Bokpoort CSP and the Future of Solar in South Africa

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CEO Redstone CSP (designate)

Bokpoort CSP – Project Overview

Overview of Company and Project

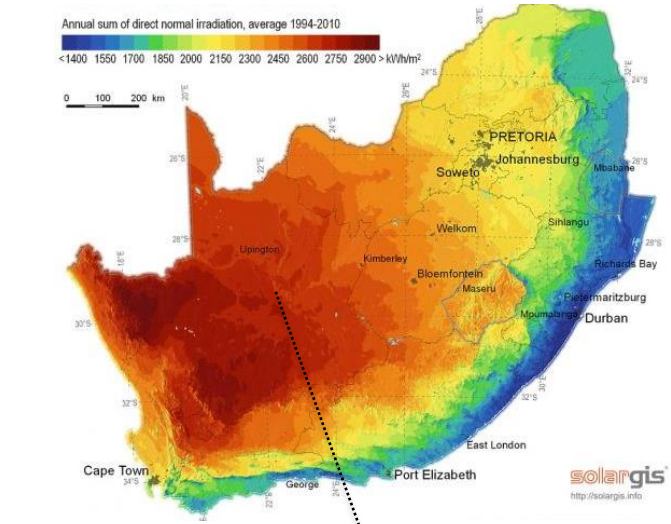
- Founded: Ring-fenced project company effective June 2013
  - Operational partner ACWA Power International: Saudi Arabian based with generation portfolio of 21GW and 2.4 million m^3/day of desalinated water
- Total staff: ±1300 during Construction peak and 62 during Operations
- The site: Bokpoort Farm, 125km south-east of Upington (300 hectare Greenfield)
- Technology used: Concentrated solar thermal trough, with wet cooling and 1300MWht molten salt thermal energy storage (9.3hrs at 50MW)
- 20 year PPA with Eskom, through the Garona Substation located next to the site

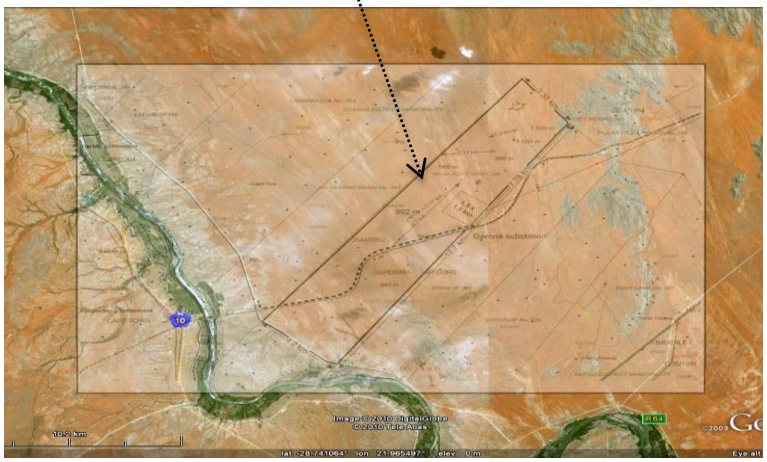
EPC - Project status

- Procurement and Suppliers: EPC consortium (Acciona, Sener, TSK, Crowie)
- 1st Synchronisation – 13th November 2015
- Early Operating Date – 6th February 2016
- COD – 19th March 2016

Site Location

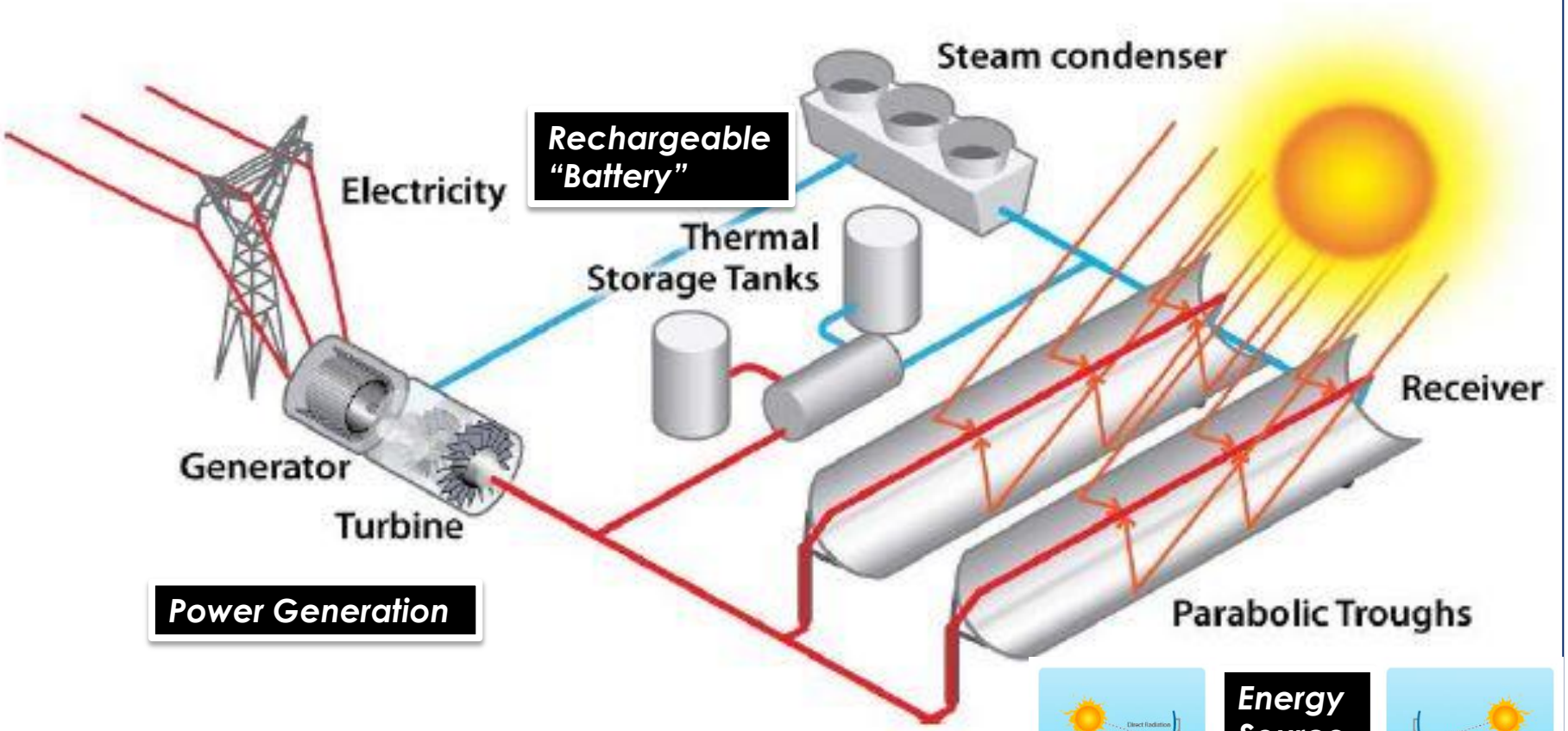
Site Coordinates: Latt. 28°44'26.96"S Long. 21°59'34.88"E





Bokpoort CSP – Plant Layout

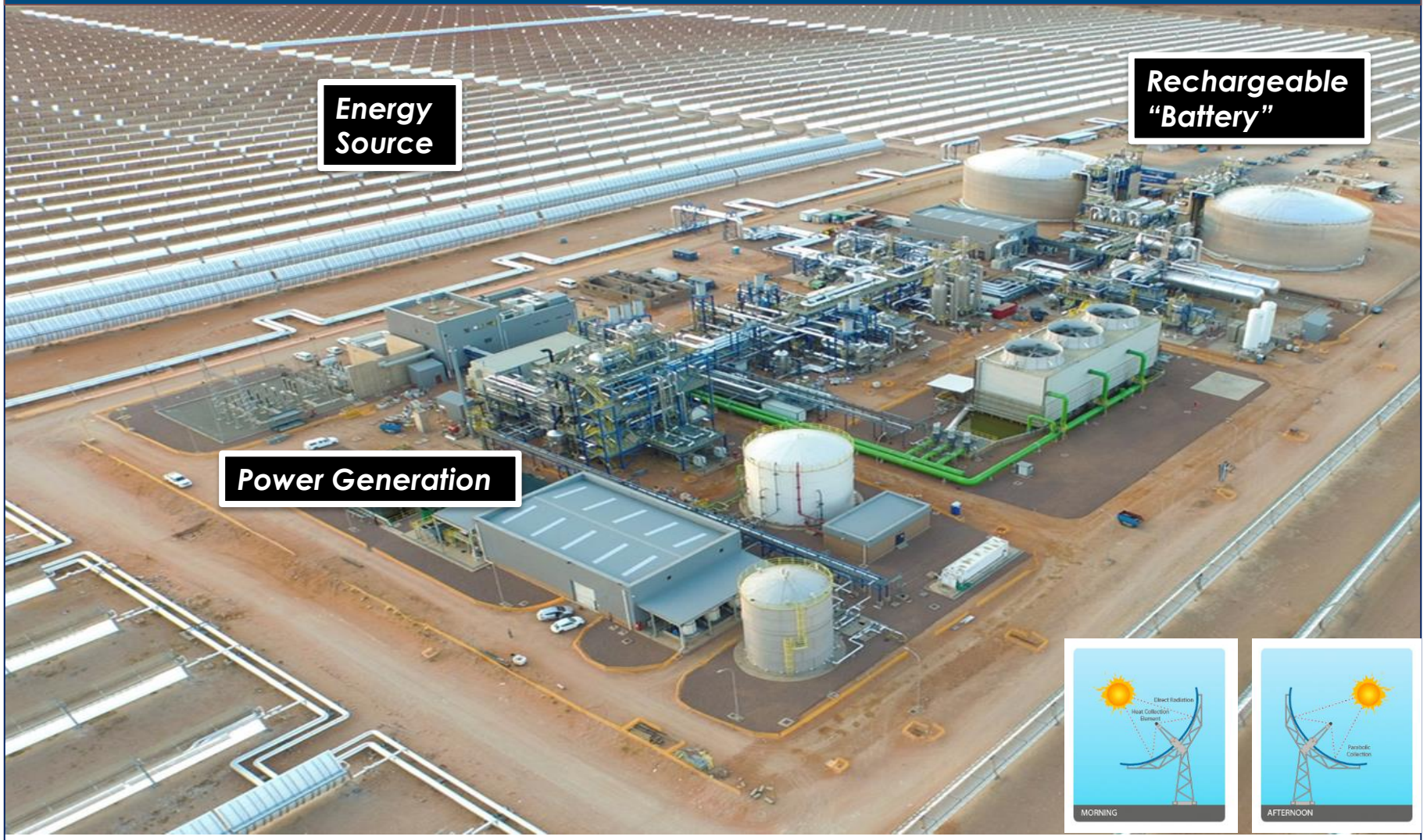
CSP Parabolic Trough Technology with Storage



- *50 MW Parabolic Trough CSP Plant: Wet Cooled*
- ***Thermal Energy Storage = 9.3 hours at 50 MW (Largest in Africa)***

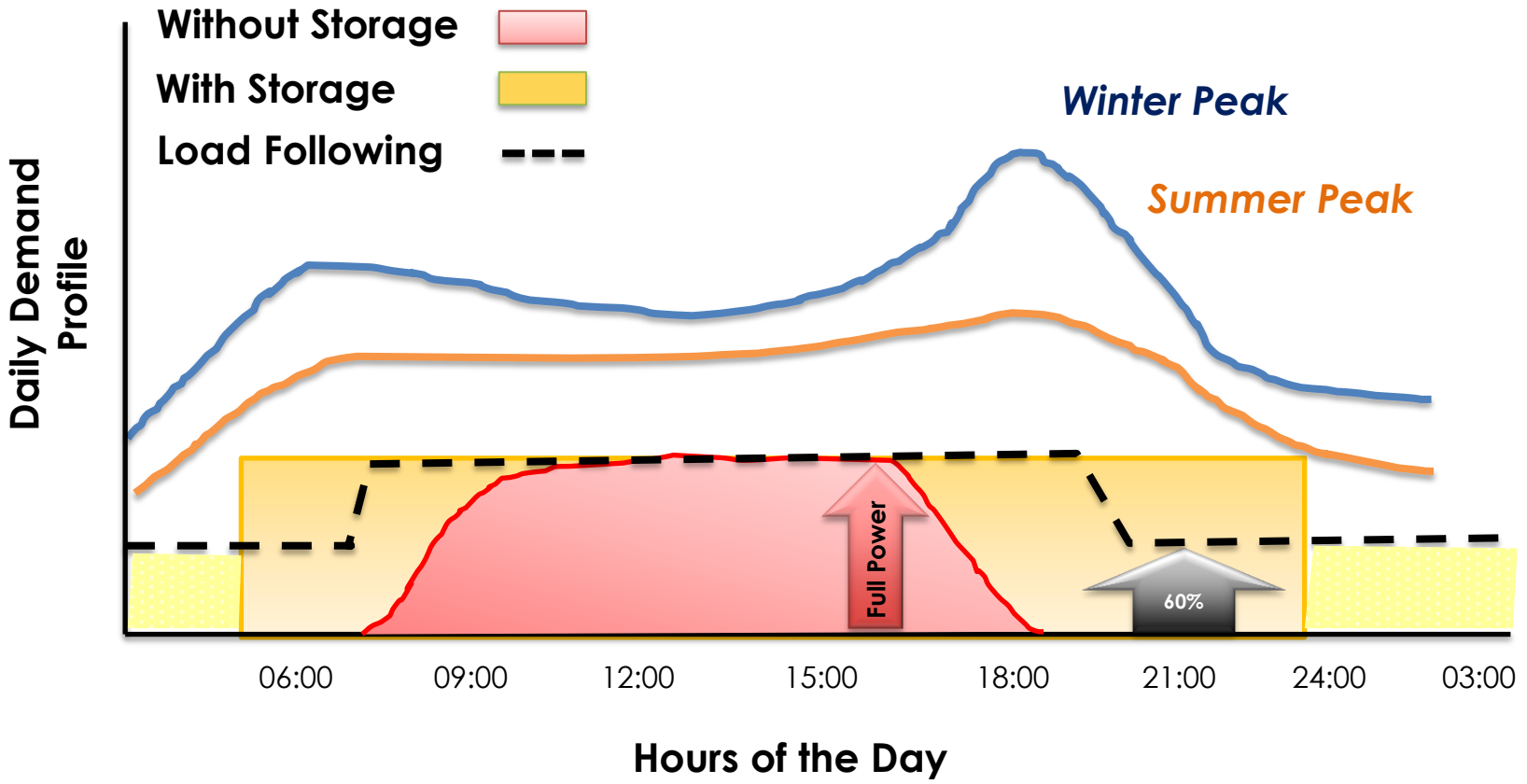
Bokpoort CSP – Plant Layout

CSP Parabolic Trough Technology with Storage



Benefit of CSP with Adequate Storage

CSP + Storage = Base maybe not yet but Load Following (depending on size)



Note: Not to Scale for Illustration Purposes only

Bokpoort CSP Delivers Record Performance

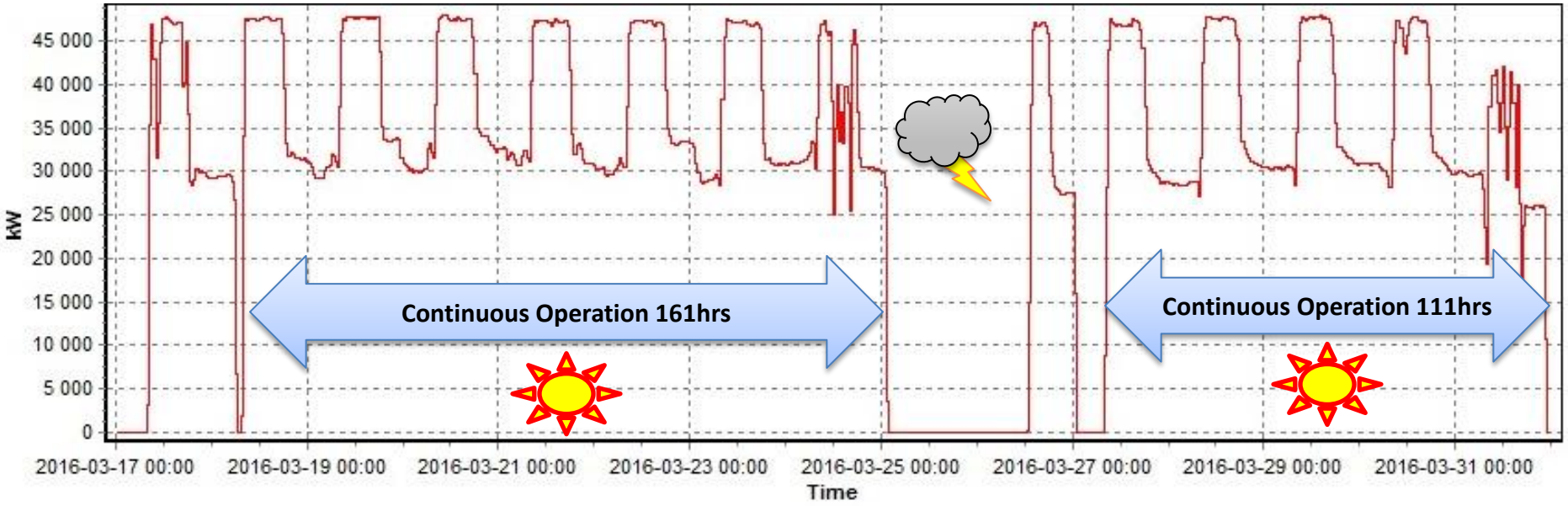
African Record*:

Busting Myths about Renewables

***Possibly World Record performance in 1st month of commercial production - TBC**

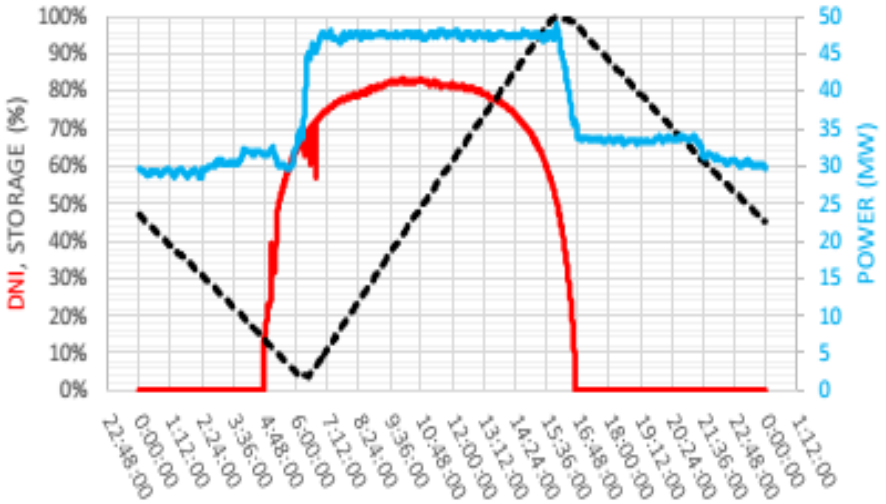
Period: 18 March 2016 7:00am to 25 March 2016 1:00am
Record: **161 hours of Operation Continuously (Base Load 100%)**
Load Factor: **76% (based on Energy Sent Out)**

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



Bokpoort CSP - Analyzing the Performance

FACILITY OPERATION 03/19/2016

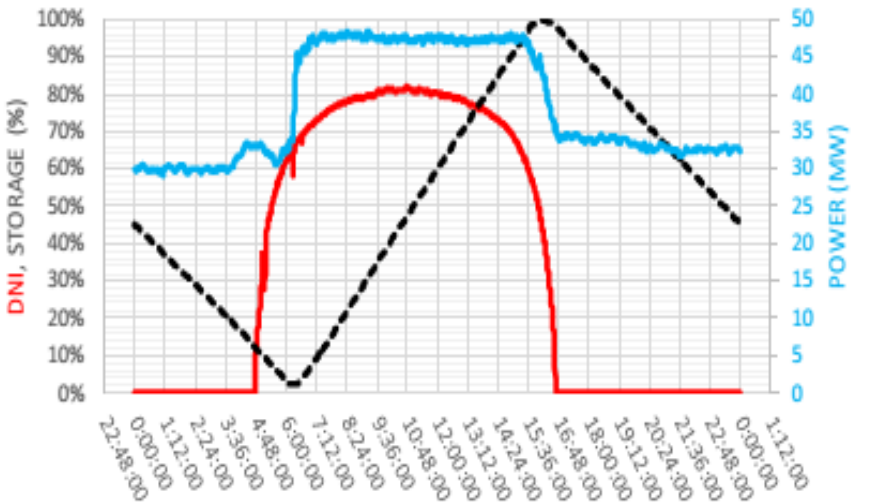


FIELD CLEANLINESS	89.5%

FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
6288	387.1	288.1	644.7	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
6058	388.6	288.7	624.9	MWht
MODEL FINAL STORAGE, SE2			420.1	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	909.78	MWh		
CPf (PLANTA)	912.70	MWh		

Daily LF = 76%
PM Var = +0.3%

FACILITY OPERATION 03/20/2016



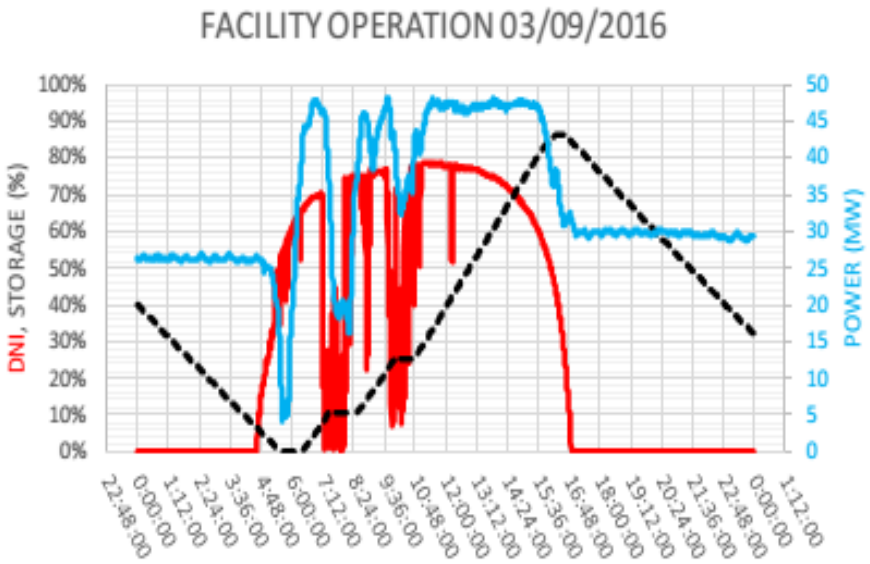
FIELD CLEANLINESS	90.4%

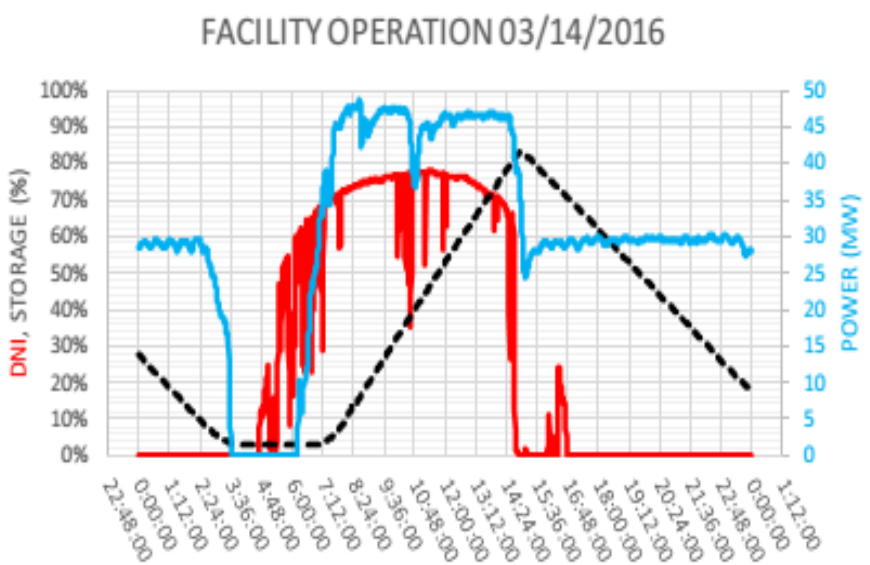
FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
6058	388.6	288.7	624.9	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
6090	388.3	286.7	639.6	MWht
MODEL FINAL STORAGE, SE2			418.7	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	915.44	MWh		
CPf (PLANTA)	929.53	MWh		

Daily LF = 78%
PM Var = +1.5%

Good Stable DNI means Good Production and Model Accuracy

Bokpoort CSP - Analyzing the Performance





FIELD CLEANLINESS	87.6%

FIELD CLEANLINESS	87.9%

FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
5443	376.4	290.3	480.7	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
4480	382.2	289.6	416.1	MWht
MODEL FINAL STORAGE, SE2			434.0	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	938.26	MWh		
CPf (PLANTA)	791.07	MWh		

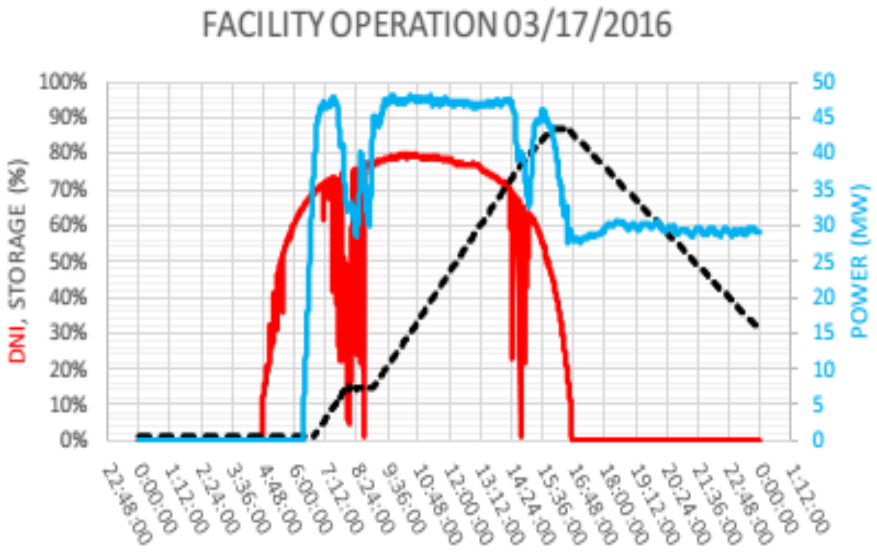
Daily LF = 66%
PM Var = -15.7%

FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
3942	384.4	290.6	364.1	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
2760	383.0	289.6	238.7	MWht
MODEL FINAL STORAGE, SE2			52.2	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	785.75	MWh		
CPf (PLANTA)	688.59	MWh		

Daily LF = 57%
PM Var = -12.4%

Erratic DNI means Lower Production and higher Model Error

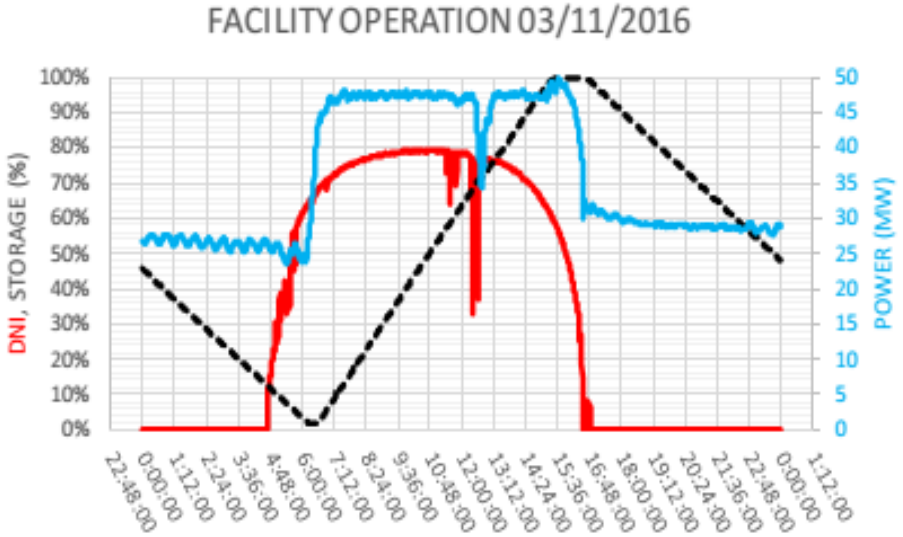
Bokpoort CSP - Analyzing the Performance



FIELD CLEANLINESS	87.8%

FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
727	374.8	289.0	22.9	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
4331	381.4	289.7	396.3	MWht
MODEL FINAL STORAGE, SE2			422.1	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	883.10	MWh		
CPf (PLANTA)	795.11	MWh		

Daily LF = 66%
PM Var = -10.0%



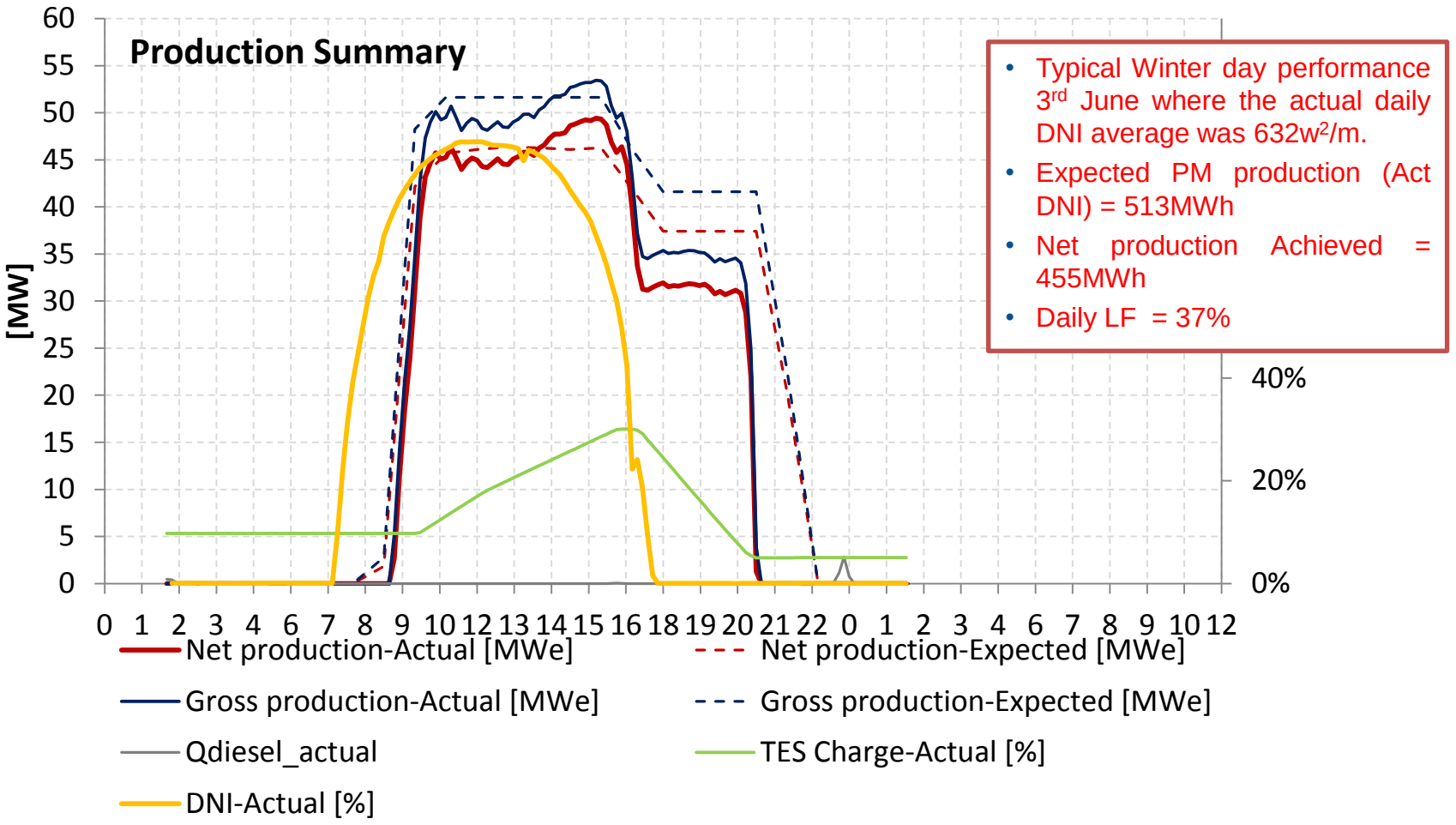
FIELD CLEANLINESS	88.0%

FACILITY INITIAL STORAGE				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE1 (FACILITY)	
6130	377.8	289.0	565.0	MWht
FACILITY FINAL STORAGE DATA				
LEVEL (mm)	T HOT (ºC)	T COLD (ºC)	SE2 (FACILITY)	
6422	384.1	288.5	637.4	MWht
MODEL FINAL STORAGE, SE2			427.1	MWht
CONTINUOS PERFORMANCE SUMMARY				
CPf (MODEL)	935.17	MWh		
CPf (PLANTA)	886.02	MWh		

Daily LF = 74%
PM Var = -5.2%

Lower Production could mean Poor Storage Management

Bokpoort CSP - Analyzing the Performance (typical Winter day)



- Typical Winter day performance 3rd June where the actual daily DNI average was 632w²/m.
- Expected PM production (Act DNI) = 513MWh
- Net production Achieved = 455MWh
- Daily LF = 37%

Current findings (within first 8 months of production) suggests that the TMY used for Model appears to be changing – higher in Summer months but Lower in Winter
This needs further verification over a longer production period

Bokpoort CSP - Operating Philosophy

- Long Term Operation philosophy is to aim towards Continuous Operation – This has been proven to be possible in March 2016
- This is likely possible over the period Sep-Mar (6months) however dropping DNI number over winter months will require stop-start regime.
- During current long term performance test period, the regime is one of maximum energy at highest Efficiency, this is aligned to proposed winter operating regime
- For long term plant health and maintenance optimization, starting/stopping impacts Turbine EOH and thus further optimization in this regard is required, in particular, over summer months
- Optimisation for life cycle is under review to establish maximum value for shareholders over PPA term
- Thus current operating regime planned:
    - Months Sept-Mar – Continuous Operations strategy (8 hrs max Power, 16 hrs 50% Power TES) – **Load Follower**
    - Months Mar-Sep – Maximum Turbine Efficiency (14-15 hrs Max Power incl during TES) – **Two shifter**

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Future of CSP in South Africa

Assumptions Regarding CSP in IRP 2010

…. Review of IRP 2010 updated version (Nov 2013)

- New CSP modelled to only start around 2030 (based on learning rate and Scenarios)
- "Big Gas" Scenario has no further CSP consideration
- All Scenarios have dependency on OCGT's with even new plant planned as early as 2022
- CSP Plant with storage can contribute significantly but allocation now will accelerate Learning Rate for LCOE to reduce rapidly – already better then OCGT
- CSP Plant are modelled as Peaking options only
- Assumption regarding lead time and Load Factor related to CSP with Storage need review based on Bokpoort Experience

	OCGT	CCGT	Wind	CSP, Parabolic Trough			CSP, Central Receiver			PV
				3hrs	6hrs	9hrs	3hrs	6hrs	9hrs	Fx tilt
Rated Capacity (MW)	115	711	100	125	125	125	125	125	125	10
Life of Programme	30	30	20	30	30	30	30	30	30	25
Typical Load Factor	**10%**	**50%**	30%	31%	37%	**43%**	32%	40%	47%	19%
Lead Time	**2**	**3**	4	4	4	**4**	4	4	4	2

CSP trough with 9hrs should be closer to 60% LF and 3 years lead time

CSP Technology Maturity

The Technology Landscape

CSP Parabolic Trough

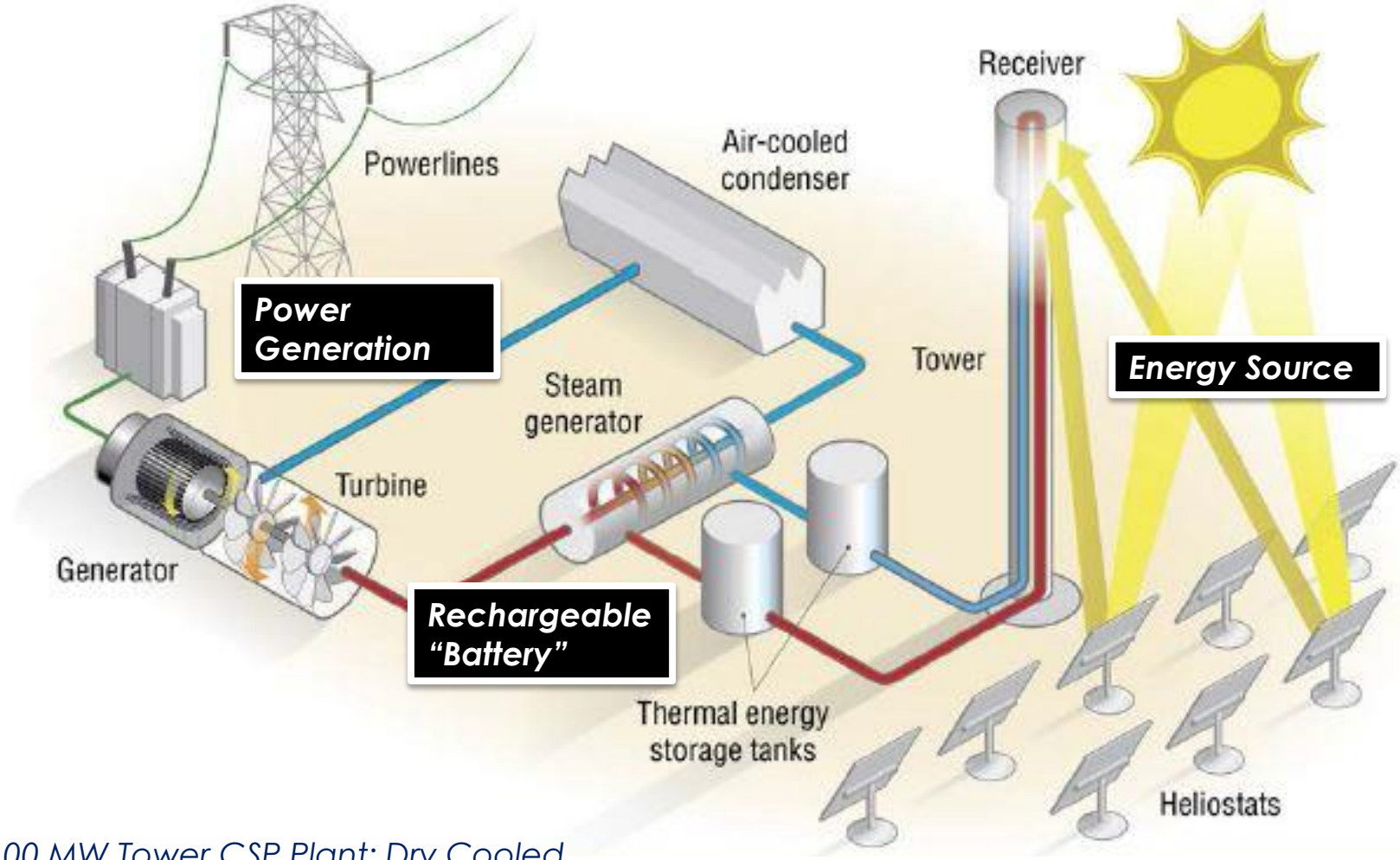
- Proven development and operational track record
- Employs single axis trackers
- “off-the-shelve” designs and systems available
- Higher energy losses/aux requirements in comparison to tower due to extensive solar field piping
- Local content opportunities high
- Lower Uncertainty – mature with 30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

CSP Central Tower

- Can reach much higher temperatures leading to greater efficiency.
- One less energy transfer step as it produces steam directly from Salt (no HTF) maximizing plant efficiency.
- The flat mirrors used in heliostats are cheaper than parabolic trough mirrors
- Can be built over more rough terrain as each heliostat’s position is independent to its neighbouring heliostats
- 30 month delivery (technology maturing but more efficient – cost effective)

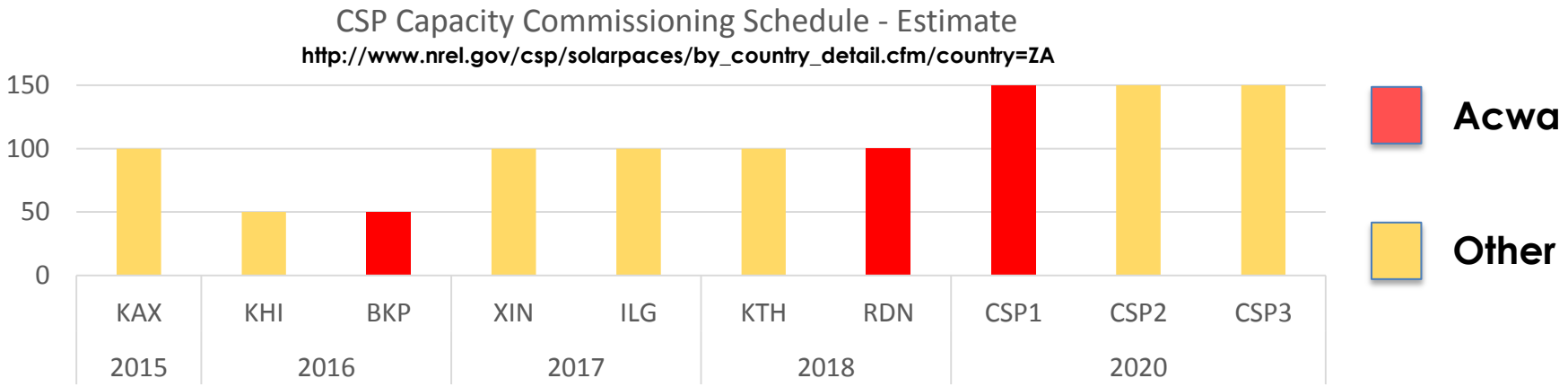
Redstone Tower CSP – Plant Layout

CSP Tower Technology with Storage



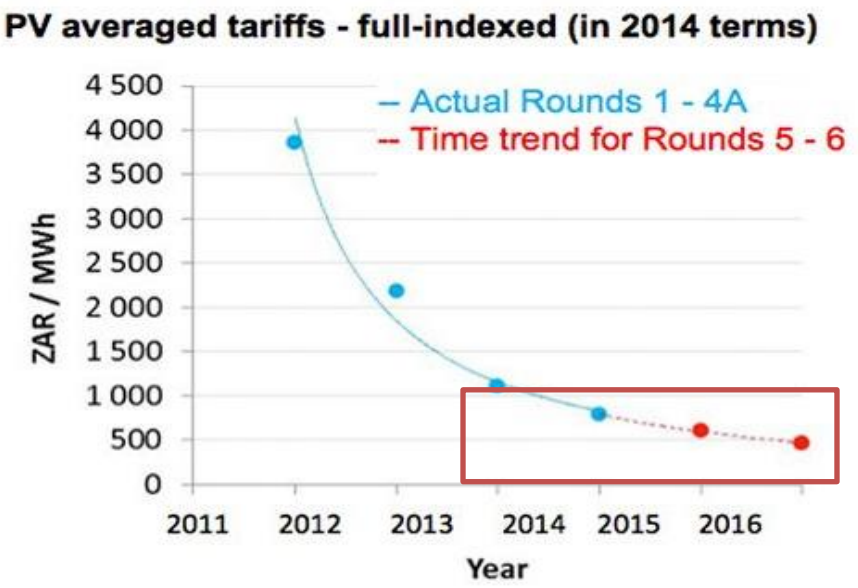
- *100 MW Tower CSP Plant: Dry Cooled*
- ***Thermal Energy Storage = 12 hours at 100 MW (Will be largest in Africa)***

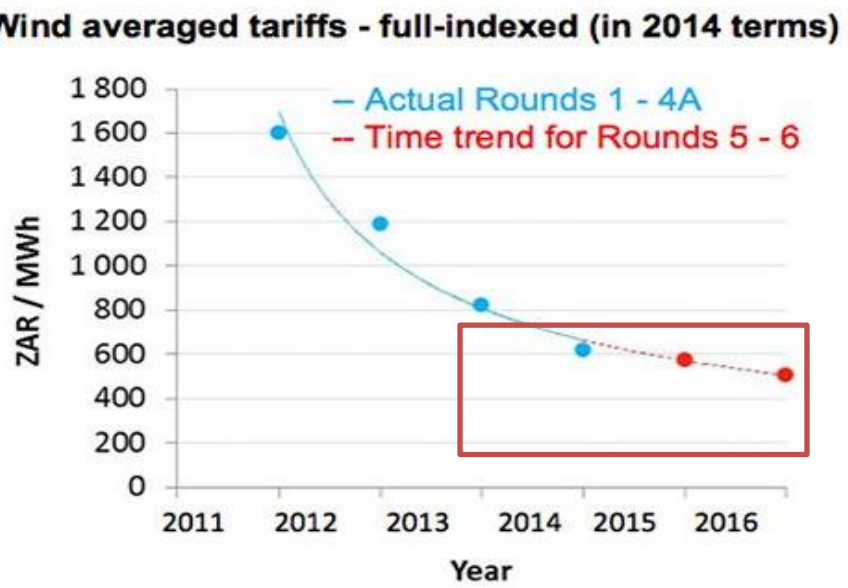
South African CSPs – Capacity and Capability

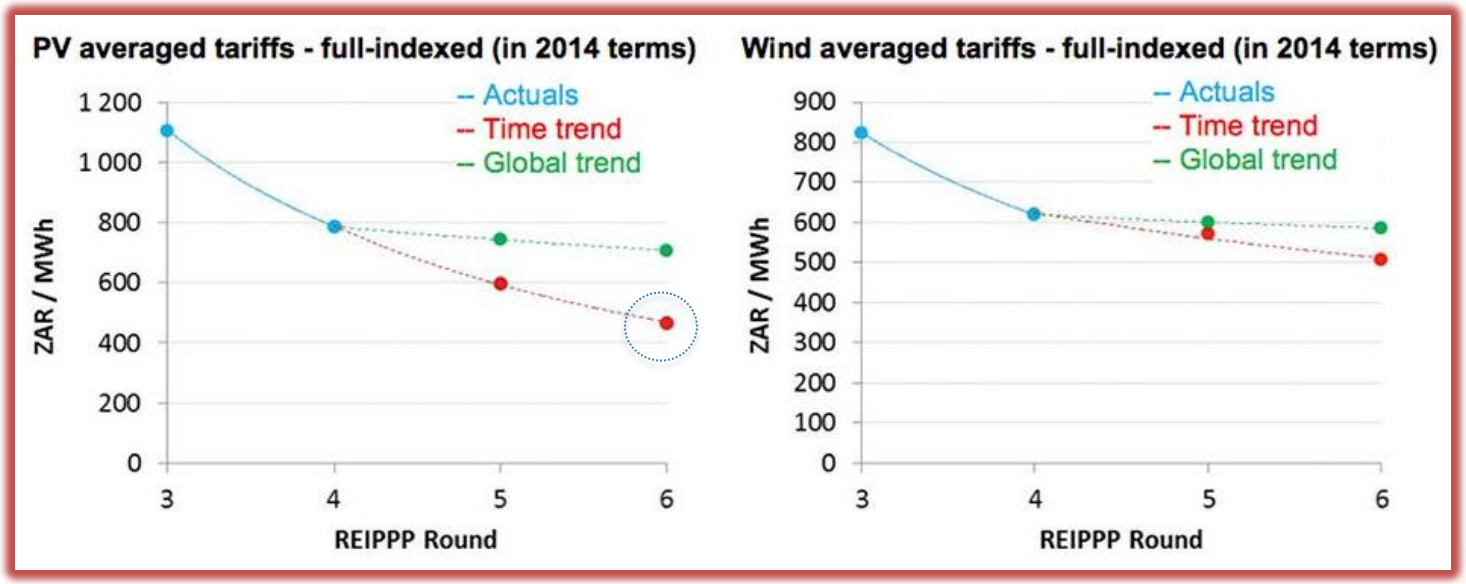


Project Name:	KaXu Solar One	Khi Solar One	**Bokpoort**	Xina Solar One	Ilanga I	Kathu Solar Park	**Redstone**	**CSP1**
Country:	South Africa	South Africa	**South Africa**	South Africa	South Africa	South Africa	**South Africa**	**South Africa**
Location:	Poffader	Upington	**Groblershoop**	Pofadder	Upington	Kathu	**Postmasburg**	**Upington**
Technology:	Parabolic trough	Power tower	**Parabolic trough**	Parabolic trough	Parabolic trough	Parabolic trough	**Power tower**	**Power tower**
Turbine Net Capacity:	100	50	**50**	100	100	100	**100**	**150**
Status:	Operational	Operational	**Operational**	Under construction	Under construction	Under construction	**Under development**	**Preferred Bidder Stage**
Start Year:	2015	2016	**2016**	2017	2017	2018	**2018**	**2019**
Thermal Storage	2-tank indirect	HP Steam Vessels	**2-tank indirect**	2-tank indirect	2-tank indirect	2-tank indirect	**2-tank direct**	**2-tank direct**
Storage Capacity:	2.5 hours	2.5 hours	**9.3 hours**	5 hours	4.5 hours	4.5 hours	**12 hours**	**7.5 hours**
Thermal Storage Description:	Molten salts	Saturated steam	**Molten salts**	Molten salt	Molten salt	Molten salt	**Molten salt**	**Molten salt**
Potential Grid Contribution	Peaking	Peaking	**Base/Load Following**	Peaking /Load Following	Peaking /Load Following	Peaking /Load Following	**Base Load**	**Base/Load Following**

Evolution of Tariffs in South Africa – Solar and Wind

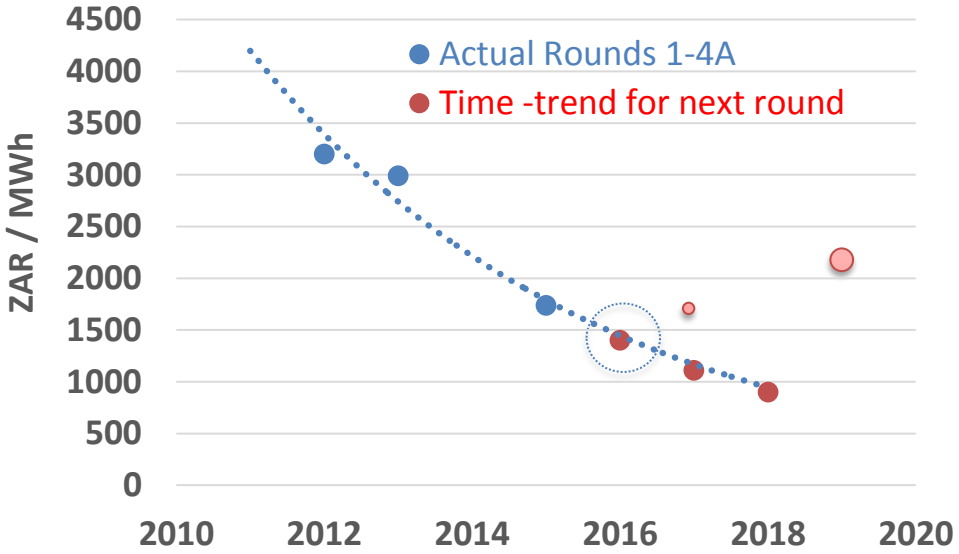




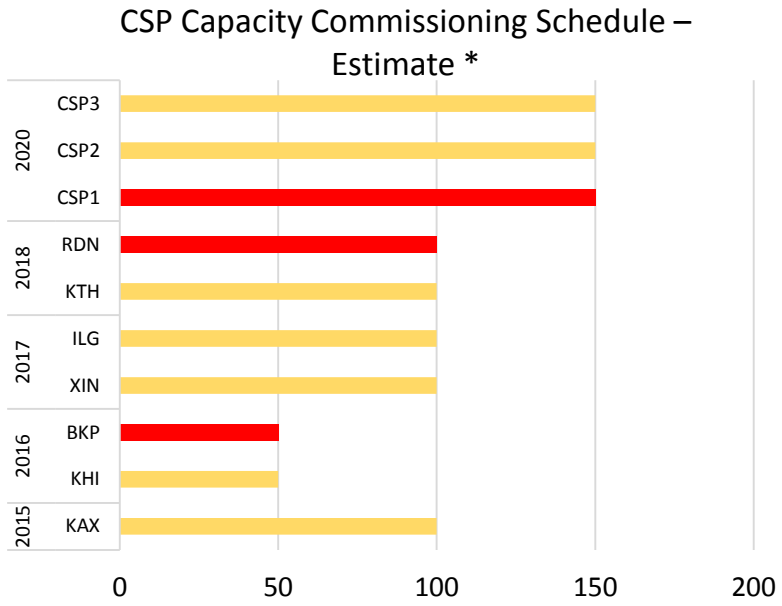


http://www.energyramblings.com/tag/reippp/

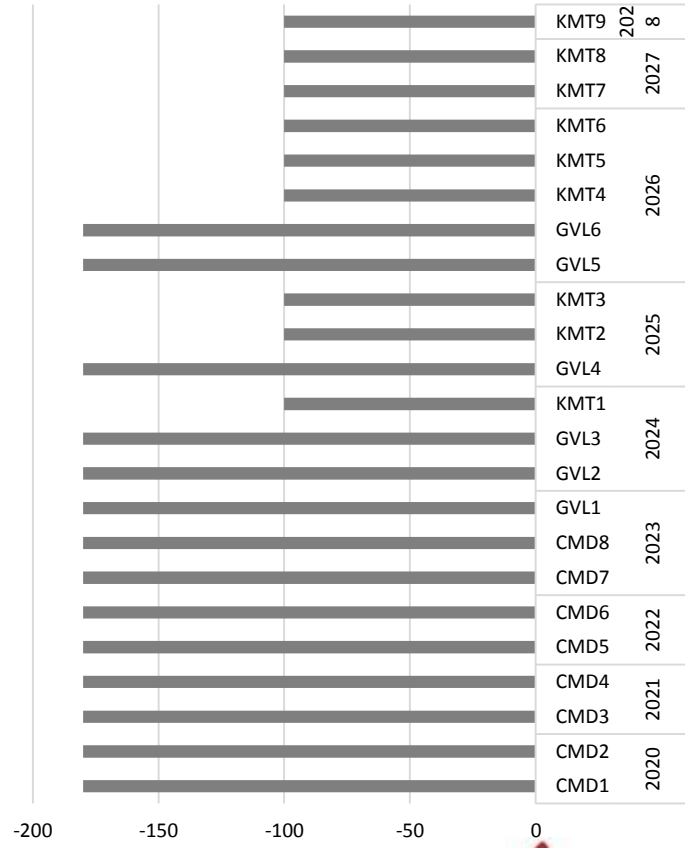
Prospects for CSP with greater allocation



Food for Thought: Why not Swop **Old Coal for New CSP (+ Adequate Storage)**



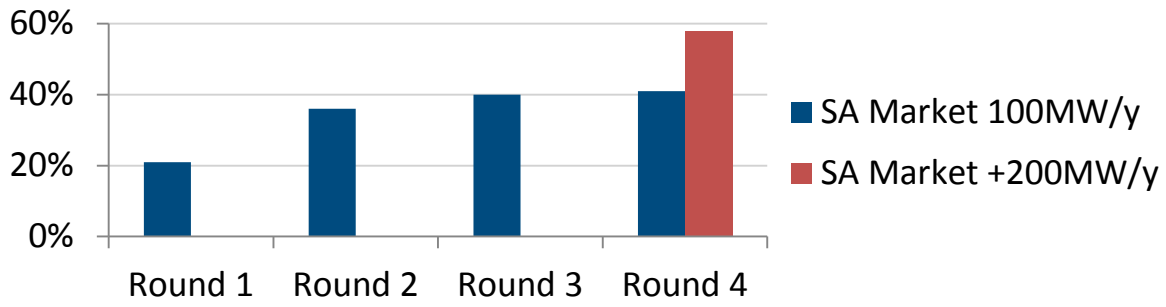
**. Old Coal Decommissioning Schedule - Estimate



** http://www.eskom.co.za/IR2015/Pages/Default.aspx

* http://www.nrel.gov/csp/solarpaces/by_country_detail.cfm/country=ZA

Possibilities that CSPs bring for Increased Local Content



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%

If CSP Market is + 200MW/year

CSP Market Size means Economies of Scale

- Repeatability (e.g. collector structure)

Bokpoort Local Content: Competence & Knowledge

Local Spend Analysis

- 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.
- **Main SA manufacturers**
  - Turnmill (Gauteng) – HTF Expansion/Overflow Vessels
  - MEAPSA (Upington) – Salt Tanks (Thermal Storage)
  - Made SA (Gauteng) – Torque Tubes, Pylons for Solar Field
  - TRP SA (Cape Town) - Torque Tubes, Pylons for Solar Field
    - Approximately 8160 tonnes of steel for all Torque Tubes
    - Approximately 1200 tonnes of steel for all Pylons
- **Main SA Pre-Assemblers and On-site Assemblers**
  - Proimtu (Upington) – HTF Solar field piping
  - CAMETO (Upington) – HCE Stainless steal piping
  - Condusav (Cape Town) – HP Power Block Piping
  - Batz (On Site) – Solar Collector Elements
- **Total Estimated training performed 100000 hours,**
  - Safety Training – 20%
  - Small Tools Use – 20%
  - Job Training & Skills Specific Training – 60%
    - On Scaffold Use, Foundation Erection, Welding Setup, Electrical Cable Pulling & Termination,

SA Manufacturing and Pre-Assembly


Steam Turbine Foundations


HTF Vessel Foundations


HTF Vessels


HTF Vessels


SCE Torque Tubes


SCE Pre-Assembly


Salt Tanks


SCE Pylon Fabrication

HTF - Heat Transfer Fluid, HCE – Heat Collector Element, SCE – Solar Collector Element

Key Socio-Economic Considerations

Local Employment: The Bokpoort Project has successfully managed to increase the number of employees from the local Municipality (averaged around 40%).

Support to Local Communities

Community Engagement

Welding apprenticeship

Solar Lighting Project – 300 homes

Palms Training Centre

(180 trained – 50% female) Courses Business skills, Problem solving skills & semi-skills training.

Topline Water Reticulation Project – provided drinking water to 77 homes)

Support to local high school

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The Proposed Way Ahead for CSP

…. We need to have a long term view on **CSP with Adequate Storage** in SA given capabilities proven by current CSP's in operation:

1. Only **storable renewable energy** with utility scale Peaking and **Base Load/Load Following Capability**
2. Flexibility in dispatch **meets SA demand profile**
3. SA is blessed with an **enviable Solar Resource**
4. Short lead times for **quick deployment possibility**
5. Extremely competitive (**LCOE – Learning rate Round 4.5**)
6. Existing SA manufacturing infrastructure complements CSP
7. Potential to increase **local content** whilst growing **local competence and knowledge**
8. Greater Socio-economic development for **local communities**

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Thank you