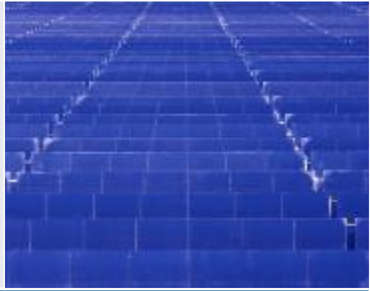









ACWA Power CSP in sub-Saharan Africa and future in SA

Nandu Bhula
CEO Redstone CSP
Deputy MD ACWA Power SA

Ryno Lacock
CEO Bokpoort CSP

ACWA POWER
كوا باور

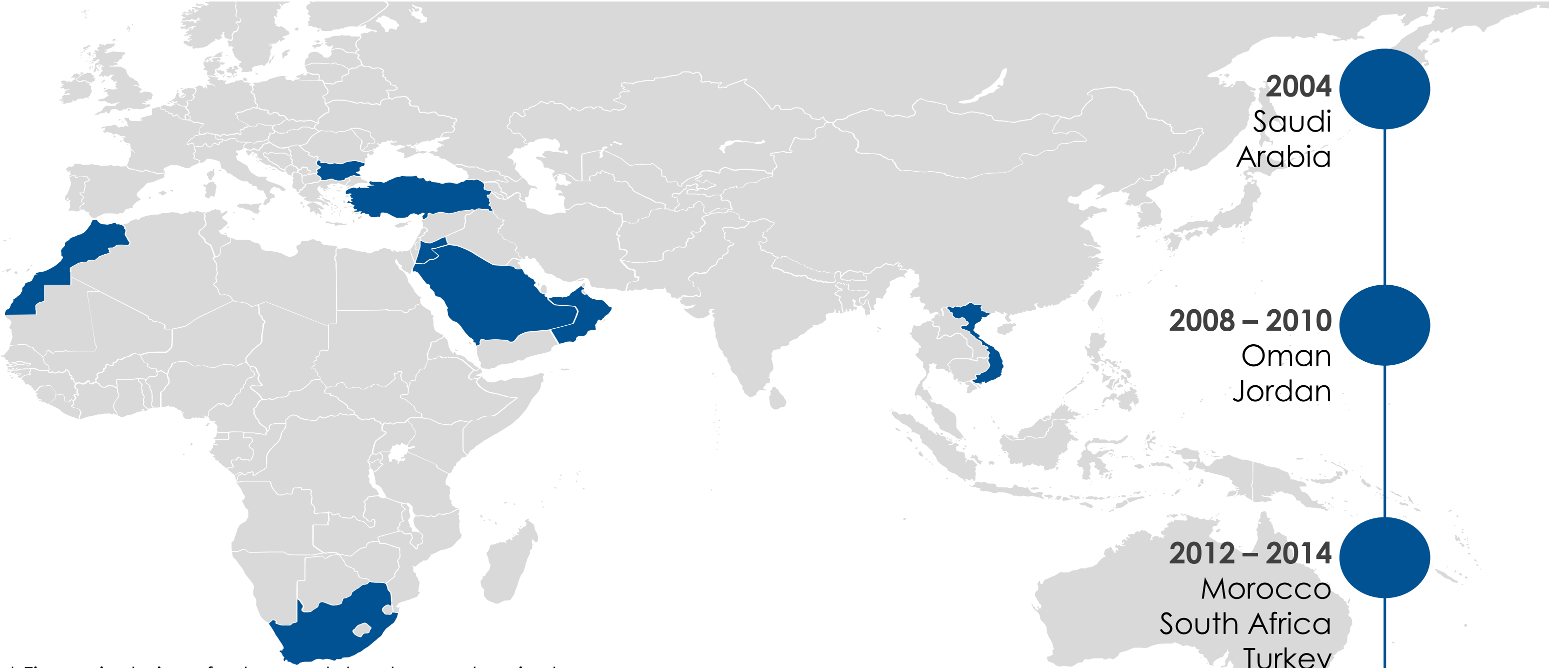
ACWA POWER أكوا باور

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...

49 Assets*	**29+** GW Power*	**3.2** Mm³ per day Desalinated Water*
11 Countries	**$30+bn** USD of Assets Under Management**	**23%** Portfolio in Renewable Energy based on Share of project cost
3,500+ Employees	**30+** Nationalities	**~60%** Local Employment in projects



2004
Saudi Arabia

2008 – 2010
Oman
Jordan

2012 – 2014
Morocco
South Africa
Turkey

2015 –
UAE
Egypt
Vietnam

* Figures inclusive of advanced development projects
** There is another $10.5 bn of projects in advanced development

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

ACWA Power CSP's in Southern Africa

BOKPOORT CSP

ACWA POWER SOLAFRICA BOKPOORT CSP POWER PLANT (PTY) LTD (RF)

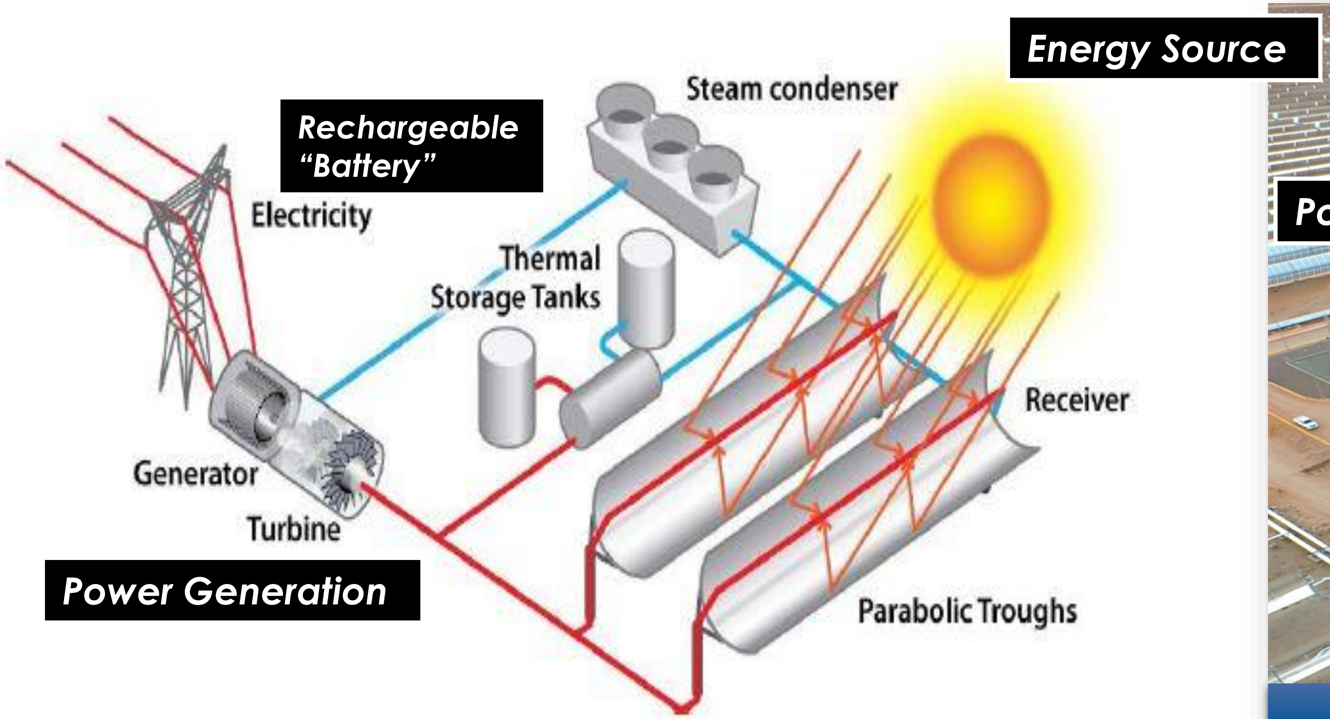
- 50 MW Parabolic trough
  - 180 loops
  - 658 000 m^2 of reflective surface
- Dowtherm A as HTF
  - 293 °C – 393 °C
- 9.3h Thermal Storage
- Wet cooling
  - Cooling Tower
  - Counter flow, induced draught CT (3 cells)

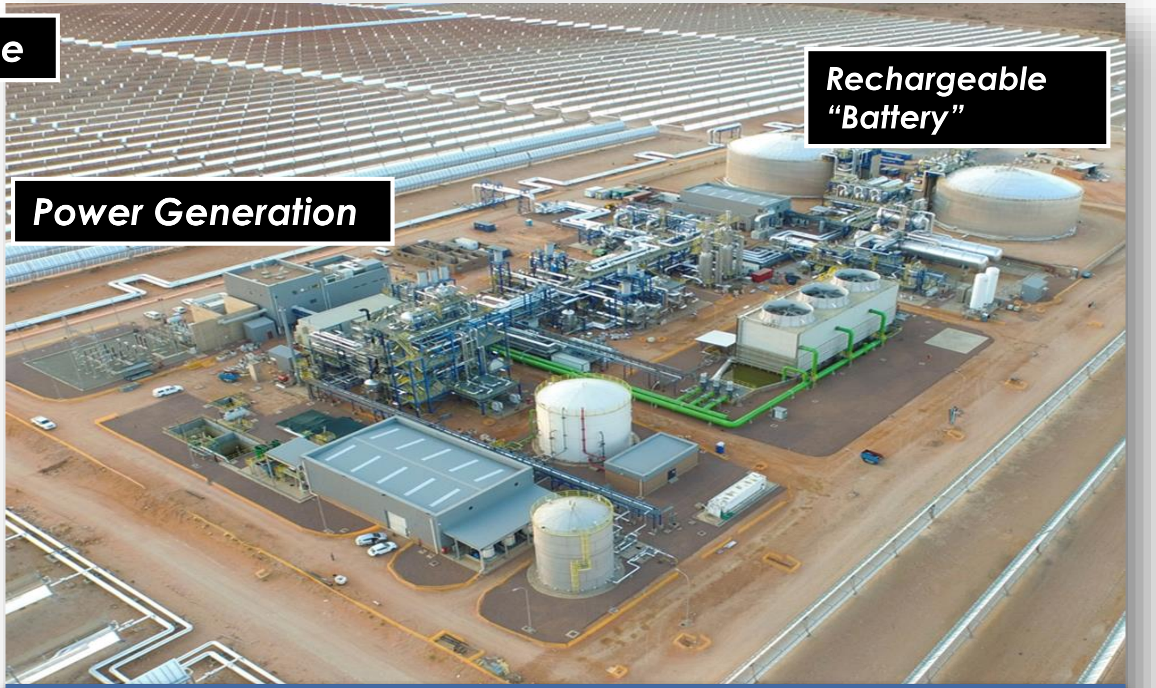
ACWA POWER REDSTONE

Solar Thermal Power Plant

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

Bokpoort 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)***

- Ring-fenced project company effective June 2013
- The site: Bokpoort Farm, 125km south-east of Upington (300 hectare Greenfield)
- Technology: Concentrated solar thermal trough & 1300MWh_t molten salt thermal energy storage (9.3hrs at 50MW)
- Total staff: ±1300 during Construction peak and 61 during Operations
- 20 year PPA with Eskom, through the Garona Substation located next to the site

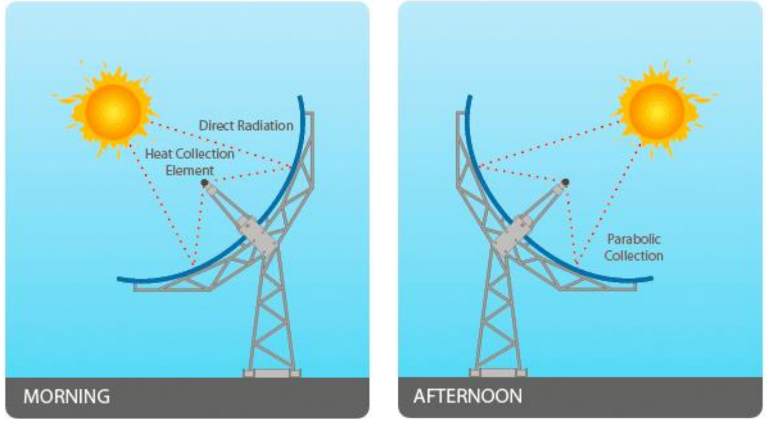
BOKPOORT CSP
ACWA POWER SOLAFRICA BOKPOORT CSP POWER PLANT (PTY) LTD (RF)

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

Bokpoort CSP – Technical Overview

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^2 of reflective surface
- SENER Trough Technology
- Schott Heat Collector Elements (25,920)
- HTF – Dow Chemical (2,640 tons)

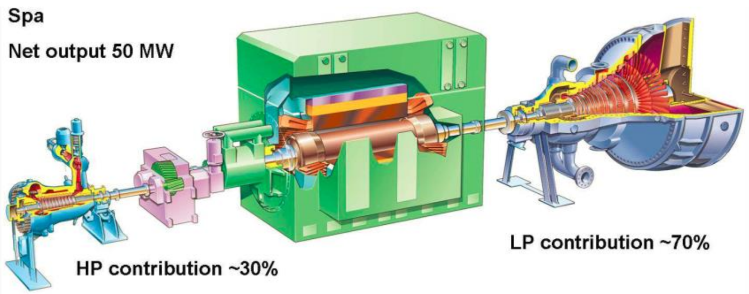


Thermal Energy Storage

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

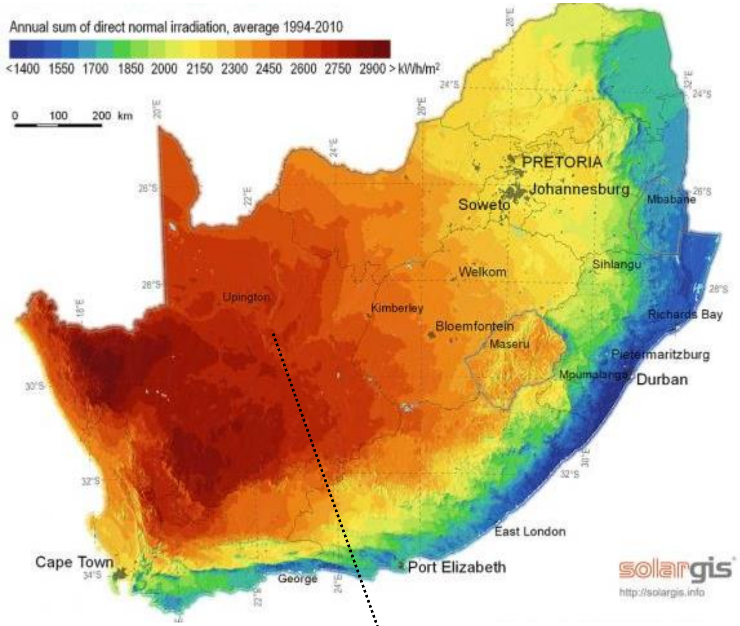
Steam Generation

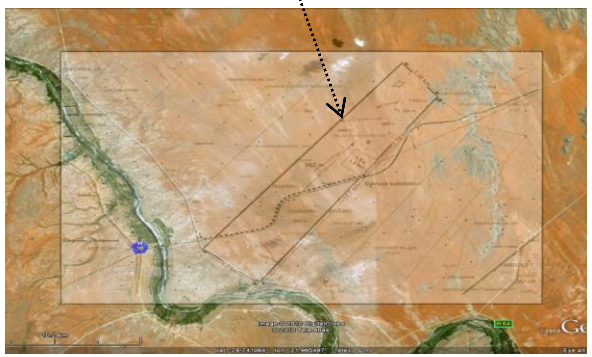
- Two Trains of Steam Generation
  - Steam Supply 103.6 bar @380ºC (@ Turbine Inlet)
  - Enthalpy 3028.7kJ/kg, Steam Flow 60.0 kg/s
- Siemens Steam Turbine SST-700
  - Single Reheat (HP, LP)
  - Siemens Generator



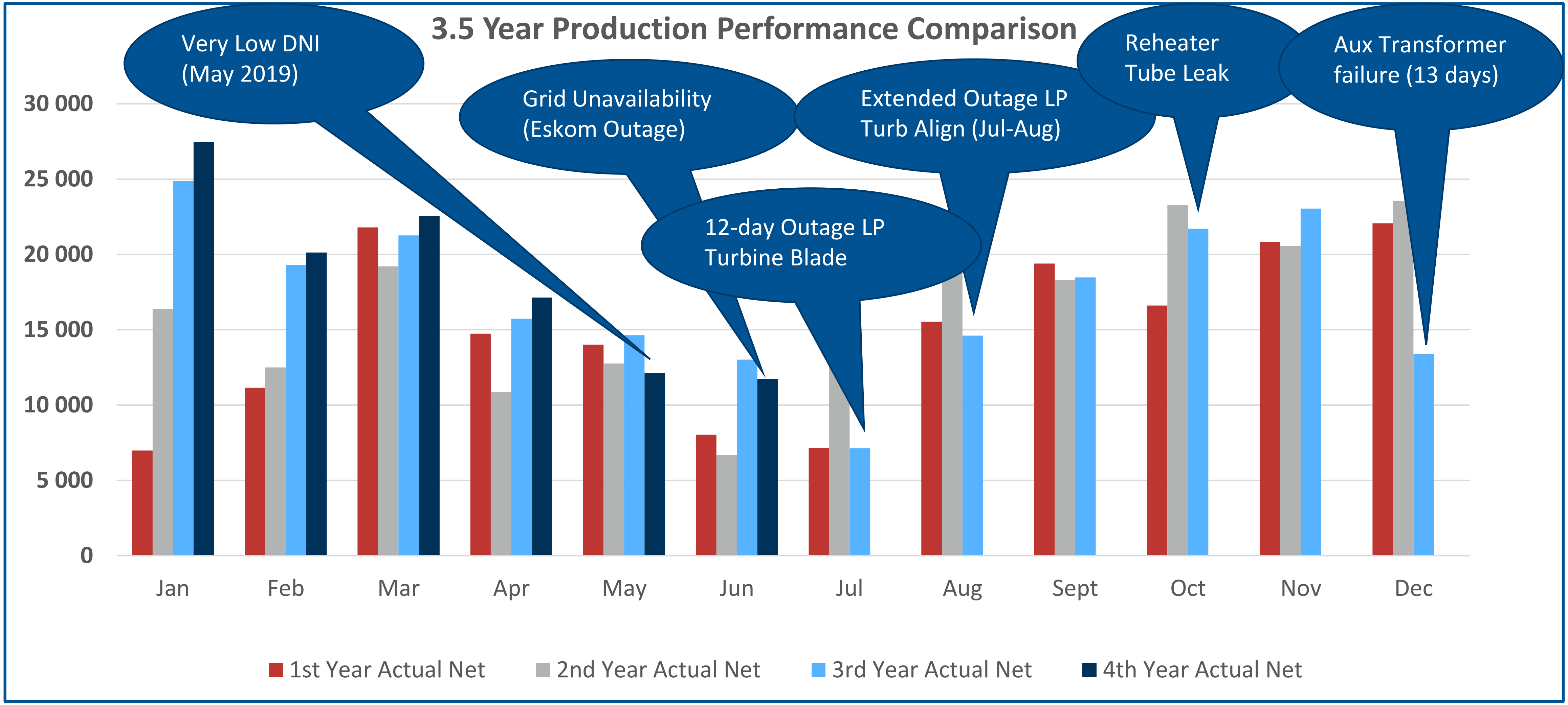
Site Location

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





Bokpoort CSP – Parabolic Trough Technology with Storage



The Technology Landscape – Trends in the CSP industry?

CSP Parabolic Trough

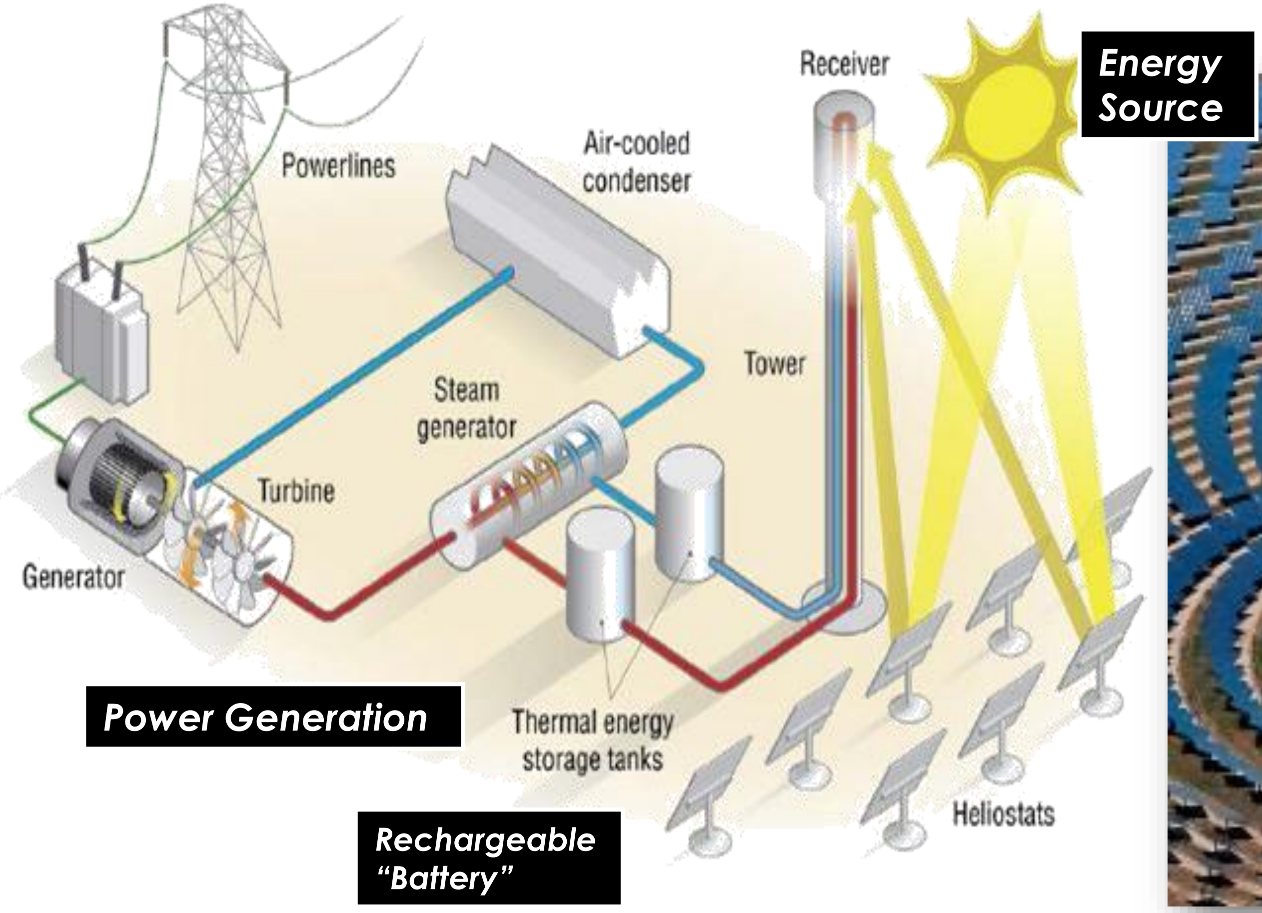
- Proven development and operational track record
- Employs single axis trackers
- "off-the-shelve" designs and systems available
- Higher energy losses/aux requirements in comparison to tower due to extensive solar field piping
- Local content opportunities high
- Lower Uncertainty – mature with 30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

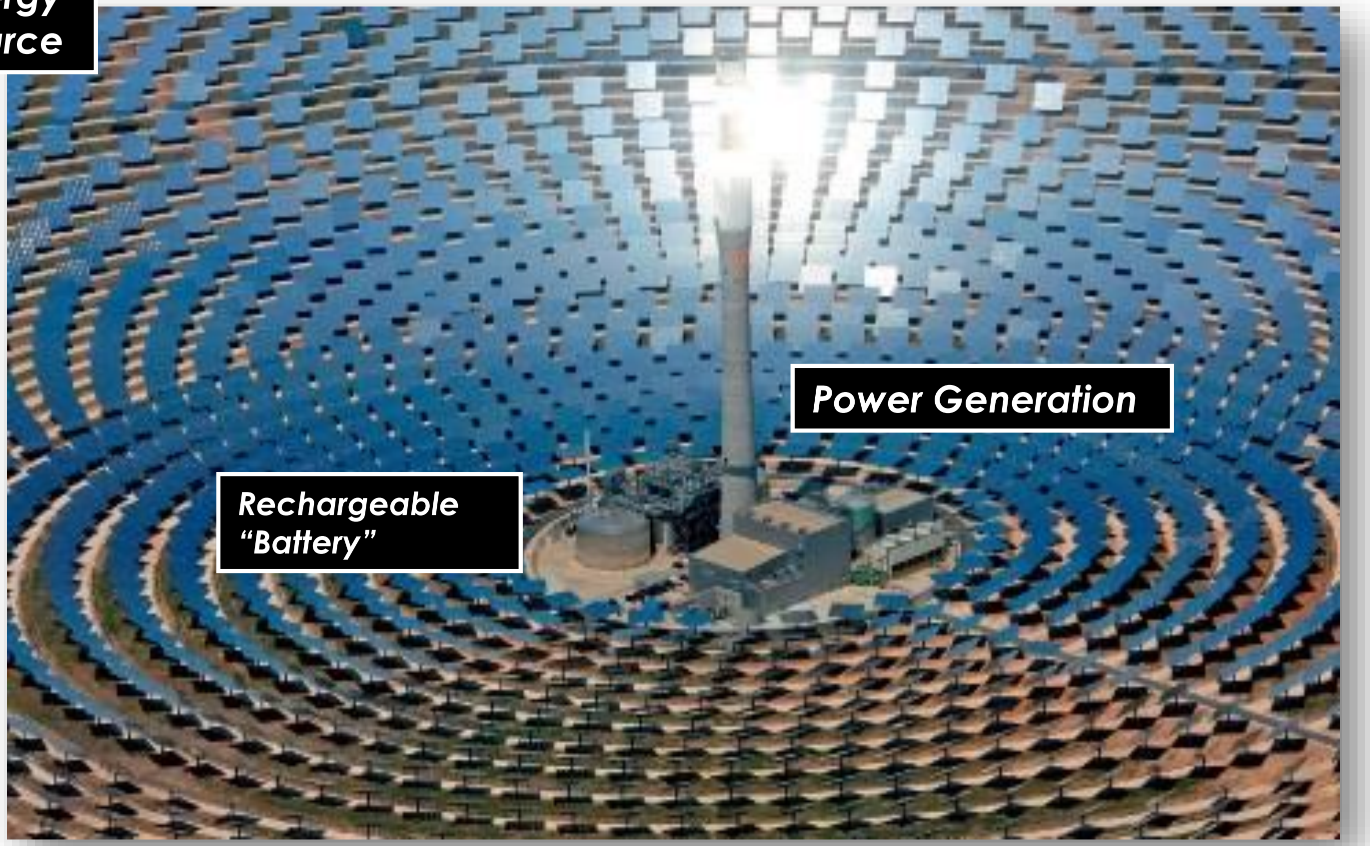
CSP Central Tower

- 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 still maturing but more efficient – cost effective)

Redstone CSP – Power Tower Technology with Molten Salt Storage

ACWA POWER





ACWA POWER REDSTONE Solar Thermal Power Plant

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

Redstone CSP – Timeline Expected

'14
ACWA Power/SolarReserve bid Redstone under the South Africa Renewables Programme IPP (Round 3.5)

'15
January 2015:
ACWA Power and its local partners recognised as preferred bidder

'16
Essential site activities done as part of project development phase in order to complete technical feasibility

'18
- **PPA signed by Eskom**
- **Implementation Agreement**

Financial Close

'19* '21* '22* '42*

Construction (25 months)

Commissioning (6 months)

Operations over 20 year lifespan,

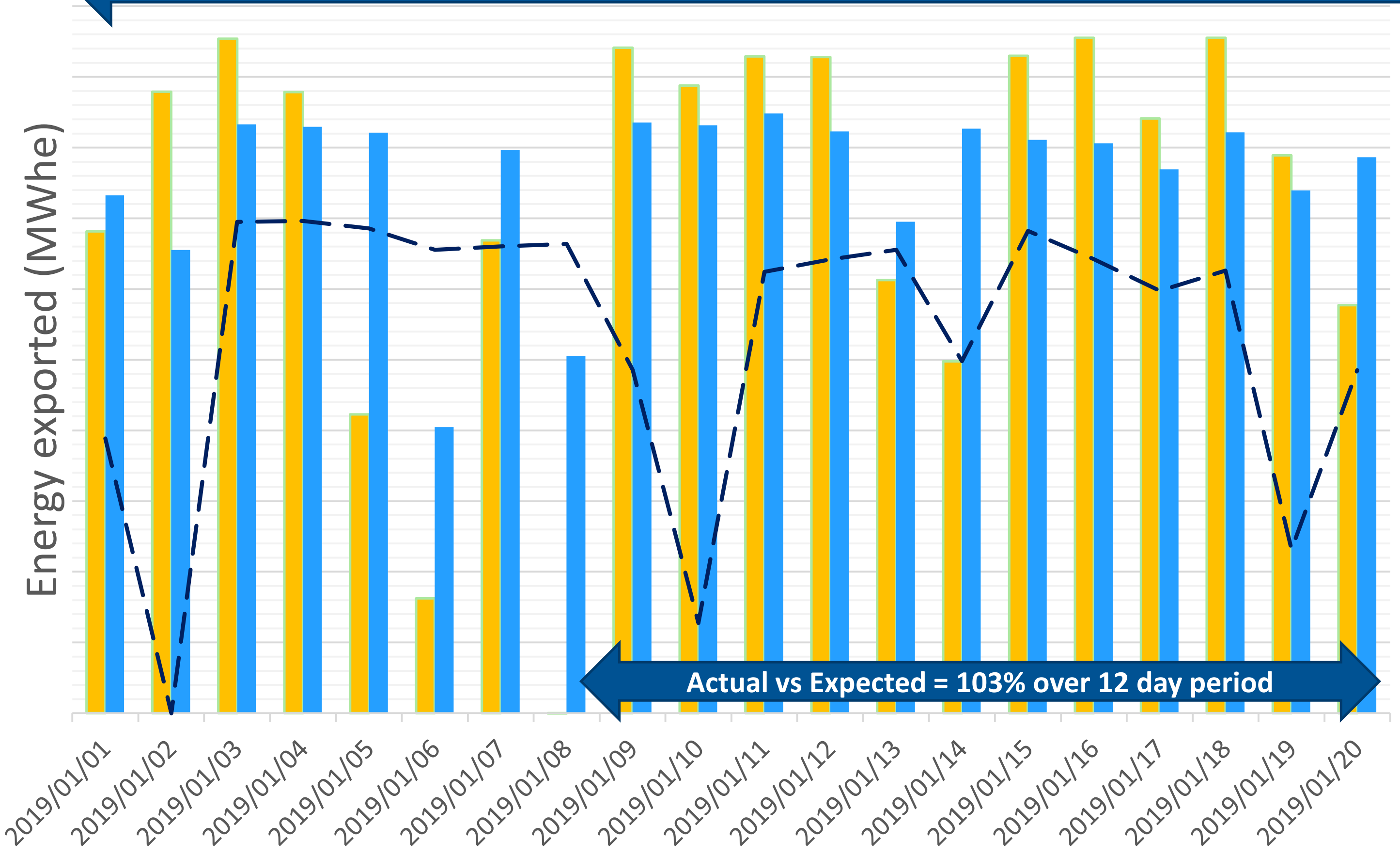
Our Key Messages

- **We are nearing financial close on our 100 MW CSP power project (FC planned for 1st Aug)**
- **Construction activities is expected to ramp up from Quarter 3 2019**
- **The Project will then Operate for a period of 20 years under a PPA with Eskom.**
- **The project is enabled by strategic partnerships with South African co-investors including BEE investor and Ownership in the hands of a Community Trust.**

Performance Expectations based on Noor III CSP

Performance over 1st Month of commercial Production

Actual vs Expected = 96% over first 3 weeks of January

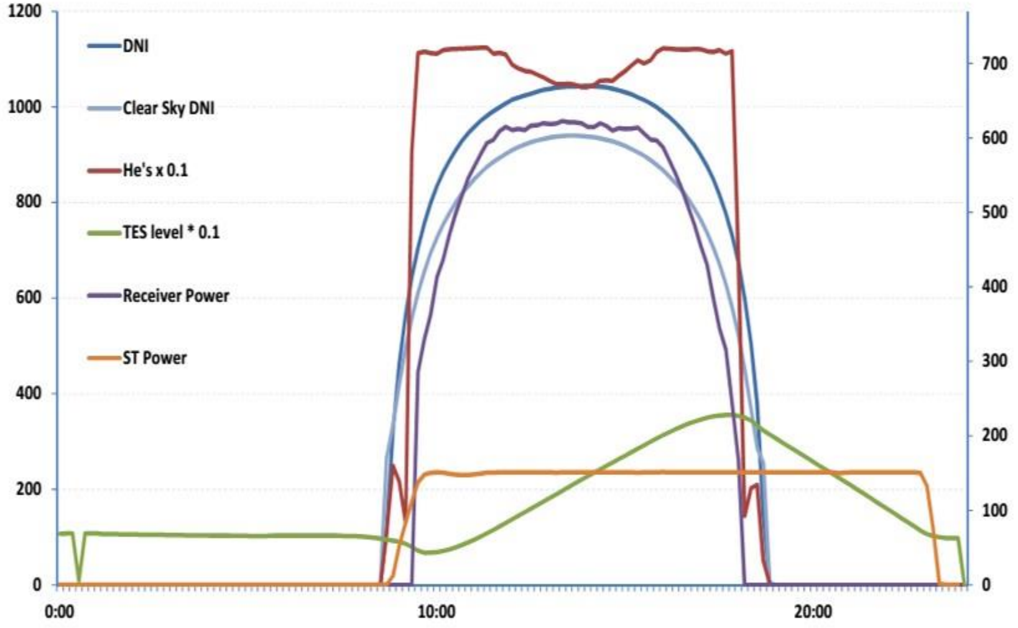


NOORo III O&M

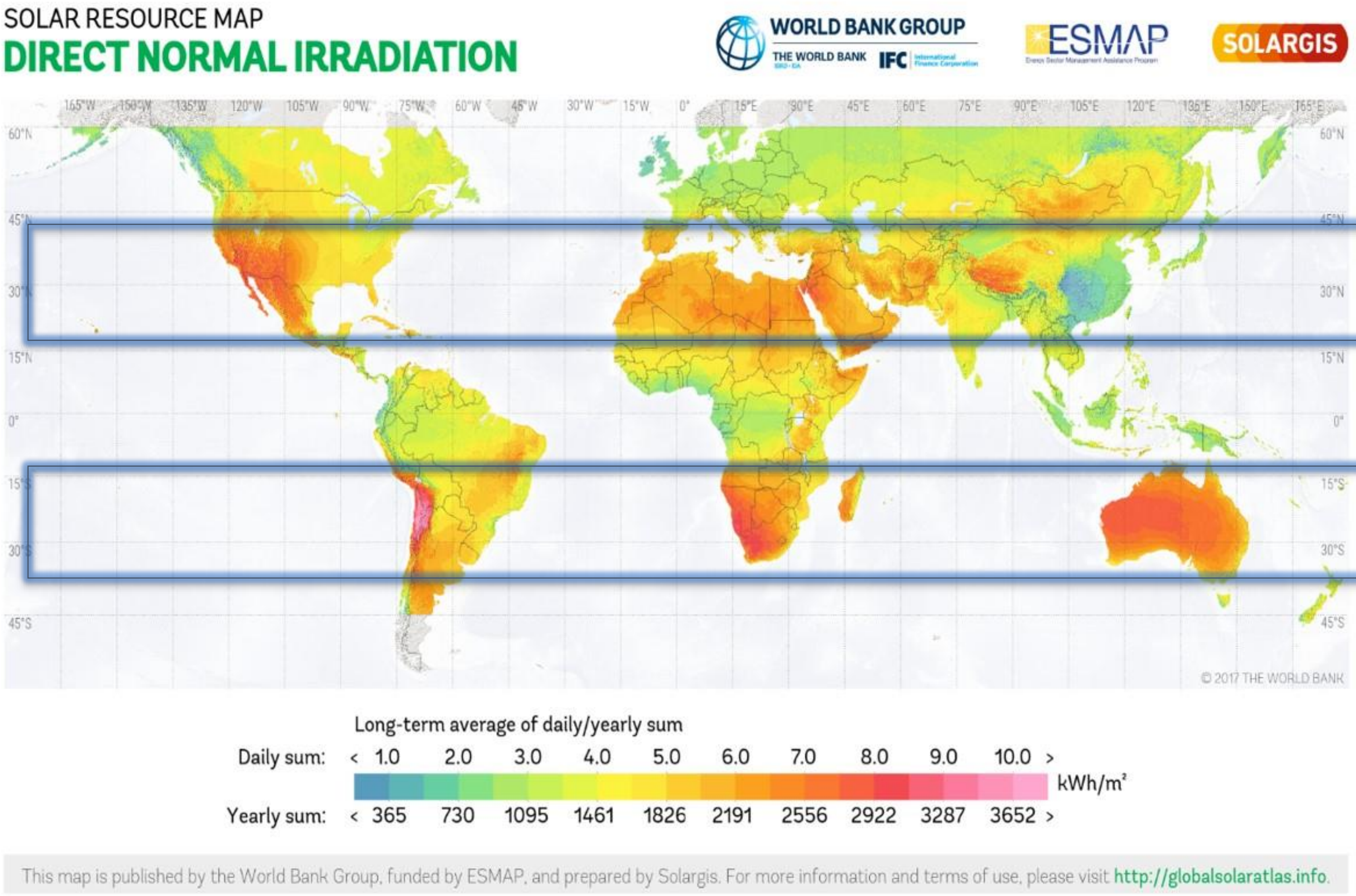
DAILY PRODUCTION REPORT

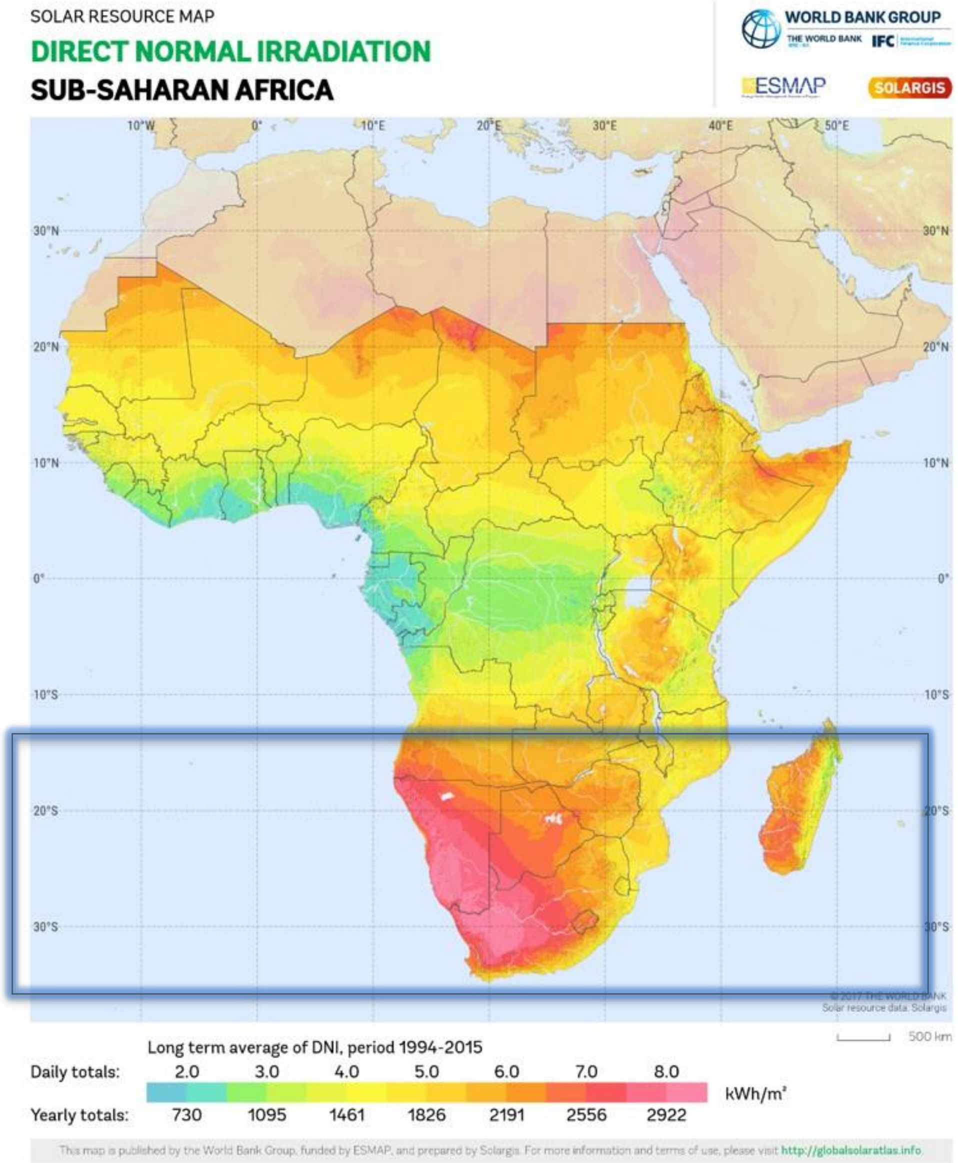
Typical day – 3rd January 2019

Date	Real Net Adjusted (MWh)	Reference Net Exp Adjusted (MWh)	Budget Gen (MWh)
2019/01/03	1908,46	1665,63	1390,10
		115%	137%



CSP – Status across the Globe

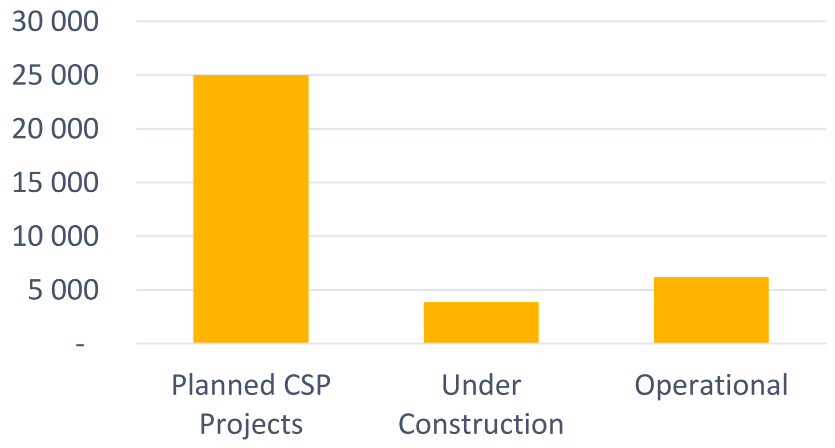




CSP – Status across the Globe

- 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

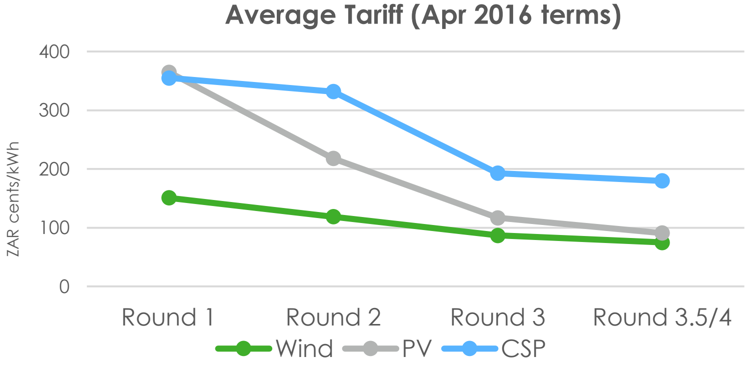
CSP is expected to record the highest growth amor renewable technologies globally



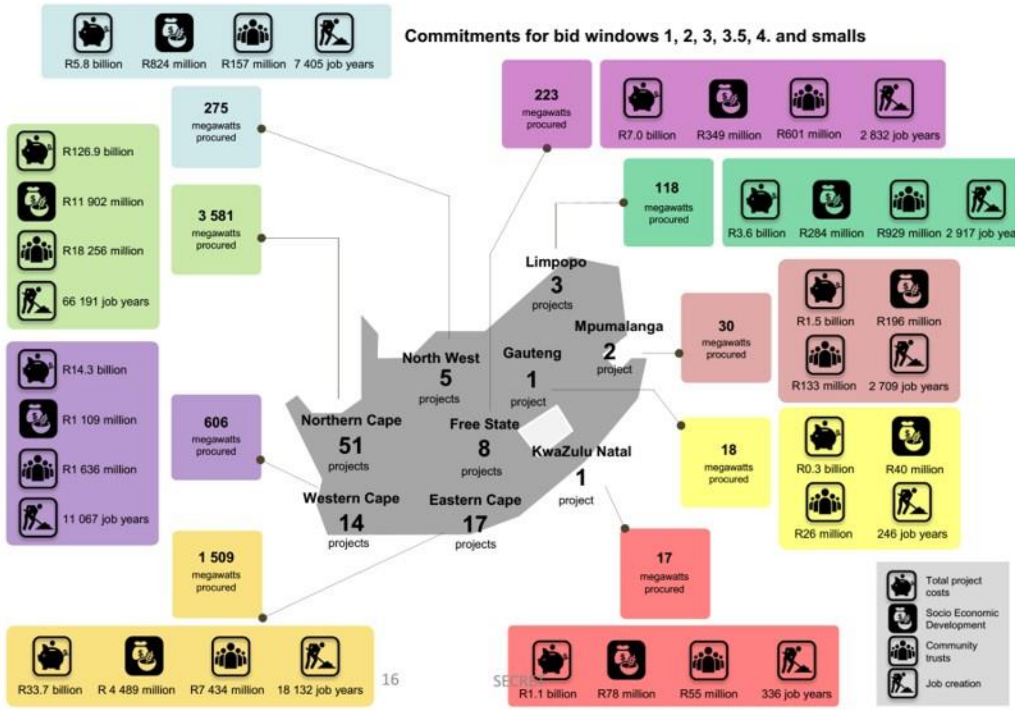
Source: https://solarpaces.nrel.gov/by-status and STASA 2018-10-15 PCE IRP presentation

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 ito 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 currently developing the 100 MW Redstone CSP project as part of Round 3.5



Tariff Reduction in % per 100MW procured:
CSP – 45% @ 7.5%/100MW
PV – 80% @ 3.5%/100MW
Wind – 55% @ 1.6%/100MW



	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**
Total	**1,426**	**28**	**1,040**	**19**	**1,457**	**17**	**200**	**2**	**2,205**	**26**	**6,328**	**92**

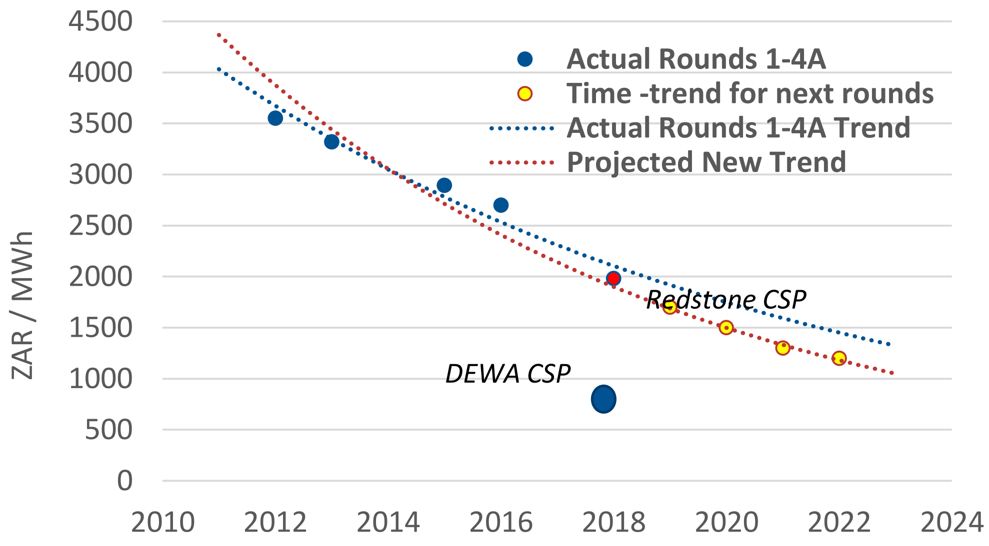
CSP – A look at the Future of CSP in South Africa

- Additional 8GW IRP allocation to Gas/Diesel & **no allocation to CSP**:
  - Without any sensitivity to **primary energy is a risk**
  - Though, IRP will make reference to **"Proxy" technologies**
- Gas/Diesel commodity vulnerable to market dynamics and while CSP overnight capital is still reducing
  - CSP can provide **effective hedge against GT's** – higher overnight capital but certain/predicable and low future costs
- A proposed allocation of capacity to CSP – can **reduce overall planning risk** (move CSP:GT ratio from 1:20 to 1:5)
  - Reference to current overnight capital of Gas to CSP about 1:5
  - Reducing dependency Gas/Diesel (which we don't have)
- **Success of Hybrid solutions world wide** will change the structure of IRP and offer opportunities for all technologies
- CSP offers huge opportunities for sub-Saharan Africa through **development of local industry** (continental hub for the technology)
  - The technology has high localisation potential
- Key aspects that can further impact the attractiveness of CSP
  - **Economies of scale** clearly impact bid tariffs (DEWA CSP et al)
  - Reduction of soft costs through de-risking – **Improved finance terms**
  - **Extension of PPA terms** to align with other Thermal technologies
  - CSP **Cost trajectories extremely positive** and technology still maturing thus huge opportunities for further **least cost planning**

CSP Market Size means Localisation Potential

SA Manufacturing Infrastructure	CSP specific
• Civil / Cooling Tower	• Parabolic Mirrors / Heliostats
• Valves & Actuators	• Collector Structure
• Pressure Vessels	• Precision Tracking Systems
• Collector Structure	• Receiver Pipes / System
• Storage Tanks	• Heat Transfer Fluid
• Piping	• W/S Cycle
• Cabling	• Engineering

35-40% → Localization Potential → **60-65%**

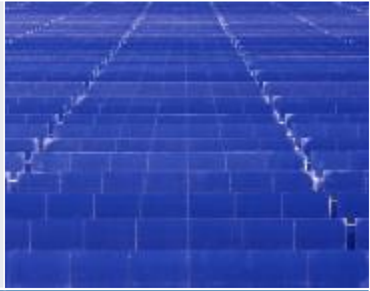


CSP – Some key considerations in favour of CSP

…. 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 **meeting SA demand profile** - PPAs to be structured to load profile – with **energy, capacity and ancillary services** contracted.
3. SA is blessed with an **enviable Solar Resource**
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. Consideration towards **PPA tenures** equivalent to other thermal plant – immediate step change
8. Easily partner with other technologies for **Hybrid solutions** leading to real "Least Cost Plan".
9. Existing **SA manufacturing infrastructure** complements CSP
10. Potential to increase **local content** whilst growing **local competence and knowledge**
11. Greater Socio-economic development for **local communities**





Water Management Challenges in a CSP Plant

Hydrocarbon contamination in Steam Cycle



JC Nel

Bokpoort CSP



ACWA POWER
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Hydrocarbon contamination in Steam Cycle

CSP operating principle:

- Solar Field: heat up Heat Transfer Fluid (HTF)
  - ~400°C, 15 bar
  - Dowtherm A: synthetic organic HTF (Diphenyl & Biphenyl)
- Steam Generation System (SGS): water -> steam
  - ~400 °C, 16-90 bar

Heat Exchangers in SGS:

- Shell and Tube (Preheater, Evaporator, Superheater, Reheater)
- Reheater:
  - Prone for tube leaks – high thermal and pressure gradients
  - hairpin design, counter flow, HTF on Shell side
  - 766 tubes, Ø20mm

Contamination:

- Steam cycle – direct leak into steam side of heat exchanger
- Waste water cycle – blowdown from steam cycle and condensate to drains

HTF Presence in Steam Cycle

Condition/State of Hydrocarbon molecules in steam:

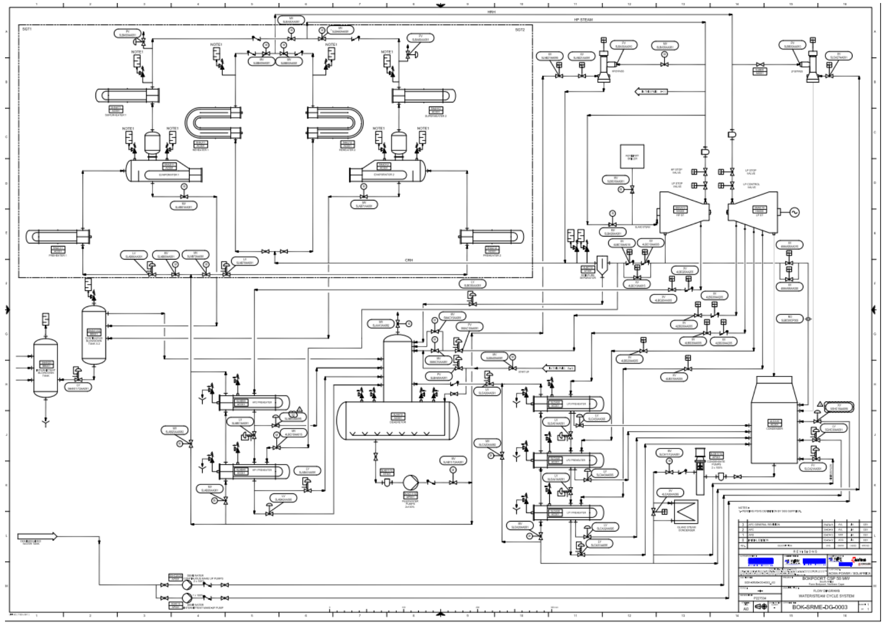
- Condition of hydrocarbon is temperature and pressure dependent (vapor/drop/emulsion)
- Operating conditions changes throughout cycle, as well as time of day
- Online hydrocarbon analyzer for superheated and reheated steam

Effect on Equipment:

- LP Turbine
  - Droplet formation biggest risk – blade damage
- Condenser
  - Oil layer on tubes – significantly reduce heat transfer (influences vacuum)
- Instrumentation

Limited options for Removal from cycle:

- Deaerator through insoluble gas stripping
- Blowdown of steam and water (keep density differences in mind)



HTF Presence in Waste Water Cycle

Water Recovery System for Condensate Drains

- Water is blown down (controlled release) from SGS to maintain quality
- Passing drain valves, leaks and inefficient operation also discharges demin water to drains, which flows to waste
- Quenched with clean water to cool down ~40°C
- Should be recovered and reused, however need to take risk of hydrocarbon contamination into account

Effect on Equipment:

- Filtration technology for recovery system
    - SGS blowdown high silica content - RO most commonly used
    - Hydrocarbon detrimental to RO membranes
- Destination of recovered water:
    - Water Treatment Plant – high risk since issue could impact production
    - Cooling Tower - safer option
        - aeration, side stream filtration
        - Impact of additional thermal load since condensate drains

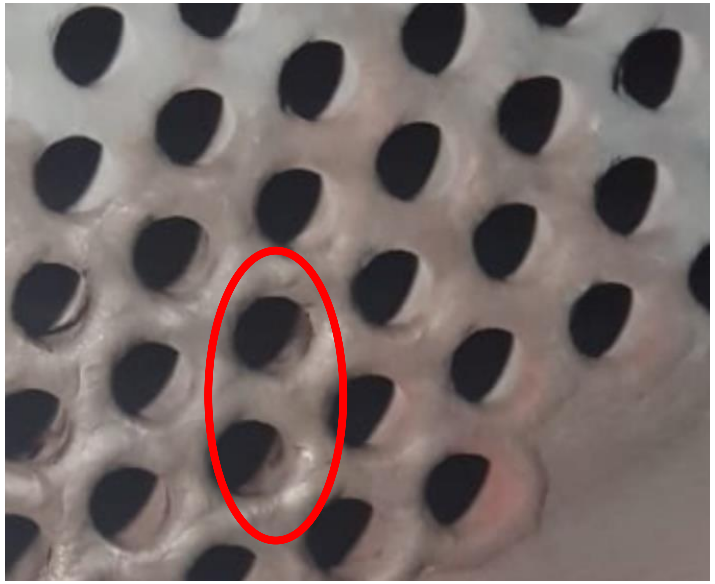
Management of Risk

Risk management:

- In order to repair a tube leak, the complete SGS train needs to be taken out of service
- Significant production loss, could be reduced if planned for during bad-weather days
- Requires clearly defined allowable limits in order to safely operate plant until best opportunity for repairs

Removal from cycle:

- If leak did occur, how to effectively remove hydrocarbons from cycle to within acceptable limits
- Without wasting unnecessary water through forced flushing or not recovering condensate drains



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ありがとうございました Teşekkürler شكرا ขอบคุณ cảm ơn bạn
நன்றி
謝謝 Asante Дякую
धन्यवाद Thank you Спасибо
Terima kasih Ngiyabonga Tak

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