The Renewable Energy Resource and Research Base in South Africa

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Renewable Energy Conference

Outline of Presentation

• Background

• Solar Energy
  • Solar Thermal Power Plants
  • Photovoltaic Systems

• Wind Energy

• Wave Energy
  • Stellenbosch Wave Energy Converter
  • Bio-Energy and Biofuels

• Challenges & Opportunities

• Future Research Highlights
Background

  - Set target of 10 000 GWh by 2012.
  - Based on 4% of total energy consumption in SA, electricity and liquid fuels.
  - Primarily from biomass, solar, wind and small-scale hydro.
  - Predicted role for SMMEs, IPPs and competition in energy markets.
- Drivers:
  - Environmental issues, such as pollution and exploitation of natural resources.
  - Climate Change due to CO₂ emissions from fossil fuels.
  - Energy security through diversification of supply.
- Sustainable development.

Centre for Renewable and Sustainable Energy
Formed in 2006 to execute the contract with SANERI for:

National Postgraduate Programme in Renewable and Sustainable Energy Studies

Renewable Energy is energy that does not disturb the natural energy balance of the earth.

Traditional energy sources

Renewable energy sources

Source: SolMic

CENTRE FOR RENEWABLE AND SUSTAINABLE ENERGY STUDIES
Solar Resource

Solar Water Heaters

- Well proven and established technology.
- Technology
  - Flat plate collectors
  - Evacuated tubes
  - Thermo-siphon
- Subsidies:
  - Solar 500 project in 2007 rolled out by the CEF
  - Eskom DSM subsidy (www.eskom.co.za/dsm)
- Most obvious, cost effective system to use solar energy, we should each have one or two on our roofs.
Bulk Solar Thermal Power Plants

- Solar towers
- Solar troughs
- Solar dishes

Concentrating Solar Power

How does it work?

- Parabolic trough collector
- Storage
- Boiler
- Generator
- Dry/wet cooling
- Grid interface
- Steam turbine
- Condenser
Concentrating Solar Power

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

Source: DLR

Concentrating Solar Power

**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

Source: DLR
Concentrating Solar Power

**Solar Dish & Stirling Engine**
- Capacity per module: 25 kW
- Few installations
- 500 MW installation is planned (20,000 dishes!)
- Eskom: Solar Dish at the DBSA in Midrand

Source: StirlingEnergySystems

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Concentrating Solar Power

**Solar Tower**
- Proven technology
  - First demonstration plants in the 80’s.
  - Commercial plants are operating in the US and Spain.
- Capacity per module: 10-100 MW

Concentrating Solar Power

Eskom, 100 MWe, CSP northwest of Upington
- Receiver – 540MW(t)
- Energy storage – 14 hours, Salt volume of 45,000 ton
- Plant capacity – 100MW(e), generating 24 hours over summer solstice
- Load factor – 70%
- Construction will take 3 years. Plant can be operational by 1st quarter 2012.
- Detailed technical risk assessment and mitigation studies have been conducted.

Research Focus
- Heliostat design
- Field layout & optimisation
- Receiver improvements
- Salt circuit re-design
- Resource characterisation

Source: Dr Louis van Heerden, Eskom Research and Innovation Department (Nov 2007)

Solar Chimney Power Plant
Solar Chimney Power Plant

Stellenbosch Research Questions – some examples
- Impact of various parameters on plant performance
  - Double glazing and anti-reflective coating
  - Various soil properties
  - Ambient wind
  - Vegetation under the collector roof
- Heat storage
- Peak or base load operation
- Optimum plant dimensions
- Optimum number/size of turbines

Cost Predictions for 200 MWe
- 0.105 - 0.268 €/kWh
- 3200 - 10 000 €/kW
Solar Thermal Energy Research

Spoke on Solar Thermal Energy

- Profs Theo von Backström and Detlev Kröger, Stellenbosch University
- Prof Josua Meyer, University of Pretoria

- Comparing various solar thermal power plants in the South African context.
- Dry cooling for solar thermal power plants.
- Fundamental heat transfer relationships for heat exchangers.
- Hybrid systems, combined cycle gas turbines augmented with solar thermal and storage.
- Solar (thermal) energy storage.

National Solar Energy Research Station

Photovoltaic Systems

- Direct conversion of sunlight into electricity by semiconductors
- Major challenges are cost and storage!
- Major roll-out of PV in Europe, Germany, France and now Spain, followed by some US states, e.g. California.
- Mostly subsidised by governments using as feed-in tariff.
- Very useful in rural applications with no access to the national grid.
Photovoltaic Systems

Photovoltaic Production

[Graph showing photovoltaic production: comparison between different regions such as Japan, US, Europe, ROW, Total, and China over years from 1994 to 2005.]
Photovoltaic Systems Research

- Activities in South Africa:
  - Nelson Mandela Metropolitan University, Dr Ernest van Dyk, and University of Fort Hare, Prof Edson Meyer, working on characterisation and testing of PV cells and panels, also Spoke on Photovoltaic Systems. Starting work on concentrated photovoltaic systems.
  - University of Johannesburg (RAU), Prof Vivian Alberts, developed a new manufacturing process for CIGSS thin-film PV cells. Currently ramping up production at Johanna Solar in Germany, possible next factory in Paarl. Cost advantage 20%-50% (Current status ?)
  - University of Cape Town (UCT). Profs David Britton and Margit Härting working on thin-film poly-crystalline silicon PV cells.
  - University of Western Cape (UWC). Prof Dirk Knoesen researching hot-wire deposition of amorphous silicone.
  - Other activities are small and scattered, usually looking at integrating PV panels into RE systems.
  - Tenesol in Ottery manufacturing solar panels from imported Q-Cells, now also SetSolar in Epping and at least two other groups interested to establish PV manufacturing plants in SA, driver may be CDMs.

Wind Energy Resource
Wind Energy Resource

Wind Energy in South Africa

Klipheuwel, Eskom Demonstration
- Wind turbines
  - Vestas V47 660 kW
  - Vestas V56 1 750 kW
  - Jeumont J48 750 kW
- Technical challenges
  - Eskom grid instability 2006 and again 2008
  - Cracked blade, failed bearing and motor
- Installation cost R 30m
- Capacity factor < 20%

Darling Wind Farm, Darlipp
- Four 1,3 MW Führlander wind turbines
- Installed February-March 2008
- Commissioned May 2008
- Expected capacity factor > 30%
Wind Energy in South Africa

Eskom Wind Farm, Skaapvlei near Lutzville
- Up to 100 wind turbines, first phase 100 MW, second phase 100 MW
- Funded by French Development Bank
- Out on tender, again

Private Developers
- Windlab System (800 MW)
- Genesis Energy (Seeland, PE)
- Darlip (7.8 MW, 13 MW, 200 MW)
- Typical areas:
  - West Coast
  - Port Elizabeth
  - Karoo?
  - Escarpment?

Wind Energy Research

Spoke on Wind Energy
- Prof Maarten Kamper, Stellenbosch University
- Prof Prag Pillay and Dr Azeem Kahn, University of Cape Town
- Working on new generation generators for wind turbines, energy storage using flywheels, integrating wind energy into local/rural grids, fault detection and condition monitoring, etc.
- Wind energy in very cold environments, Antarctica, also identified by the IEA as an area of current research.

- University of North West, composite blade technology for wind turbines.
- Smaller activities at NMMU, DUT, UL.
Wind Energy Research

Wind Map of South Africa

- Consortium consisting of:
  - SAWEP, South African Wind Energy Project
  - SANERI
  - Riso, National Laboratory for Sustainable Energy, Denmark
  - CSIR
  - South African Weather Services
  - University of Cape Town

Planning to use meso scale modelling and wind monitoring to develop an accurate wind atlas of South Africa.

Wave Energy Resource

Source: Joubert (2008)
Wave Energy Resource

(Geustyn, 1983)
The Cape southwest coast has the best documented wave energy resource along the SA coastline.

(Joubert 2007)
Modelled the annual average wave power using hindcast wave data

Stellenbosch Ocean Energy Research Group

Ocean Energy Research Group at Stellenbosch University

- Prof Deon Retief & Johan Müller
- Established as a response to the oil crises in the seventies.
- Funded by DeBeers, Murray & Robberts, Boart and LTA.
- Resource assessment, including tidal, OETC and tidal flows.
- Identified wave energy as the most promising resource.
- Developed the SWEC, Stellenbosch Wave Energy Converter.
Stellenbosch Wave Energy Converter

- Wave Crest
- Wave Trough
- Under-Sea Cable to Shore
- Turbine and Generator
- Air-Chambers
- Openings with Valves
- High Pressure Duct
- Low Pressure Duct

Biomass Resource

- Map showing biomass potential in South Africa
- Legend:
  - Proven: boundaries
  - Tees: Biomass energy potential
  - 0-50 Gt/ha
  - 51-100 Gt/ha
  - 101-500 Gt/ha
  - 501-1000 Gt/ha
  - 1001 Gt/ha and more

- Copyright: CSIR
- Map source: CSIR, CERTIFICATE TECHNOLOGY
Biomass

• Agricultural waste:
  ▪ Bagasse, used in sugarcane industry to fire boilers.
  ▪ Woodchips and cuttings from forestry operations.
  ▪ Corn and wheat husks and stalks.
  ▪ Manure.

• Energy crops:
  ▪ Bio-Ethanol: Maize, corn, sugarcane, etc.
  ▪ Bio-Diesel: Soya beans, Jithropa, palm oil, algae, etc.
  ▪ Others: Switch grass, Triticale, etc.

**Biodiversity Risk**

*Fuel vs Food* debate,

Second generation conversion processes - lignocelluloses into ethanol.

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**Biofuels Research**

Activities in South Africa:

• Stellenbosch University, Prof Emile van Zyl (SANERI Senior CoER : Biofuels) and his team members Profs Hansie Knoetze, Harro von Blottnitz (UCT) and Drs Johann Gorgens and Marinda Bloom will focus on the 2nd generation lignocellulose conversion technologies, which include the following activities:
  • second generation technologies for the one-step fermentation of starch to ethanol,
  • the use of lignocellulose as feedstock for biofuels production by biochemical and thermo-chemical conversion,
  • process modelling for integrating biofuels and high-value chemicals production in biorefineries, and
  • costs and life-cycle analyses to evaluate the environmental and economic impacts of these technologies.

• University of North West (UNW), Prof Sanette Marx (SANERI Assoc. CoER : Biofuels), primarily focuses on the improving of 1st generation technologies, including algal biodiesel, and the adaptation of these technologies for use by particularly rural communities.

• University of Cape Town (UCT). Prof Sue Harrison is working on algae production in bioreactors for biodiesel and biomass production.

• University of Western Cape (UWC). Prof Don Cowan’s team will use metagenomics in search for cellullases working at extreme temperature for efficient conversion of lignocellulose to ethanol.

• BioSciences, CSIR. Mr. Dheepak Maharaj initiated a project on algal production in pond systems for biodiesel production.

• Various small and scattered activities over the country, primarily looking at biodiesel production.
Hydro Energy

- Existing:
  - Hydroelectric power stations at Gariep (360 MW) and Vanderkloof (240 MW)
  - Caharo Bassa in Mozambique
  - Kunene river in Namibia/Angola

- Energy Storage:
  - Steenbras, Palmiet and Drakensberg
  - New Braamhoek (Ingula) and Project Lima (Steelpoort)

- Micro and Small Hydro:
  - Small installations, < 100 kW
  - Run-of-river systems
  - Small Hydro, eg. Bethlehem Hydro, 7 MW

- Future:
  - Inga in the DRC, Grand Inga 40 GW (Eskom’s current installed capacity)

Others

- Bio Digesters
  - Large potential for domestic biogas production, cooking heating and electricity generation

- Ocean Energy
  - Agulhas ocean current, Eskom currently conducting measurements
  - Tidal energy is not feasible in SA

- Energy from waste
  - Incinerators, coupled to boilers
  - Landfill to gas, harvesting of methane from capped landfills and converted to electricity using a gas engine or turbine.

- Durban Landfill Projects
  - La Mercy & Marianhill landfills
  - 0.5 MW & 1.1 MW
  - CDM Projects
  - Bisasar Road 1 MW now online.
Energy Challenges in SA

- **Energy security.** Eskom will not be able to supply sufficient electricity to the country in the short to medium term.
- **Carbon emissions.** With 90% of electricity generated from coal and Sasol converting coal to liquid fuel, SA is one of the higher per capita emitters of CO₂ in the developing world. The key uncertainty is what will happen after the Kyoto Protocol expires in 2012.
- **Lack of direction and leadership.** The SA Government has not set out a clear path of how to achieve the renewable energy targets set in the White Paper, and those actions listed were not carried out.
- **Funding and incentives.** Renewable energy receives a fraction of the energy research funding, there are no incentives for independent power producers to produce energy from renewable resources.

Energy Opportunities in SA

- **RE resources.** South Africa has extensive, proven resources of renewable energy, in particular solar energy, wind energy, wave energy, and biomass production.
- **Expertise.** In a number of areas, South Africa has world-class research expertise and facilities to support local RE projects that, at the same time, can also make an international contribution.
- **Community awareness.** Recent energy crises and blackouts made everyone aware of the risks of our current dependence on a single utility mainly generating electricity from coal. The opportunity exists to roll out RE in the current period of electricity shortage.
- **Funding.** The energy sector in SA has always been well funded, PBMR’s R 5 billion is an example of this. Minister of Finance announced a new tax on electricity generated from non-renewable sources of 2c/kWh to be implemented in 2009.
Future Research Highlights

- Solar Thermal Energy
  - Conversion
  - Cooling
  - Storage
  - Demonstration plants (100 MW CSP) and, National Solar Energy Research Centre
- Photovoltaic
  - Cost reduction
  - Concentrated photovoltaic systems
- Wind Energy
  - Wind map of South Africa
- Bio-Energy
  - Second generation conversion technologies of lignocelluloses
  - Reliable source for bio-diesel
- Wave Energy
  - Reliable wave energy converters
  - Environmental impacts and approval processes

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