @380°C (@ Turbine Inlet)
  - Enthalpy 3028.7kJ/kg, Steam Flow 60.0 kg/s
- Siemens Steam Turbine SST-700
  - Single Reheat (HP, LP)
  - Siemens Generator

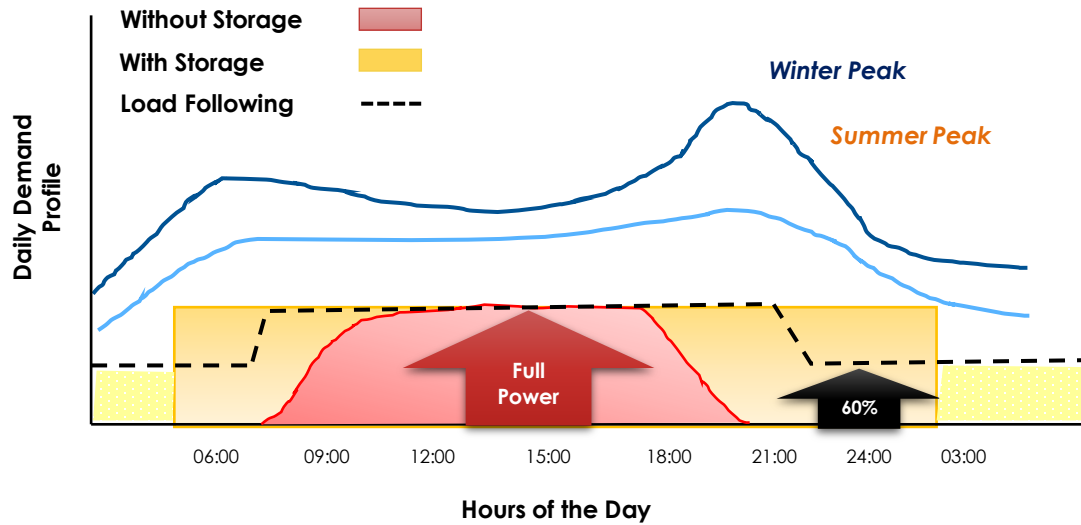


## Site Location

**Site Coordinates:** Latt. 28°44'26.96"S Long. 21°59'34.88"E



# Bokpoort CSP – Parabolic Trough Technology with Storage



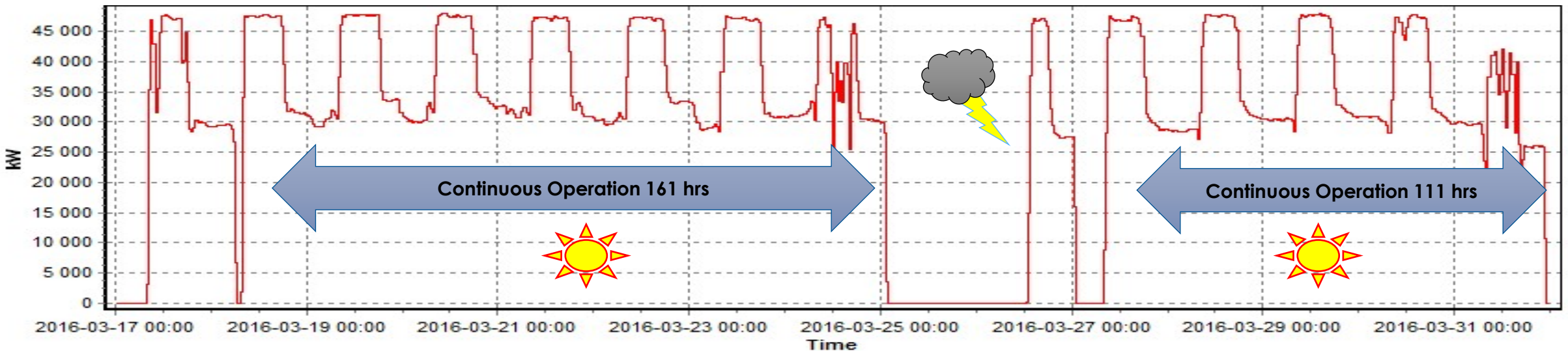
Note: Not to Scale for Illustration Purposes only

CSP + Storage (adequate) = Load Following/Base Load (depending on size)

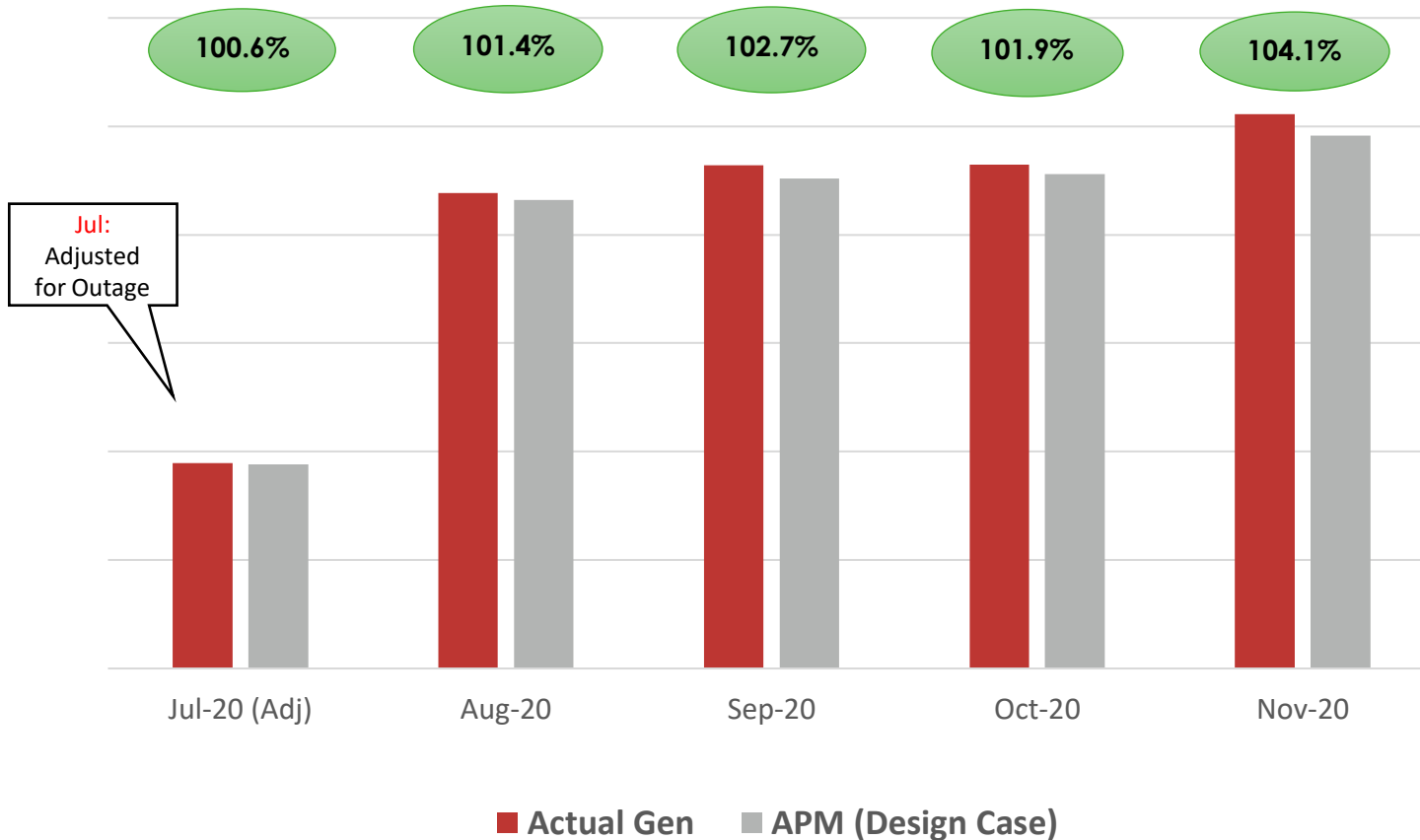
## African Record\*:

Period: 18 March 2016 7:00am to 25 March 2016 1:00am  
 Record: **161 hours of Continuous Operation (Time on Load: 100%)**  
 Load Factor: **76% (based on Energy Sent Out)**

Period: 17 March 2016 8:00am to 31 March 2016 11:00pm  
 Record: **310/352 hours of operation (Time on Load: 88%)**  
 Load Factor: **66% (based on Energy Sent Out)**



## Recent Production Performance



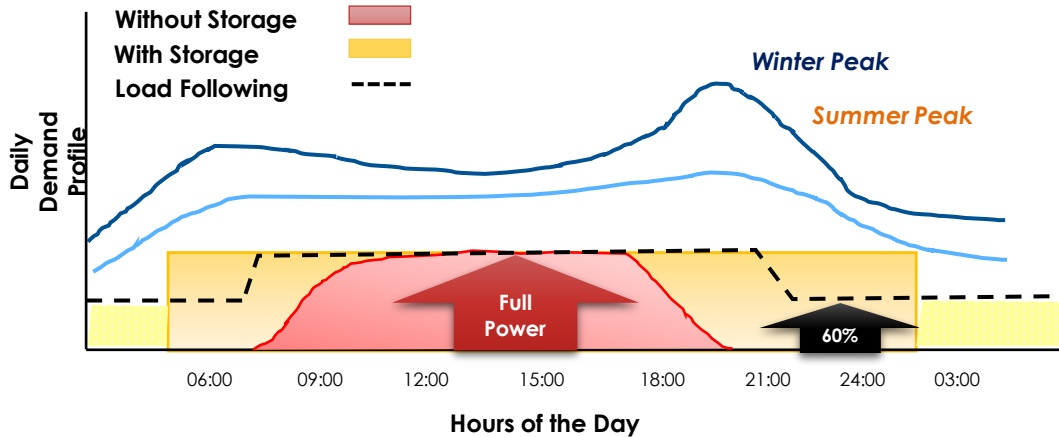
## Sustaining Design Expectations

- Key focus during Jun/Jul outage season, was to address long standing issues:
  - Condensor/Cooling Tower Efficiency
  - HTF Control Valve replacement
  - Superheater Efficiency
- Negotiations started with Lenders for consideration towards refinancing for greater shareholder value
- **Key CP was to exceed 100% performance expectations from Model over continuous period**
- **Successfully Achieved in Nov 2020**
- **Refinancing is now possible (huge vote of confidence from our lenders)**

**Cumulative Generation Performance: 102.4% to Model and 101.0% to Base case**

Production Records			
Max Daily Production (MWh) – All time	1077 (30 <sup>th</sup> Nov 2020)		<i>Representing 21.5 hrs at max load in the day</i>
Daily Load Factor – All time	89.8%		
Max Daily Production (MWh) - Winter	902 (31 <sup>st</sup> Aug 2020)		<i>Representing 18.0 hrs at max load in the day</i>
Daily Load Factor - Winter	75.2%		
Max 3-day Consecutive Prod (MWh)	3080 (28 <sup>th</sup> -30 <sup>d</sup> Nov 2020)		<i>Representing 20.5 hrs at max load per day</i>
Max 3-day Load Factor	85.6%		
Max 7-day Consecutive Prod (MWh)	7044 (10 <sup>th</sup> -16 <sup>th</sup> Oct 2020)		<i>Representing 20.1 hrs at max load per day</i>
Max 7-day Load Factor	83.8%		
Max 10-day Consecutive Prod (MWh)	9998 (12 <sup>th</sup> -21 <sup>st</sup> Oct 2020)		<i>Representing 20.0 hrs at max load per day</i>
Max 10-day Load Factor	83.3%		
13 Day Continuous Operations Record (MWh)	12831 (10 <sup>th</sup> -22 <sup>st</sup> Oct 2020)		<i>Representing 19.7 hrs at max load in the day</i>
Load Factor over the 13 days (312 hrs)	82.3%		

# Bokpoort CSP – Parabolic Trough Technology with Storage



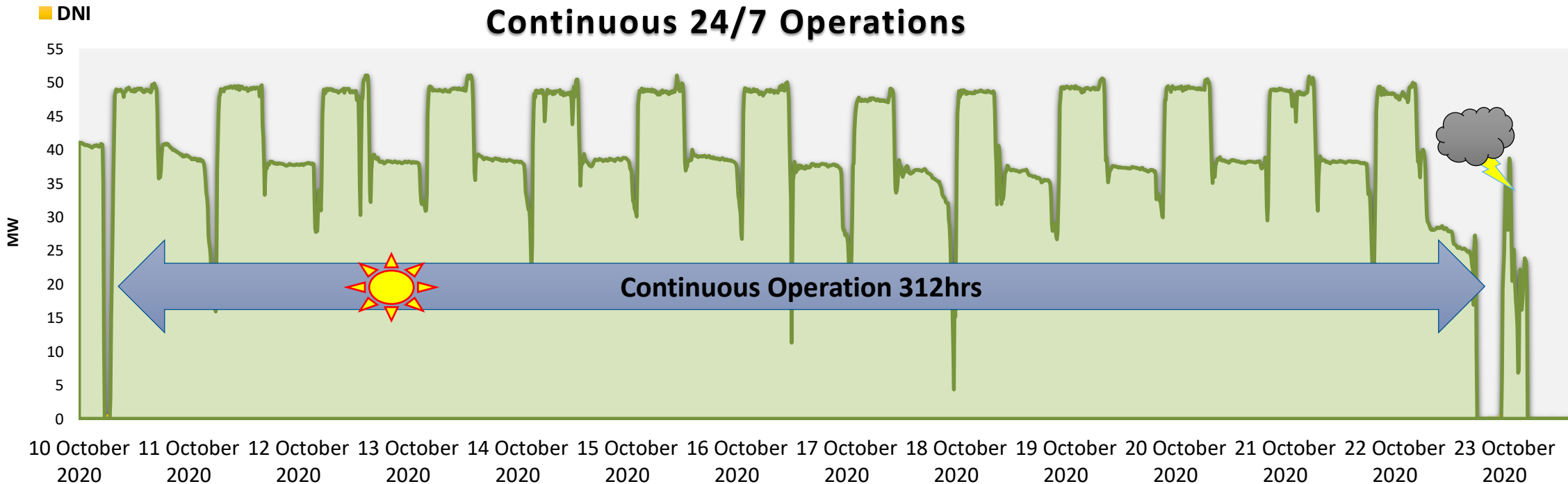
Note: Not to Scale for Illustration Purposes only

**New Record Period: 10 October 2020 to 23 October 2020**  
**Record: 312 hours of Operation Continuously (Load Following)**  
**Load Factor: 83% (based on Energy Sent Out)**

Previous Period: 18 March 2016 to 25 March 2016  
**Record: 161 hours of Operation Continuously (Load Following)**  
**Load Factor: 76% (based on Energy Sent Out)**

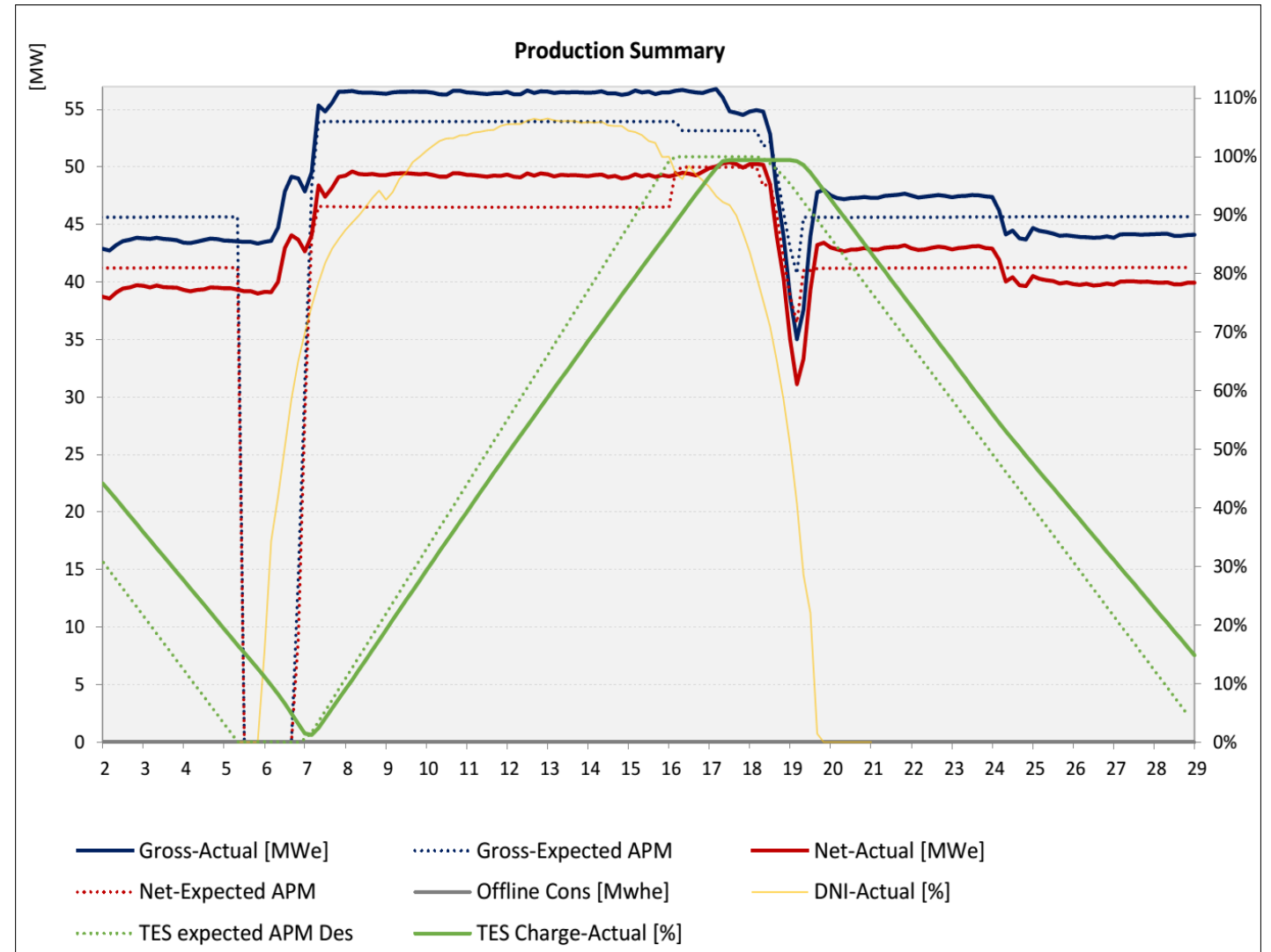
## New African Record:

### Continuous 24/7 Operations



# Typical Clear Sky Summer Day Production profile

Main Production Data (5-5h loc)	Day
<b>DNI [kWh/m2]</b>	
Actual	12.2
TMY - expected	9.3
ratio [%]	131%
Clear Sky	12.2
ratio [%]	100%
<b>Total Net Gen. [MWh]</b>	
Actual (corrected by TES energy dif)	<b>1 055</b>
<b>Design Expectation ACWA Mod</b>	
corrected by TES energy dif	1 002
ratio TES corrected [%]	<b>105.3%</b>
<b>Budget Expectation *)</b>	848
ratio [%]	<b>127.0%</b>
*) Budget Exp based on APM	
Actual Net (0:00 to 0:00, Local)	1 077
Actual Gross (0:00 to 0:00, Local)	1 208
<b>Gross Gen. [MWh]</b>	<b>1 212</b>

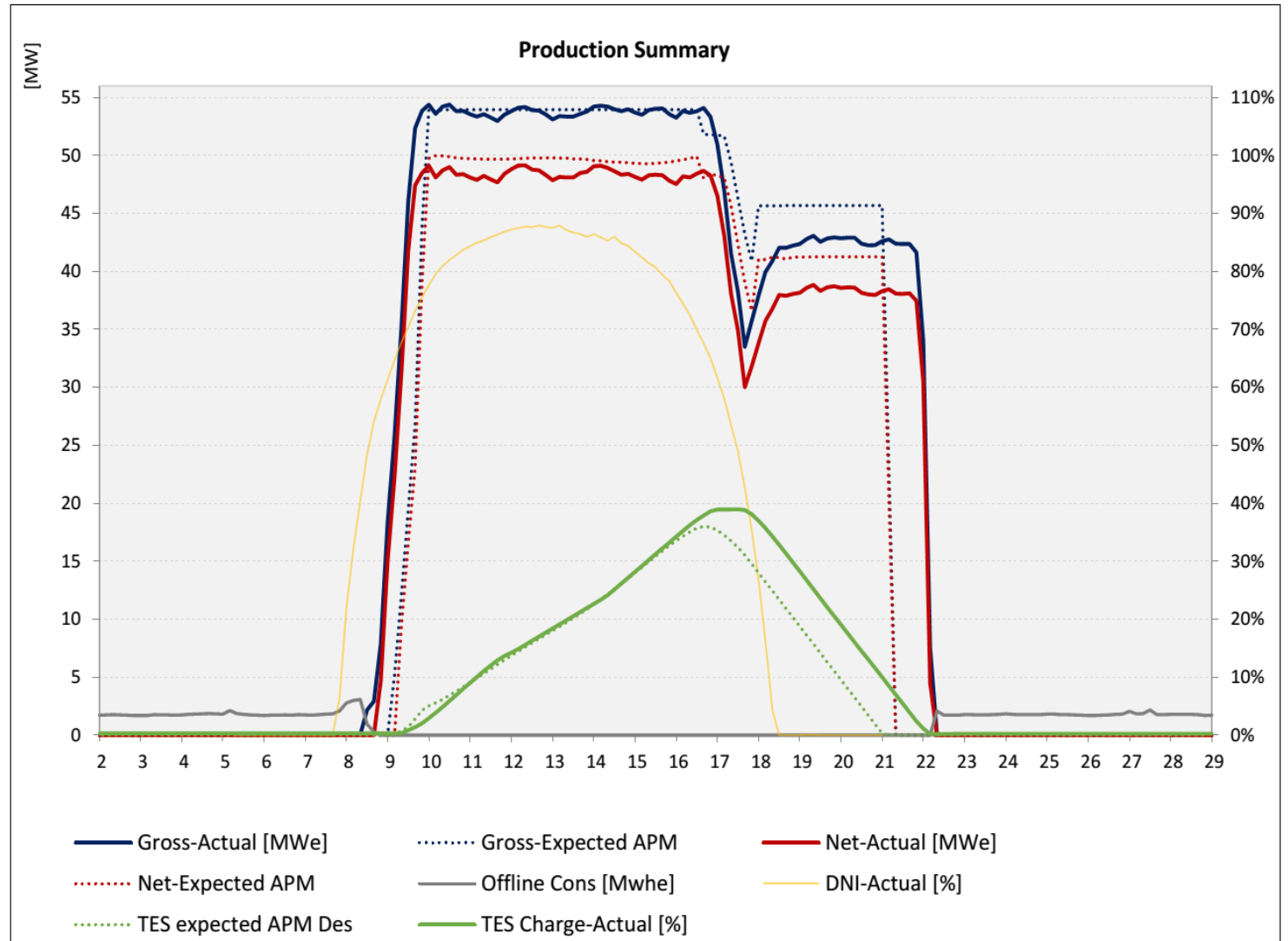


Plant offers full flexibility in Summer hence the production strategy is based on minimizing plant start/stops to reduce EOH on turbine, plant efficiency focus is not necessary given sufficient energy yield from solar field – can be optimized to suit specific grid requirements and PPA optimizations



# Typical Winter Day Production profile

Main Production Data (5-5h loc)	Day
<b>DNI [kWh/m2]</b>	
Actual	7.5
TMY - expected	7.3
ratio [%]	102%
Clear Sky	8.9
ratio [%]	84%
<b>Total Net Gen. [MWh]</b>	
Actual (corrected by TES energy dif)	<b>569</b>
<b>Design Expectation ACWA Mod</b>	
corrected by TES energy dif	539
ratio TES corrected [%]	<b>105.6%</b>
<b>Budget Expectation *)</b>	594
ratio [%]	<b>96.0%</b>
*) Budget Exp based on APM	
Actual Net (0:00 to 0:00, Local)	570
Actual Gross (0:00 to 0:00, Local)	634
<b>Gross Gen. [MWh]</b>	<b>634</b>

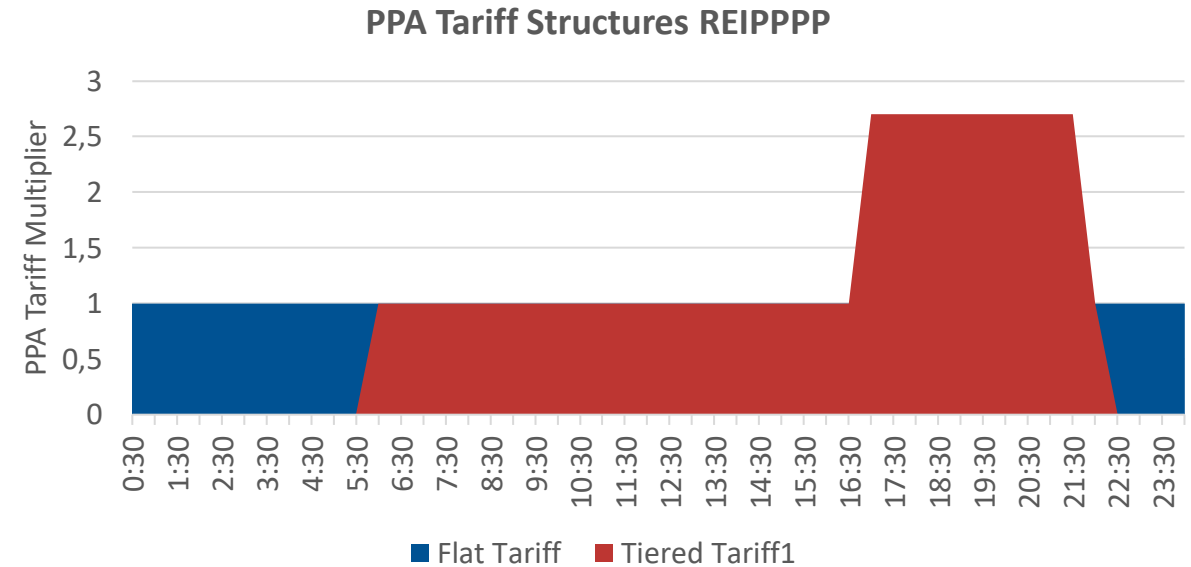


In winter, a high efficiency strategy is adopted to ensure that maximum energy is yielded from the solar field. The plant is still fully capable of delivering between the key demand hours of 8am – 10 pm.

## Production Load factors Seasonal Performance

Season	Spring/Summer Season: Oct - Mar	Autumn/Winter Season: Apr - Sep
Load Factor (Energy Basis)	60% - 75%	45% - 60%

Typical Month	LF (Based on Actual : Max Energy)		
	Off Peak (22pm-6am)	Standard (6am - 3pm)	Peak (4pm-10pm)
Summer	52%	68%	76%
Spring	48%	66%	76%
Winter	12%	54%	61%
Autumn	26%	52%	67%



- Clearly **Bokpoort is delivering in accordance to SA's demand profile** needs and consistently towards the Peak demand periods in aid of the grid
- The Storage capacity can also be **optimized to guarantee highest load factors over the Peak** (this is largely dictated by the Grid needs and agreed PPA)

# CSP: Great potential for Localisation

- Bokpoort total local value add (in ZAR) - Approx R1.6 Billion
- Large portion of Local value add in Civil works: Concrete, Reinforcing steel, structure steel etc.
- Achieved around 40% Local spend
- Redstone expected local value add expected around 43% but has potential to be more

**If CSP Market is + 200MW/year**

**CSP Market Size means Economies of Scale**

## SA Manufacturing Infrastructure

- Civil / Cooling Tower
- Valves & Actuators
- Pressure Vessels
- Collector Structure
- Storage Tanks
- Piping
- Cabling
- Other

35-40%

## CSP specific

- Parabolic Mirrors / Heliostats
- Collector Structure
- Precision Tracking Systems
- Receiver Pipes / System
- Heat Transfer Fluid
- W/S Cycle
- Engineering

60-65%



## Bokpoort CSP – African Community Project of the Year 2015

Excelled in all aspects targeted for this category with Key contributions:

- Impact on skills development & focus on community upliftment.
- The contribution to the community from the onset of construction was recognized as setting a new standard for IPP's



**Support to Local Communities:** The Project has targeted key community well being initiatives focusing on ensuring the needs of the community are taken into consideration



**Solar Lighting Project – 300 homes**

**Water Reticulation Project – drinking water to 77 homes)**

**Primary – Teachers and Bicycles and Road Safety**

## Bokpoort CSP – SANEA Energy Project of the Year 2016

According to SANEA/SANEDI the ACWA Power SolAfrica Bokpoort CSP was awarded for:

- its innovative design which enables the plant to operate almost as a base load-facility and
- secondly, the successful manner in which the socio-economic commitments of the project are being met



## Bokpoort CSP – Large Scale Renewable Energy Project of the Year 2016/2017

**Local Employment:** The Project has successfully managed to increase the number of employees from the local Municipality (averaged around 60%).

**Skills Development:** The Project has also successfully started the focus on development of youth from Crèches through Schooling to Further Studies.



**Palms Training Centre (180 trained – 50% female)**



**Welding apprenticeship**



**Educational material for 7 Crèches**

.... We need to have a long-term view on **CSP with Adequate Storage** given capabilities proven by Bokpoort and other CSP's in operation:

1. Especially for countries like SA that is blessed with an **enviable Solar Resource**
2. CSP is a utility scale **storable renewable energy option** that can provide **Base Load/Load Following Capability**
3. Flexibility in dispatch **meeting SA demand profile** - with **energy, capacity and ancillary services** value add services.
4. Short lead times for **quick deployment possibility**
5. Maturing technology world-wide with **positive cost reduction trends through greater allocation - economies of scale and accelerated learning curves**
6. Serves as **effective hedge against fuel commodity prices** while securing cost benefits from a certain CSP learning curve.
7. Easily partner with other technologies for **Hybrid solutions** leading to greater cost benefit and higher availabilities
8. For developing countries like **SA, our manufacturing infrastructure** complements CSP
9. Potential to increase **local content** whilst growing **local competence and knowledge and increase employment opportunities in the renewable sector**

Bokpoort's consistent and record-breaking performances is making a strong case for CSP's inclusion in any energy mix



Je vous remercie Danke obrigado  
 mihi koe рақмет сізге  
 Teşekkürler شكرا  
 謝謝 Asante மகிமை  
 धन्यवाद Thank you  
 Terima kasih Ngiyabonga Tak

**Saudi Arabia**

Building 1,  
 Ground Floor,  
 Business Gate  
 Office Complex,  
 Airport Road  
 P.O. Box 22616  
 Riyadh 11416  
 T: +966 1 2835555  
 F: +966 1 2835500

**Saudi Arabia**

King Abdulaziz  
 Branch Rd,  
 Ash Shati,  
 Jeddah,  
 23613  
 T: +966 12 618 9000

**UAE**

The One Tower, 41<sup>st</sup>  
 Floor, Barsha Heights,  
 Sheikh Zayed Road,  
 P.O. Box 30582  
 Dubai  
 T: +971 4 5090555  
 F: +971 4 3859625

**China**

2101 Tower B,  
 Ping An International  
 Financial Center,  
 No. 1-3,  
 Xin Yuan Nan Lu,  
 Chao Yang District,  
 P.O. Box 10027,  
 Beijing  
 T: +86 10 5979 2330  
 F: +86 10 8438 1078

**Egypt**

Plot 176,  
 Second Sector,  
 City Center Giza  
 Systems Building,  
 New Cairo,  
 Cairo  
 T: +202 23 225 500

**Jordan**

Amman-Khelda,  
 Al Khalideen Suburb,  
 Al Hakam Bin  
 Amro Street -  
 Bldg No. 22  
 P.O. Box: 2564  
 Amman 11953  
 T: +962 6 534 0008  
 F: +962 6 535 7210

**Morocco**

65 Avenue  
 Mehdi Ben Barka,  
 Souissi,  
 Rabat 10100  
 T: +212537714164  
 F: +212537714165

**Oman**

South Lobby Roof  
 Top,  
 Grand Mall,  
 P.O.Box: 163,  
 PC: 136,  
 Al Khwair,  
 Muscat  
 T: +968 22065 752  
 F: +968 22063 753

**South Africa**

7th Floor,  
 90 Grayston Drive,  
 Sandton,  
 Johannesburg,  
 2196  
 T: +27 117224100

**Spain**

Empresarios  
 Agrupados  
 Calle Magallanes 3,  
 28015  
 Madrid

**Turkey**

Barbaros Plaza,  
 Emirhan Caddesi,  
 No.113 Kat.19,  
 Dikilitas,  
 Besiktas  
 Istanbul  
 T: +90 212 259 3396  
 F: +90 212 259 3397

**Vietnam**

11th floor,  
 BIDV Tower 194,  
 Tran Quang Khai St.,  
 Hoan Kiem District,  
 Hanoi  
 T: +84 43 935 2966  
 F: +84 43 935 2969