Transition modelling

Presentation to the NEET workshop:

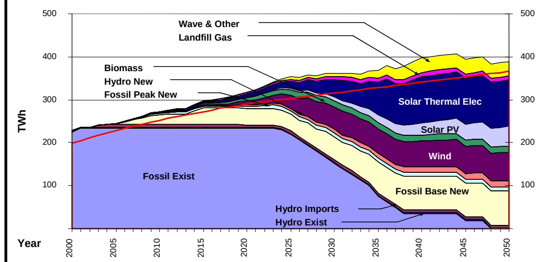
Energy technology collaboration

IEA, SANERI, REEEP, FFF

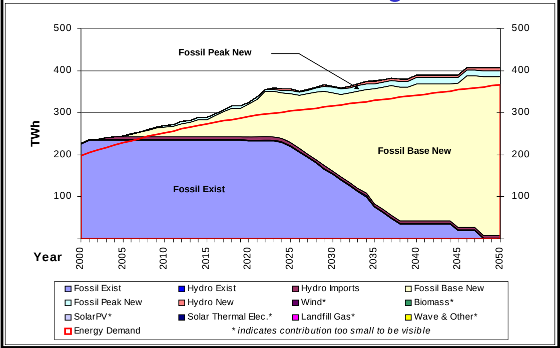
20 - 22 February 2007
Johannesburg, South Africa
Sandton Convention Centre

Jason Schäffler
Nano Energy

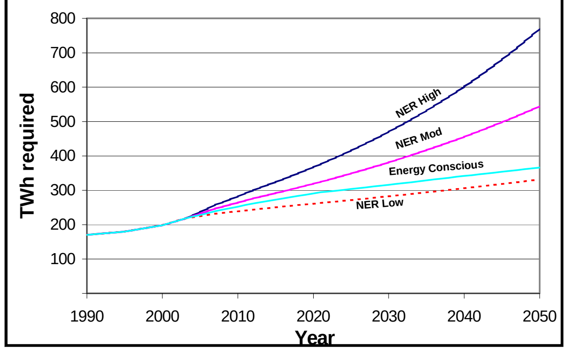
Progressive RE: electrical demand matching



Business as usual – energy demand matching



Electricity demand predictions



Thank you.

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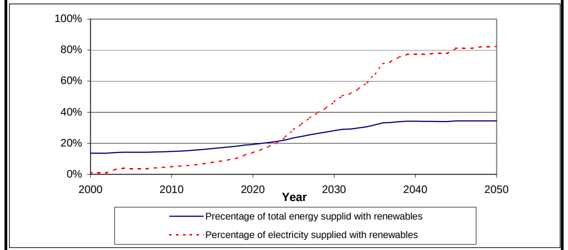
Trends in long term demand

- Used DME IEP and NER IRP as starting point (up to 2022 only)
- Factors to consider
  - Energy intensity per unit GDP reduces
  - Average domestic energy consumption increases to more 'middle income levels' – gradually.
  - High income users become more efficient (reduce slope of energy/income graph
  - Population growth expected to be 'muted' as a result of HIV/AIDS

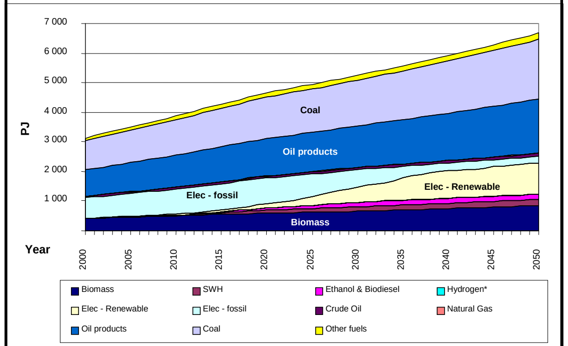
Resource overview

Category	Current energy (TWh)	Total potential (TWh annually)	Maximum scenarios (TWh annually)
Hydro	1	15	15 (43 Import)
Wind	-	106	80
PV	-	-	85
Solar thermal	0.5	-	56*
Solar Thermal Electric	-	-	184
Wave,Geo,Ocean	-	70	70
Biomass	106	44 (375*)	94*
Landfill Gas	-	10	10

Progressive RE: RE contribution



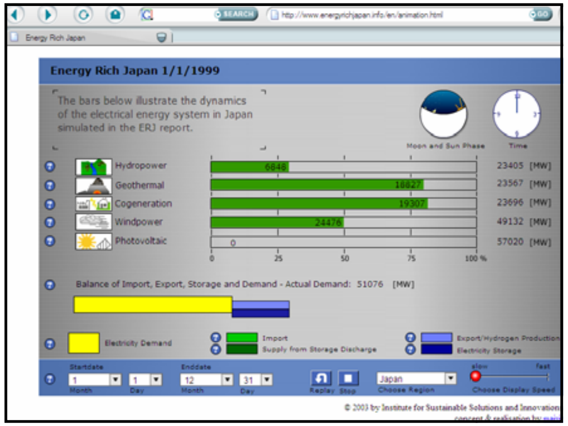
Progressive RE: energy by resource



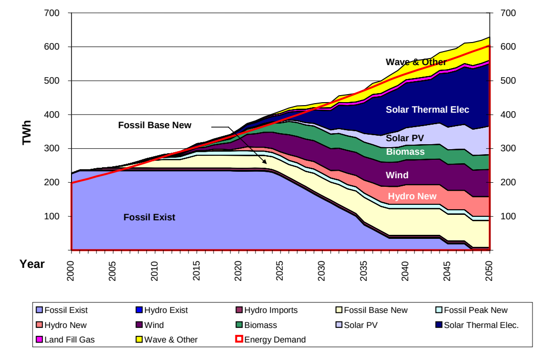
* indicates contribution too small to be visible

A Lot: but not enough?

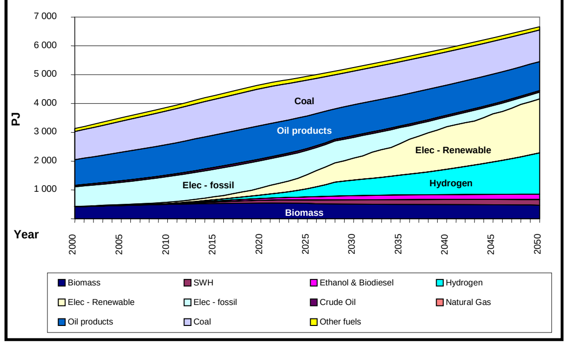
- Electricity can be largely renewable >70%
- Renewable energy portion of total energy demand can grow >30%
- Total demand growth has been restrained
- Yet- fossil fuel consumption grows!
- Does not significantly mitigate climate change contribution



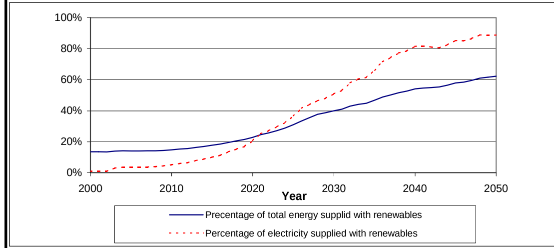
High RE: Electricity supply



High RE: total energy mix



High RE: RE contribution



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Absolute contributions to the energy mix

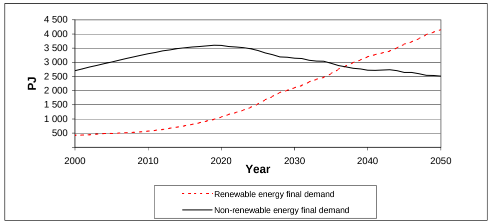

Fig 5-13,
p 53

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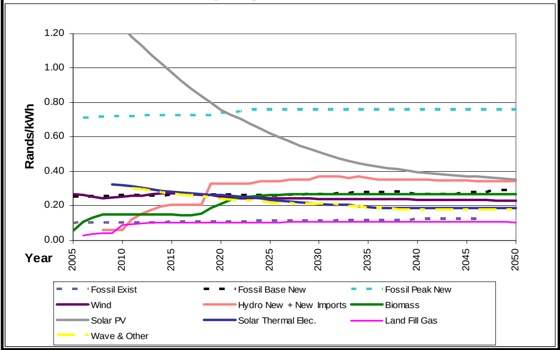
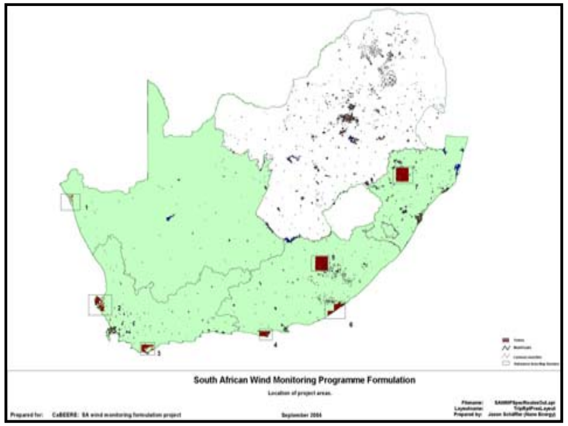
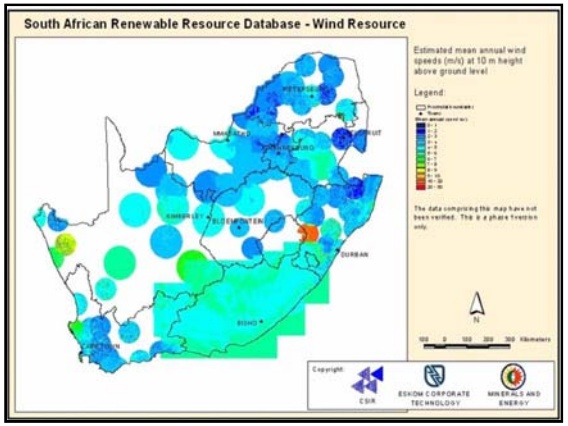
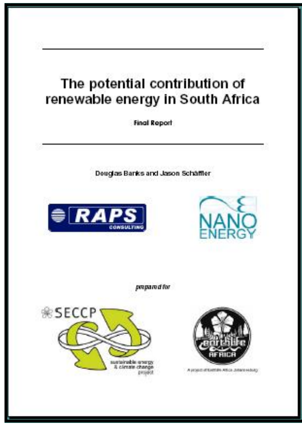
16

Progressive RE: technology cost projections









The potential contribution of renewable energy in South Africa

Final Report

Douglas Banks and Jason Schäffler

prepared for

Study

- www.seccp.org.za
- www.restio.co.za
- www.nano.co.za

Findings

- 2020: 15 to 20% electricity is possible
  - Total energy > 20% more difficult
- 2050:
  - Renewable electricity >> 50%
  - Renewable contribution to total energy: 35 to 40%

However, fairly bold steps could be taken that would allow reduction in fossil fuel usage
  - Greater electricity usage (provided using RE)
  - Hydrogen production (or equivalent easily stored and transported fuel)
  - Renewable electricity: > 70%
  - Renewable contribution to total energy: > 50%

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Energy consumption and efficiency

- The scale of the challenge is enormous
- Study has assumed significant energy efficiency interventions (double, not triple by 2050)
- But, is strong motivation for even more energy efficiency if increase in fossil fuel usage is to be controlled (may be more cost effective)

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Other observations

- Time is short
  - industries have a very low base to start from (even 20% growth rates take time to yield significant impact)
  - Large energy projects have long lead times
- Resource base assessment – reliable transparent data required, especially for:
  - wind, biomass, hydro, pumped storage
- Current planning does not look far enough ahead
- Current planning does not really give serious consideration to large scale renewable energy contributions

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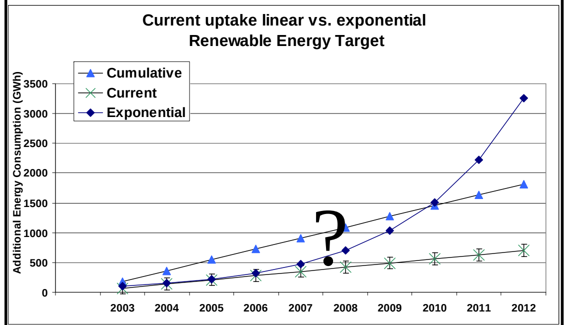
Initiatives on this path

- SAWEP, SWH, and Biofuels
- Renewable Energy Market Transformation (REMT)
- Subsidy Office in the DME
- Tradable Renewable Energy Certificates (TRECs)
- Renewable Energy Target Monitoring
- National Integrated Resource Planning (NIRP3)
- Second Integrated Energy Plan
- Renewable Energy Regulatory Framework

Target Contribution 2004 (GWh) 70.1													
Non electrical (GWh) 69.4					Electrical (GWh) 0.7								
Thermal 69.4		Mechanical 0		Liquid fuels 0	Grid 0				Off-grid 0.7				
Biomass thermal	Solar thermal	Hydro Mechanical	Wind mechanical	Biofuels	Solar electrical grid	Wind electrical grid	Biomass electrical grid	Hydro electric grid	Solar electric off-grid	Wind off-grid	Biomass electrical off-grid	Hydro electric off-grid	
0	69.4	0	0	0	0	0	0	0	0.3	0.4	0	0	



Energy Policy and RE

- May 2004 - renewable-energy white paper (White Paper on the Renewable Energy Policy, November 2003, General Notice 513 of 14 May 2004),
  - government's vision is an energy economy in which modern renewable energy increases its share of energy consumed and provides affordable access to energy, thus contributing to sustainable development and environmental conservation (para 1.1).
  - energy bill which was proposed in 2003 which would allow the minister to make regulations regarding minimum contributions to the national energy supply from renewable energy resources (para 3.1.6).
  - to meet the long-term goal of a sustainable renewable-energy industry, the government has set a target that approximately four percent of the estimated electricity demand by 2013 should be contributed by renewable energy, mainly from biomass, wind, solar and small-scale hydro (para 5).
  - A renewable-energy strategy would be developed to translate the goals and objectives in the white paper into a practical implementation plan (para 11).

Electricity Regulation Act

- The Bill, as introduced in 2005 and subsequently enacted as an Act of Parliament (Electricity Regulation Act 4 of 2006 - 5 July 2006) states that the Minister may, in consultation with the National Energy Regulator,
  - determine the types of energy sources from which electricity must be generated, and the percentages of electricity that must be generated from such sources (s 46(1)(b))
  - determine that electricity thus produced may only be sold to the persons or in the manner set out in such notice (s 46(1)(c)),
  - determine that electricity thus produced must be purchased by the persons set out in such notice (s 46(1)(d)). The Regulator, in issuing a generation licence, is bound by any such ministerial determination (s 46(3)(a))
  - may facilitate the conclusion of an agreement to buy and sell power between the generator and the purchaser of that electricity (s 46(3)(b))
  - the Minister may, by notice in the Gazette, make regulations regarding the types of energy sources from which electricity must be generated (s 47(4)(n))
  - the percentages of electricity that must be generated from different energy sources (s 47(4)(o)).

Electrical RE regulation

- The Electricity Regulation Act 2006 envisages regulations regarding the type of energy sources from which electricity must be generated, and the percentages of electricity that must be generated from these different energy sources.
  - production/distribution/consumption obligation
- The introduction of a Tradable Renewable Energy Certificate (TREC) system would allow for monitoring and administration of obligations or other support mechanism
  - such as a 'top-up feed-in tariff'

Different revenue streams

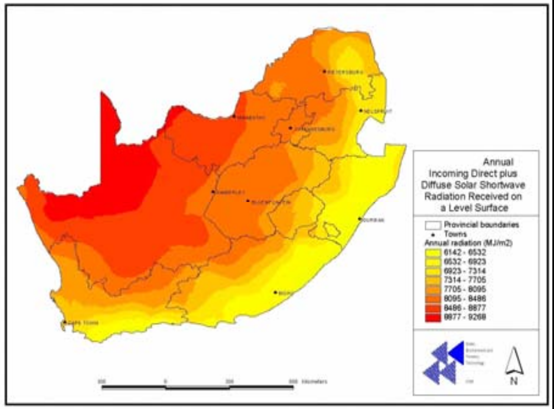
- Physical power
- Emissions reductions
  - consideration given to use of existing infrastructure (Designated National Authority (DNA) or generation licensing)
- TRECs – 'green' attributes
  - Attributes include:
    - Local environment
    - Public benefit – job creation…
    - Other externalities – avoided morbidity

Approach to the scenario study

- Time and research resources were constrained so….
  - **Simplify** – have limited variables in approach
  - Identifying the possible, highlight the key issues and opportunities
- Assessed renewable energy resources and technologies (literature and consultation)
- Developed **simple demand model** (2005 to 2050) for
  - Electricity
  - Total energy
- Simple 'illustrative model' used to
  - Produce **energy supply scenarios for electricity**
  - **Energy supply scenarios** for non-electricity energy supply
- Population of the model informed by
  - Resource availability
  - Generic cost curves for energy from different resources
- Used available cost information to estimate
  - Cost of electricity

Renewable resources

- Solar
  - Photovoltaics
  - Thermal electric power generation
  - Direct thermal (water, space heating, cooking, process heat)
- Wind
- Hydro
  - Generation
  - Pumped storage
- Biomass
  - Woodfuel (direct thermal)
  - Biomass power generation
  - Biomass – liquid fuels
- Wave, Ocean current, Geothermal and other options



Solar

- PV electricity generation
  - Resource is excellent, contribution not limited by resource or even land availability but manufacture and intermittency
- Solar thermal electric
  - 25 – 40MW/Km^2, use balanced with other technologies with inclusion of linked thermal storage options
- Solar thermal heating
  - 55TWh by 2050 from conservative extrapolation of World Bank 2004 43TWh annually by 2020.

Wind

- Wind resource assessment – early days
- Wind speed data
- Physical land area available
- 4100 km^2 at >6.5m.s^{-1}
- Load factors of 24% – 37% yields 106TWh
- Potential for installed capacity of 50GW (30GW/ (80TWh) in High scenario)
- Land avail, electrical storage, peak load management and visual impact

Economic analysis estimate

- Contained in final report
- 60 TWh all sites (180TWh national e^- consumption
  - Danish 15.3% nationally 7000 turbines
  - Energy-rich Japan
- Class 1 sites **0 – 500 GWh** annually
  - Sensitivity a function of datum sets and GIS model resolution
  - Will be informed by commissioned local projects
- More recently a 100 TWh estimate

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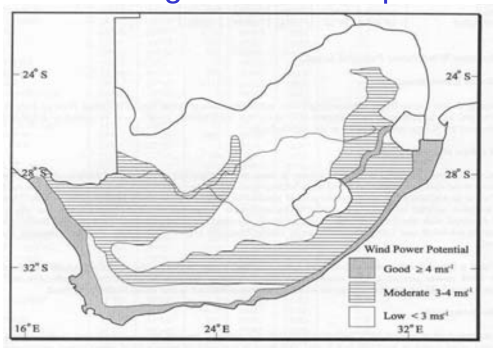
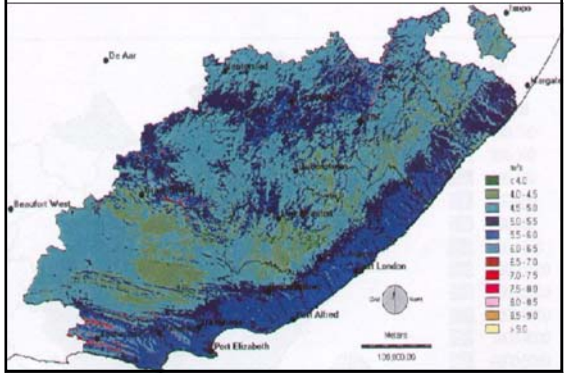
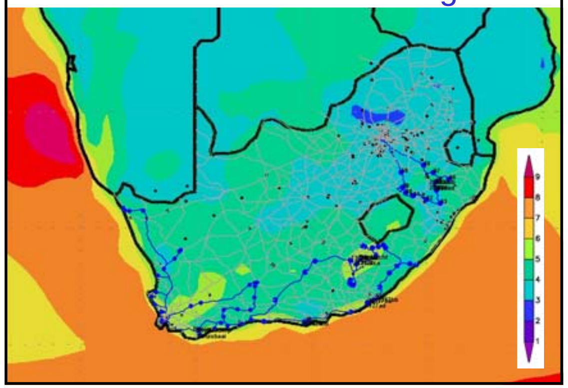
Existing resource maps



Modeling results



Meso-scale modeling



Methodology.

- Wind probability distribution function
  - Assumed Weibull A and k
  - Calculated A using fixed k and 'known' ave speed
- Annual output per SEGP determined – into economic model as load factor
- Number of turbines per resource category
  - GIS based model
  - Total area above which resource occurs (2D)
  - 'Practically realisable' limiting factors: roads, Dx, incompatible land use.
  - Turbine density

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Model refinement

- **Further provincial hub-height models**
  - 3D roughness effects
  - Accessibility
- TOU/production impacts on sales price
- Geographical criteria
- Mini-grid hybrid market
  - Alignment Homer and electrification planning
- Iterations through phases of target-driven RE strategy.

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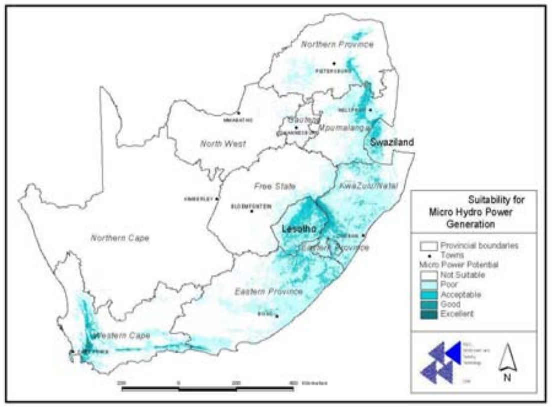

Hydro

- 50W (pico) to multi GigaWatt installations
- Total hydropower potential 7.8 GW
- Depends on topography, water flow rate and change in height
- Progressive used 70% of this at 30% load factor
  - 14.6 TWh (5.5 GW)
- High scenario imports additional 6.5 GW at higher load factor
- Current costs ~11 – 58 c/kWh

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Regional Hydro Potential

- Theoretical regional large scale hydro potential amounts to a massive 100GW
  - White Nile in Uganda, the Zambezi, Zaire, Rufiji, Shire and Cunene ~70GW
  - Zaire at Inga is capable of yielding 40 GW.
  - Zambezi and tributaries can yield about 11 GW
- Imported hydro by 2050? Cahora Bassa 16-year lead time and bad debt (2 GW).
- Concerns regarding supply security and political stability only 7GW to scenarios.
- Proportion to SA vs. other Southern African countries (economic growth elsewhere in the region
  - A large Zambian-DRC transmission interconnector which is being upgraded from 220MW to 500MW capacity at the moment is reportedly being driven by supply to the SAPP in general rather than just SA.

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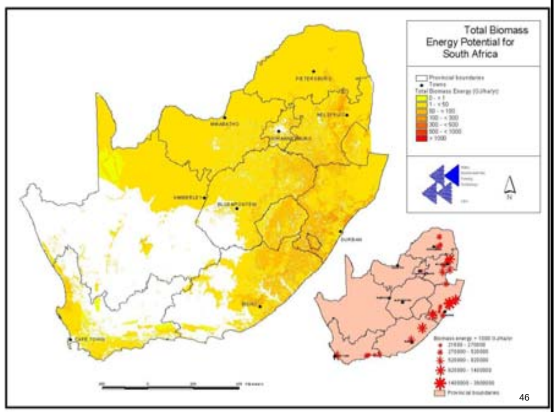

Biomass

- Currently estimated 8.7 to 14% of primary consumption (sustainability?)
- 4300 km² sugar cane and 13000 km² plantations
- Sugar cane, forestry, sawmill & pulp and paper wastes 12.7 TWh annually.
- Additional land another ~4TWh
- Progressive uses 16.4 TWh electrical
- Other estimates greater than 400TWh annually (
- Biofuels 42TWh (150 PJ) in progressive
  - Biodiesel (~20% Diesel consumption)
  - Bio-ethanol and others
- High - 43TWh electrical and 180 PJ biomass derived liquid fuels

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Landfill gas

- Estimated at 830 MW (6.5TWh annually at 90%)
- Function of composition and quantity of material in landfill
- Adding sewage derived methane gives 7.3 TWh
- 1% growth annually gives ~10TWh by 2050

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Wave, Ocean Current, Geothermal and other

- Wave 25 – 50 MW/Km over ~900 Km
- With 75% suitable for converter installation we get 18 GW generating 70 TWh.
- Have assumed 500 MW for geothermal
- Progressive scenario 4.2 GW
- High scenario 8.7 GW

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Market Assessment and projected contribution

- Current rate is insufficient
  - Market price for renewable energy is unlikely to reach competitive levels at this point in time.
  - See draft Appendix F: Executive summary
- Enabling statement by government for development of RE
- Results from existing market assessments
  - Such as1% of Cape Town consumers equivalent to RE target in 1 year.
  - Estimates of willingness to pay for TRECs
- Green funding and mechanisms report
- Quantify anticipated change in rate of uptake vs. that required by the target (NIRP2, IEP1, other)
- Geographically dispersed green customers, circumventing physical trade barriers.
- Estimated change in number and energy contribution of currently marginal projects included in motivation

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The potential of renewable energy in South Africa

Results from a scenario exercise to 2050

Banks, Douglas[1] and Schäffler, Jason[2]

Based on research commissioned by the Sustainable Energy & Climate Change Project, Earthlife Africa Johannesberg (Banks & Schäffler, 2005, Potential of RE in SA).

Abstract

Energy use in South Africa is currently dominated by reliance on coal and oil. This is not sustainable in the long term, leads to environmental damage, renders the country vulnerable to international oil price fluctuations, contributes to exchange rate risk and the greenhouse gases emitted contribute to global climate change. The research presented in this paper has three main parts. Firstly, a demand assessment indicates that energy consumption might treble if current planning trends are followed. Arguments are presented for energy efficiency and demand curtailment to limit energy demand growth to double current levels. Secondly, available data on renewable energy resources was coupled with information on technology trends to provide indications of the potential for electricity, liquid fuels and hydrogen to be generated from renewable resources. Thirdly, three energy supply scenarios were developed. Two of these scenarios illustrate the contribution that renewable energy could make to electricity supply generation and to the total energy supply mix for the country. The research indicates that more than 50% of electricity energy could be supplied using renewable resources by 2050. If South Africa develops a significant hydrogen (or similar) component to the economy, then it is also possible to have more than 50% of total energy needs met using renewable resources by 2050.

In February 2006, an additional appendix, outlining an investigation into the costs of various scenarios developed, was added to the study. The key findings were:

- The renewable energy scenarios are likely to have a significantly lower total cost of generated electricity in the medium to long term.
- Given the assumptions used, the Business as Usual scenario ends up with an annual electricity cost of R125 billion by 2050, while the Progressive Renewable scenario has annual costs of about R100 billion.
- Also important is that the Progressive Renewable scenario indicates cost of energy savings by 2015 or perhaps even sooner, the results provide strong impetus to prepare for a change in the energy economy sooner rather than later.
- However, these renewable energy scenarios are likely to have a higher capital investment requirement, with the total capital investment required being of the order of R 760 Billion for the Progressive Renewable scenario, as against R 660 Billion for the Business as Usual case.
- The capital investment estimates presented in the paper also provide a clear illustration of the scale of investment in different technologies that would be required if we are to achieve a significant shift to more sustainable electricity generation in the future.
- The huge scale of required investments indicated in these scenarios also provides powerful motivation to focus on energy conservation and energy efficiency.

As with any scenario work, the results are not intended to be predictive, they have been produced using a fairly simple yet transparent modelling approach to allow readers to grapple with the magnitude and scope of the electricity supply challenge that lies ahead of South Africa. The authors' primary objective is to stimulate debate and to highlight the critical importance to our economy of long term energy planning decisions, and the need to undertake detailed public benefit work to understand electricity generation cost evolution and technology development for a range of generation methodologies.

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