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CSP Innovations in South Africa
– Experience and Lessons Learnt in Khi, Kaxu and Xina

Julian Lopez

Agenda

1. Why CSP for South Africa?
2. 100MW Kaxu – first CSP plant in South Africa
3. 100MW Xina – CSP for peak times
4. 50MW Khi – first CSP tower in South Africa
5. Next technological steps for CSP

1653 MW in operation and 420 MW under construction

Europe

- PS10 & PS20, the first and second commercial solar power towers in operation worldwide
- Solnova 1, 3 & 4, Helioenergy 1&2, Solacor 1&2, Helios 1&2, Solaben 1, 2,3&6: 13 parabolic trough plants in operation (50 MW each)
- 5 photovoltaic plants in operation

America (U.S.A. & Chile)

- Solana (AZ): the largest solar power plant in the world, a 280 MW parabolic trough plant with 6 hours of storage, in operation
- Mojave (CA): 280 MW parabolic trough plant, in operation
- Atacama I (Chile): 210MW. 110MW Molten salt tower + 100 MW PV, under construction.

Africa & Middle East

- Hassi R'mel (Algeria): 150 MW ISCC hybrid plant in operation
- Shams-1 (Abu Dhabi): 100 MW par. trough plant in operation
- Kaxu Solar One & Khi Solar One (South Africa): 100 MW trough plant and 50 MW solar power tower both in operation
- Xina Solar One (South Africa): 100 MW parabolic trough aprox 5 hours of TES under construction
- Ashalim (Israel) : 110MW pareabolic trough under construction

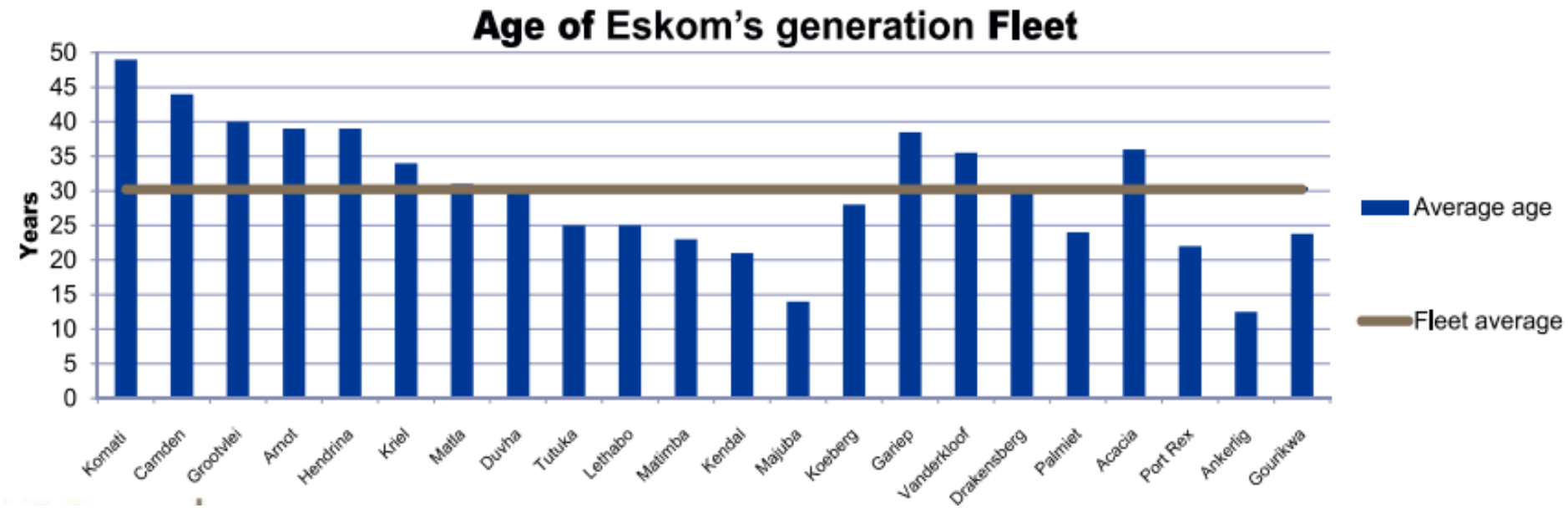
1

Why CSP for South Africa

Load shedding back to South Africa in 2014 and 2015

- Both Medupi and Eskom's Kusile power station are delayed from the initially planned April 2011
- South Africa grid has sometimes operated with a buffer of only 1% of its capacity.
- Massive maintenance backlog on Eskom's ageing power stations has forced the utility to continue repair work beyond the summer.
- Eskom said it was prepared to introduce rolling blackouts this winter in some parts of the grid to prevent a complete system collapse
- Main issues this year
  - Rain floods brought down critical transmission lines and coal was wet
  - Performance of coal power stations very volatile in summer. Dry-cooling becomes a problem when day temperatures are high

Aging of South Africa's Power Park

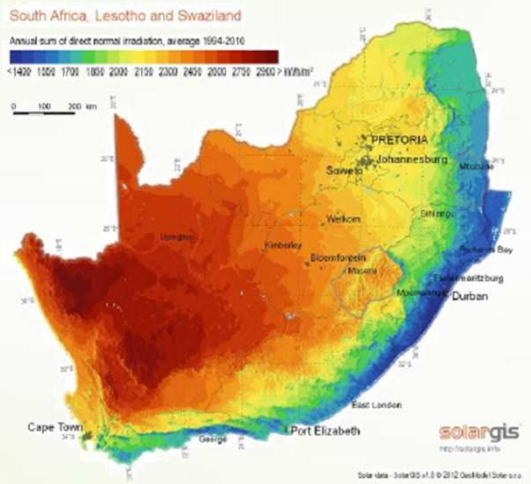


Source – Integrated Results Presentation 31 March 2013 (Eskom)

- Eskom power stations are aging and significant replacement capacity is required
- Conventional steam plants can easily operate in access of 30 years, even to 50 or 60 years. Yet CSP plants with steam generators have to make their business case over 20 years – which makes them seem more expensive

CSP's value proposition

The **solar resource quality** in SA is amongst the best in the world, while SA's **land availability** is not a constraints.



CSP's value proposition:

- Positive influence on **grid** operation **and system stability** (e.g. energy storage, dispatchability, inertia, reactive power, predictable and reliable power)
- **Large scale** generation, **modularity** and **replicability**
- **Hybridisation** potential
- Positive impact on **socio-economic development**, as a result of the increase on available energy, job creation potential and local manufacturing potential
- Reduced **greenhouse gas emissions**
- Positive impact on **land and water use**
  - CSP uses less surface area than other renewable technologies;
  - Dry cooling systems reduced water requirements

energy

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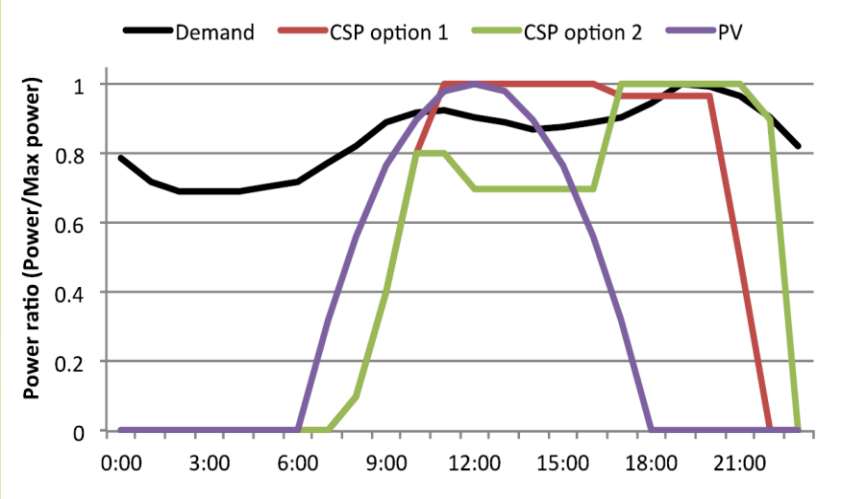
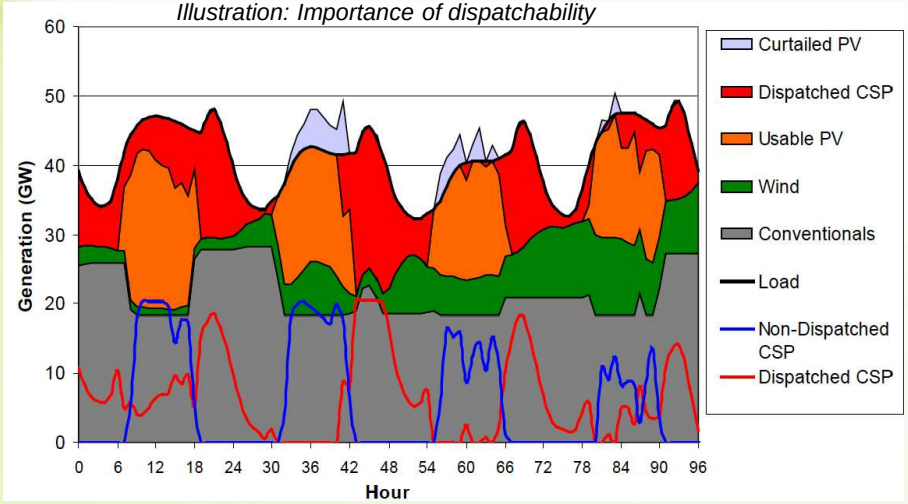
CSP can deliver electricity consistently during peak times

- CSP with heat energy storage is the only renewable energy technology with the ability to deliver electricity consistently during peak times, when it is needed most.





CSP option 1: If CSP plant is run in the conventional mode (e.g. seeking maximum power always) and the excess of energy is stored to keep the plant generating full load once the sun start setting down. (Typical operation mode adopted by Spanish CSP plants)

CSP option 2 (Hybrid): Adapt the power output to the demand, reducing the load during the central hours of the day where PV can provide cheaper electricity and shift that energy to extend the generation until later hours without requiring a larger storage system

energy
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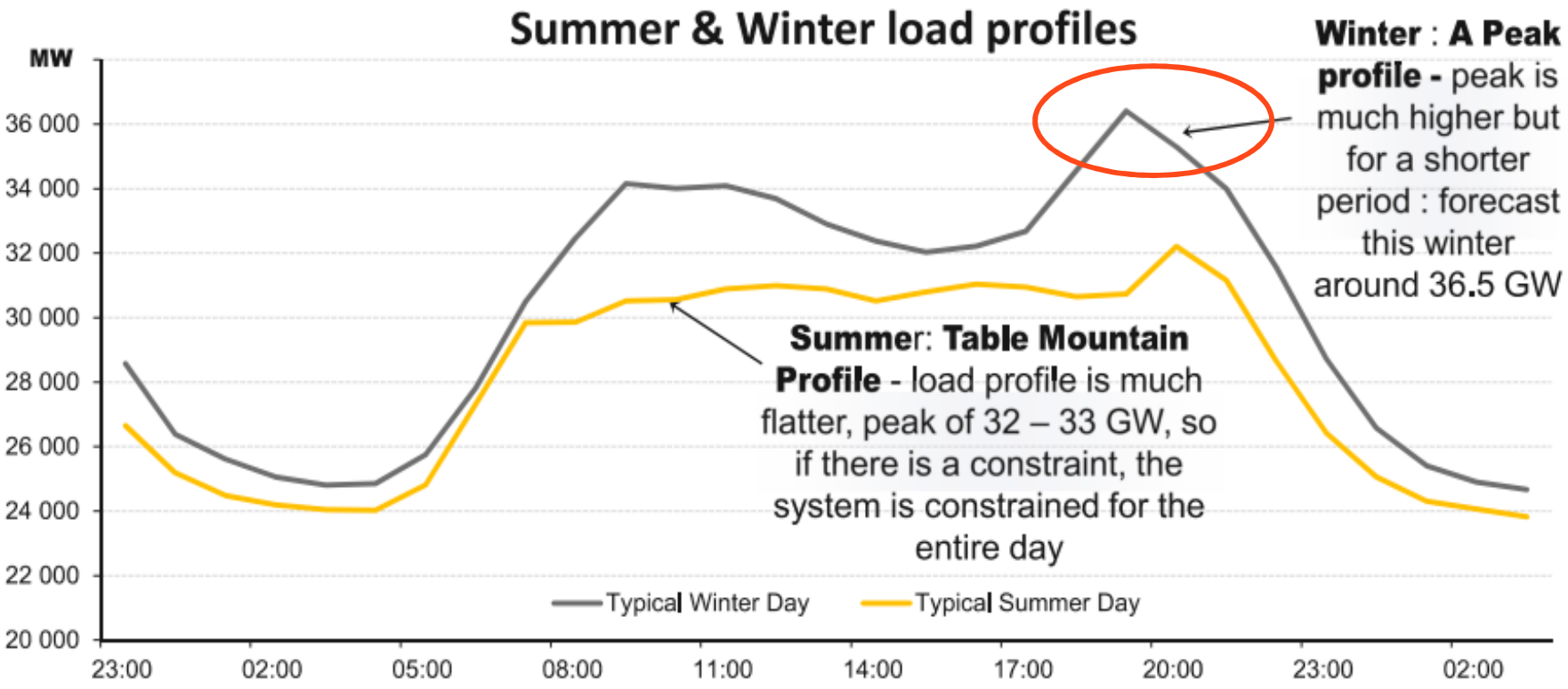
Sources:

1. *CSP Today and Groupe Reaction; Part 1: CSP vs PV in South Africa – Assessing the current Situation*
2. *Paul Denholm, PhD and Mark Mehos, National Renewable Energy Laboratory: Boosting CSP Production with Thermal Energy Storage (06/01/2012)*

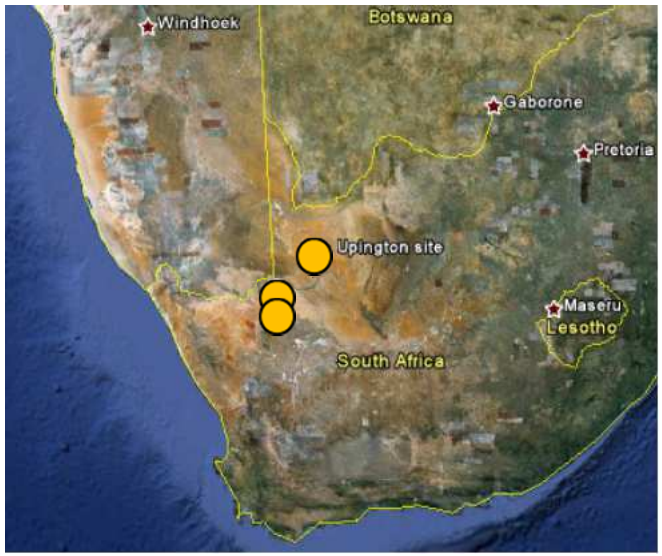
South Africa daily load profiles

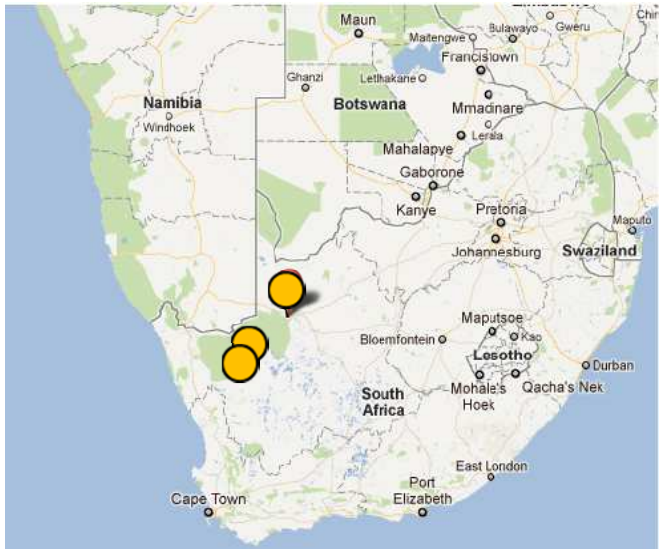


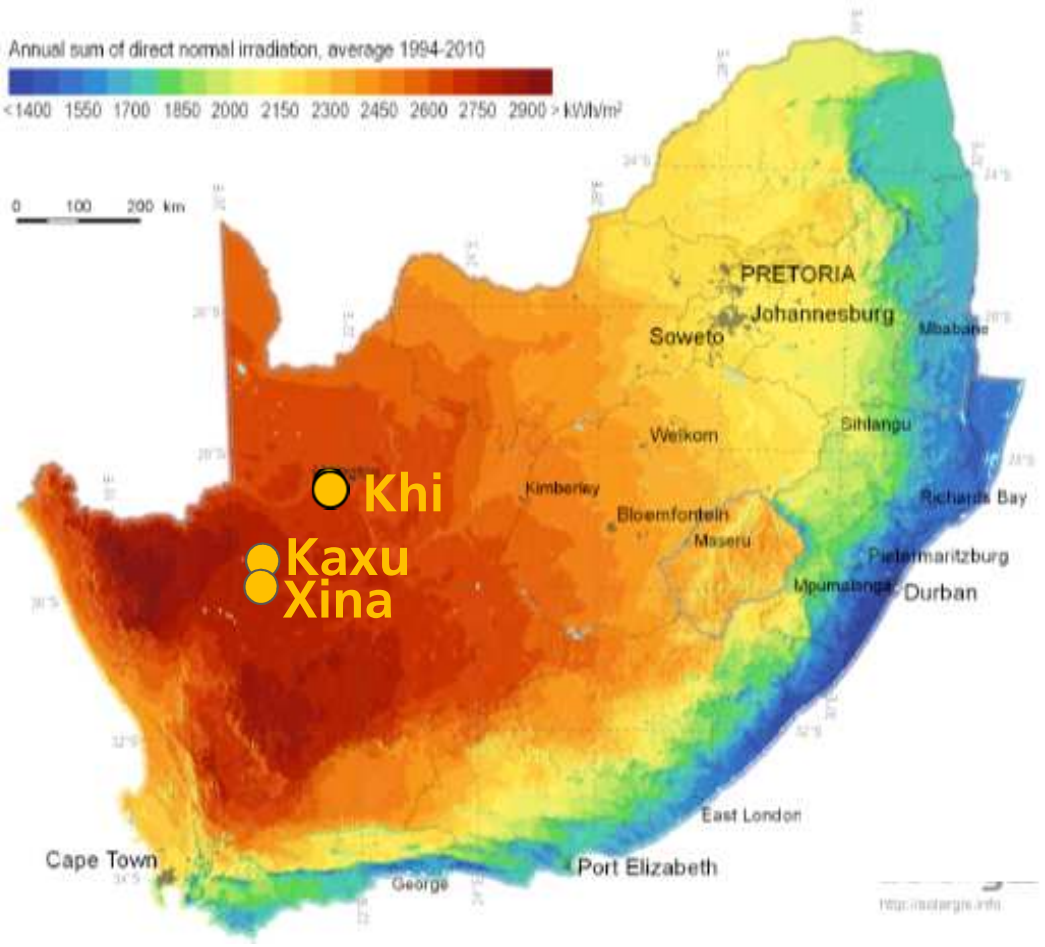
Source – State of the Power System Quarterly Update; Brian Dames (Eskom)

- Critical 5 hour evening peak – currently met with diesel or some pumped storage

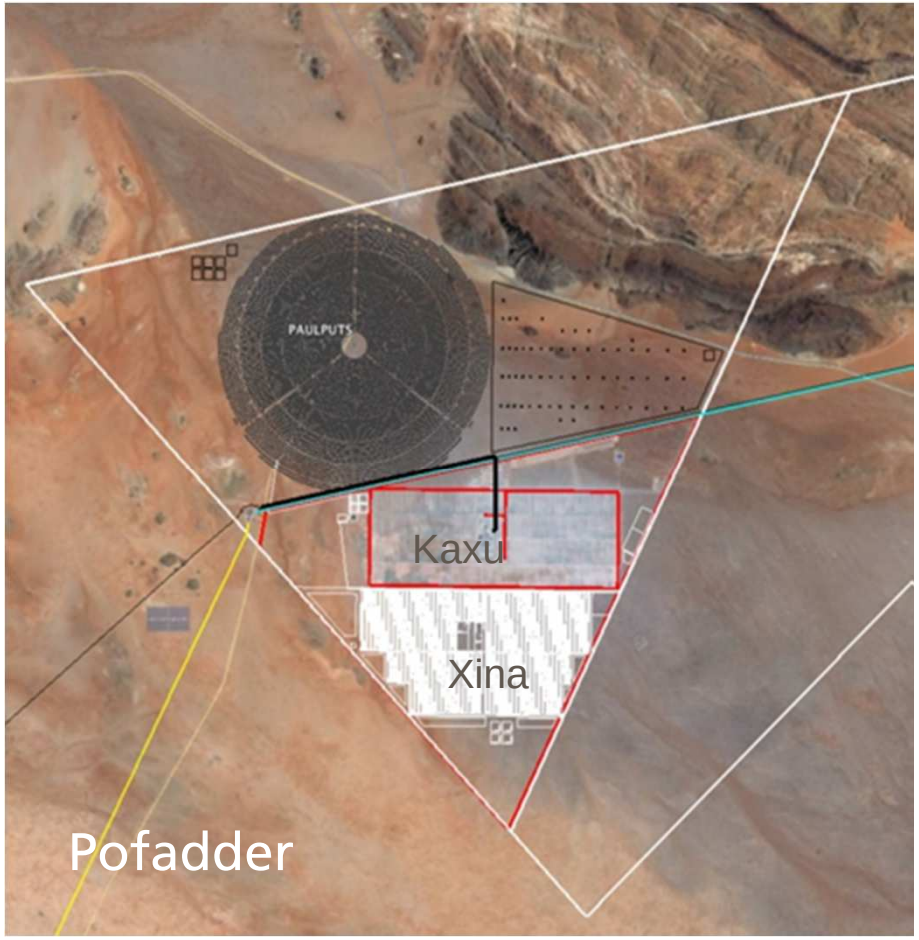
The Kalahari enjoys over 2900 kWh/m2 DNI

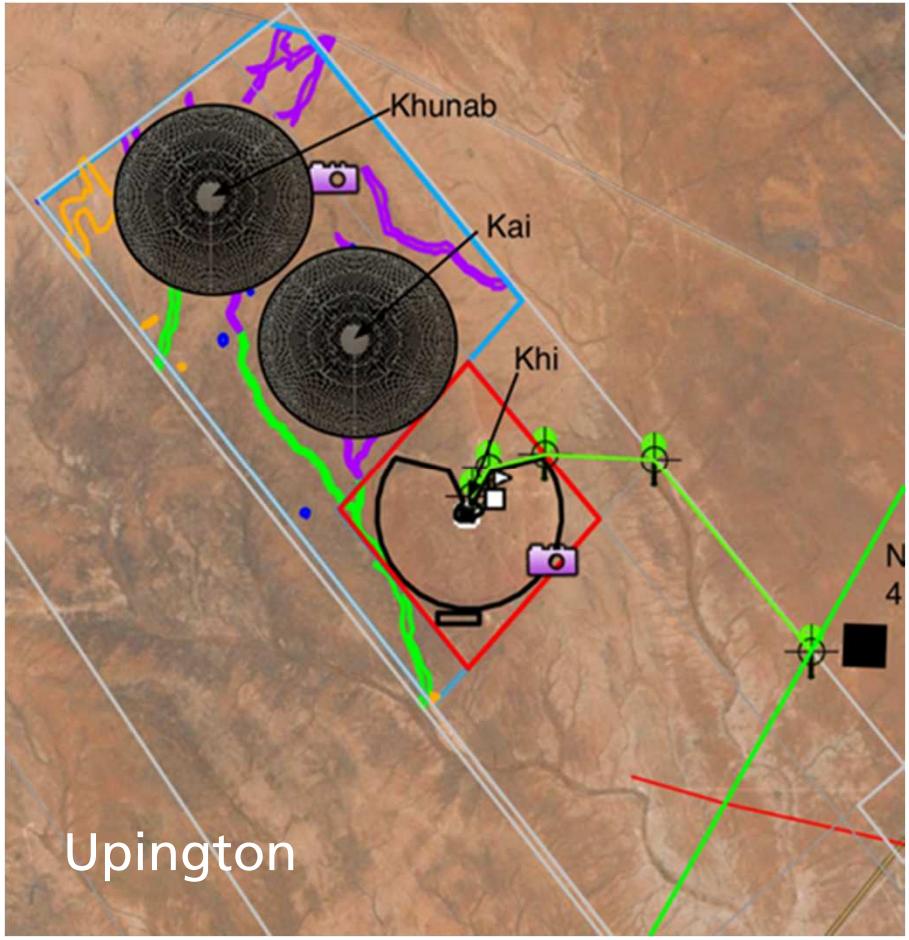






The sites of the Khi, Kaxu and Xina projects





2

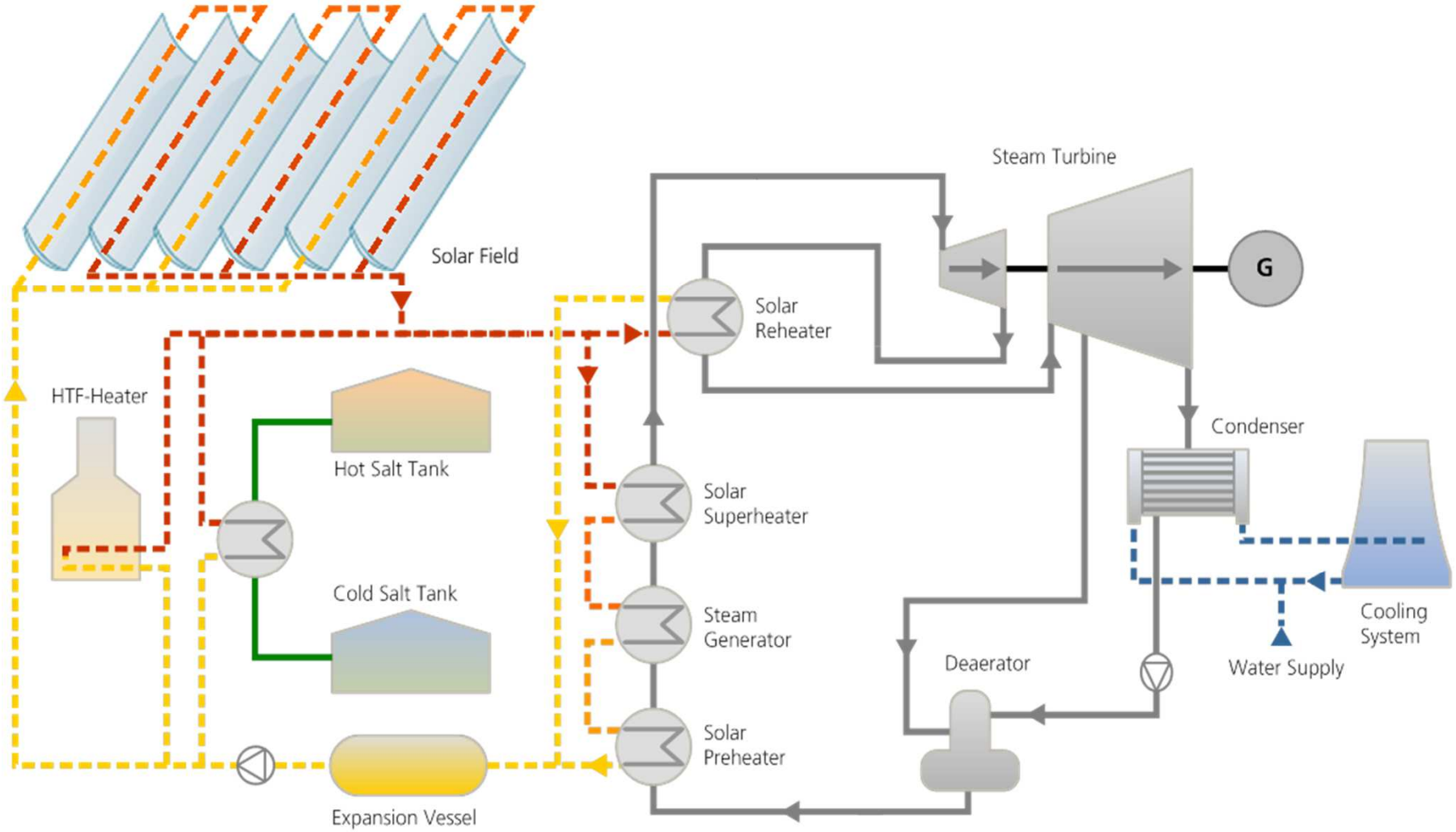
100MW Kaxu - first CSP in South Africa

100 MW Kaxu started Commercial Operation on Feb 6, 2015

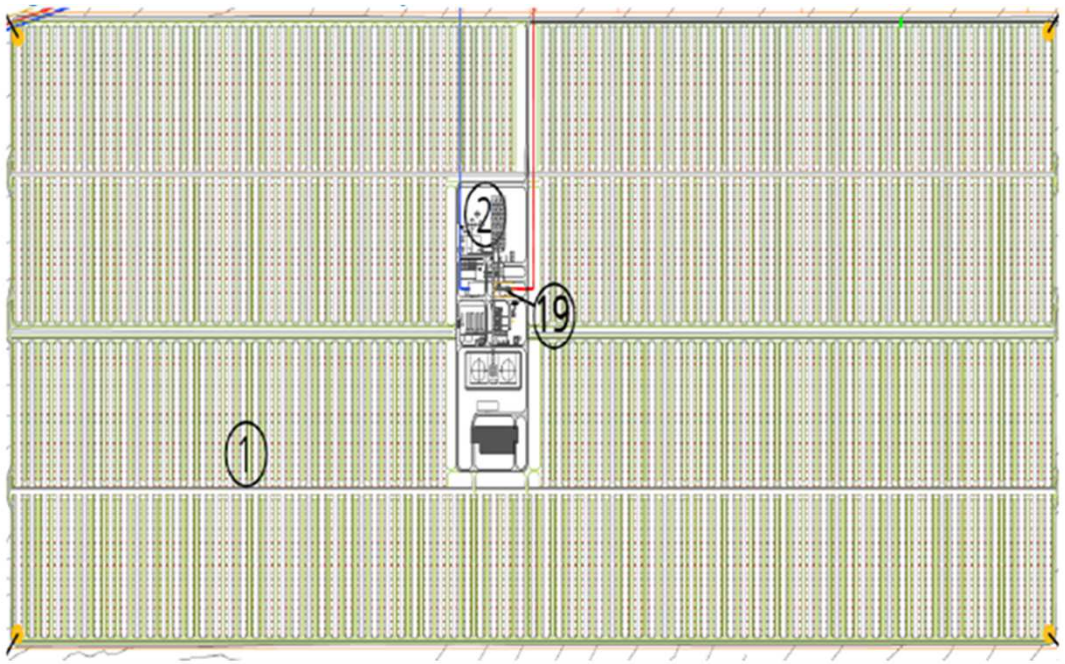
First year of commercial operation

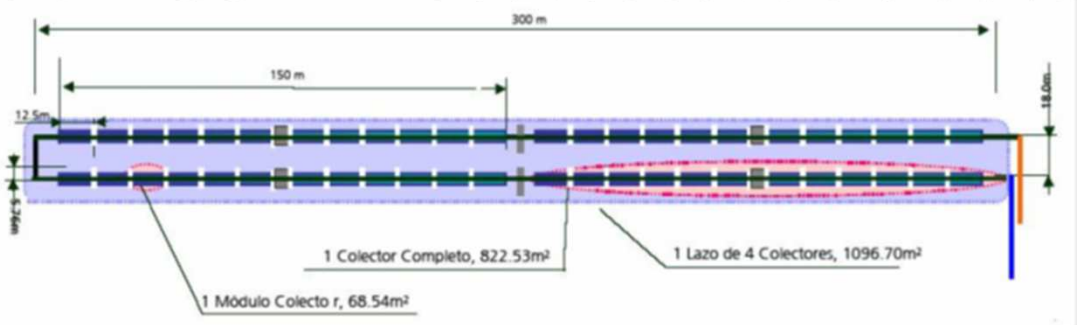
- **Kaxu Solar One**
  - 817,500 m2 solar field in 250 loops
  - 2.5 h molten 2 tank salt storage with approx. 22,000 t salt
- **South African Partners**
  - IDC Industrial Development Corporation
  - Kaxu Community Trust
- **Achievements**
  - 03.08.2011 Bid Window 1 announced
  - 07.11.2011 Award
  - 05.12.2012 PPA Signed and Financial Close
  - 06.12.2012 EPC Notice to proceed to EPC
  - 06.02.2015 Scheduled Commercial Operation Date
  - 06.02 2015 Achieved Commercial Operation Date
  - 02.03.2015 Inauguration with Economic Development Minister Ebrahim Patel

Kaxu and Xina Functional Principle



817.500 m2 Kaxu parabolic trough solar field





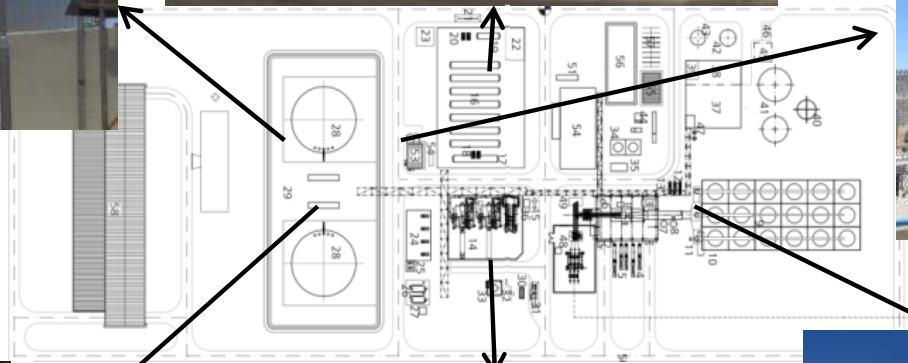
- The Kaxu solar field comprises 1.200 solar parabolic trough collectors (type E2) units.
- The collectors are grouped in 300 parallel loops of four (4) collectors each, and distributed over a surface area of 817.500 m^2
- Each loop has a length of 123,75 m and is oriented in North-South direction.

Kaxu Power Island and Storage System

Molten salt storage tanks

HTF expansion vessels

Nitrogen Tanks



Salt/HTF heat exchangers

LPG Tanks

Turbine hall and ACC

Kaxu Molten Salt Thermal Energy Storage System

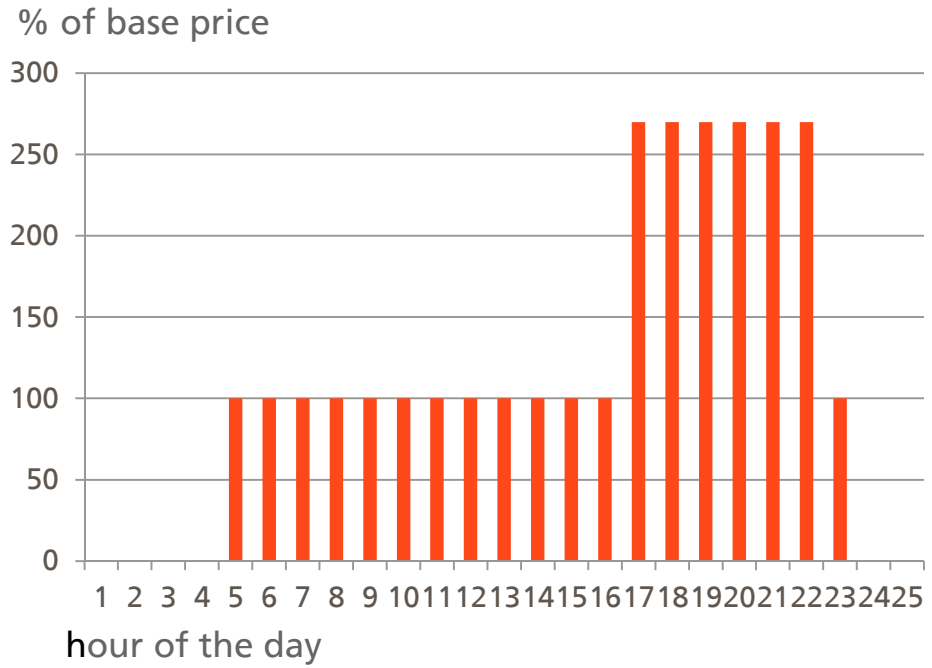
- 2,5 hours storage capacity
- 2-Tank molten salt storage
- 291ºC cold tank temperature
- 381ºC hot tank temperature
- ca. 20.000t of eutectic salt, binary mixture of $NaNO_3$ and KNO_3, with a melting temperature of 221°C

3

100MW Xina - CSP for peak times

South Africa CSP Tariff Structure from BW 3 onwards

	Time of day for Delivery of Energy Output	Percentage of Base Price payable
Standard Time:	Every day 5:00am to 4:30pm 9:30pm to 10:00pm	100% of the Base Price
Peak Time:	Every day 4:30pm to 9:30pm	270% of the Base Price
Night Time:	Every day 10:00pm to 5:00am	0% of the Base Price



- The Xina storage system has been designed to run the plant for about 5hours at full load during the PPA's Peak Time between 16:30 and 21:30h, when the tariff is 270% of the Base Price during Standard Time

Financial Close 13.3.15

- **Xina Solar One**
  - 853,306 m2 solar field in 168loops
  - 5.5 h molten 2 tank salt storage with 47,717t salt
- **South African Partners**
  - IDC Industrial Development Corporation
  - PIC Public Investment Corporation
  - Kaxu Community Trust
- **Achievements**
  - 19 Aug 2013 Bid Submission
  - 04 Nov 2013 Award
  - 12 Dec 2014 Signature PPA
  - 13 Mar 2015 Financial Close
  - 20 Mar 2015 Notice to Proceed to EPC
- **Objective**
  - 01 Aug 2017 Scheduled Com. Operation Date

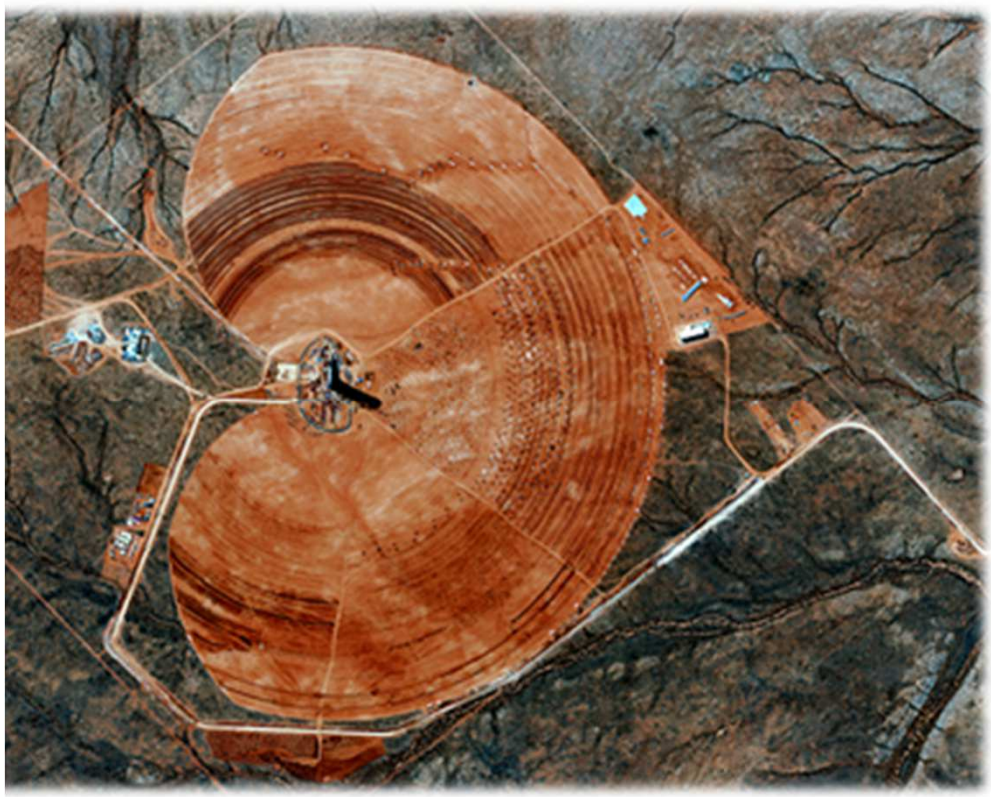
100MW Xina

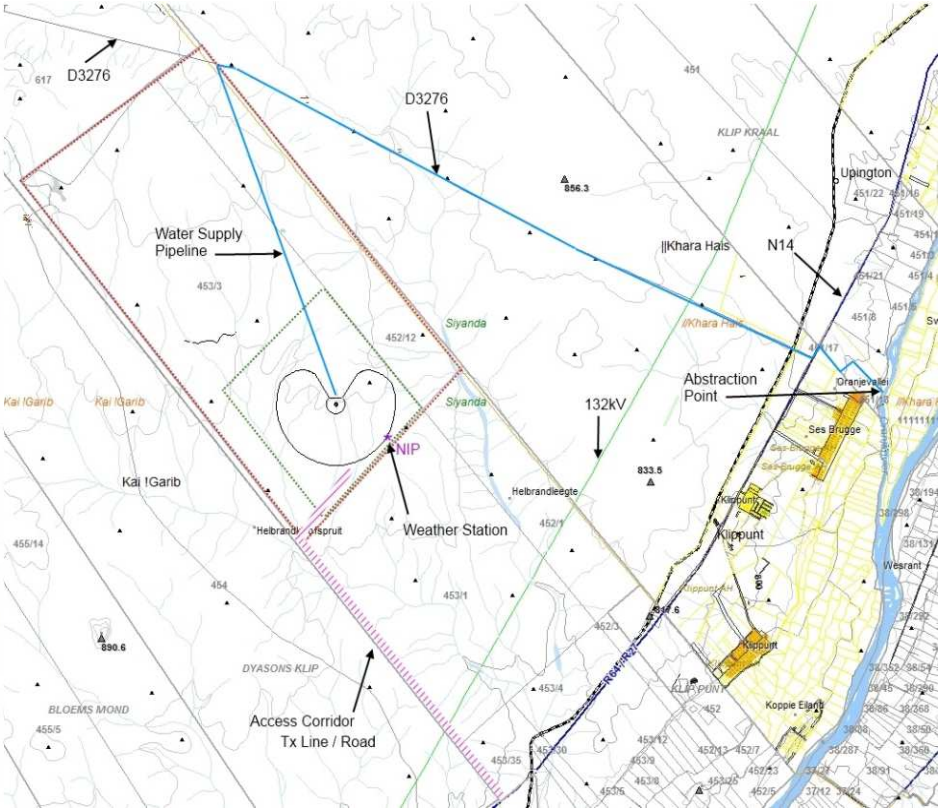
4

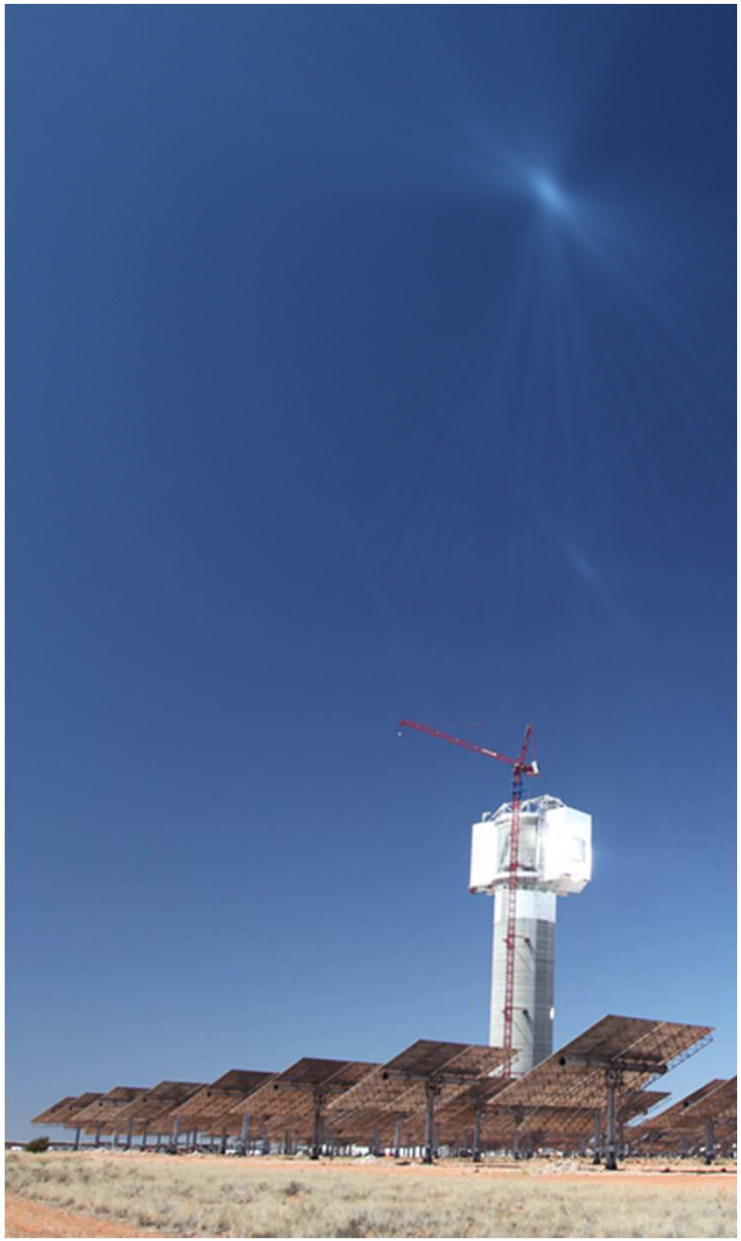
50MW Khi - first CSP tower in SA

50MW Khi started Commercial Operation 5 February 2016

Khi site location and water abstraction



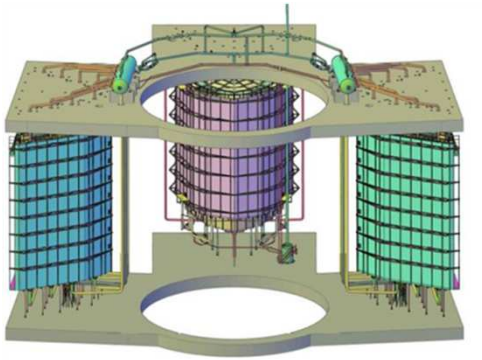


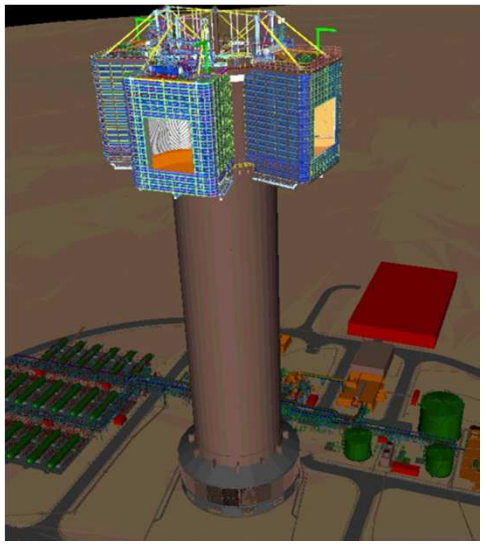


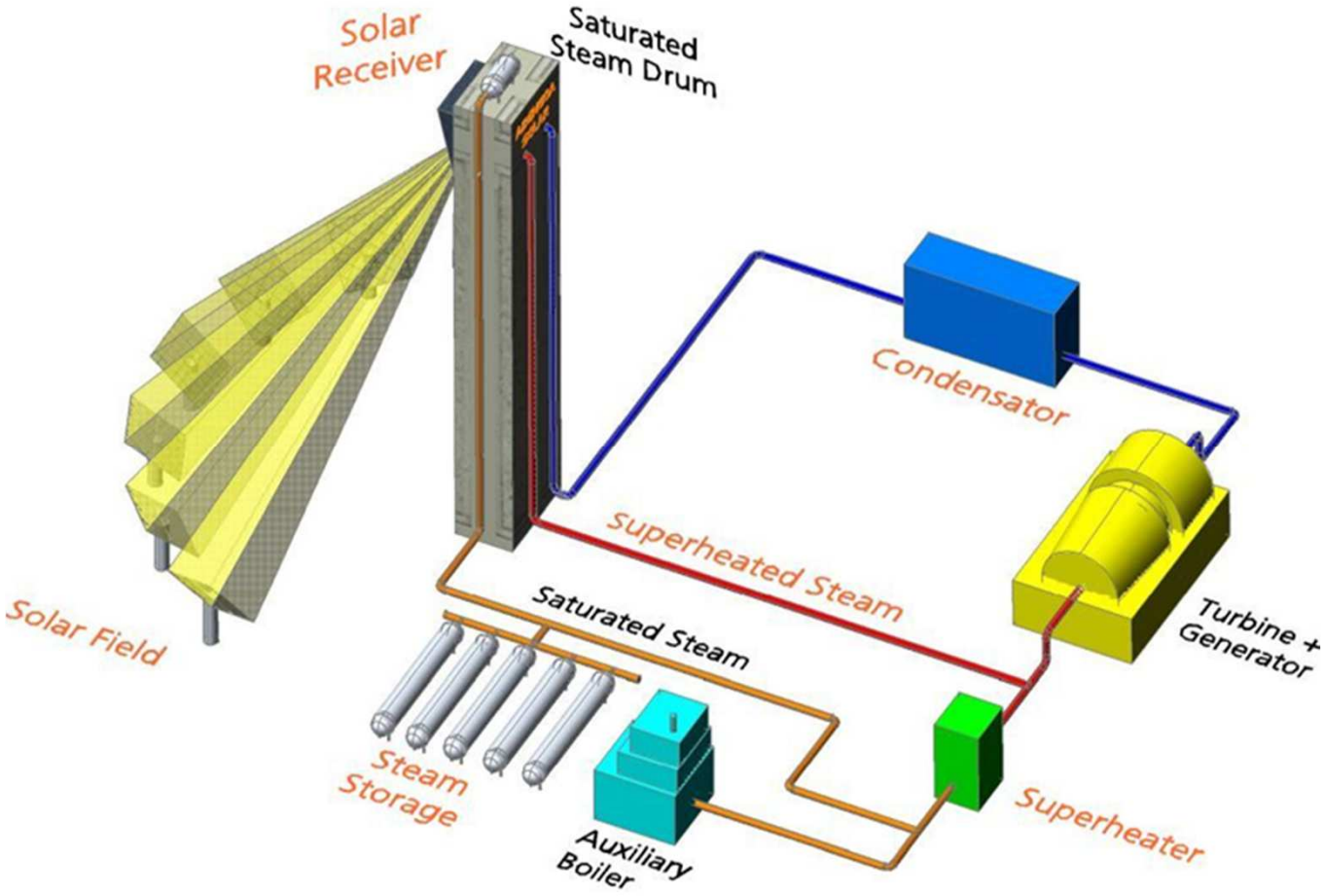
Commercial Operation 5 Feb 2016

- **Khi Solar One**
  - Capacity of 50MW and app 2.7 hours of steam storage.
  - Some 4100 heliostats, of 140m2
  - Natural Draft Cooler integrated into Solar Tower structure
- **South African Partners**
  - IDC Industrial Development Corporation
  - Khi Community Trust
- **Achievements**
  - 03.08.2011 Bid Window 1 announced
  - 07.11.2011 Award
  - 05.12.2012 PPA Signed and Financial Close
  - 06.02 2015 Achieved Commercial Operation Date

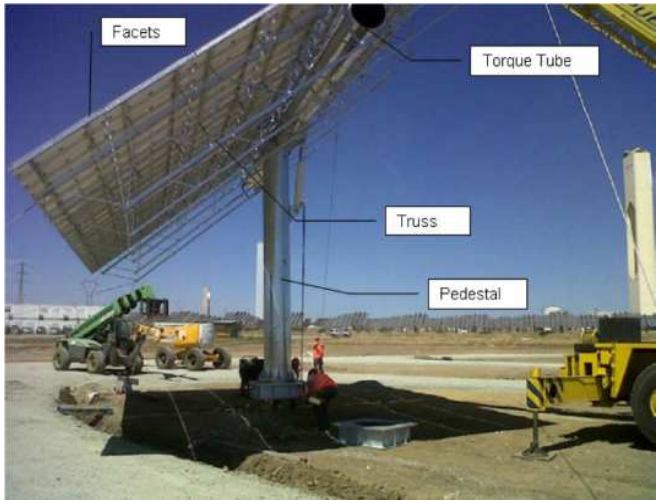
Innovative superheated steam receiver

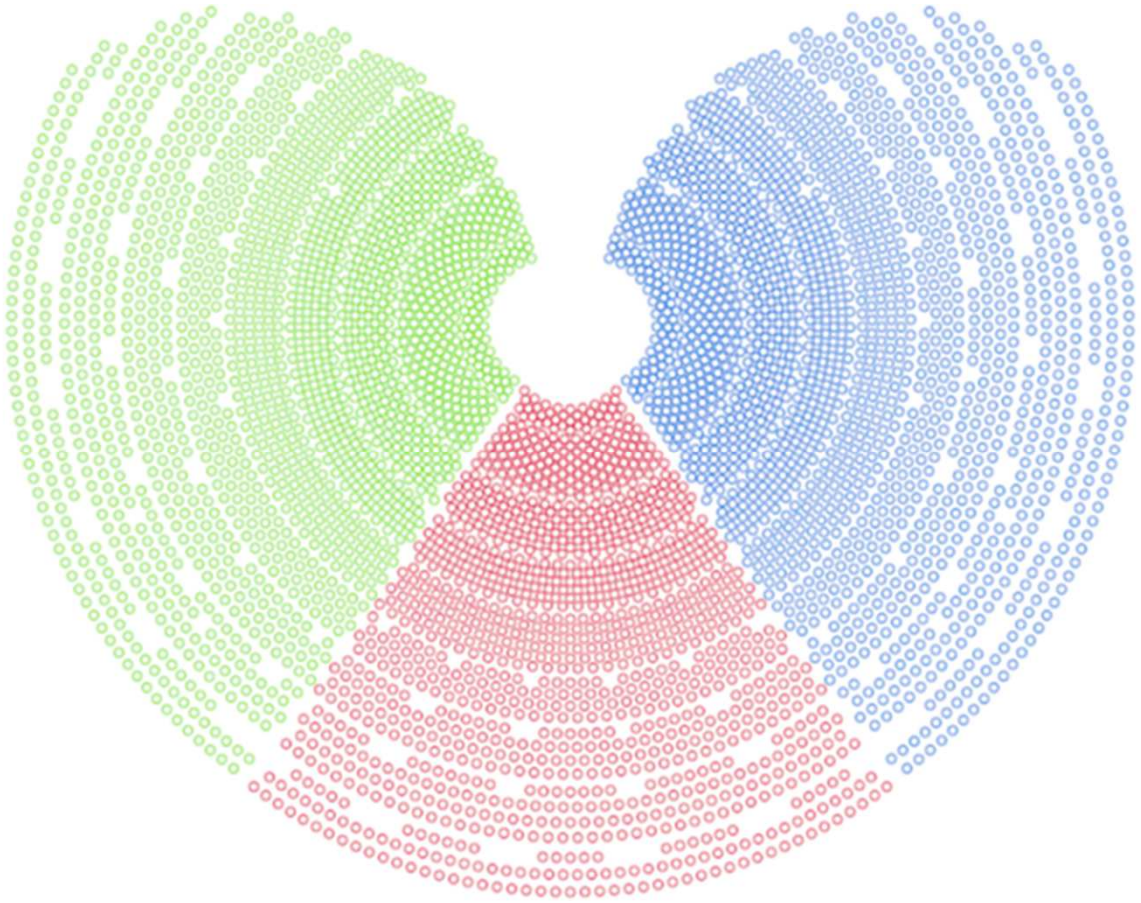






4,120 heliostats of 140 m^2 totaling 571,320 m^2

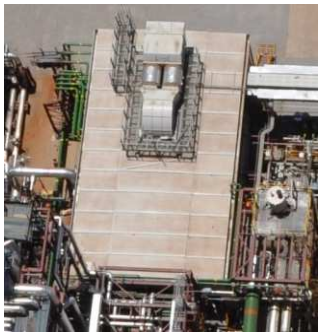




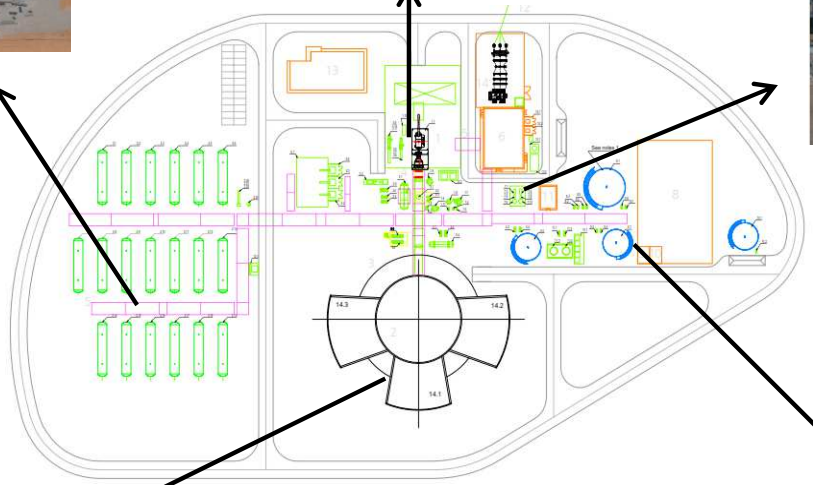
50MW Khi

Steam storage

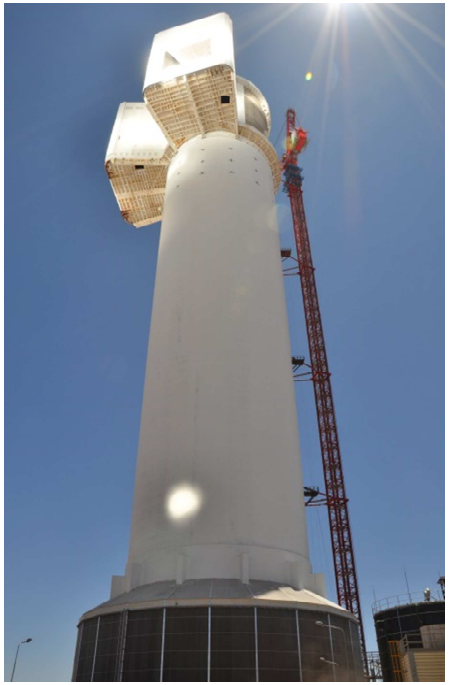
Turbine



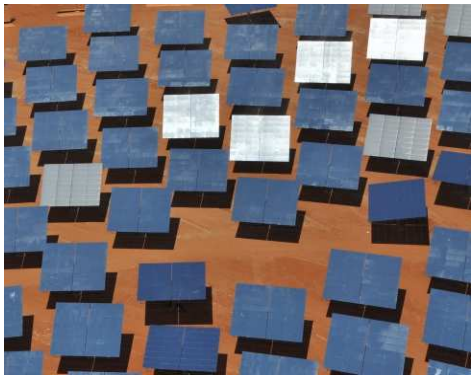
Plant substation



Water reservoir and clean up



Tower



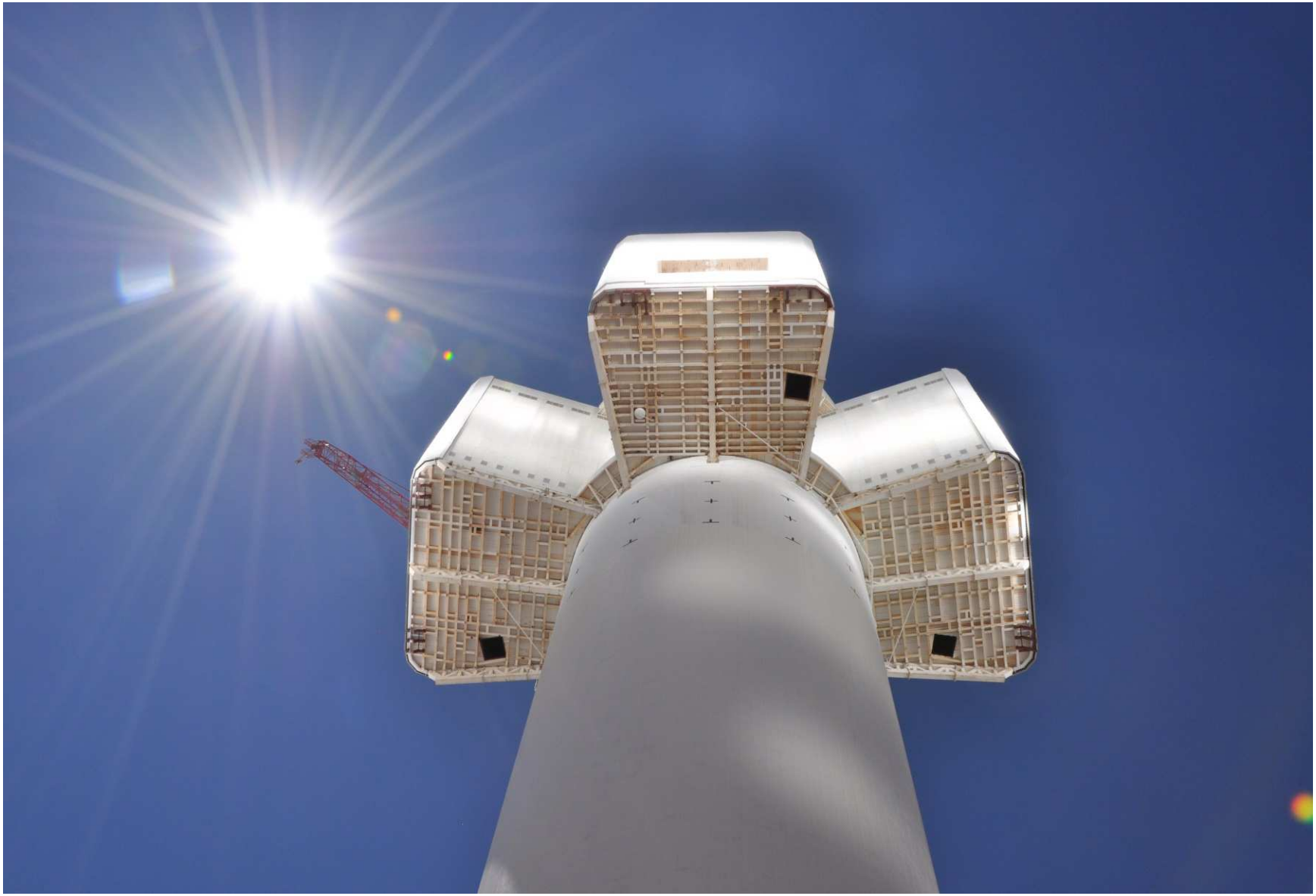
Solarfield

IDC
Industrial Development Corporation

Job Creation – What does this mean ?

- Some 1300 people are currently employed on the Khi site, 90% of which are South African citizens.
- Of the South African citizens, 1080 are non-white (app 70%).
- Of the people working on the site 804 are from the local communities – communities located within a 50km radius of the project site.
- Two specialist manufacturing facilities have targeted people from the nearby, historically disadvantaged communities. The heliostat manufacturing facility and the Rioglass mirror panel manufacturing plant have identified, trained and employed people from these communities. This accounts from some 200 positions.

50MW Khi



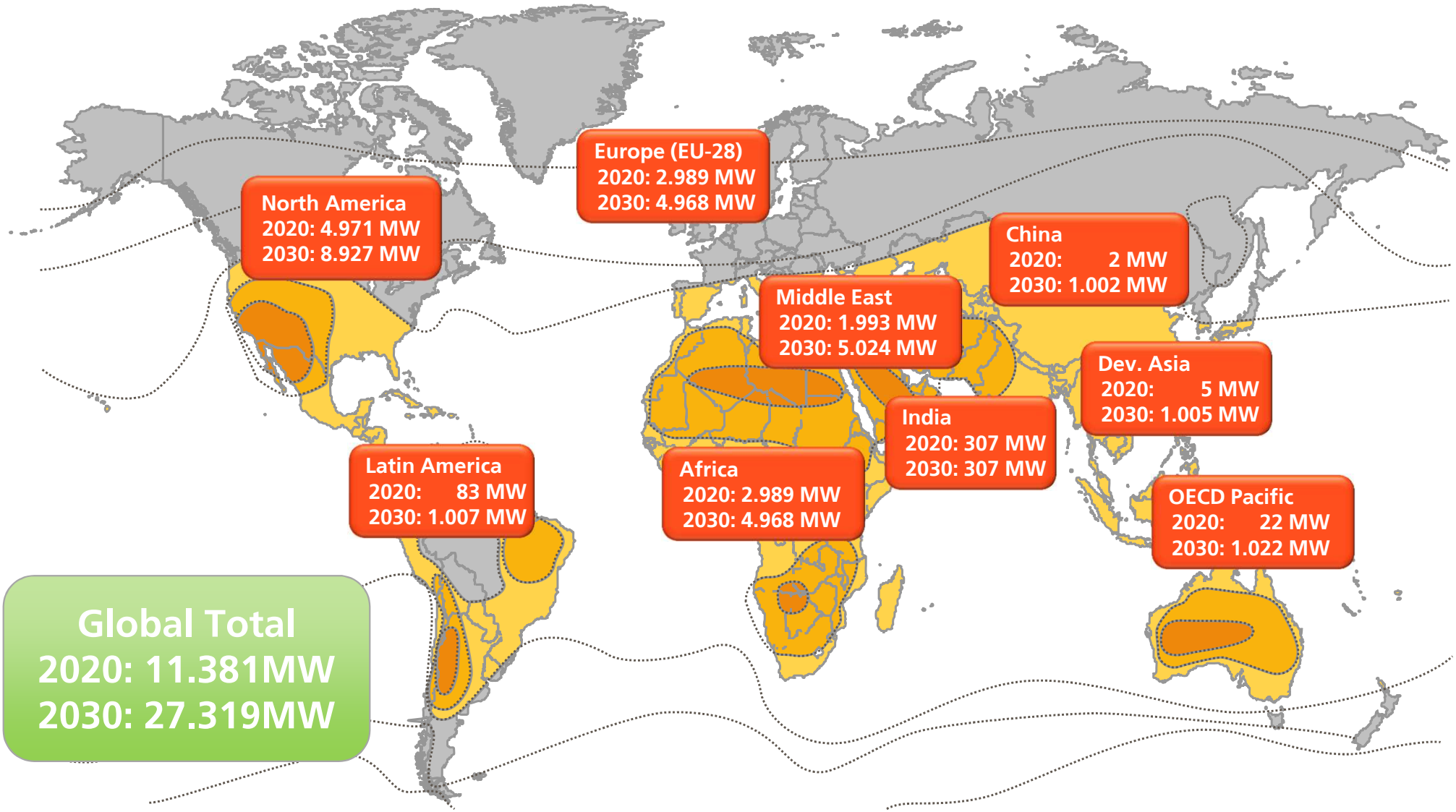
5

Next technological steps for CSP

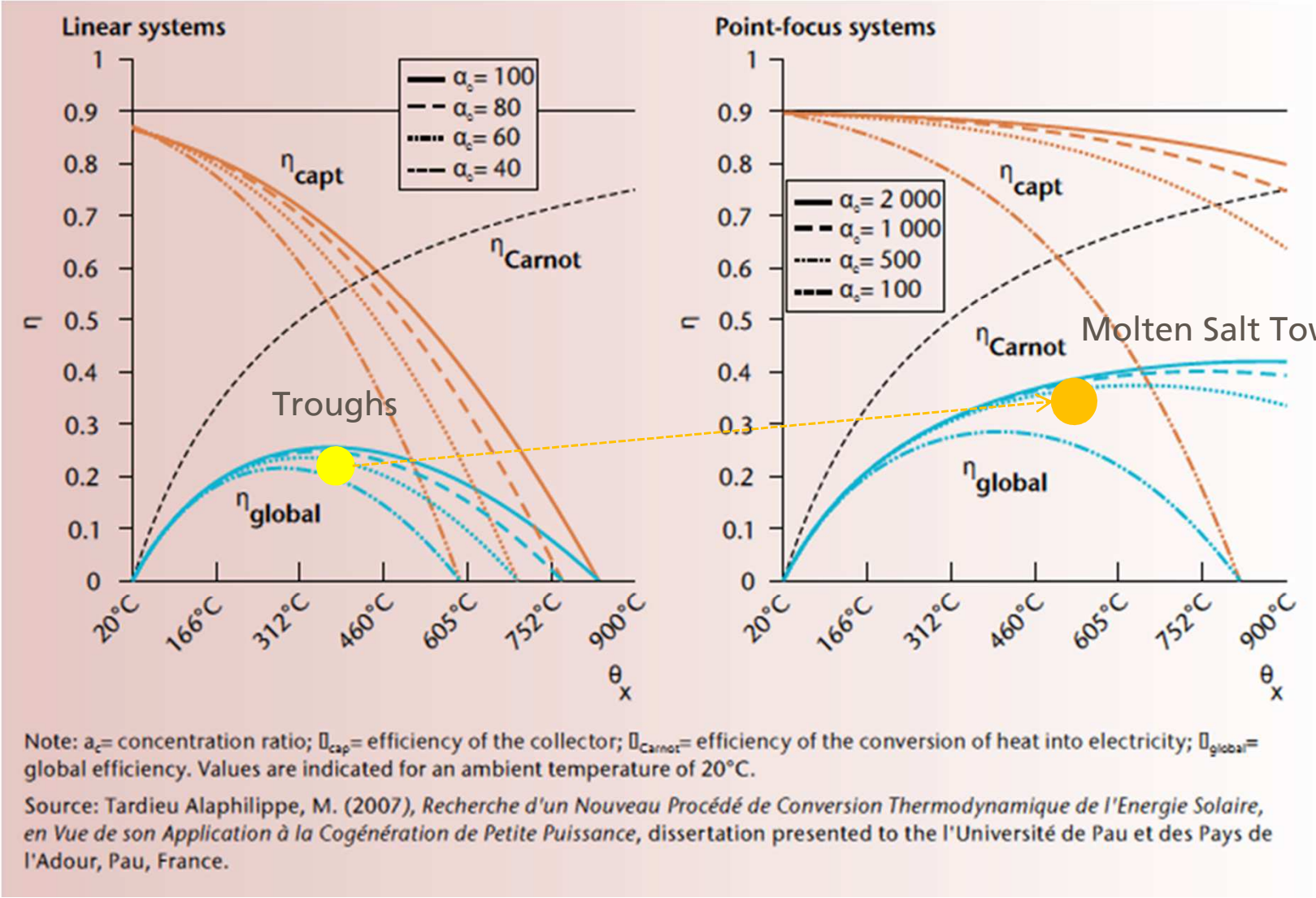
IEA Technology Roadmap Solar Thermal Electricity 2014

- Global deployment of STE today about 5GW compared with some 200 GW PV and over 430GW wind
- STE is firm and can be dispatched at the request of power grid operators, in particular when demand peaks in the late afternoon/evening, while PV generation is at its best in the middle of the day.
- IEA predicts that the value of STE will increase further as PV is deployed in large amounts, which shaves midday peaks and creating or beefing up evening and early morning peaks.
- Combined with long lead times deployment of CSP plants would remain slow in the next ten years compared with previous expectations.
- Deployment would increase rapidly after 2020 when STE becomes competitive for peak and mid-merit power in a carbon-constrained world, ranging from 30 GW to 40 GW of new-built plants per year after 2030.
- Adding STE to PV, solar power could provide up to 27% of global electricity by 2050, and become the leading source of electricity globally as early as 2040.
- IEA's 2014 roadmap's vision is 1 000 GW of installed CSP capacity by 2050 – an 11% (almost unchanged from the goal in IEA's 2010 roadmap)

Outlook for cumulative installed capacity of STE per region



Increase Cycle Temperature and Concentration



Note: a_c= concentration ratio; η_{cap}= efficiency of the collector; η_{Carnot}= efficiency of the conversion of heat into electricity; η_{global}= global efficiency. Values are indicated for an ambient temperature of 20°C.

Source: Tardieu Alaphilippe, M. (2007), *Recherche d'un Nouveau Procédé de Conversion Thermodynamique de l'Energie Solaire, en Vue de son Application à la Cogénération de Petite Puissance*, dissertation presented to the l'Université de Pau et des Pays de l'Adour, Pau, France.

Thank You for Your Attention!

Any Questions?