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Potential to develop a concentrated solar power industry in South Africa

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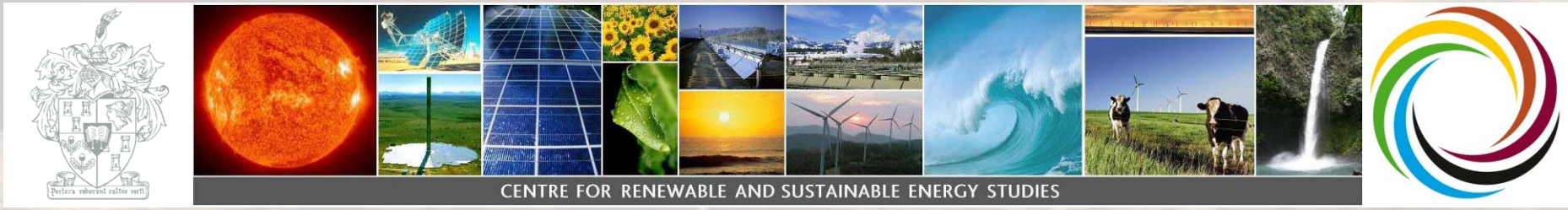
Stellenbosch Forum Lecture, 18 August 2010



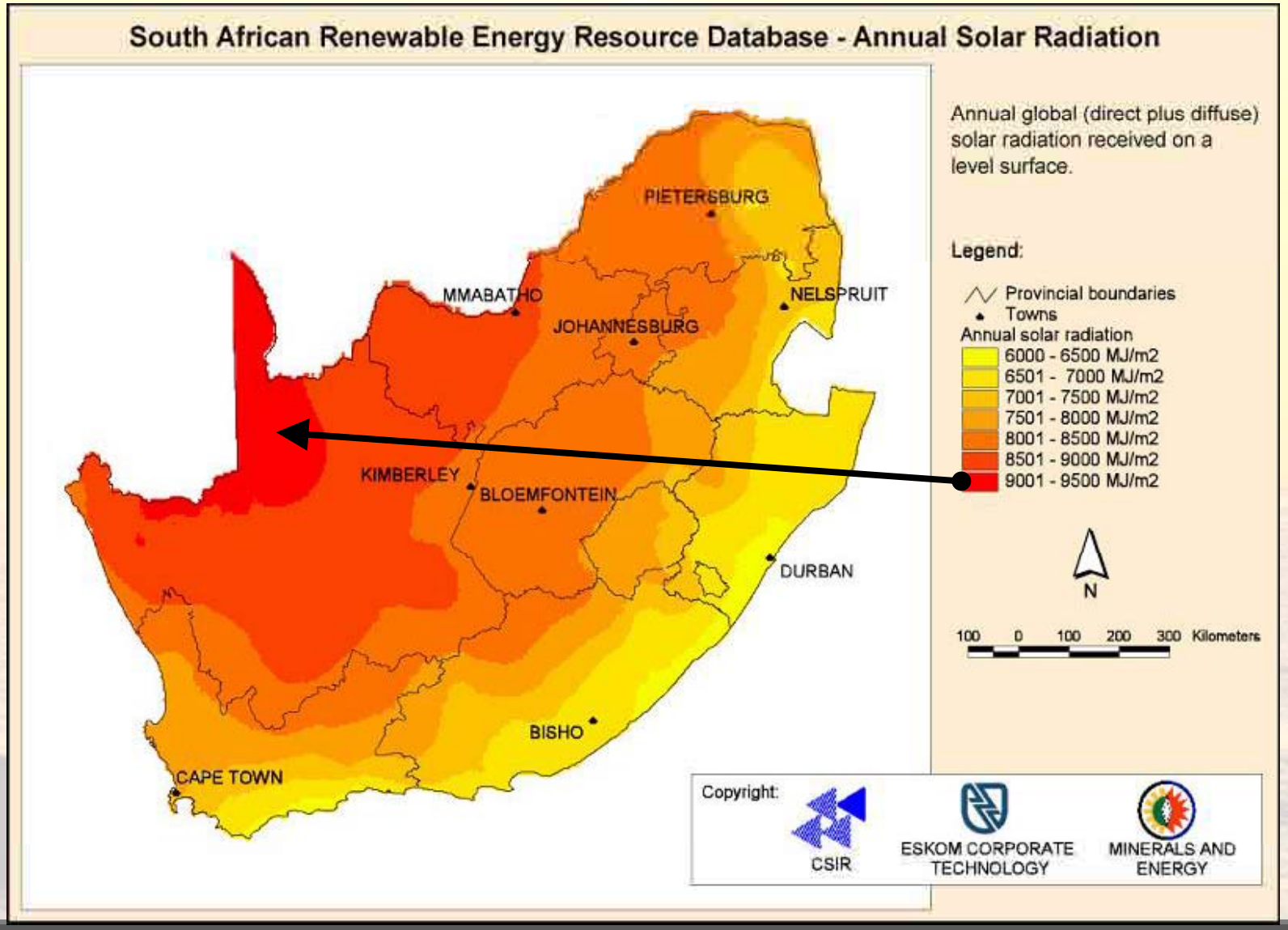
Outline of Presentation

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- Solar Resource in South Africa
- Conversion Technologies
- Opportunities for CSP Industry in SA
- Research and Development Opportunities
- Conclusions

Solar Energy Resources (1)

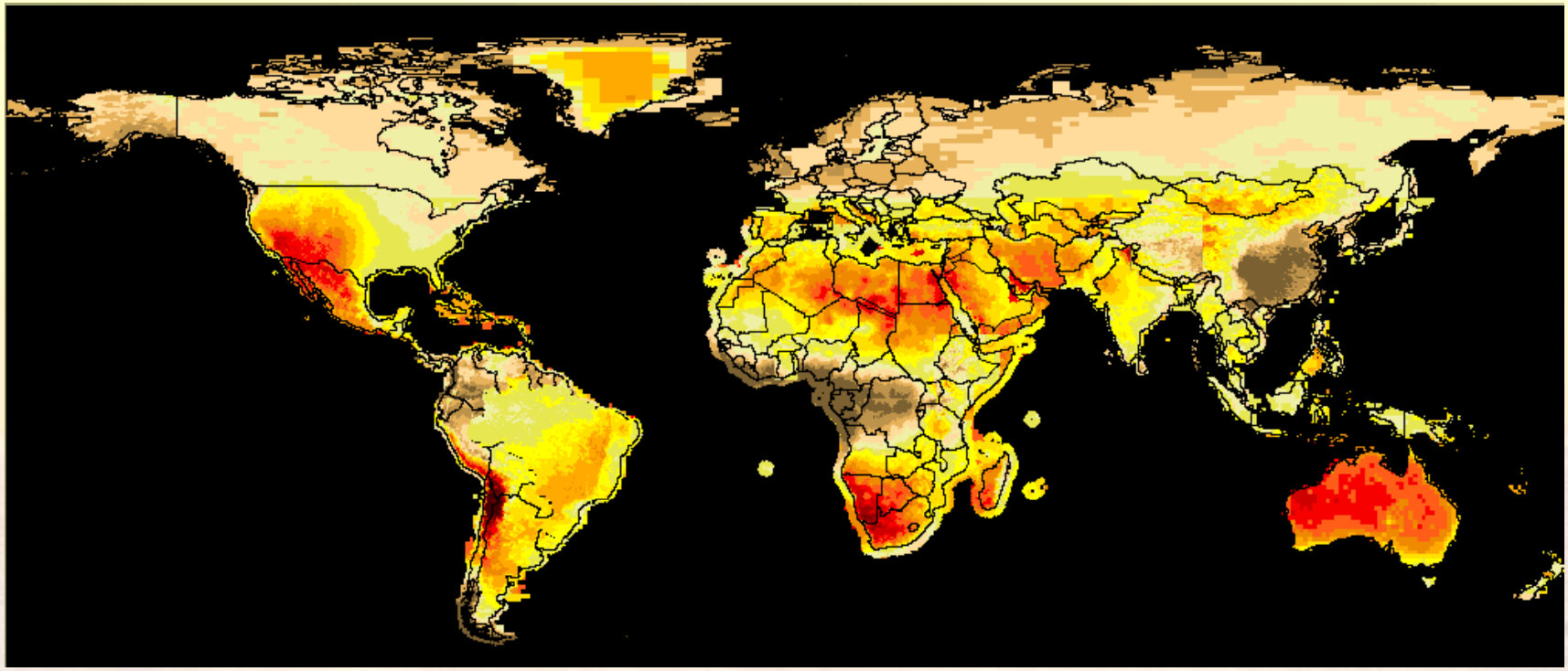
RENEWABLE & SUSTAINABLE ENERGY STUDIES



Solar Energy Resources (2)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

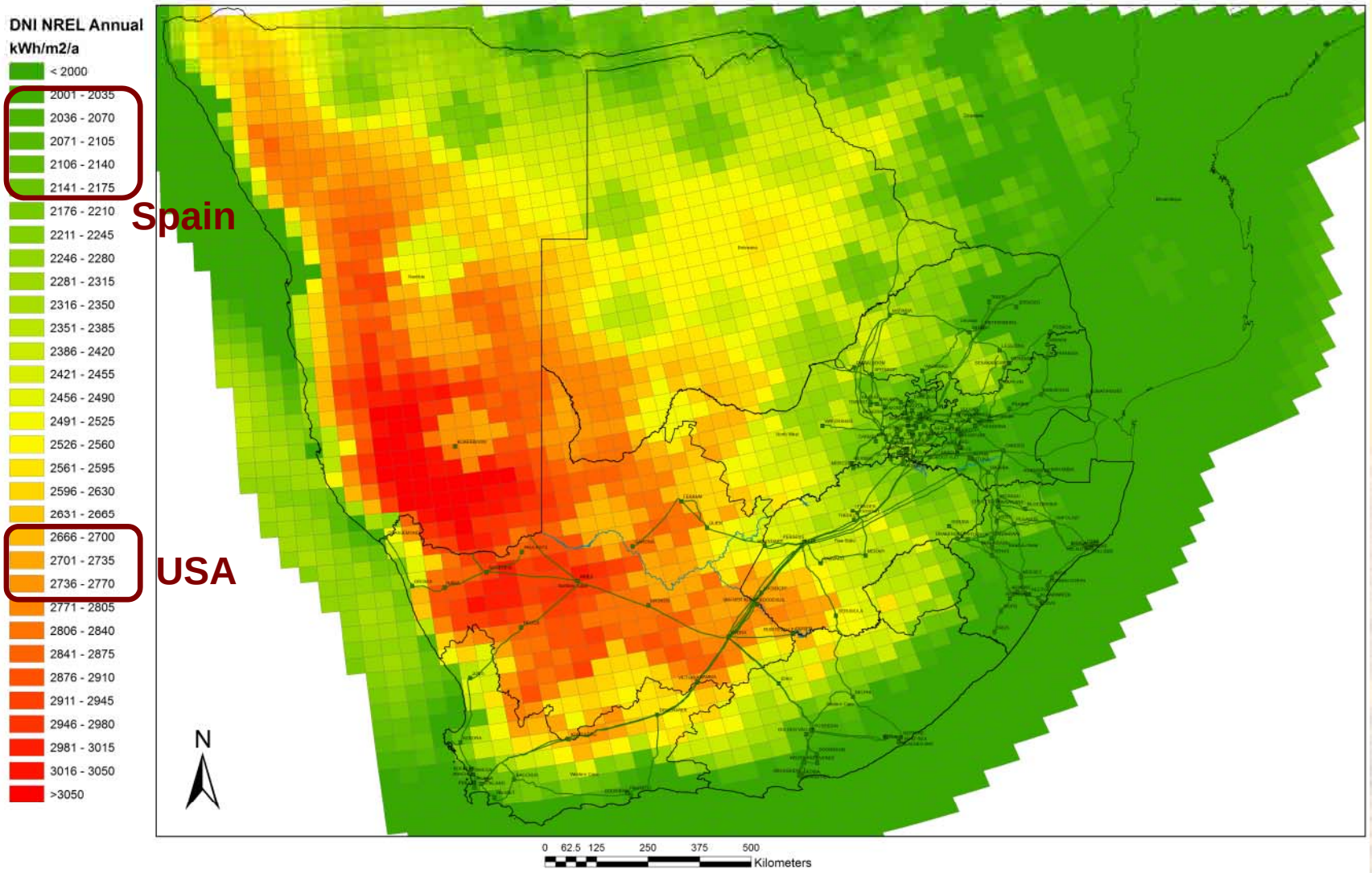
- Direct Normal Irradiance (DNI) solar resource worldwide



Solar Energy Resources (3)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

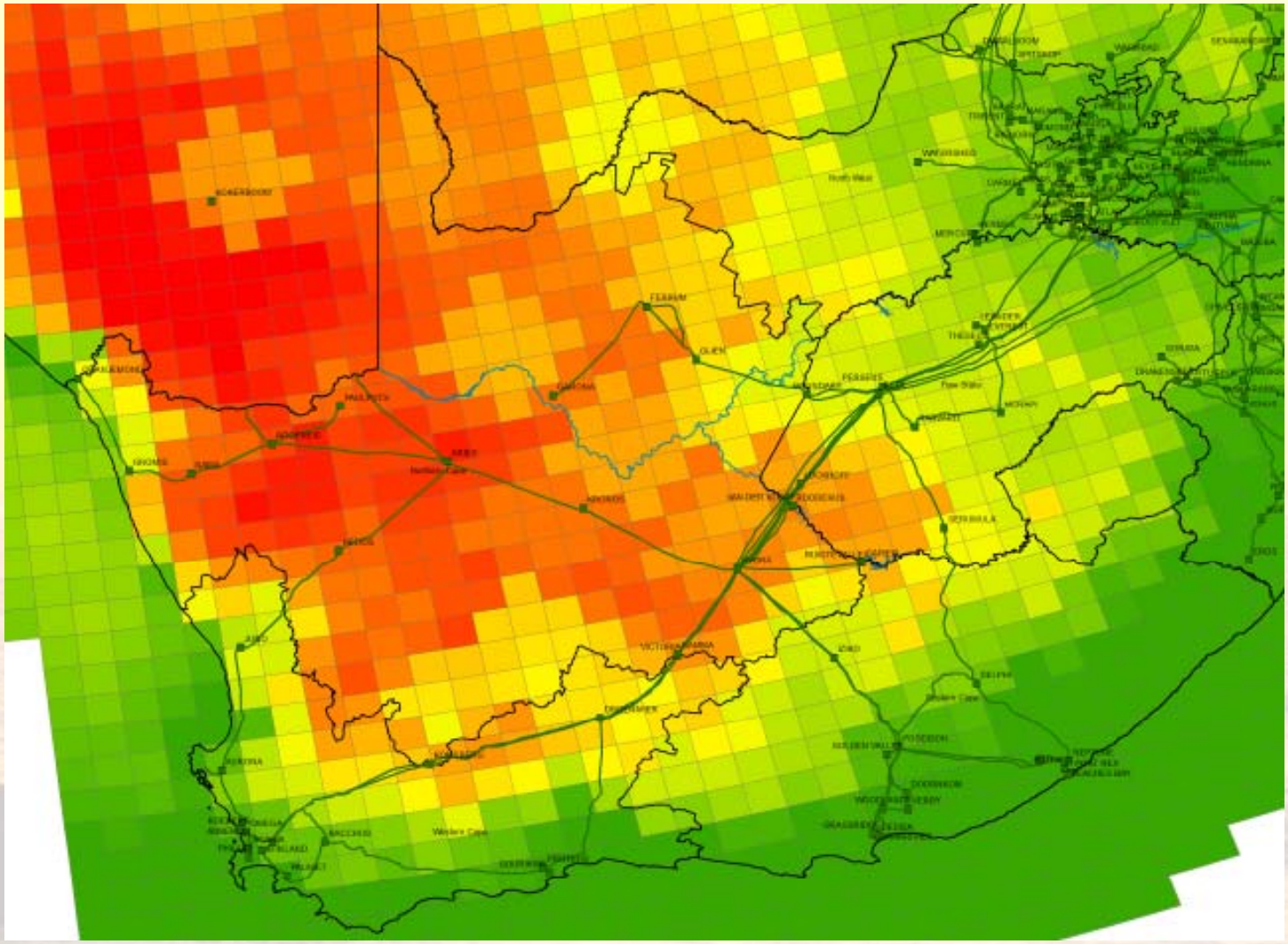
- South Africa DNI solar resource and Eskom transmission lines



Solar Energy Resources (4)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- South Africa DNI solar resource and Eskom transmission lines

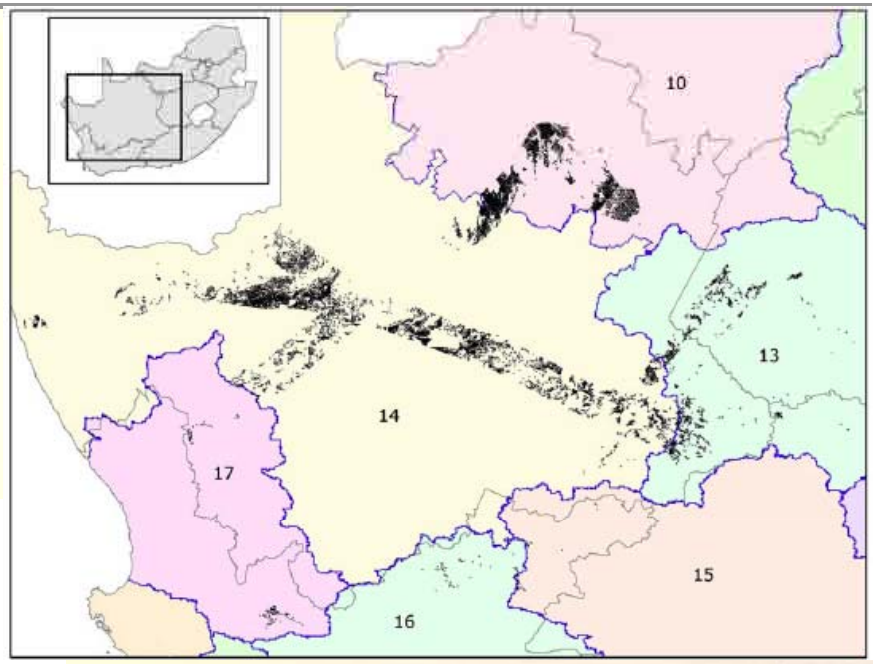


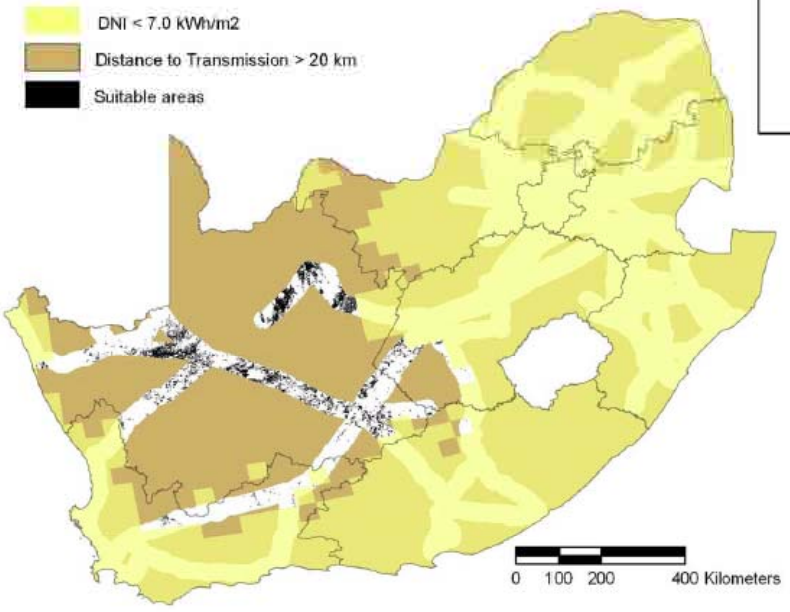
Solar Energy Resources (5)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- DNI > 7,0 kWh/m^2 on average per day
- Distance to grid < 20 km (10 km)
- Flat area, slope < 1%
- Non-sensitive land-use areas

Total available 548 GW in South Africa, 510 GW in the Northern Cape





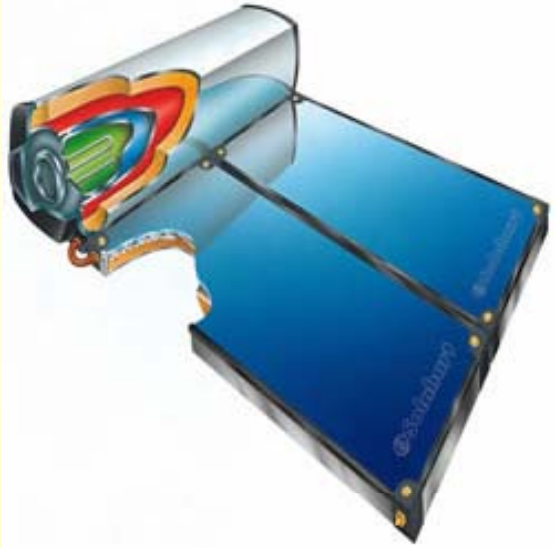
Fluri, 2009

	NC		FS		WC		EC	
Proximity to transmission, km:	<20	<10	<20	<10	<20	<10	<20	<10
Average DNI: 7.0–7.5 kWh/d	105.8	55.0	24.8	11.6	9.9	4.7	1.6	0.1
7.5–8.0 kWh/d	260.4	146.3	0.5	0.5	0.6	0	0	0
>8.0 kWh/d	144.1	83.8	0	0	0	0	0	0

Conversion Technologies (1)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **Solar Thermal**
  - Solar Water Heaters
  - Commercial Solar Water Heating & Cooling
  - Easy implementable technology with guaranteed returns



- **Solar Electricity**
  - Photovoltaic modules
  - Concentrated Solar Power (CSP) plants
  - Necessary for large scale solution to energy crises

Conversion Technologies (2)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

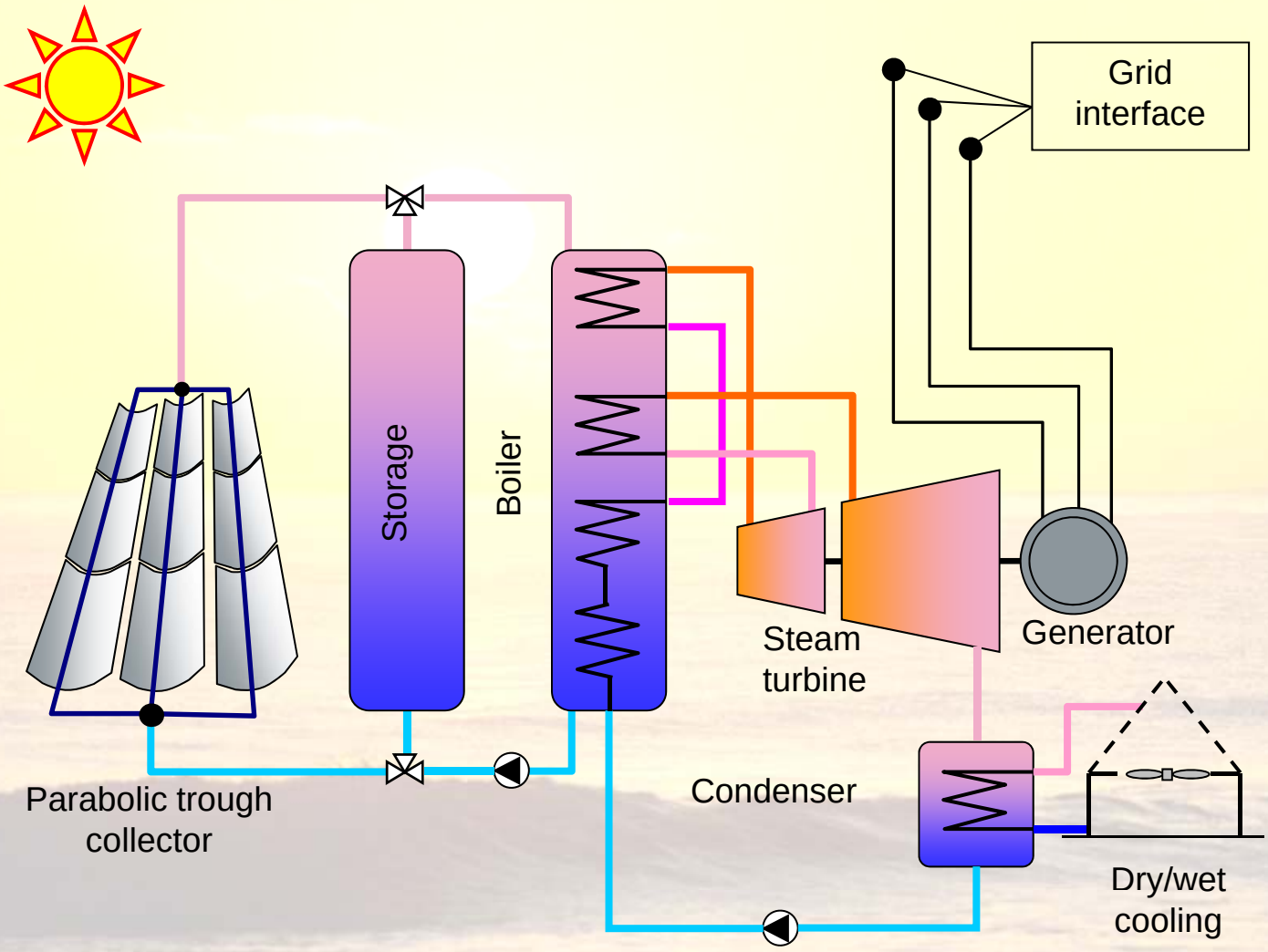
Solar dishes

Parabolic Troughs

Central Receivers

Conversion Technologies (3)

RENEWABLE & SUSTAINABLE ENERGY STUDIES



Conversion Technologies (4)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Parabolic trough

- Proven technology
  - Oldest plant in operation since 1984
  - Recent commercial plants built in Nevada (64 MW) and Spain (2x50 MW)
  - Number of new plants under construction
- Capacity per module: 30-80 MWe
- Globally installed capacity: 418 MW
- Storage: 7.5 hours
- Hybridisation: Natural Gas

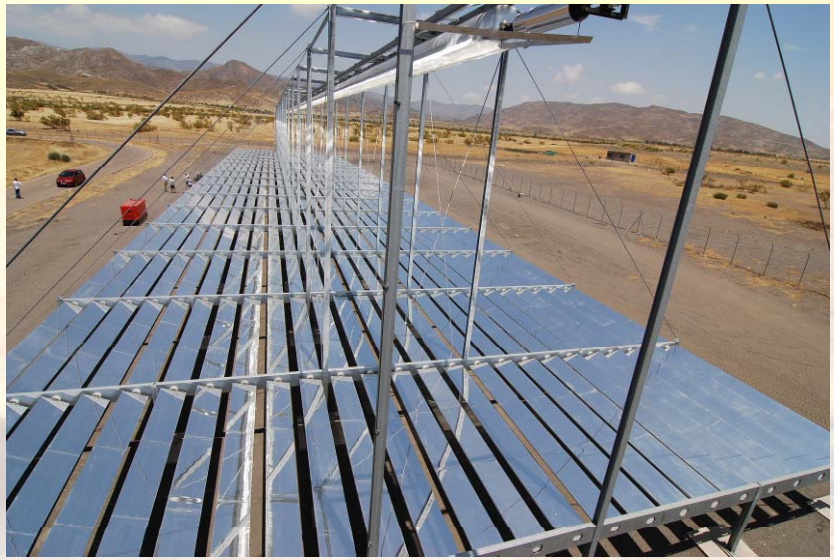
Nevada SolarOne - commissioned in 2007

Conversion Technologies (5)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Fresnel reflectors

- Several prototypes have been built
- First commercial installation due in 2010
- Advantages:
  1. Direct steam generation
  2. Less wear and tear
  3. Lower cost



Conversion Technologies (6)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Solar Tower

- Developing technology
  - First demonstration plants in the 80's.
  - Commercial plants are under construction in the US and Spain.
  - Very high temperature

- Capacity per module:

  2.5-150 MWe

Conversion Technologies (7)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

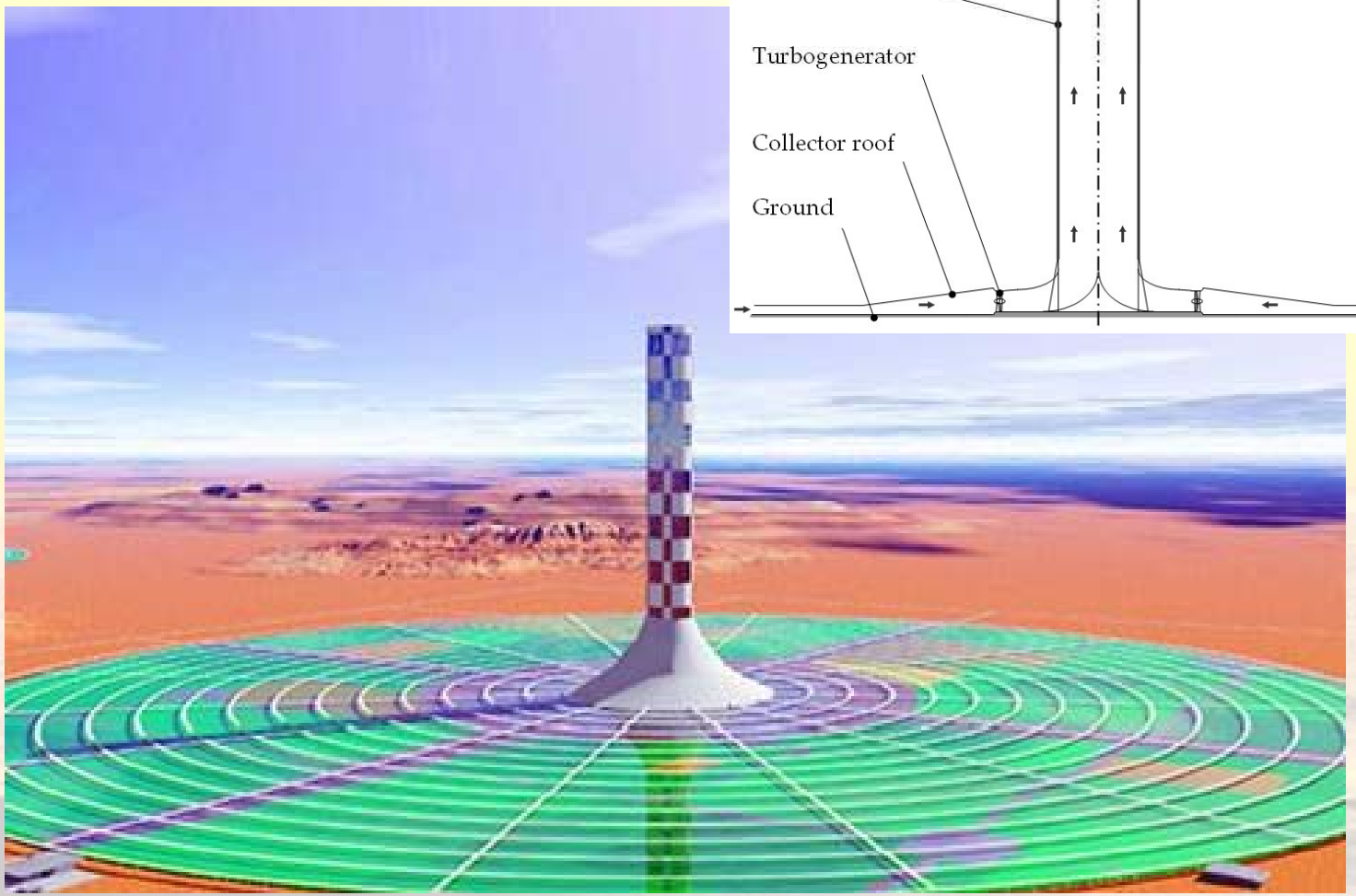
Solar Dish & Stirling Engine

- Capacity per module: 25 kW
- Few installations
- 500 MW installation is planned (20 000 dishes!)

- Eskom: Solar Dish used to be at the DBSA in Midrand

Conversion Technologies (8)

RENEWABLE & SUSTAINABLE ENERGY STUDIES



South African CSP Industry (1)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **What are the advantages of CSP over PV?**

PV switches off if a cloud passes over the sun, CSP has thermal inertia, or storage, to continue producing electricity

PV generates electricity, which is difficult to store, CSP collects thermal energy which can be more readily stored

PV generates most electricity at noon, CSP, with storage, can follow load/demand better

PV well-established industry, high barriers to entry for R&D and manufacturing, CSP new and developing industry, scope for SA to make a contribution

- **What are the advantages of PV over CSP?**

PV technology is proven over many years, possible to get warranties for as long as 25 years, first CSP plants only now approaching 25 years

PV has less (no) moving parts and hence more reliable (except that currently inverters need to be replaced at least once over the 25-year period)

PV is very modular, small, medium and large installation can be easily realised

PV plants can be smaller, 1 MW and up, not much to be gained with “economies of scale”

PV use less water than CSP with wet or dry-air cooling

South African CSP Industry (2)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **Where does electricity from large-scale CSP plants fit in?**

Wind energy: R 1.08/kWh (R 0.98 to R 1.23)

CSP: R 1.23/kWh (R 1.18 to R 1.47)

PV: R 1.91/kWh

Eskom: R 0.46/kWh

(Stellenbosch Munic: R 1.00/kWh)

- **Renewable Energy Feed-In Tariff**

CSP Trough with 6 hour storage	R 2.10/kWh
CSP Trough with no storage	R 3.14/kWh
CSP Tower with 6 hour storage	R 2.31/kWh
(Wind	R1.25/kWh)

- **REFIT Status?**

Waiting for finalisation of the selection criteria . . .

Waiting for publication of IRP 2010 . . . .

Waiting for establishment of the ISO . . . .

South African CSP Industry (3)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

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Cost in R/kWh	CCI/DoE	CSIR/DST	SARi/DPE/WWF
CSP (No Storage)	0.99 – 1.15	0.84 – 1.64	1.18 – 1.47
CSP (With Storage)	0.76 – 1.12	0.65 – 1.11	1.18 – 1.47
PV	0.59 – 1.12	1.91	-

- · **Cost of Electricity from Coal?**

- CCI: R 0.70 – R 0.93/kWh by 2013
- CSIR/DST: R 0.46/kWh, with externality cost
- NERSA MYPD: R 0.416 (2010/11); R 0.523 (2011/2012); R 0.659 (2012/13)
- ESKOM FD: R 0.82/kWh "to be an economically viable company"

Grid parity for electricity from CSP before 2020

CCI: Clinton Climate Initiative

SARi: South African Renewable Energy initiative

South African CSP Industry (4)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **Why establish a CSP industry in SA?**

Primary source of electricity from renewable energy resources in the medium to long term

Potential for South Africa to make a technology contribution, e.g. dry-air cooling

Many components of a CSP plant are “low-tech” that can easily be produced in South Africa, e.g. mirrors, aluminium tubing, piping, tubes, etc.

Not only power plants, but component manufacturing facilities as well

Large job creation potential and positive social impact, environment, climate and economic

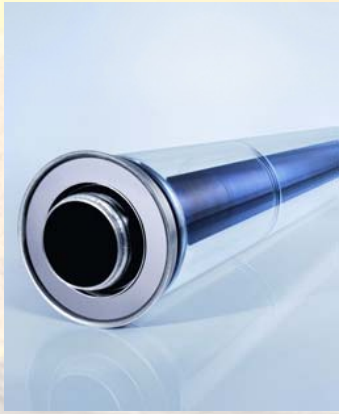
- **Job creation potential on power plants (O&M)**

Coal: 0.2 jobs/MW

Nuclear: 0.5 Jobs/MW

Wind: 0.25/MW

CSP: 0.45 – 1.0 jobs/MW



- **Job creation potential including manufacturing industry?**

As many as 20 000 in CSP technology alone

South African CSP Industry (5)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **Which components can be manufactured in SA?**
  - Steel and/or aluminium supporting structures
  - Mirrors, flat mirrors easy, curved mirrors will require specialised equipment
  - Receiver tubes, may be possible for OEM to establish a local factory
  - High temperatures boilers, pipes and construction
  - Supporting infrastructure, e.g. pipes, valves, pumps, foundations
  - Turbines and generators, probably not
- **What will be required to achieve this?**
  - Clear indication from the SA Government that there will be a large number of CSP plant built in SA in the medium to distance future, 1-5 GW(?)
  - First orders placed by Eskom or IPPs for CSP plants
  - Additional incentives to make production in SA more attractive than importing
  - Technology base to support local production and further development
- **How soon can this be done?**
  - Very soon, some even for the first plants

R&D Opportunities (1)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

In a recent national project to determine the research focus areas in solar energy the following four areas were defined:

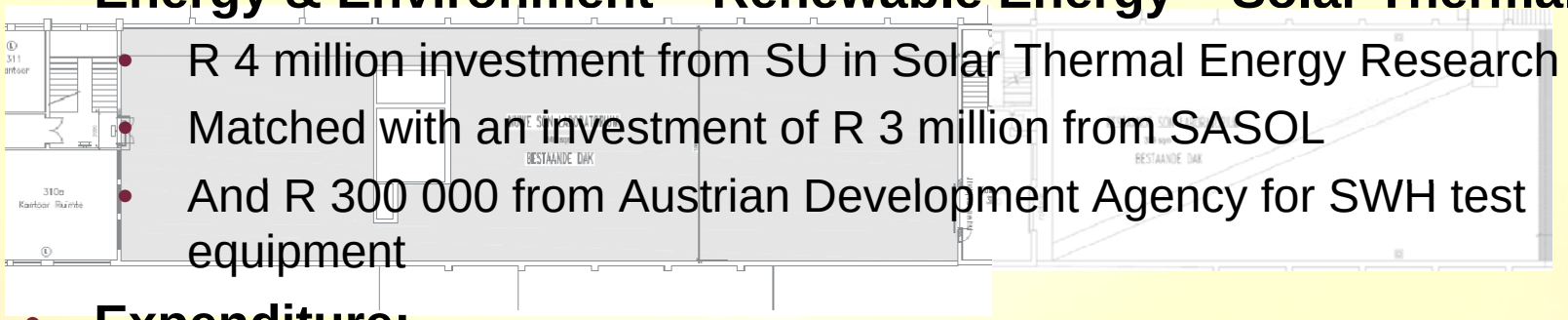
- **Solar Resource Measurement and Assessment**
  - Ground measurement stations
  - Updating of satellite derived solar resource data
  - National solar resource data and knowledge base
- **Photovoltaic Systems**
  - Quality standards and testing support
  - Cell and module technologies, including concentrating PV cells
- **Concentrated Solar Power Technology**
  - Cooling , dry-air and hybrid
  - Thermal storage
  - System modelling and integration
- **Industrial Solar Heating and Cooling**
  - Non tracking systems, also concentrating

R&D Opportunities (2)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

HOPE Project

- **Energy & Environment – Renewable Energy – Solar Thermal**
  - R 4 million investment from SU in Solar Thermal Energy Research
  - Matched with an investment of R 3 million from SASOL
  - And R 300 000 from Austrian Development Agency for SWH test equipment



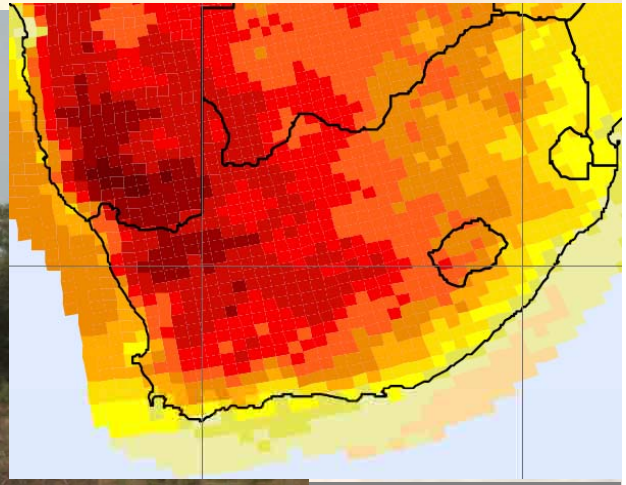
- **Expenditure:**
  - Appointed full-time senior researcher, research engineer and technician
  - R 1,1m to expand our Solar Roof Laboratory, R 700k for equipment
  - Support three doctoral and four masters' students
- **Focus Areas**
  - Thermal energy storage, two PhDs
  - Dry-air cooling, one PhD
  - SunSPOT, and other hybridisation of CSP plants, one PhD
  - Heliostat design optimisation, one masters, one post-doc

R&D Opportunities (3)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Solar Resource Measurement & Assessment

- **Measurements**
  - New Stellenbosch measurement station
  - Commercial projects, with the DLR
- **Correlation**
  - Update models that convert satellite data
  - Improve accuracy of all available solar data
- **Production Estimates**
  - Use data, with other inputs, to predict solar electricity production



R&D Opportunities (4)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

Solar Thermal Energy Storage

- **Natural Materials**
  - Rocks, natural material available on-site
- **Phase-Change Materials**
  - Combination of metals with special heat exchanger

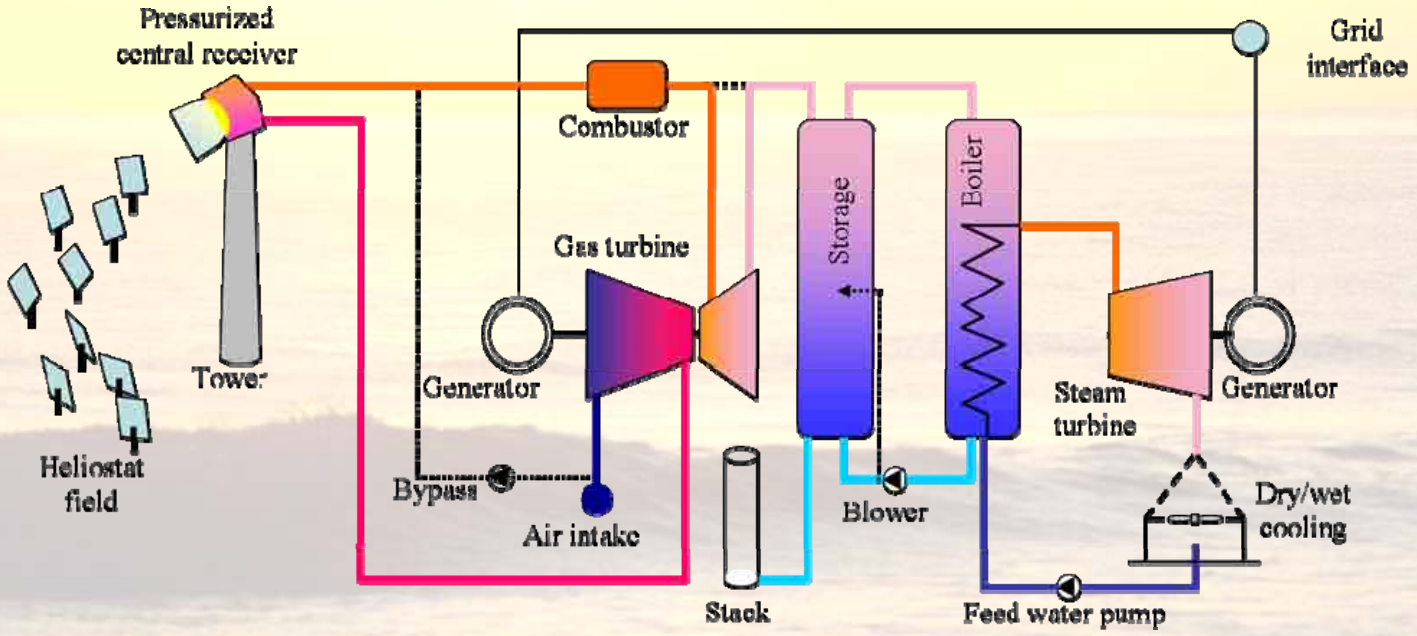
Thermal Energy Storage
Research: Using Local Rock

R&D Opportunities (5)

RENEWABLE & SUSTAINABLE ENERGY STUDIES

SunSPOT – Combined Cycle

- **Gas Turbine**
  - Conventional fuel, with some solar
  - Collect waste and solar thermal energy
- **Steam Cycle**
  - Used stored thermal energy at night with higher efficiencies



Conclusions

RENEWABLE & SUSTAINABLE ENERGY STUDIES

- **Solar Resource**
  - South Africa has one of the best solar regimes in the world
  - Of all renewable energy resources it is by far the most abundant
  - Needs to be measured, mapped and better understood
- **CSP Technology/Industry**
  - Technology has been proven e.g. parabolic troughs, but scope exists for further technology development and cost reduction
  - South Africa/Stellenbosch has key expertise, e.g. dry-air cooling, that can make significant contributions to the implementation and cost reduction of CSP plants, in SA and elsewhere
  - CSP systems and components are well within SA's industry's capabilities to manufacture and install, this will stimulate a new industry to develop, install, operate and ***manufacture*** CSP plants
- **Research and Development**
  - New opportunities to use existing expertise
  - Stellenbosch: solar resource measurement and assessment; solar thermal storage; dry-air cooling; systems modelling and optimisation

Conclusions

RENEWABLE & SUSTAINABLE ENERGY STUDIES

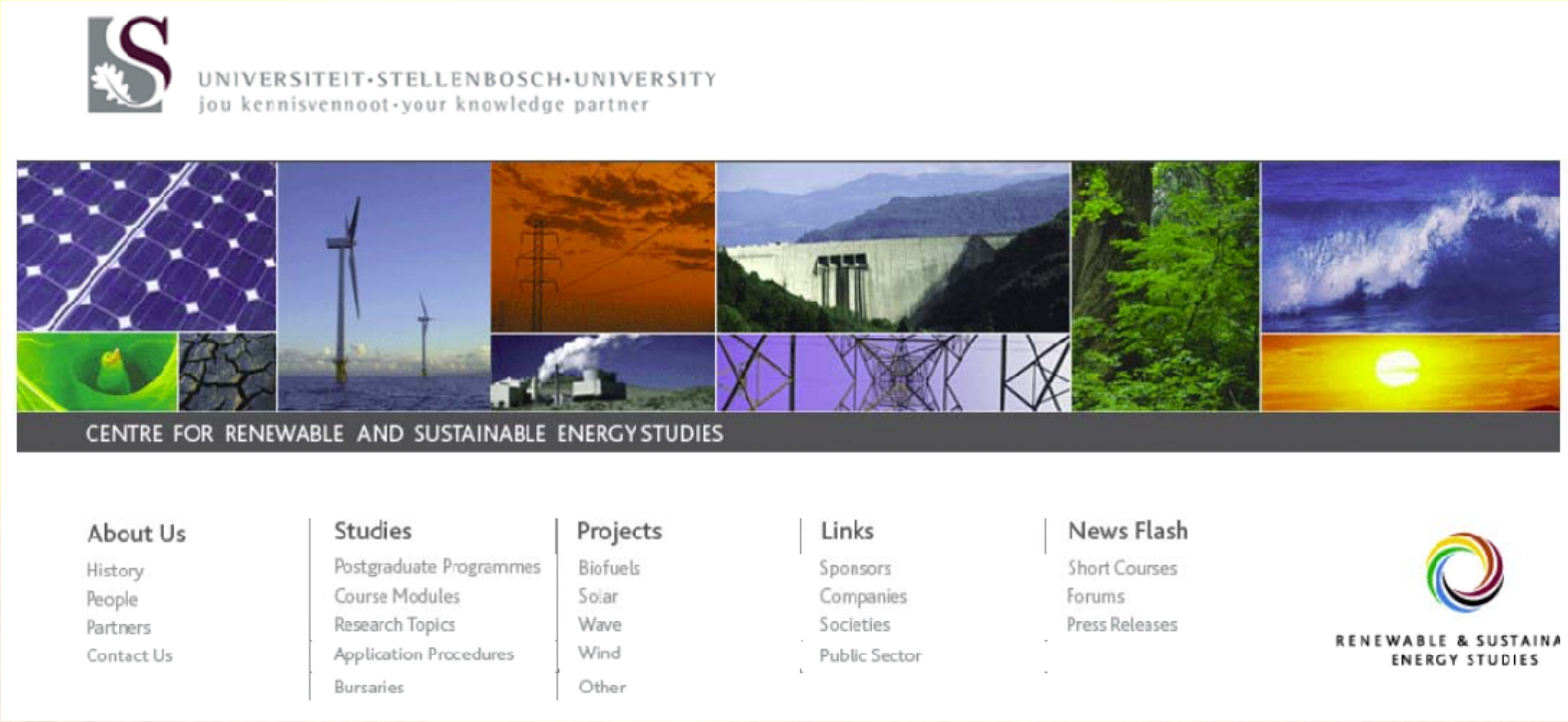
SA can choose to be a follower or a leader

Acknowledgements

- Riaan Meyer, CRSES
- Paul Gauche, M&M
- Andrew de Wet, M&M
- Dr Tom Fluri, M&M
- Other colleagues and students

Contact Information

RENEWABLE & SUSTAINABLE ENERGY STUDIES



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