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SOLAR THERMAL ENERGY RESEARCH GROUP

Increasing performance & reducing cost

CSP today

9 April, 2014 – Cape Town

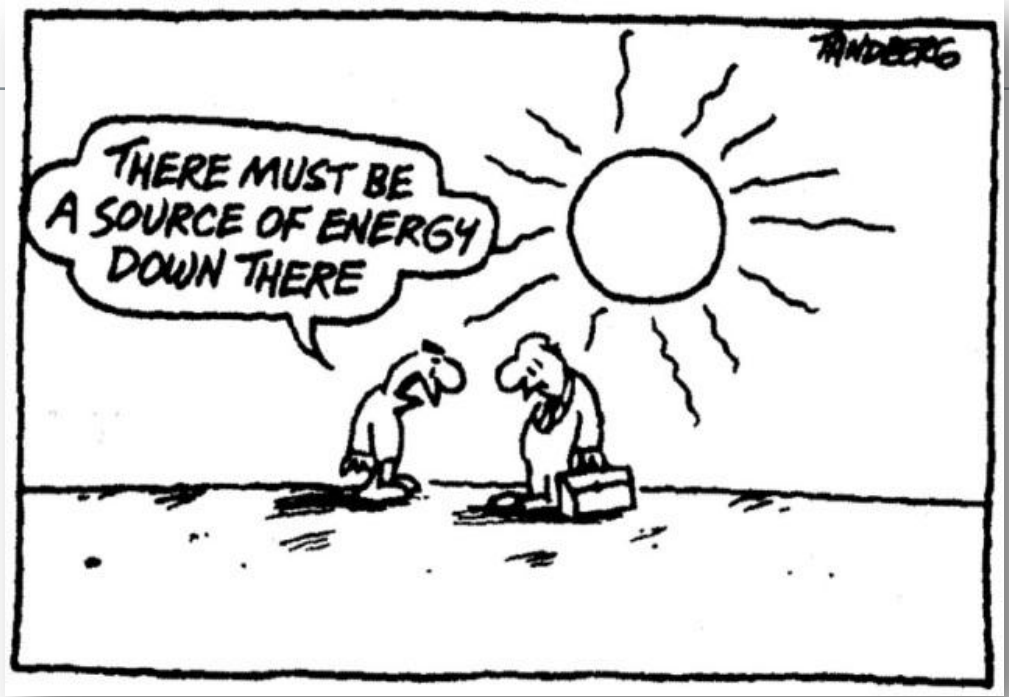
Paul Gauché

Solar Thermal Energy Research Group (STERG) – Stellenbosch University

Contributors: Christina Auret (Eskom), Sebastian Giglmayr (Technikum Wien), Cebo Silinga (CRSES), Sol Luca de Tena (CTAER), others…

Agenda

- **Set the stage – where we are today**
- **How to add 3+ GW of CSP now and save money**
- **STERG is positioned to help**



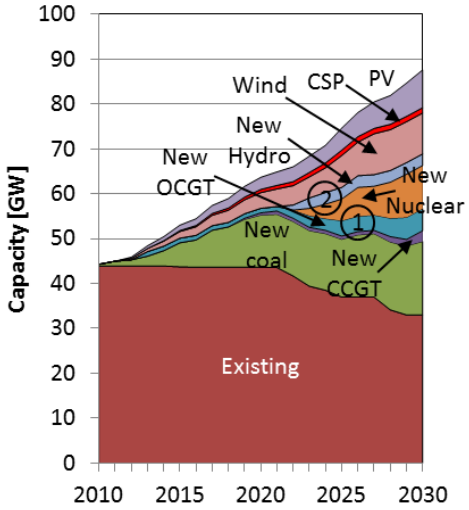
Ron Tandberg, Australian cartoonist

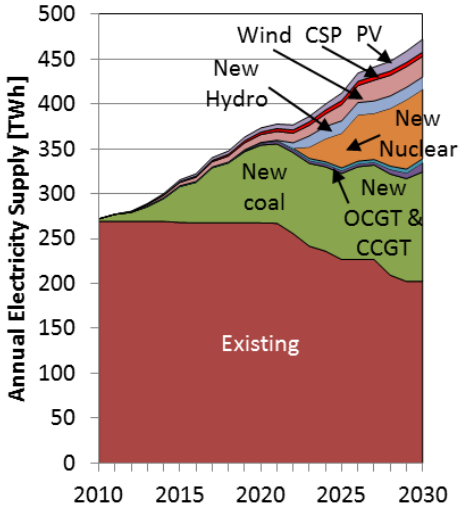
Where we are today

SET THE STAGE

IRP & REIPPPP

- IRP: Integrated Resource Plan 2010 – 2030
- REIPPPP: Renewable Energy Independent Power Producers Procurement Program
  - Implementation of IRP
  - Current round change: 2-tariff for CSP



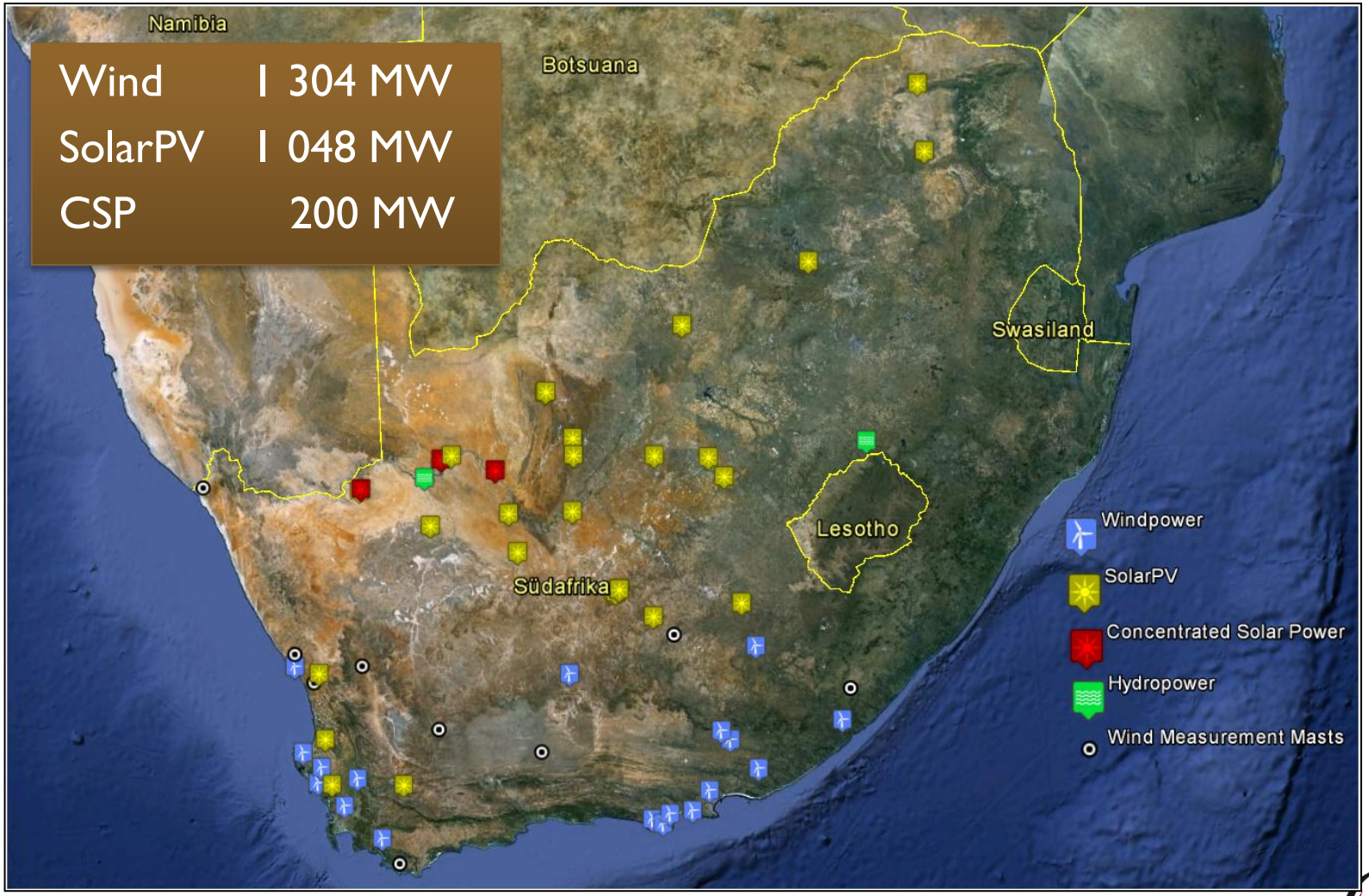


Round 3	No of Bids	MW taken by Preferred Bidders	Maximum MW allocated for Bid Window 3
Solar photovoltaic	6	435	401
Wind	7	787	654
Concentrated solar	2	200	200

		Bid Window 3	Bid Window 2	Bid Window 1
CSP	Price: Fully Indexed (Ave Rand per MWh) (Base Apr '11)	R 1 460*	R 2 512	R 2 686
PV	Price: Fully Indexed (Ave Rand per MWh) (Base Apr '11)	R 881	R 1 645	R 2 758

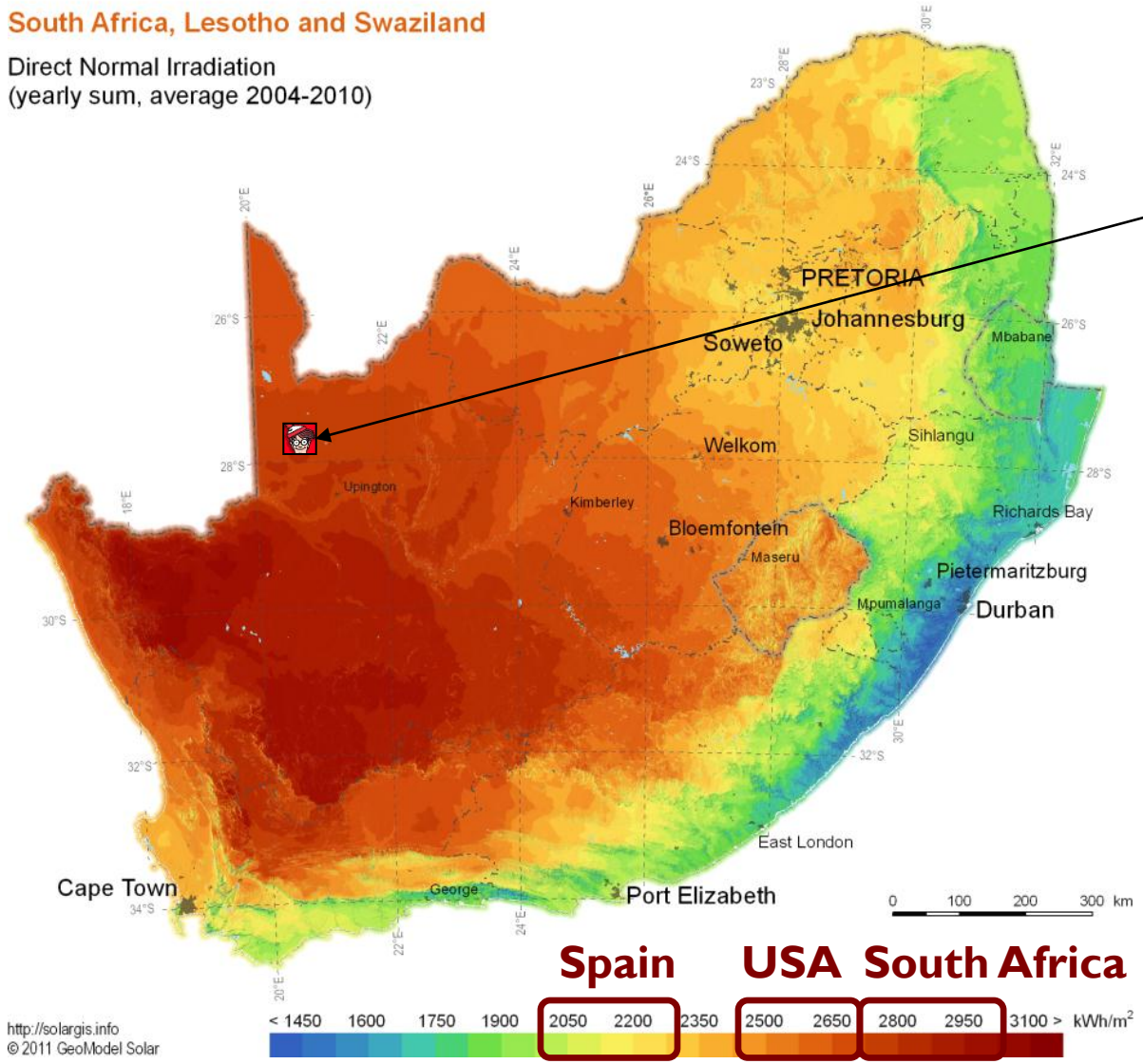
R10.00 ~ $1.00 * plus 270% multiplier 4:30pm – 9:30pm

REIPPPP Rounds 1 & 2



Wind	1 304 MW
SolarPV	1 048 MW
CSP	200 MW

Where's Waldo? Space for 2010 national electricity demand by solar electricity



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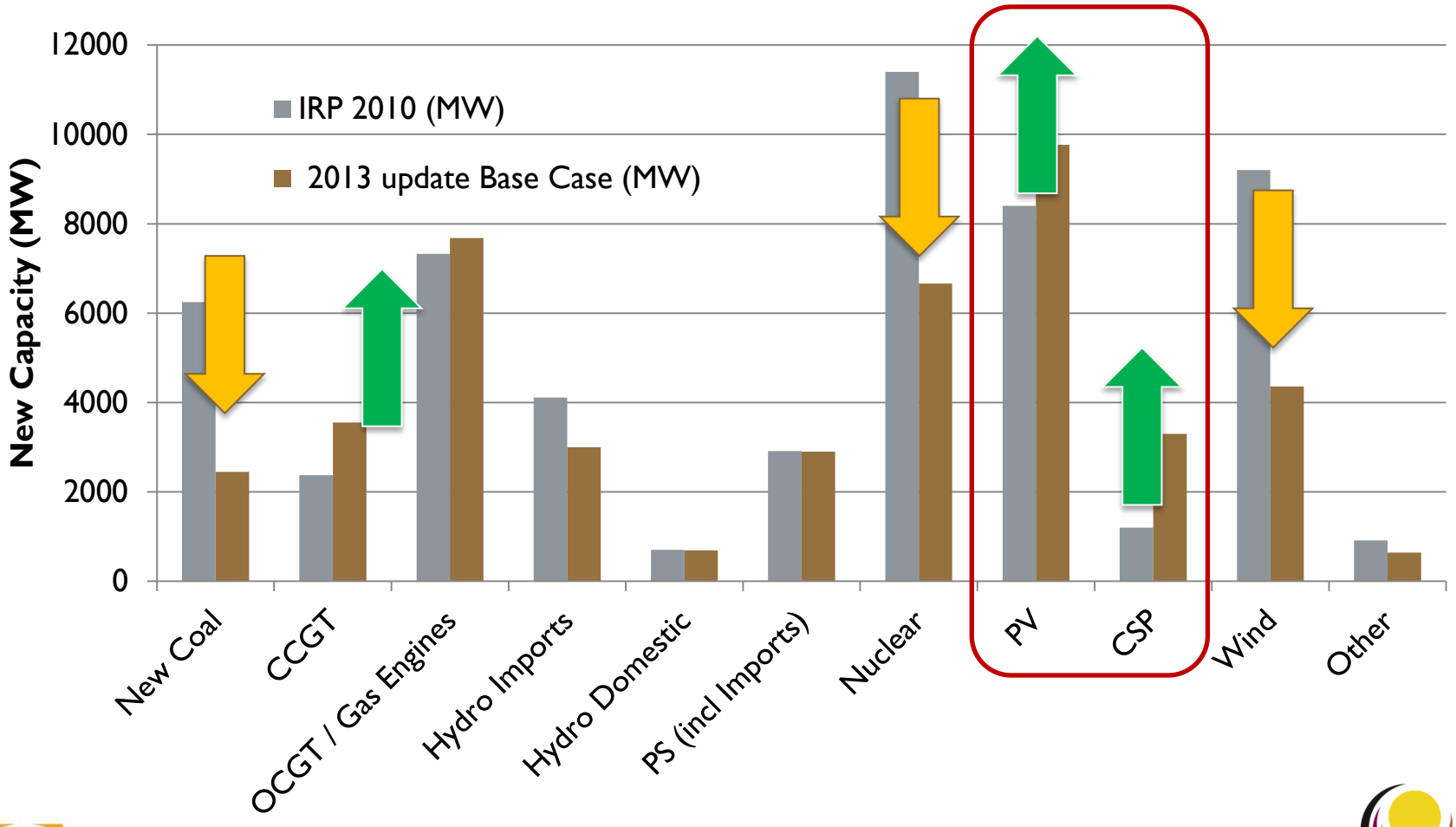
Draft IRP Update



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Cost of capital

By Lucy Woods - 28 January 2014, 09:17 | In News, Power Generation, Finance

Bill Clinton calls for global fund to reform 'unequal' energy finance

As an alternative to current finance mechanisms Clinton suggested "a global financing facility" for renewable energy similar to the 'Global Fund'. Image: World Economic Forum

Former US president Bill Clinton has called for global investment in renewable energy and changes to the "inequality" of current financing mechanisms in the energy sector.

At the ThomasLloyd Clean Tech Congress Europe in Frankfurt last week, Clinton highlighted long-term finance options is "what we do with traditional energy and coal fire power plants", whereas currently investors and providers of solar and wind have to provide "all the money upfront".

Clinton argued that no one has "explained to people adequately" that there is "inequality in financing opportunities" for renewable energy and energy efficiency projects.

At the forum for European investors on 24 January, titled 'Meet Asia. Meet renewable energy's future', Clinton told investors an "analytical and actual financing framework" enabling capital investment in clean energy and efficiency should be financed over "the life of the benefits".

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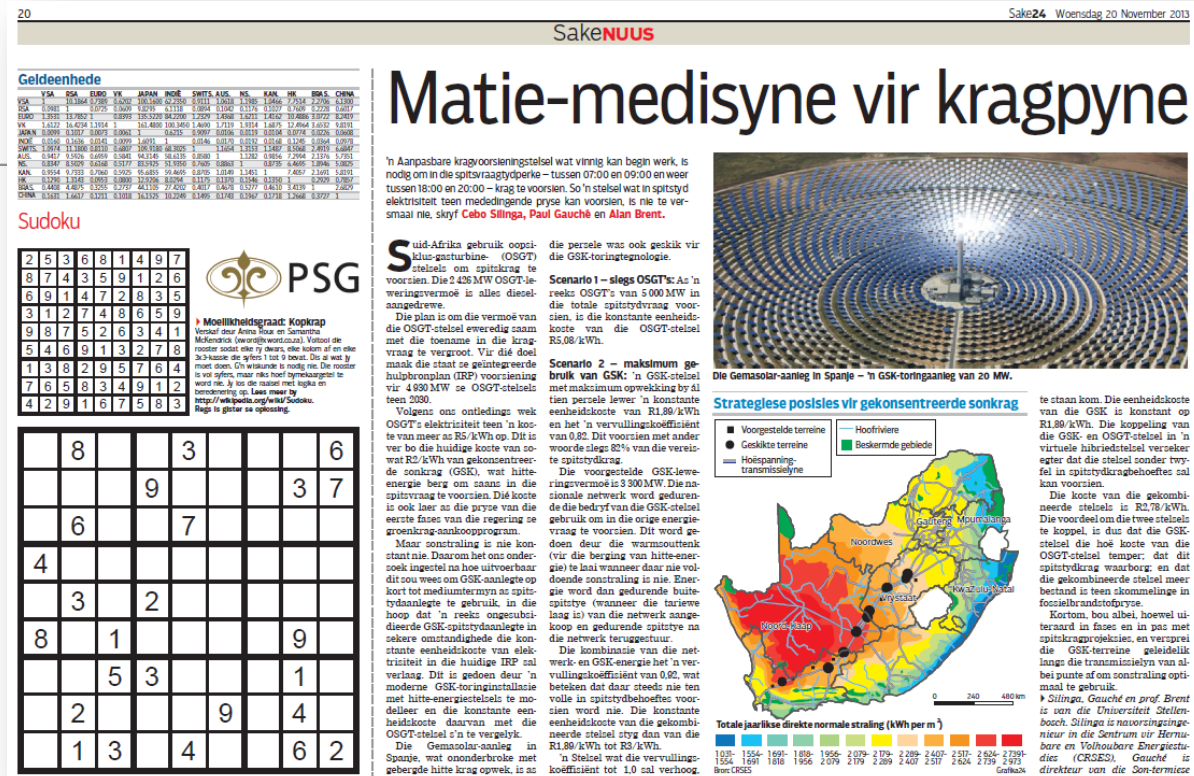

SakeNUUS

Geldeenhede

	VSA	RSA	EURO	VK	JAPAN	INDIË	SWITS.	AUS.	NS.	KAN.	HK	BRAS.	CHINA
VSA	1	10.1864	0.7389	0.6202	100.1600	62.2350	0.9111	1.0618	1.1985	1.0466	7.7514	2.2706	6.1300
RSA	0.0981	1	0.0725	0.0609	9.8295	6.1118	0.0894	0.1042	0.1176	0.1027	0.7609	0.2228	0.6017
EURO	1.3531	13.7852	1	0.8393	135.5220	84.2200	1.2329	1.4368	1.6211	1.4162	10.4886	3.0722	8.2419
VK	1.6122	16.4234	1.1914	1	161.4800	100.3450	1.4690	1.7119	1.9314	1.6875	12.4964	3.6532	9.8191
JAPAN	0.0099	0.1017	0.0073	0.0061	1	0.6215	0.9097	0.0106	0.0119	0.0104	0.0774	0.0226	0.0608
INDIË	0.0160	0.1636	0.0141	0.0099	1.6091	1	0.0146	0.0170	0.0192	0.0168	0.1245	0.0364	0.0978
SWITS.	1.0974	11.1800	0.8110	0.6807	109.9180	68.3025	1	1.1654	1.3153	1.1487	8.5068	2.4919	6.6847
AUS.	0.9417	9.5926	0.6959	0.5841	94.3145	58.6135	0.8580	1	1.1282	0.9856	7.2994	2.1376	5.7351
NS.	0.8347	8.5029	0.6168	0.5177	83.5925	51.9350	0.7605	0.8863	1	0.8735	6.4695	1.8946	5.0825
KAN.	0.9554	9.7333	0.7060	0.5925	95.6855	59.4695	0.8705	1.0149	1.1451	1	7.4057	2.1691	5.8191
HK	0.1290	1.3143	0.0953	0.0800	12.9206	8.0294	0.1175	0.1370	0.1546	0.1350	1	0.2929	0.7857
BRAS.	0.4408	4.4875	0.3255	0.2737	44.1105	27.4202	0.4017	0.4678	0.5277	0.4610	3.4139	1	2.6829
CHINA	0.1631	1.6617	0.1211	0.1018	16.1525	10.2249	0.1495	0.1743	0.1967	0.1718	1.2668	0.3727	1

Sudoku

2	5	3	6	8	1	4	9	7
8	7	4	3	5	9	1	2	6
6	9	1	4	7	2	8	3	5
3	1	2	7	4	8	6	5	9
9	8	7	5	2	6	3	4	1
5	4	6	9	1	3	2	7	8
1	3	8	2	9	5	7	6	4
7	6	5	8	3	4	9	1	2
4	2	9	1	6	7	5	8	3

Moeilikheidsgraad: Kopkrap
Verskaf deur Anina Roux en Samantha McKendrick (xword@xword.co.za). Voltooi die rooster sodat elke ry dwars, elke kolom af en elke 3x3-kassie die syfers 1 tot 9 bevat. Dis al wat jy moet doen. G'n wiskunde is nodig nie. Die rooster is vol syfers, maar niks hoef bymekaargetel te word nie. Jy los die raaisel met logika en beredenering op. **Lees meer by http://wikipedia.org/wiki/Sudoku. Regs is gister se oplossing.**

	8			3				6
			9				3	7
	6			7				
4								
	3		2					
8		1					9	
		5	3				1	
	2				9		4	
	1	3		4			6	2

Matie-medisyne vir kragpyne

'n Aanpasbare kragvoorsieningstelsel wat vinnig kan begin werk, is nodig om in die spitsvraagtydperke – tussen 07:00 en 09:00 en weer tussen 18:00 en 20:00 – krag te voorsien. So 'n stelsel wat in spitstyd elektrisiteit teen mededingende pryse kan voorsien, is nie te versmaai nie, skryf **Cebo Silinga, Paul Gauché** en **Alan Brent.**

Suid-Afrika gebruik oopsiklus-gasturbine- (OSGT) stelsels om spitskrag te voorsien. Die 2 426 MW OSGT-leweringsvermoë is alles dieselaangedrewe.

Die plan is om die vermoë van die OSGT-stelsel eweredig saam met die toename in die kragvraag te vergroot. Vir dié doel maak die staat se geïntegreerde hulpbronplan (IRP) voorsiening vir 4 930 MW se OSGT-stelsels teen 2030.

Volgens ons ontledings wek OSGT's elektrisiteit teen 'n koste van meer as R5/kWh op. Dit is ver bo die huidige koste van sowat R2/kWh van gekonsentreerde sonkrag (GSK), wat hitte-energie berg om saans in die spitsvraag te voorsien. Dié koste is ook laer as die pryse van die eerste fases van die regering se groenkrag-aankoopprogram.

Maar sonstraling is nie konstant nie. Daarom het ons ondersoek ingestel na hoe uitvoerbaar dit sou wees om GSK-aanlegte op kort tot mediumtermyn as spitstydaanlegte te gebruik, in die hoop dat 'n reeks ongesubsidieerde GSK-spitstydaanlegte in sekere omstandighede die konstante eenheidskoste van elektrisiteit in die huidige IRP sal verlaag. Dit is gedoen deur 'n moderne GSK-toringinstallasie met hitte-energiestelsels te modelleer en die konstante eenheidskoste daarvan met die OSGT-stelsel s'n te vergelyk.

Die Gemasolar-aanleg in Spanje, wat ononderbroke met gebergde hitte krag opwek, is as 'n verwysingsaanleg gebruik om die persele was ook geskik vir die GSK-toringtegnologie.

Scenario 1 – slegs OSGT's: As 'n reeks OSGT's van 5 000 MW in die totale spitstydvraag voorsien, is die konstante eenheidskoste van die OSGT-stelsel R5,08/kWh.

Scenario 2 – maksimum gebruik van GSK: 'n GSK-stelsel met maksimum opwekking by ál tien persele lewer 'n konstante eenheidskoste van R1,89/kWh en het 'n vervullingskoëffisiënt van 0,82. Dit voorsien met ander woorde slegs 82% van die vereiste spitstydkrag.

Die voorgestelde GSK-leweringsvermoë is 3 300 MW. Die nasionale netwerk word gedurende die bedryf van die GSK-stelsel gebruik om in die orige energievraag te voorsien. Dit word gedoen deur die warmsouttenk (vir die berging van hitte-energie) te laai wanneer daar nie voldoende sonstraling is nie. Energie word dan gedurende buitespitstye (wanneer die tariewe laag is) van die netwerk aangekoop en gedurende spitstye na die netwerk teruggestuur.

Die kombinasie van die netwerk- en GSK-energie het 'n vervullingskoëffisiënt van 0,92, wat beteken dat daar steeds nie ten volle in spitstydbehoeftes voorsien word nie. Die konstante eenheidskoste van die gekombineerde stelsel styg dan van die R1,89/kWh tot R3/kWh.

'n Stelsel wat die vervullingskoëffisiënt tot 1,0 sal verhoog, sal veel duurder wees. As alter-

Die Gemasolar-aanleg in Spanje – 'n GSK-toringaanleg van 20 MW.

Strategiese posisies vir gekonsentreerde sonkrag

Voorgestelde terreine
Geskikte terreine
Hoëspanning-transmissielyne
Hoofriviere
Beskermde gebiede
Gauteng
Mpumalanga
Noordwes
KwaZulu-Natal
Vrystaat
Noord-Kaap
0 240 480 km

Totale jaarlikse direkte normale straling (kWh per m²)

1031-1554 | 1554-1691 | 1691-1818 | 1818-1956 | 1956-2079 | 2079-2179 | 2179-2289 | 2289-2407 | 2407-2517 | 2517-2624 | 2624-2739 | 2739[1]-2973

Bron: CRSES Grafika24

te staan kom. Die eenheidskoste van die GSK is konstant op R1,89/kWh. Die koppeling van die GSK- en OSGT-stelsel in 'n virtuele hibriedstelsel verseker egter dat die stelsel sonder twyfel in spitstydkragbehoeftes sal kan voorsien.

Die koste van die gekombineerde stelsels is R2,78/kWh. Die voordeel om die twee stelsels te koppel, is dus dat die GSK-stelsel die hoë koste van die OSGT-stelsel temper; dat dit spitstydkrag waarborg; en dat die gekombineerde stelsel meer bestand is teen skommelinge in fossielbrandstofpryse.

Kortom, bou albei, hoewel uiteraard in fases en in pas met spitskragprojeksies, en versprei die GSK-terreine geleidelik langs die transmissielyn van albei punte af om sonstraling optimaal te gebruik.

Silinga, Gauché en prof. Brent is van die Universiteit Stellenbosch. Silinga is navorsingsingenieur in die Sentrum vir Hernubare en Volhoubare Energiestudies (CRSES), Gauché is direkteur van die Son-termiese Energienavorsingsgroep (Stera).

The value of CSP looking at various measures

HOW TO ADD 3+ GW OF CSP NOW AND SAVE MONEY

SOLAR THERMAL ENERGY RESEARCH GROUP

Spatial-temporal systems analysis

- We develop and use fundamental technical models
  - Conventionals (Coal, Nuclear, OCGT, etc)
  - Pumped storage
  - Renewables (Wind, PV, CSP)
- Our analysis goal is good accuracy in the system
  - Technology + Location + Time (Resource, Demand, Price)
- Our objective is lowest cost + secure + flexible system
- Our primary partner is a leader in their field

GeoModel SOLAR

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Scenarios for a South African peaking CSP system in the short term

C. Silinga[b], P. Gauché[a]

[a]Solar Thermal Energy Research Group (STERG), University of Stellenbosch

[b]Centre for Renewable and Sustainable Energy Studies (CRSES), University of Stellenbosch

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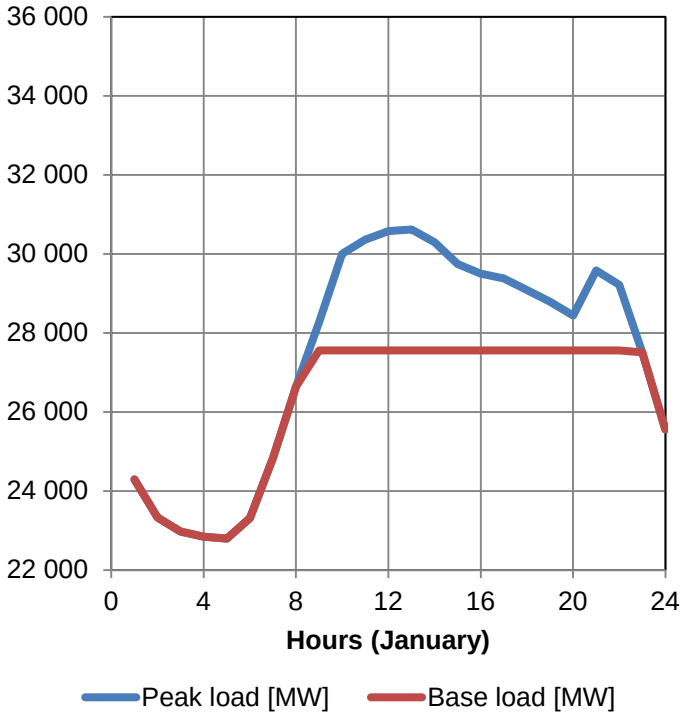
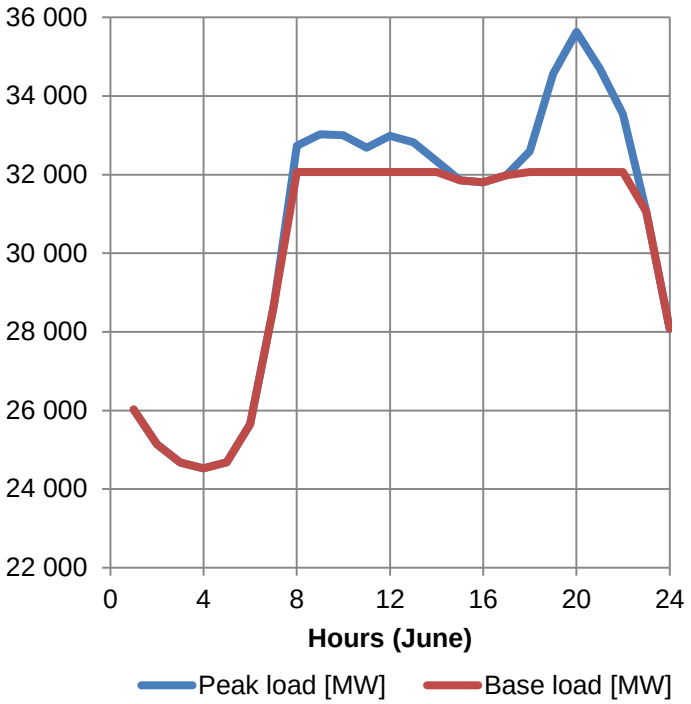
Load demand

- Take 90% of the maximum hourly demand in each day as the daily baseload limit





National load demand data: Eskom, 2010

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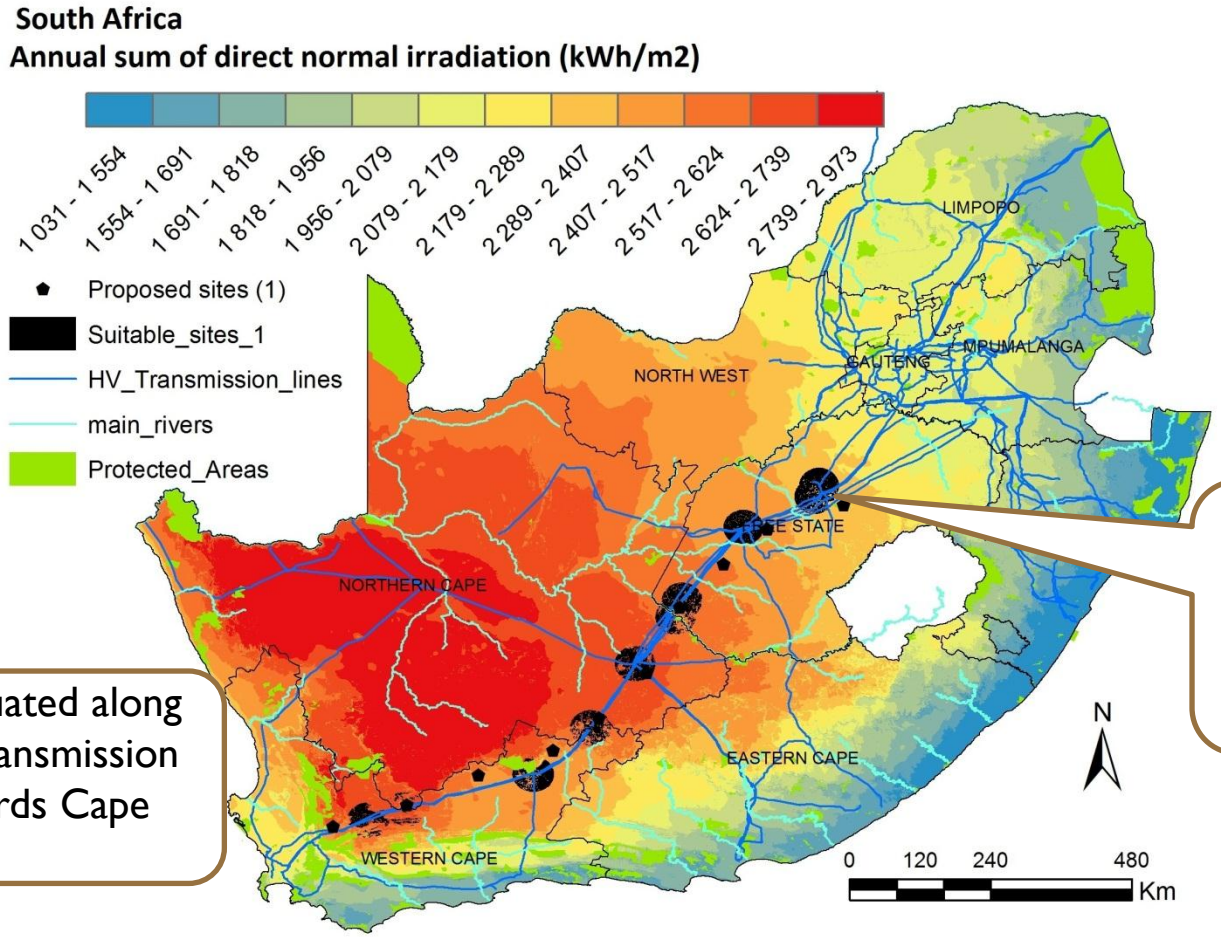
CSP scenario: peaking power fuel saver



Site average DNI: 2,636.43 kWh/m2/a

Proposed sites : situated along the high capacity transmission line running towards Cape Town

Solar data – SolarGIS data © 2012 GeoModel Solar s.r.o.
Grid infrastructure GIS data, Eskom, 2011

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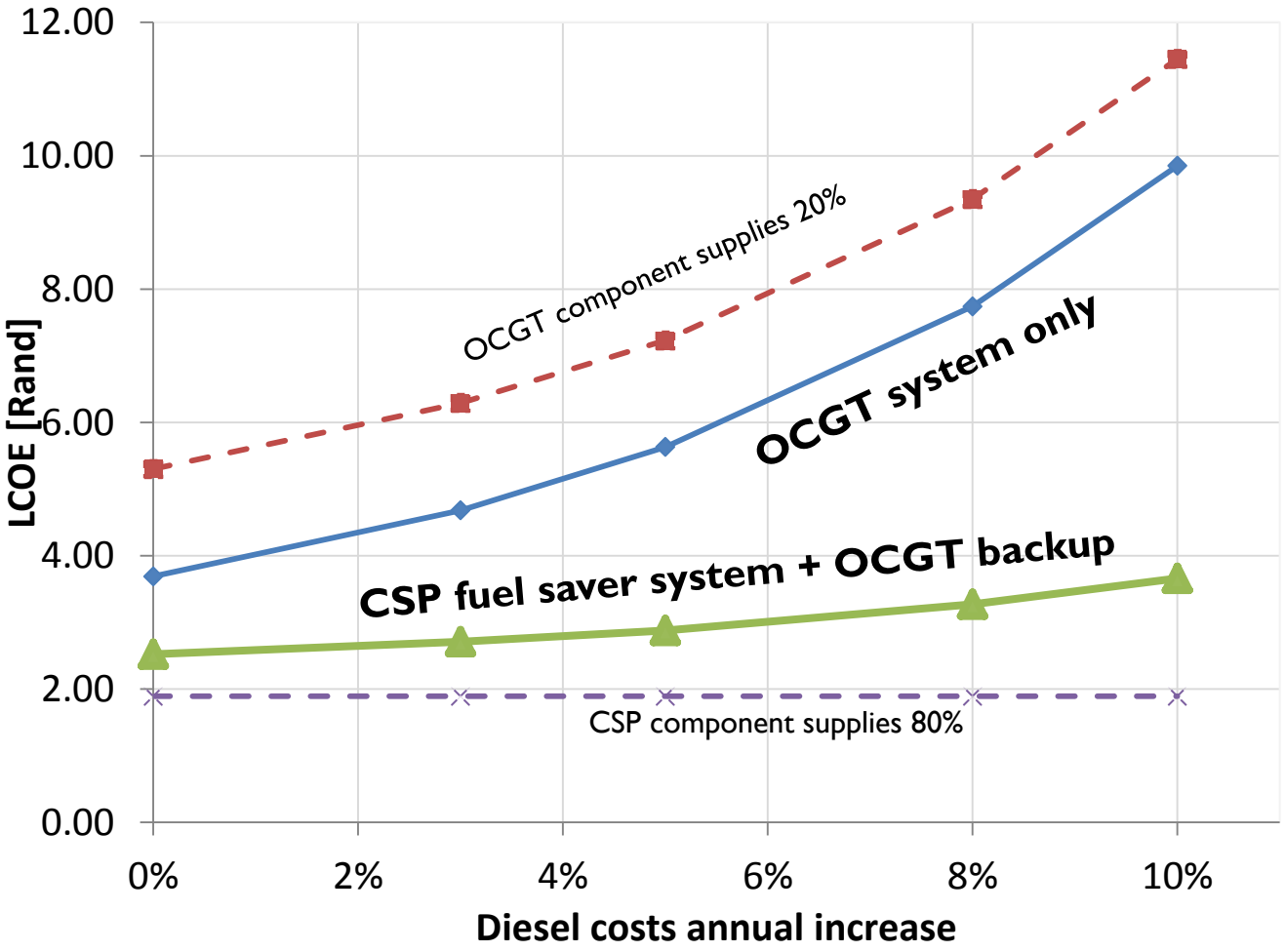
3.3 GW CSP + 5 GW* OCGT < 5 GW OCGT

Updated



2014 Diesel wholesale (~R13.30/l)

*We have not optimised this yet

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Effect of PV and CSP on coal fired power station capacity factors

C. Auret[a] & P. Gauché [b]

[a]Eskom Specialization Centre in Renewable Energy at Stellenbosch University

[b]Solar Thermal Energy Research Group (STERG), University of Stellenbosch

Second Southern African Solar Energy Conference
SASEC 2014
27-29 January 2014, Port Elizabeth, South Africa

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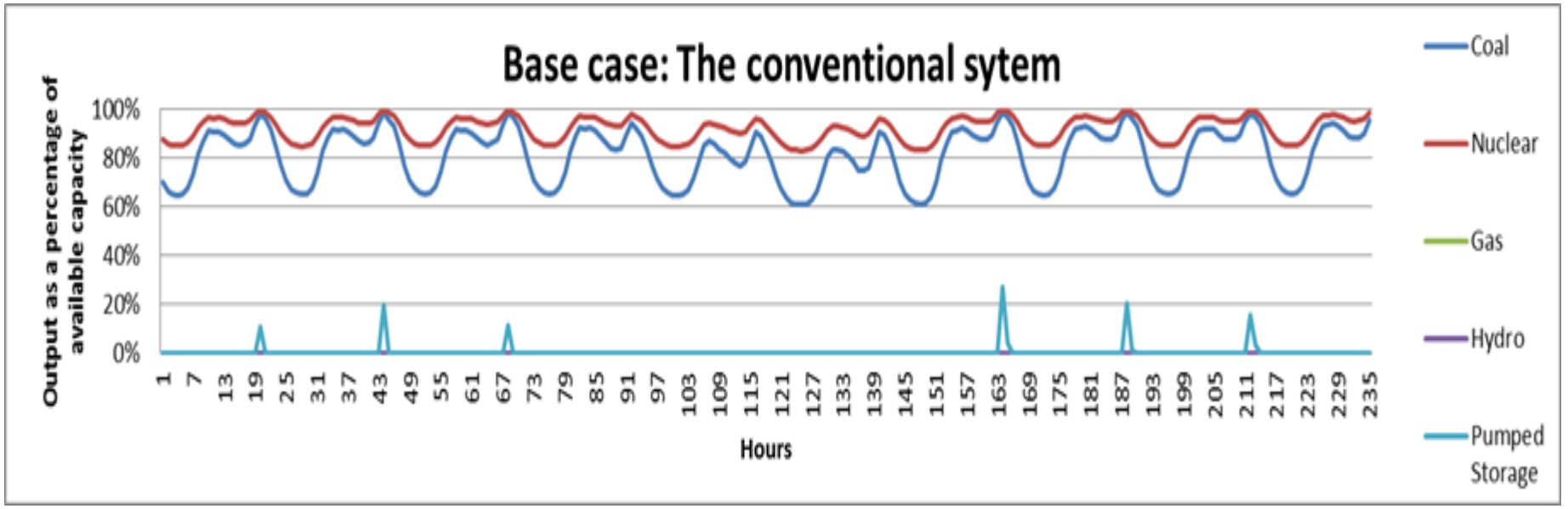
Conventional System



- Model maintains a 15% reserve margin
- No outages deferred
- Low use of peaking plant

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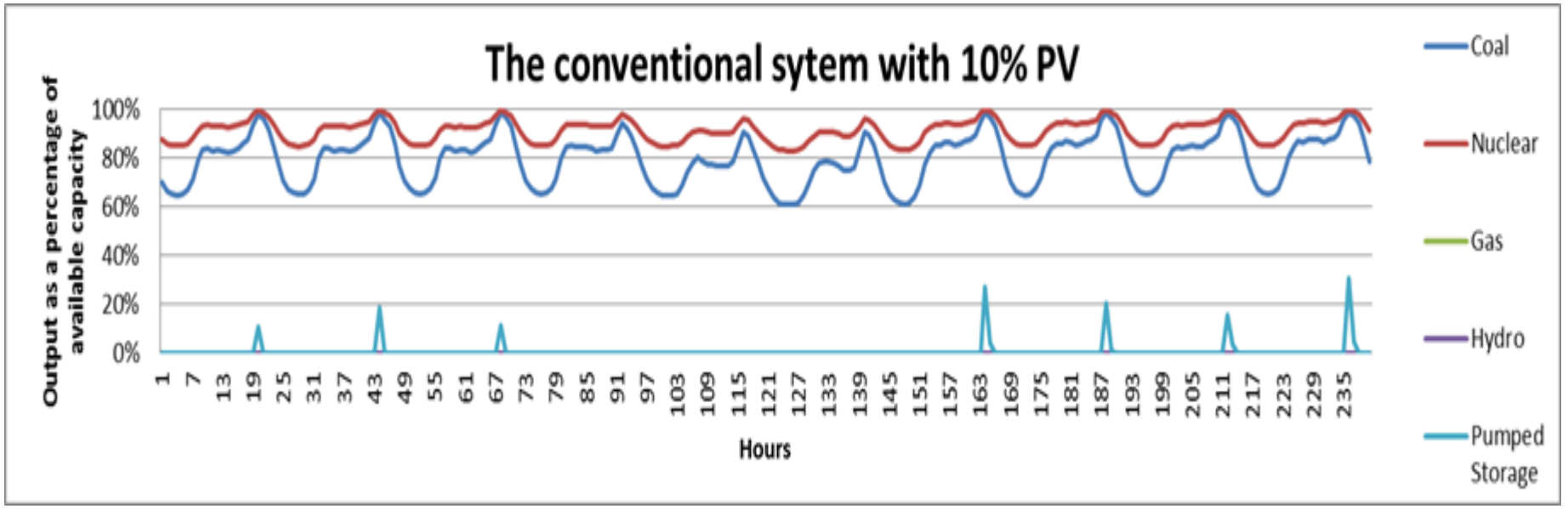
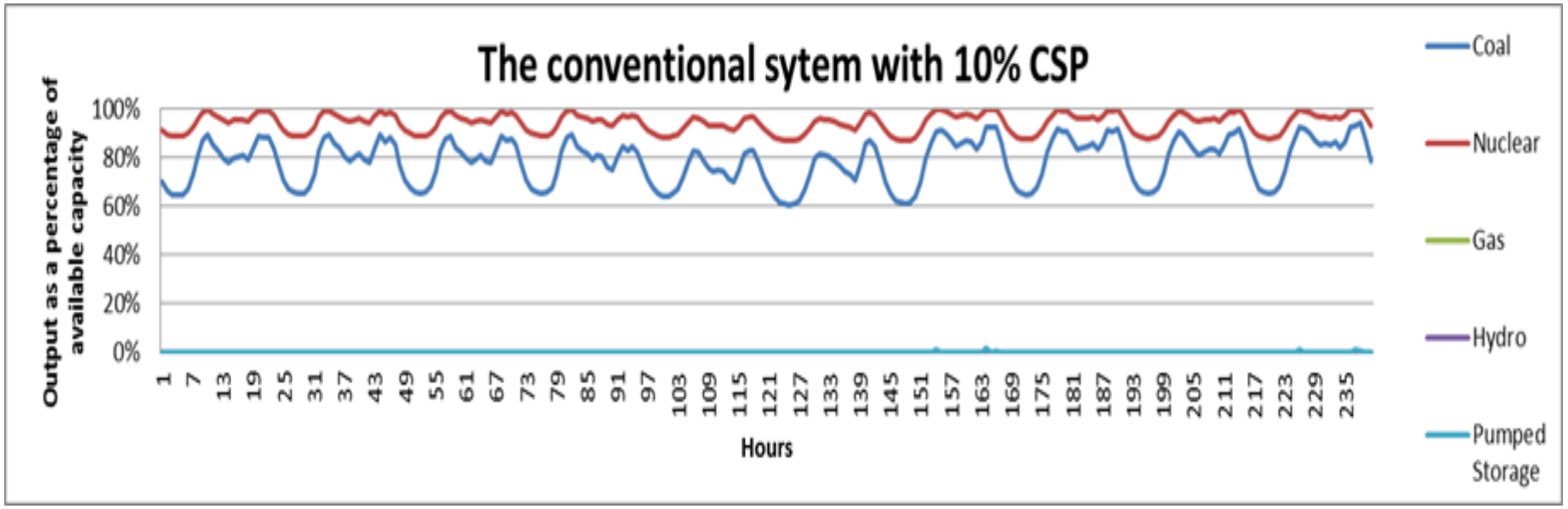
10% PV



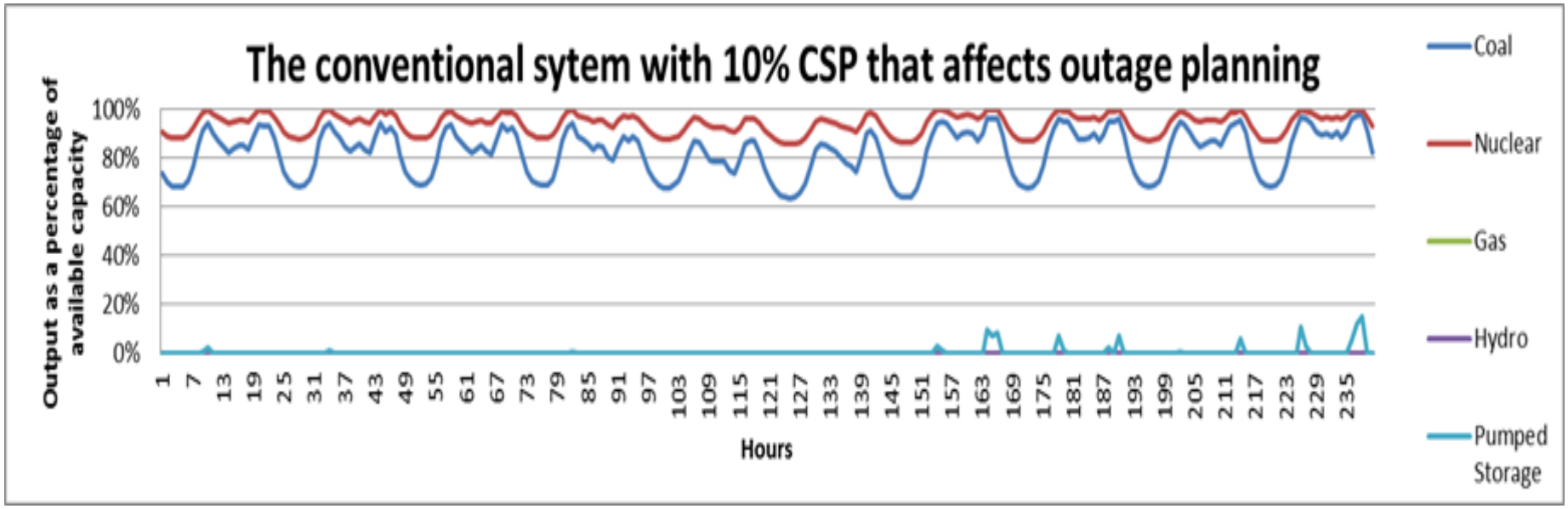
- Running coal plant capacity factors suppressed
  - Not below 80%
- No change to outages
- Peaking dropped slightly 234 GWhr to 211 GWhr

10% CSP



- Coal Capacity Factors suppressed during peak times
- Outages not affected
- Peaking reduced to 10 GWhr

10% CSP and low reserve margin



- Number of planned outages doubled
- Peaking dropped to 163 GWhr
- Minimum capacity factor increased on running coal plant

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Utility-scale PV [Wind and CSP] power and energy supply outlook for South Africa in 2015

Sebastian Giglmayr[a], Alan Brent[b], Paul Gauché[c] & Hubert Fechner[a]

[a] Urban Renewable Energy Systems, University of Applied Sciences (UAS), Vienna, Austria

[b] Centre for Renewable and Sustainable Energy Studies (CRSES), University of Stellenbosch

[c] Solar Thermal Energy Research Group (STERG), University of Stellenbosch

SASEC 1st Southern African Solar Energy Conference

Second Southern African Solar Energy Conference
SASEC 2014
27-29 January 2014, Port Elizabeth, South Africa

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Analysis results

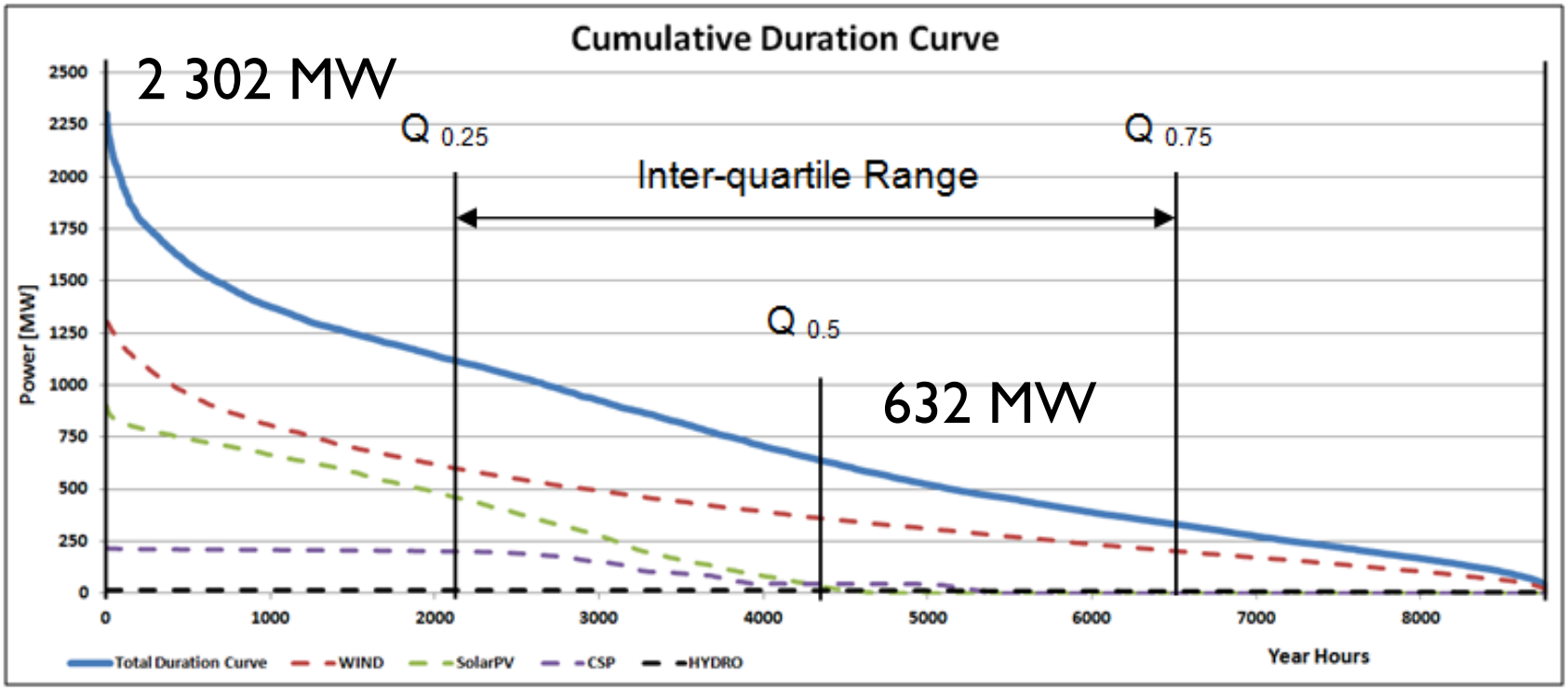
- Renewable energy (RE) annual yield: **6.4 TWh**

	Wind power	SolarPV	CSP	Hydro power
Delivered energy [GWh]	3 685	1 906	752	99
Maximum actual power [MW]	1 302	900	217	14

- Maximum power: **2 302 MW** (95 % of rated capacity)
- Minimum power: **27 MW** (1.1 % firm capacity)
- Annual RE share of **2** % according to IRP 2010 forecast
- Capacity RE share of **5** % according to *Eskom* projection

Analysis results

System duration curve (frequency distribution)



Conclusions in our analysis

- ☑ CSP presents an economically sensible solution today as a fuel saver to peaking/dispatch
- ☑ Reduces fuel price volatility & adds reserve margin
  - ☑ (The system likes it)
- ☑ Drives the learning rate
  - ☑ Reduce cost of technology
  - ☑ Increase local supply chains
  - ☑ Distributed & top to bottom employment
  - ☑ Reduce cost of capital

- ☒ Not shown – work is ongoing, but Solar and Wind still don't seem to play too well. We probably need backup for about 20% – 30% even in the long run.

* And friends

STERG* IS POSITIONED TO HELP

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Primary associations

SASTELA

EU SOLARIS
The European Research Infrastructure for Concentrated Solar Power

Primary funders

???

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation

Eskom

sasol
reaching new frontiers

http://concentrating.sun.ac.za

ABOUT STERG

SOLAR THERMAL ENERGY RESEARCH GROUP

First SA university CSP research group

STERG at Crescent Dunes, Nevada
SolarPACES 2013 tour

~ 75 Members in July 2013
From/at: SU, UCT, Wits, CSIR, UKZN, NMMU, NWU, Eskom, Sasol, Germany, China, Holland, etc.

And now announcing our newest sponsor

technology innovation

AGENCY

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technology innovation
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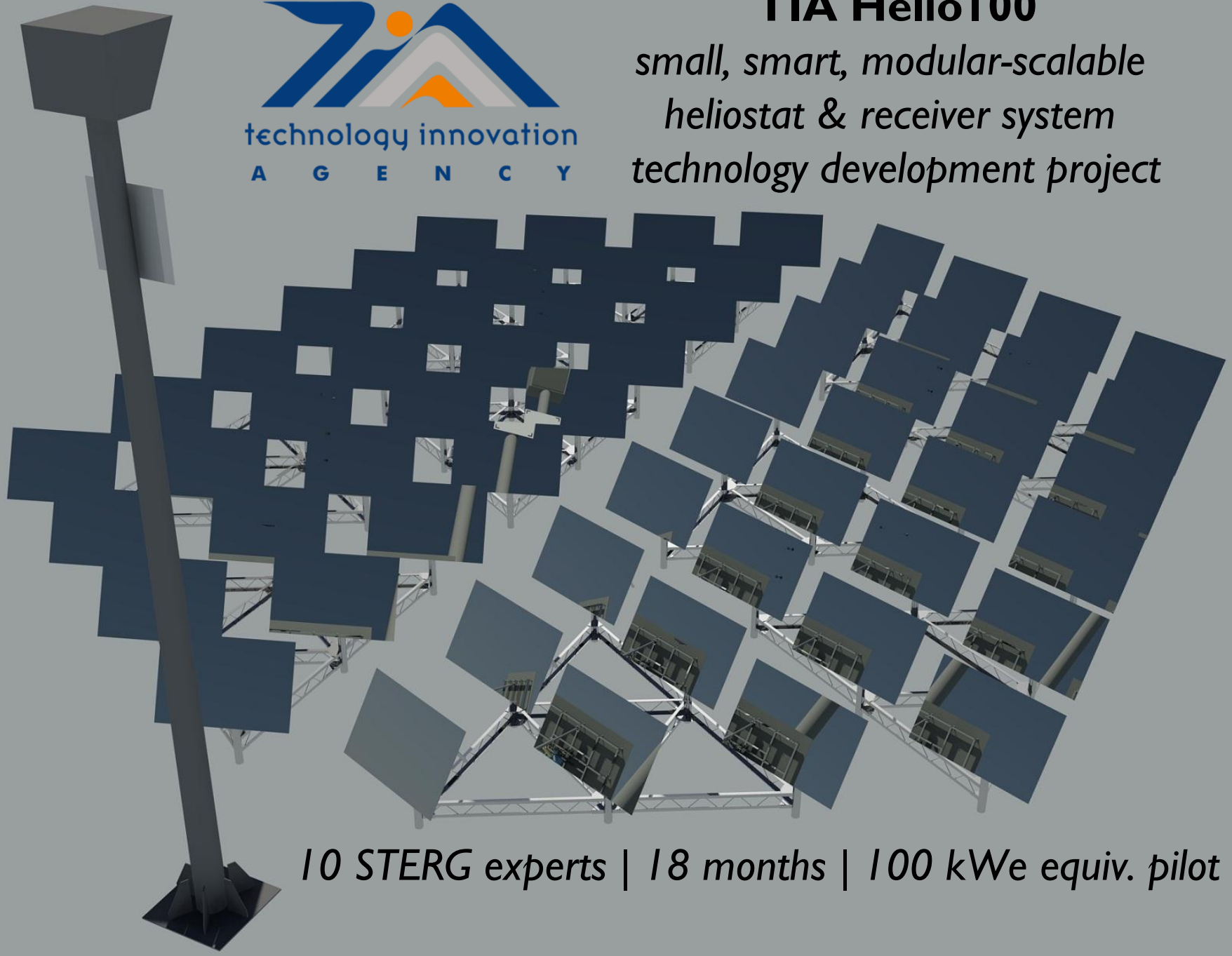
TIA Helio100

small, smart, modular-scalable
heliostat & receiver system
technology development project

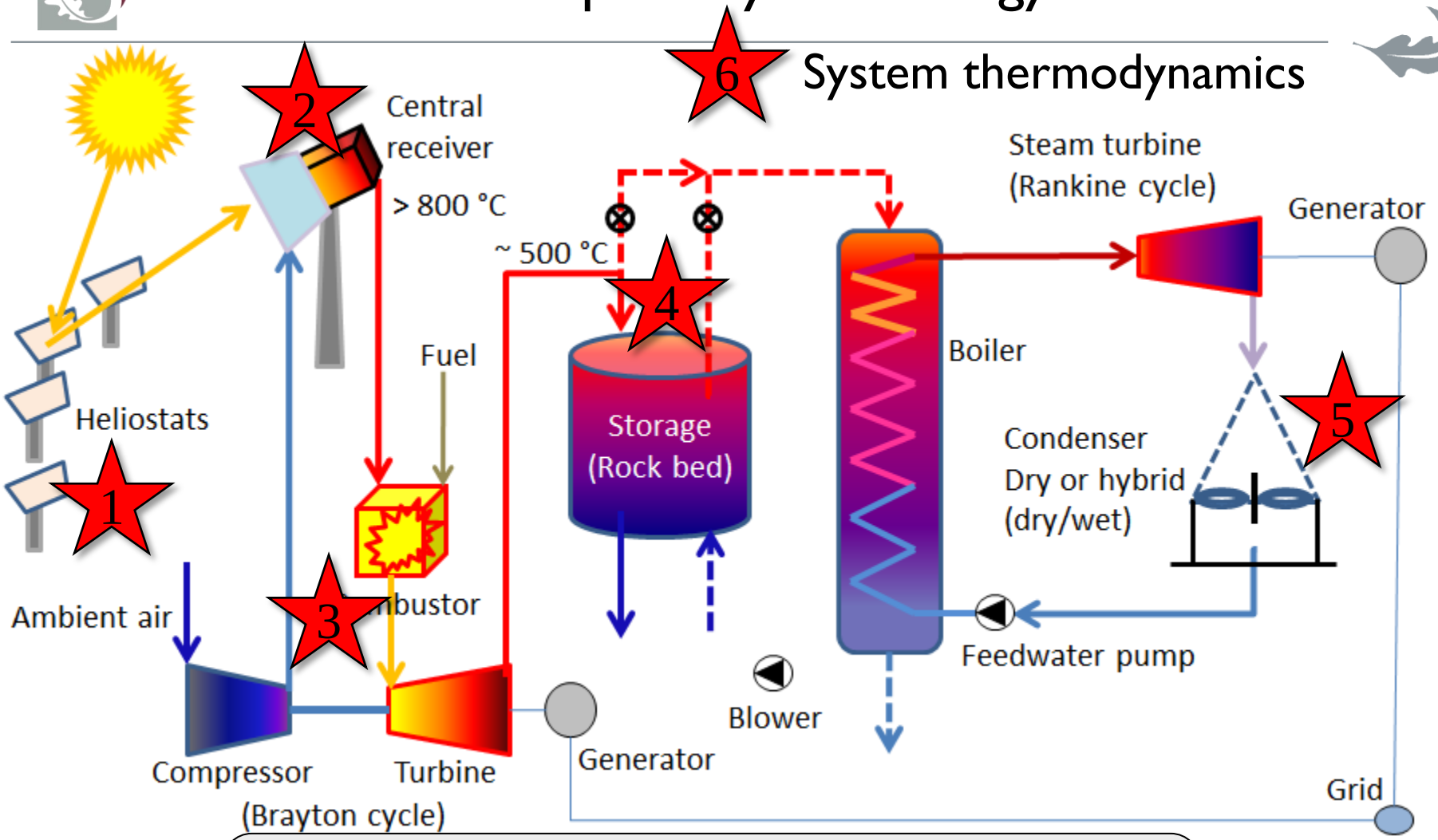


10 STERG experts | 18 months | 100 kWe equiv. pilot

STERG infrastructure & resources

- Staff: 8+ (researchers, administrative, engineering and technical support)
- 1,000 m^2 solar roof laboratory, staff office, workshop & control room
- Sasol Helio40 – 40 m^2 heliostat system
- 18 m lattice tower (soon with receiver test facility)
- 600 °C,1.5 m^3 packed bed storage rig & 1,200 °C kiln
- Solar & weather resource station with free web download
- 25 kWe Eskom McDonnel Douglas Stirling Dish
- + multiple other Mech Eng facilities

SUNSPOT primary technology



15+ Projects from distribution to system to components focused on SUNSPOT

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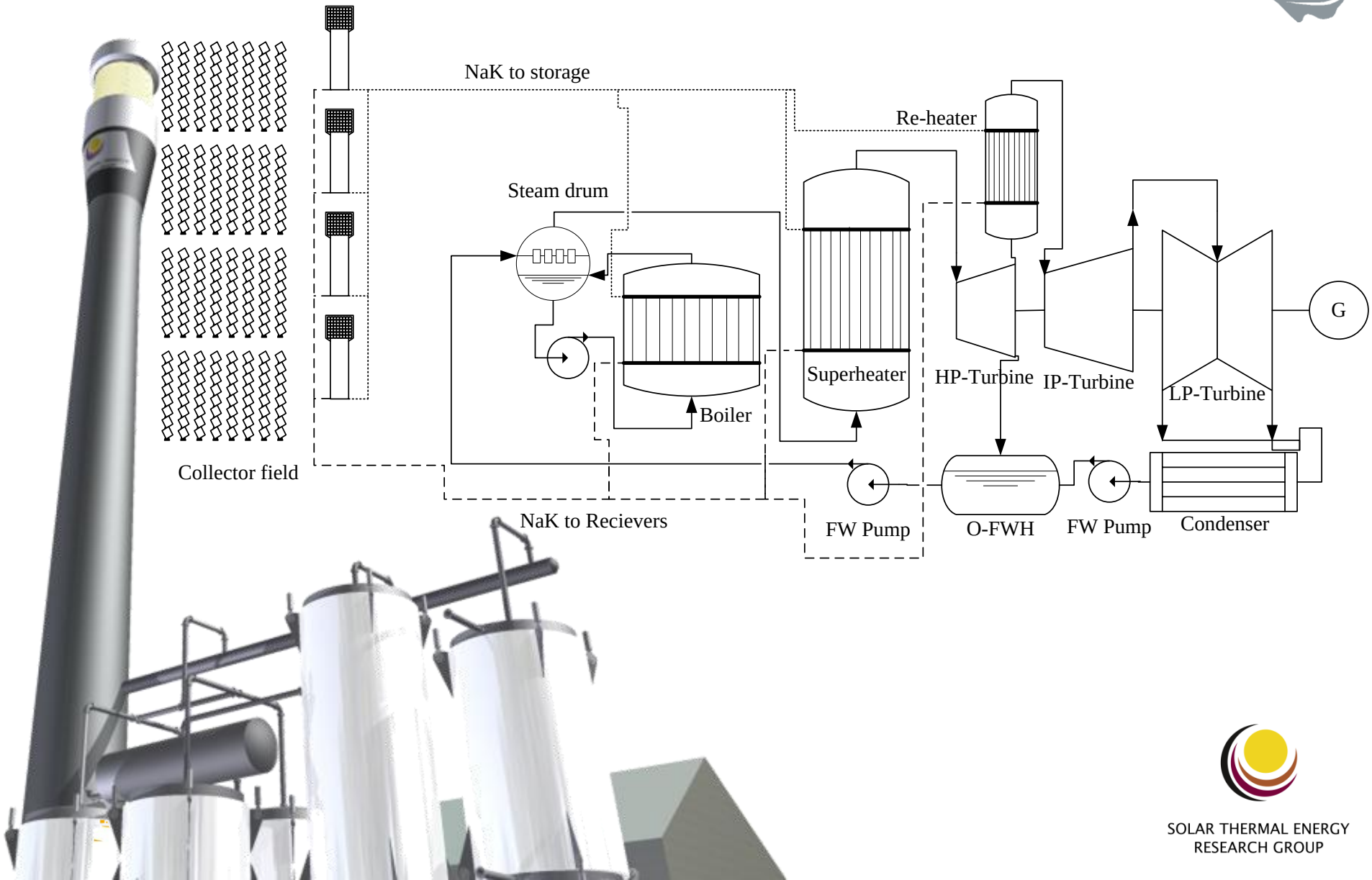
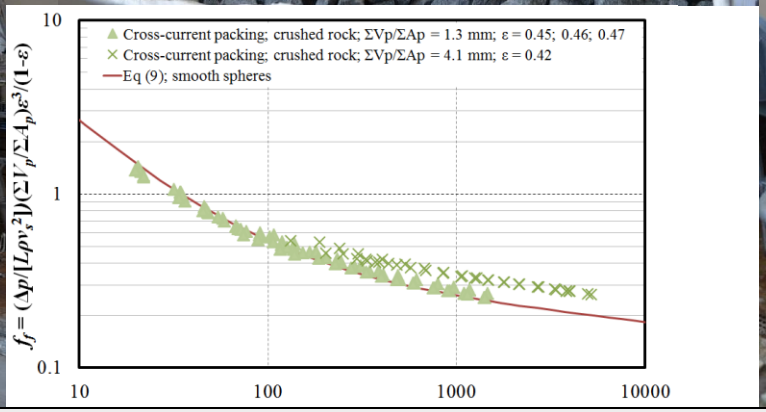
Industrial cooling system performance R&D

Prof HCR Reuter (PrEng, PhD)

Potential concepts: Metallic phase change material – Direct steam generation from storage



Packed bed storage research



Our "**Sauna**". Thermal cycling of 2 – 3 tons of material between 600 °C and ambient.

SOLAR THERMAL ENERGY RESEARCH GROUP

Announcing: DLR – Stellenbosch MoU

- DLR: The German Aerospace Centre & Stellenbosch University
- MoU to collaborate in the R&D of CSP technology

- DLR is currently the leading CSP R&D entity (as far as we can tell)
- Stellenbosch has quickly become one of the leading CSP university groups in the world

DLR

SOLAR THERMAL ENERGY RESEARCH GROUP

International cooperation in CSP/STE research infrastructures

Stellenbosch University is an expert member in the Technical and International Cooperation Advisory Board of the CSP/STE Research Infrastructure (RI) coordination project EU-SOLARIS, which is:

- Identified in the intergovernmental European Strategic Forum on Research Infrastructure (ESFRI) 2010 Roadmap.
- Developed by the most significant CSP/STE Research centres in Europe, the Spanish Ministry of Innovation and Competitiveness and the European STE Industry Association, ESTELA.
- Coordinated by CTAER (Spain).

ESFRI European Strategy Forum on Research Infrastructures

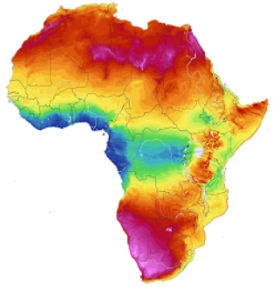
EU SOLARIS
The European Research Infrastructure for Concentrated Solar Power

CTAER

Scope, vision and goals

- To be ***the reference Research Infrastructure (RI)*** for Concentrating Solar Thermal (CST) and Solar Chemistry technologies, in order to optimise RI development and Research and Technology Development (RTD) coordination;
- EU- SOLARIS ***is expected to be the first of its kind,*** where industrial needs will play a significant role and private funding will complement public funding.
- To ***support excellence*** in scientific and technological development.
- Provide the most complete, high quality ***scientific infrastructure portfolio*** at international level, facilitating researchers' access to highly specialised research infrastructure through a single access point;
- ***Link the scientific communities***, ***industry*** and ***universities*** involved in the Solar Thermal Electricity sector;
- ***Increase the efficiency*** of the economic and human resources required;
- Provide efficient ***resources management*** to complement research and to avoid unnecessary technological duplication and repetition

Geographical distribution of EU-SOLARIS partners



concentrating.sun.ac.za

2nd Annual STERG SolarPACES Symposium

17 July 2014

Stellenbosch, South Africa

SOLAR THERMAL ENERGY RESEARCH GROUP

2014: Sasol Helio40 opening, Abengoa & Eskom keynotes, typical attendees: SU, UKZN, UP, CSIR, DST, Eskom…

We invite you to attend. Visit our website for more info

SOLAR THERMAL ENERGY RESEARCH GROUP

DST/NRF Renewable Energy Scholarships

science & technology
Department:
Science and Technology
REPUBLIC OF SOUTH AFRICA

NRF National Research Foundation

DST believes in CSP R&D – asked me to announce the following

- Renewable energy scholarships for Master + PhD
- Seeking better representation in SA for postgrad engineering studies
- To be announced May 2014 – see NRF website or concentrating.sun.ac.za
- Applications close 31 July 2014 for 2015+ studies.

Acknowledgements:

GeoModel Solar, SASOL, Eskom,

DST/NRF, TIA, Stellenbosch University

Contact details:

Paul Gauché

paulgauche@sun.ac.za

visit us:

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