"Greentech"

Tracking renewable energy and energy efficiency technology innovations relevant to the Western Cape of South Africa

Department of Economic Development and Tourism

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Contents

Glossary

CLEAN DEVELOPMENT MECHANISM The CDM is the United Nations carbon trading instrument between industrialised (Annex 1) and industrialising (Annex 2) countries.

CONFERENCE OF PARTIES Annual gathering of signatories to the United Nations Framework Contract on Climate Change. The 15^{th} COP was held in December in Copenhagen, Denmark.

GIGAWATT HOUR (GWh) An energy unit in which electricity consumption is measured. 1 GWh = 3,600 GJ (Gigajoule) (Joule, unit of energy).

INTERNATIONAL ENERGY AGENCY (IEA)

ENERGY SERVICES COMPANIES ("ESCOS") develop, arrange financing and install EEPs on a "paid from savings" basis within host facilities. Share of savings are paid to the ESCO.

GREENHOUSE GAS Gases (primarily carbon dioxide CO_2, methane CH_4, and nitrous oxide N_2O) in the Earth's lower atmosphere that trap heat, causing an increase in the Earth's temperature and leading towards the phenomenon of global warming.

INDEPENDENT POWER PRODUCER (IPP) IPPs are defined as typically limited-liability, investor owned enterprises that generate electricity either for bulk sale to an electric utility or for retail sale to industrial or other customers with certain conditions, following a determination made by the Minister of Energy in terms of section 34(1) of the Act.

INITIAL PUBLIC OFFERINGS (IPOS) The first sale of shares or stocks by a private company (the issuer) to the public.

KILOWATT HOUR (kWh) One thousand kilowatt hours equates to one gigawatthour. A kilowatt-hour (kWh) is one unit of electricity; one 60 Watt light bulb burned for one hour will use 0.06 kWh (60 Watts) x (1 kilowatt/1000 Watts) x 1 hour) = 0.06 kWh

LEVELISED COST OF ELECTRICITY/ ENERGY (LCOE) The cost of producing energy (usually electricity) once all costs over the lifetime of en energy source have been included. LCOE is the minimum price at which energy can be sold of the plant is to break even.

NATIONAL INTEGRATED RESOURCE PLAN (NIRP) In theory the NIRP is a least cost plan that assesses a variety of demand and supply side options to meet customer electricity needs under environmental and social considerations. Contracts are awarded under the NIRP in accordance with a set of criteria released by NERSA.

NATIONAL ENERGY REGULATOR OF SOUTH AFRICA (NERSA) The regulator is responsible for overseeing the operations and price setting of the State owned enterprise ESKOM.

POWER PURCHASE AGREEMENT (PPA) Agreement issued by ESKOMs Single Buyer Office to purchase from an IPP.

RENEWABLE ENERGY FEED-IN TARIFF (REFIT) A mechanism to promote the deployment of renewable energy that places an obligation on specific entities to purchase the output from qualifying renewable energy generators at pre-determined prices.

RENEWABLE ENERGY (from White Paper on Renewable Energy, 2003, DME) Renewable energy harnesses naturally occurring non-depletable sources of energy, such as solar, wind, biomass, hydro, tidal, wave, ocean current and geothermal, to produce electricity, gaseous and liquid fuels, heat or a combination of these energy types.

REDs Regional Electricity Distributors are proposed to be established through an Electricity Supply Industry restructuring bill which will combine Eskom Distribution and South Africa's municipal suppliers into six regional electricity distributors.

RENEWABLE ENERGY PURCHASE AGREEMENT (REPA) Renewable Energy Purchasing Agency in ESKOM's single buyer office.

Human well-being and economic growth are inextricably dependent on energy

Supply, demand and the environment dictate the global energy regime

Energy regime changes that are taking place coincide with the on-set of industrialisation in the majority world

The energy system a Century from now will be very different from that of today

1. Introduction

Human well-being and economic growth are inextricably dependent on energy, but the impact of energy choices in determining development and growth has been under-acknowledged (Mathews, 2010). This is changing. There are three fundamental variables in the global energy balance: "demand", "supply" and the "environment" and all three are in a state of unprecedented flux. This flux contributed to the global recession of 2008/9[2] and brings into focus the importance of energy decisions for growth and development.

Critically the energy regime changes that are taking place coincide with the on-set of industrialisation in the majority world – a phase of economic development that is likely to be energy intensive. The challenge of meeting future energy demand is likely to define a new set of "winners" and "losers" in the global energy regime, and the economic success stories of the coming century are likely to be defined by those regions, cities and companies that are able to decouple their economies from the emission of greenhouse gases.

Currently the Western Cape is a passive dependent on South Africa's energy regime. In addition to the global challenges, South Africa confronts supply shortfalls, the need for institutional reform, growing demand, unequal access to energy, rising prices and mounting pressure to assume responsibility as the world's 13th largest (and a disproportionately intense) emitter of greenhouse gases.

This study was undertaken on behalf of the Western Cape Province's Department of Economic Development and Tourism (DEDAT) that will enable the provincial department to play an effective role in supporting innovation in the energy sector. The study seeks answers to four strategic questions:

- Why change in the provincial energy sector is essential for economic growth?
- What change is likely over the next forty years?

[2] Between 1985 and 2004, the world spent between 1.75% - 2.25% of its GDP on oil. When the oil price peaked at US$ 120 bbl in early 2008, the world spent 8% of its GDP on oil (UBS, 2008), exposing a multitude of fragile financial deals, creating fragility in other deals and making a recession difficult to avoid.

- Who is likely to drive this change?
- How is this change likely to be realised and financed?

The report is descriptive not normative. It draws on the available data and case studies in the global renewable energy sector. Collectively the information points to the necessity of renewable energy if economies and societies are to continue to develop. Central to the findings is the potential for the Western Cape Province to distinguish itself from the national energy regime, establish greater energy independence and a share of the country's energy sector. To realise this potential will require investments that are configured both technologically and institutionally, and which are embedded in social awareness.

The provincial government has a role to play in this process. South Africa's energy sector is highly regulated and a significant component of the challenge arises from the market failure caused by externality costs and un-reconciled supply and demand. This is not the sort of economic environment in which private sector firms can be expected to contribute the definitive solution. Rather, an entrepreneurial interaction between private investors, the provincial and local governments in the Western Cape and research centres is required. This collaboration should be tailored to meet the specific needs and opportunities of the province.

The focus in this study is on renewable energy supply and energy efficiency technologies. Spatial planning, sectoral shifts, building material and regulations and behaviour change, all of which are able to have a profound impact on energy demand and the environmental impact of energy, fall beyond the remit of this study. The focus on technology does not obviate the need for regulatory and institutional reform; the type of reform that will both facilitate the uptake of technology and result in the sectoral and behavioural shifts towards less carbon intensive economies.

The report is structured according to the terms of reference:

- Section 2 covers trends in the global energy sector.
- Section 3 describes the Western Cape energy sector in the context of the country's energy regime.
- Section 4 describes those renewable energy sub-sectors that are most relevant to the Western Cape and maps innovation and role players in these sub-sectors. .
- Section 5 financing, governance, planning and research and development tasks for the DEDAT in facilitating the emergence of a renewable energy sector in the Western Cape.
- Section 6 concludes.

Until recently the transition to renewable energy was viewed as an economic cost. More recently however it is being seen as an opportunity to foster a more secure, labour intensive and sustainable economy and society. As Dow and Downing (2007) point out, "Renewable

Growth in demand has is expected to double between 2005 and 2030

The growth in the supply of "easily accessible" oil and gas is expected to drop below the rate of growth in demand for the first time in 2015

The unrestricted increase of carbon emissions in the atmosphere will commit the world to more than 4°C warming by the end of the century

It terms of the energy required to fuel economic growth and development in the world's poorest countries, the past is not repeatable.

energy could be the technological key to economically and socially sustainable societies". It is the potential for renewable energy technologies to contribute much needed economic and social reform that makes their adoption imperative. This reform will retain competitive advantage in the short term and develop new competitive advantages in the medium term.

2. Trends in the global energy technology markets

2.1 Origins of global change

Over the 20th Century global economic growth correlated closely with the consumption of electricity and the emission of greenhouse gases. Figure 2 clearly shows the impact on emissions, via the economy, of two World Wars and economic recessions. The ability of fossil fuels to provide relatively low cost and highly concentrated forms of energy was central to the industrial revolution and associated economic growth. It also gave rise to a set of closely linked sectoral and geographical interests characterised by organisations such as OPEC and the large oil and transport companies that have determined much of the subsequent economic and political activity. The limited ability of this regime to balance global demand and supply while simultaneously addressing environmental impacts underscores the need for change.

- On the demand side, global energy consumption in 2008 was $5*10^{20}$ joules (equivalent to 15 TerraWatts of power). Oil multi-nationals refer to the pending "step-change" in energy demand as countries such as India and China industrialise (Shell, 2009). Growth in demand has increased at an average of 3.4 per cent per annum over the past century and is expected to double between 2005 and 2030 (IEA, 2009).

- Supplying this energy is a major economic activity. Currently 82 per cent of global energy is supplied from fossil fuels (oil, coal and gas). Fossil fuels represent a finite resource and whilst the stock of known reserves is large and growing, the growth in the supply of "easily accessible" oil and gas is expected to drop below the rate of growth in demand for the first time in 2015 (Shell, 2009).

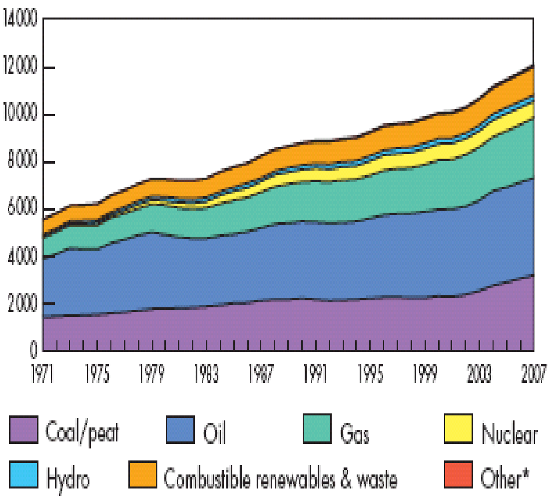

Figure 1a: Global primary energy production by fuel source. Source IEA (2009)

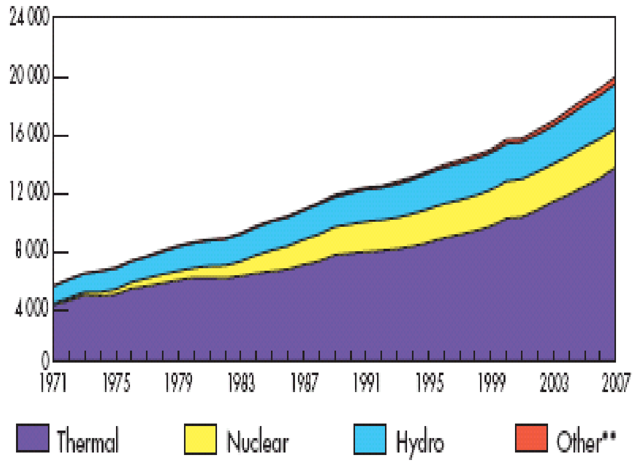

Figure 1b: Global electricity supply by fuel source. Source IEA (2009)

- Environmental impacts relate to the disruption of terrestrial and hydrological systems during the mining of fossil fuels and the emission of greenhouse gases when these fuels are burnt. Cumulative greenhouse gas emissions since the 1850s have already raised atmospheric temperatures 0.81°C (IPCC, 2009). Under business as usual emissions would increase four-fold by 2050 and commit the world to more than 4°C warming by the end of the century. Such a temperature increase would usher in uncontrollable climate change and severe economic and social costs (IPCC, 2007).

In terms of energy, then, and specifically the energy required to fuel economic growth and development in the world's poorest countries, the past is not repeatable. As Jeremy Bentham of Shell's Global Business Environment points out, "Everybody knows that the energy system a century from now will be very different from that of today". Elsewhere the talk is of a, "low carbon economy" (Gordon Brown, 2009) a "re-industrial revolution" (Hawken et al., 1999), an "ecological civilisation" (Hu Jinato, 2009) and a "global green new deal" (UNEP, 2009).

What is less clear is exactly how this will be achieved.

Decoupling depends on renewable energy and energy efficient technologies, sequestration technologies and geo-engineering.

Renewable energy and energy efficiency technologies offer the greatest proven potential

Energy technologies have particularly long lead times. Incremental or linear changes will not deliver the required solutions

"Renewable energy could be the technological key to economically and socially sustainable societies,"

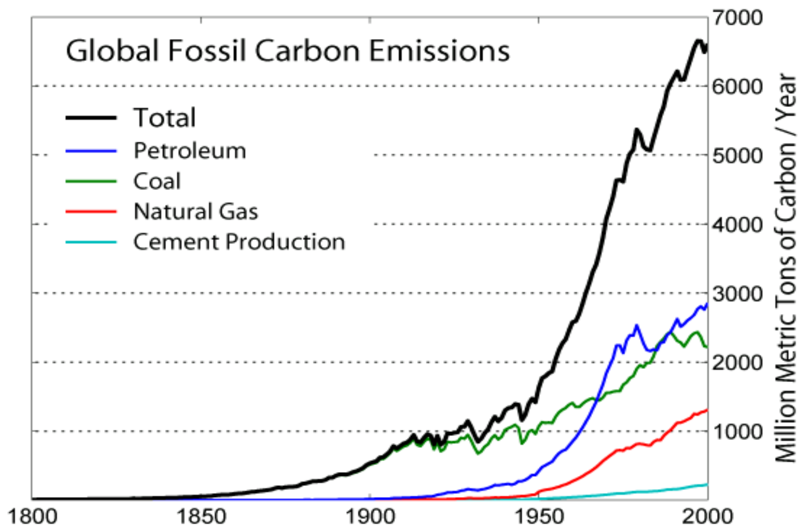

Figure 2: Atmospheric CO_2 emissions 1800-2000, total and by activity (Source: IEA, 2005).

The challenge of "decoupling" economic growth from the emission of greenhouse gases is not easy. In spite of the acknowledged need for reform, public subsidies to the global fossil fuel industry still totalled R2.2 trillion in 2008 (WRI, 2009), but four related categories of technology, each subject to its own innovation path, have emerged in response to the challenge:

i. **Renewable energy technologies:** In the long run (50 – 100 years) economies will be powered by renewable energy sources which currently include wind, solar, biomass (including first and second generation biofuel and waste to energy), biogas, hydro-energy (which includes tide and wave energy) and geothermal energy. Most of these technologies have existed for some time, but are currently the focus of intense innovation aimed at lowering their cost and increasing the ease with which they can be assimilated into national energy systems.

ii. **Energy efficiency technologies:** In the immediate term energy efficiency technologies have an important role to play both in reducing the quantum of energy that needs to be substituted and in reducing the rate of greenhouse gas emissions, thereby providing time in which to make the transition to renewable energy. The IEA estimates that every R1 spent on energy efficiency saves R2 in energy supply capacity (IEA, 2009).

iii. **Sequestration technologies:** Carbon capture and storage (CCS), or "end-pipe" technologies, aim to reduce the release of greenhouse gases from fossil fuel burning equipment into the atmosphere. Trees, grasslands, the ocean, engineered vaults and stable geological structures are considered possible repositories for the atmospheric carbon dioxide that is raising temperatures. Sequestering CO_2 in geological structures has been practiced in Norway for over 30 years, and more recent projects exist in Algeria and Canada. The capture of CO_2 in disused mine shafts and saline ocean trenches and aquifers is being researched by ESKOM (via the Central Energy Fund) in South Africa. The "as yet unproven" potential for this approach to offer an expedient solution to emissions is even referenced in the World Bank's recent review of ESKOM's loan application, but CCS remains controversial with adversaries pointing out that the gas might escape as geology changes.

iv. **Geo-engineering:** Geo-engineering involves technologies that manage the physical impacts of global warming. Solar irradiation reflectors and altering the composition of the atmosphere so as to reduce solar irradiation are among the options under review. As yet these technologies are considered unproven, even dangerous, in their current form.

In spite of the challenges 2008 proved to be the first year that investment in new renewable power generation (R1.05 trillion) exceeded investment in fossil fuel capacity (R825 billion) (UNEP, 2009). The need for change has not been exclusively predicated on issues of supply, demand and the need to reduce greenhouse gas emissions. The formation of a domestic renewable energy sector has the potential to contribute to local priorities on a number of fronts:

- **Employment creation:** Individual estimates vary but concur on the fact that the renewable energy sector is more labour intensive than the fossil fuel industry, and already employs more people than the fossil fuel energy sector. The International Labour Organisation (ILO) (cited in UNEP, 2009) claims that the production of renewable energy is on average 20-fold more labour intensive per unit of energy produced than fossil fuel energy. Renewable energy jobs tend to be more geographically dispersed than fossil fuel jobs. The job creation potential of the renewable energy constituted an important rationale behind the allocation of government bail-out packages in the wake of the 2008/9 recession. For South Africa, specifically, the attraction is not only new labour intensive sectors, but also the ability to transform the economic structure away from the labour un-intensive minerals and energy focus towards a more labour absorbing, diverse and sustainable economic structure.

- **Predictable costs:** Coal, gas, oil and uranium are expensive commodities, the prices of which fluctuate greatly. As inputs into the global energy system, their price fluctuation is responsible for considerable macro-economic uncertainty. This volatility and uncertainty is seldom factored into the selection of energy sources (Awerbush et al., 1996). Fuel prices are typically assumed to be constant in energy sector analysis, but this is not case. The economic viability of the Koeberg Nuclear Power Station, for example, is unavoidably linked to China's nuclear roll-out and its impact on the price of Uranium-235. Under business as usual the price of coal is set to double over the next five years as scarcity mounts (Bloomberg, 2009). In contrast, renewable energy typically has negligible and very predictable operating and maintenance costs once capital has been installed (United States DOE, 2008). A renewable energy driven economy, provided it can avoid the price distorting impacts of fossil fuel cartels such as OPEC, would contribute to macro-economic stability.

- **Water scarcity:** Global water shortages, alone, provide enough motives to seek alternatives to fossil fuel. As global water shortages exert economic constraints in many regions, the relative water efficiency of renewable energy will become essential. Relative to water efficient coal-fired power stations, wind turbines, for example, save 2,200 litres of water per MWh of electricity generated (The United States DOE, 2008). Utility scale solar requires some water for cooling, but significantly less than is used in the mining and burning of coal and all renewable energy sources avoid the water contamination impacts of coal mine leachate. ESKOM receives water at preferential rates relative to households and manufacturers, but still required R1.26 billion in 2009/10 to purchase the water it needed (NERSA, 2009). The opportunity cost of this water to the South African economy is significantly more than the paid amount ;paid by ESKOM.

- **Decentralisation and secure supply:** Decentralising energy production away from fossil fuel based power plants towards a more diffuse system of smart-grids powered by multiple sources has many attractions. Diffuse supply cannot be as easily disrupted when a single utility or critical transmission node experiences problems. Decentralised power supply also reduced transmission losses. Transmission losses currently account for 6.07 per cent of South Africa's energy (proportionately 107th out of 131 countries that measure) (UNSD, 2010). Decentralised networks and multiple energy sources also represent a distribution of revenue and employment in the energy sector.

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Employment

Costs

Predictability and macro-economic stability

Decentralisation

Secure Supply

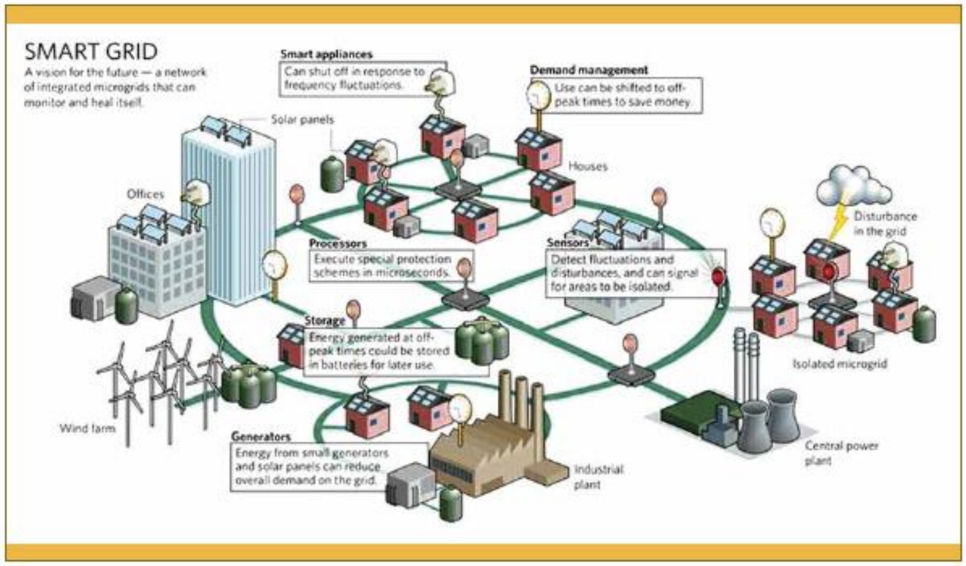

Figure 3: Stylised representation of an urban smartgrid (Source: Urbanecoist.com)

An analysis of investments in renewable energy warrants a mention of nuclear fission energy. In 2007 the world produced 2,719 TWh of nuclear energy, with the United States (30.8 per cent of global supply), France (16.2%) and Japan (9.7%) leading production (IEA, 2007). Nuclear energy, which does not emit greenhouse gases, may have a role to play in mitigating climate change, but the radioactive uranium-235 isotope is not an infinite or renewable resource. More critically, no acceptable means of disposing of the radioactive by-product (which has a half-life of 24,000 years) is currently available and unless they can be situated on the coast the volume of water required to cool nuclear plants makes them unsuitable in water scarce environments. The most limiting attribute of nuclear energy, however, is simply its cost. Whilst nuclear energy can be generated at relatively low marginal costs (R0.30-R0.38 per KWh) (UK ERC, 2007) at current uranium prices, the combined cost of constructing nuclear fission plants and decommissioning by-product is almost impossible to predict but inevitably extremely high.

South Africa appears to be recommitting itself to expanded nuclear capacity in spite of earlier recognition that nuclear power was unaffordable. A R600-R900 billion tender is alleged to have been awarded to the French company Areva as part of ESKOM's New Build programme (Greyling, 2009).

In total R1,163 trillion was invested in "sustainable energy" technologies in 2008.

Investment in China grew in every technology type and asset class in 2009.

Investment was complemented by the component of bail-out packages that was earmarked for green technologies.

Wind and then solar attracted the most investment, but investment growth was greatest in solar technologies

The renewable energy sector already employs more people than the fossil fuel energy sector, and is estimated to be 20 times more labour intensive per unit of energy produced.

The hydrogen economy is renewable but, like nuclear, is currently some way off commercial viability and has not progressed significantly in the past five years. It is not discussed in this document in spite of an ongoing research project into hydrogen technologies hosted by the University of Stellenbosch.

2.2 Global investment trends

In total R1,163 trillion was invested in "sustainable energy" technologies in 2008. Lobby groups suggest this investment needs reach R3,750 trillion per annum if greenhouse gas emissions are to peak in 2020 and then decline, as is recommended by the best understanding of climate science (UNEP, 2009; UNFCCC, 2009; WRI, 2009). 2008 was, however, the first year in which investment in new renewable energy was greater than investment in new fossil fuel energy, and an assessment of the technologies and locations that benefitted from investment provides insight into the evolving nature of the sector.

The renewable energy constituted 4.4 per cent of the recorded global energy supply in 2008,[3] but this was up from 3.9 per cent in 2007 (UNEP, 2009) and investment in renewable energy grew 13 per cent in the year while global demand for electricity grew by only 2.4 per cent in 2008. New renewable energy capacity for the year amounted to 40 GW globally – 25 per cent of all new capacity in the year – and this was complemented by an additional 25 GW of new hydro-electric power (which is not considered classically renewable due to the environmental impact of large dams) and 0.5 GW of nuclear which is not renewable but is low carbon (New Energy Finance, 2009).

Figure 4 illustrates the geographic spread of renewable energy growth over the past seven years.

[3] 6.2 per cent if large hydro-power is included.

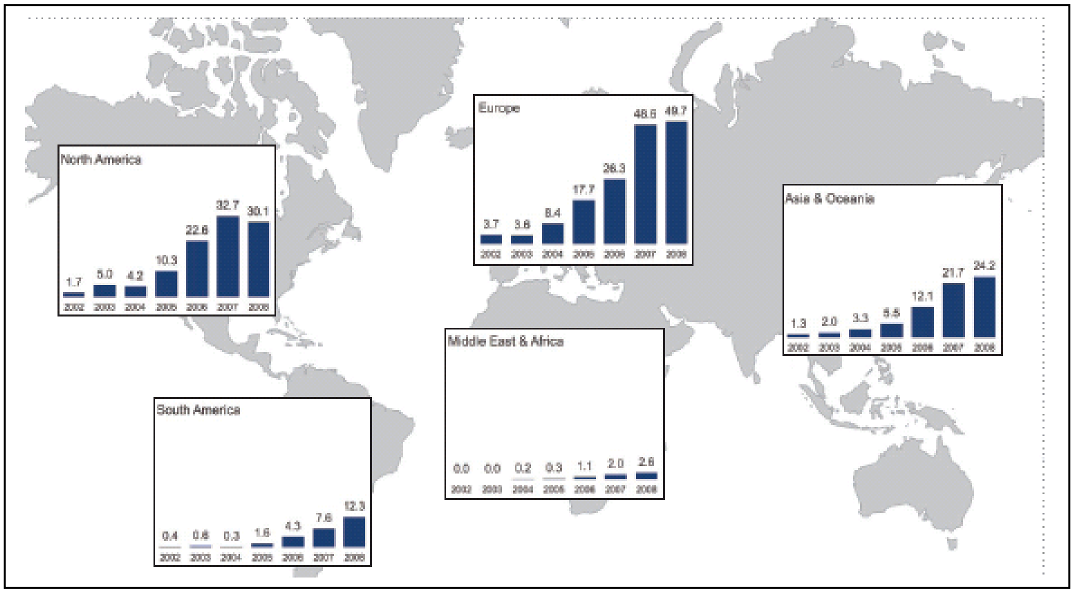

Figure 4: Geographic spread of renewable energy investment 2002-2008.

Investment was complemented by the component of bail-out packages that was earmarked for green technologies. By April 2009 the G-20 countries had committed an estimated R21 trillion of fiscal stimulus; R1.3 trillion (6 per cent) of this money was allocated to "green stimuli" (New Energy Finance, 2009). China and South Korea stand out in this regard, with 34 per cent and 78 per cent of their respective fiscal support packages being channelled towards "green investments" (UNEP, 2009).

The break-down of investment in renewable energy across different technologies (Table 1) reflects sentiment regarding the relative merits of these technologies at the global level.

Table 1: Technological breakdown of global renewable energy capacity, investment, investment growth and employment (2008)

<table>
<tr><th></th><th>Power generation capacity (MW)</th><th>Annual growth in capacity (%)</th><th>Annual investment (R)</th><th>Investment growth (%)</th><th>Total employment</th></tr>
<tr><td>Wind</td><td>121</td><td>29</td><td>388.5</td><td>1</td><td>300,000</td></tr>
<tr><td>Solar (grid connected)</td><td>13</td><td>70</td><td rowspan="2">247.5</td><td rowspan="2">49</td><td>170,000</td></tr>
<tr><td>Solar for hot water and heating</td><td>145</td><td>15</td><td>624,000</td></tr>
<tr><td>Biofuels</td><td>79 (billion litres)</td><td>34</td><td>126.75</td><td>-9</td><td>1,174,000</td></tr>
</table>

Biomass and waste to energy	52		59.25	-25	
Mini-hydro	85	8	40.5	26	9,000
Geothermal	10	4	15	2.0	25,000
Ocean (tide, wave)	0.3	None	n/a	n/a	
Large hydro	860	3.5	n/a	n/a	30,000

Source: REN21 Renewables Global Status Report (2009); UNEP (2009); UNEP/ ILO/ Worldwatch Institute (2009).

Wind energy attracted the greatest proportion of global investment in renewable technologies (R388.5 billion) in 2008. This investment allowed wind capacity to expand by 29 per cent in the year, but annual investment growth was only 1 per cent. Solar (R247.5 billion) provided the second most attractive renewable technology and significantly received 49 per cent more investment than in 2008. Investment in biofuels fell sharply in response to concerns over food security impacts and falling oil prices (Ren21, 2009).

The private investment mapped in Table 1 and Figure 4 took a variety of forms. R144.8 billion was invested through venture capital and private equity funds (up 43 per cent on the previous year), loan finance amounted to R876 billion (up 12.9 per cent on the previous year) and significantly loan finance to developing countries (R274.5 billion) grew by 27 per cent while loans to OECD countries declined in value by 1 per cent (UNEP, 2009). The balance of private investment was channelled through clean energy funds and enterprise incubators. UNEP reported 338 renewable energy incubators globally in 2008, one fifth of which involved solar companies. The presence of incubators (most of which have some public backing) reveals the perception that the renewable energy sector remains risky. Globally share values in renewable energy sector fell by 51 per cent in 2008 as private investors retreated to "safer" options but rebounded by an even greater extent in 2009. In both instances the flux was greater than that in global stock markets (Recharge, 2010).

Motivated by a share of new industries and markets, companies, cities and countries have begun repositioning themselves in the changing energy regime (see Table 2).

Table 2: Country rankings for renewable energy indicators

Indicator	#1	#2	#3	#4	#5
Existing renewable power capacity (end 2008)	China	United States	Germany	Spain	India

New capacity investment (2008)	United States	Spain	China	Germany	Brazil
Existing wind capacity (end 2008)	United States	Germany	Spain	China	India
Existing Solar (grid-connected)	Germany	Spain	Japan	United States	South Korea
Existing SWH capacity	China	Turkey	Germany	Japan	Israel

Source: Ren21 (2009 update) Renewables Global Update Report

Investment figures for 2009 are still emerging but Bloomberg indices suggest a 5.6 per cent decline (R1.087 trillion) in investment relative to 2008. The Asia-Oceania region, and particularly China, dominated renewable energy activity in 2009. The region attracted 25 per cent more investment than in 2008 (R279.8 billion); more than the America's and only R36.8 billion less than Europe. Investment in China grew in every technology type and asset class and the country recorded a watershed IPO of R19.5 billion in the company China Longyuan Power (Bloomberg New Energy Finance, 2010).

Renewable energy leaders all built their industries on the back of domestic policies and supply to the domestic market, but have pursued very different strategies in other ways.

China's growth in renewable energy was necessitated by the country's inability to meet domestic demand using its traditional energy source of coal. China's growth was achieved on the back of public investments in manufacturing capacity in the electrical goods sector, and much of the market expansion was able to draw on local suppliers. The country sought collaborations with lead technology companies on utility scale applications but was quick to standardise and domesticate more labour intensive technologies in the solar-thermal sector – a good example of how "innovation" and "mimicking" can co-exist. China is the world's leading manufacturer and exporter of photovoltaic (PV) cells and solar water heaters. Companies such as Suntech Power, LDK Solar and Orisi benefited from domestic subsidies but have rapidly developed export markets to become major manufacturers and exporters of technology.

Taiwan and Korea, like China, have used their large technology companies such as Samsung and LG, to enter the market whilst at the same time supporting smaller start-ups such as Motech, Solartech, E-ton and Neo-Solar (Mathews, 2010).

As of 2013 (global) renewable energy is expected to be cheaper than fossil fuel energy

This cross-over will not be as immediate in South Africa

At the global scale the financial case for renewable energy is unambiguous.

Given the lead times between investments and energy flows and the lifespan of utility scale energy plants, the manner in which costs are likely to change should form an important component of energy investment decisions

Europe's success has been established on the back of a half century of research, innovation and experimentation, motivated by environmental concerns and the strategic behaviour of technology companies such as Siemens Energy, Dong Energy, Vestas and traditional oil companies (Shell plc and British Petroleum plc). While Scandanavia and Germany have provided Europe's traditional renewable energy innovation centres, Spain has capitalised on its comparative advantage in solar and wind energy to develop a number of utility scale projects - the 30 MW PS10&20 projects near Seville, the 60 MW Parque Fotovoltaico Olmedilla de Alarcon near Madrid and the Navarra Wind Farm Project. The innovation efforts of European companies have been either state-owned or state funded, motivated by a blend of protectionist industrial policy and a pursuit of recognised public goods. Dong Energy, the Danish company that is now a leading player in the global wind energy market, developed around North Sea gas interests, and remains 73 per cent state-owned.

North American enterprises, such as Peregrine Power, GE Energy, Clipper Wind Power and SunPower have, like all United States energy companies, developed under the protection of import duties but have also benefitted from significant private equity. The United States leads global wind capacity (25.2 GW) and competes with Brazil for the status of world's largest biofuel producer. The United States' energy policies are motivated by domestic interests: energy security and low-cost energy in the case of wind power and support for rural economies in the case of biofuels.

2.3 Global cost trends

As a critical input into economic activity, the cost of energy is clearly important. Costs vary across technologies and locations and price comparison is complicated by the discrepancy between prices and costs, varying lifetime of different technologies and the inclusion or exclusion environmental impacts (Corey, 1981; Awerbush et al 1996). In addition cost estimates are highly contingent upon the selected discount rate in any calculation (Nordhaus, 2007; Stern and Taylor, 2007). Awerbush, whose analysis is supported by Anderson (2007) makes a case for discount rates of 1-3 per cent for renewable energy, and for the discount rates applied to fossil fuel energy sources to be higher so as to reflect the riskiness of fuel supply. This is in contrast to the approach adopted by the IEA which applies discount rates of 5-10 per cent to projects and does not distinguish between renewable end fossil fuel energy on the basis of fuel risk, thereby biasing cost

Renewable energy leaders all built their respective industries on the back of domestic policies and supply of domestic markets

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Europe's success has been established on the back of a half century of research, innovation and experimentation, motivated by environmental concerns and the strategic behaviour

analysis against renewable energy.

Ideally energy costs are reported as the "levelised cost of energy or electricity" (LCOE), that is all costs and benefits over the lifetime of the energy source. As of 2013 renewable energy is expected to be cheaper than fossil fuel energy (WRI, 2009). This cross-over will not be as immediate in South Africa where abundant coal reserves and the fact that most of this energy is generated in coal fired power stations that have been paid off, ensure that electricity is between 30 – 40 per cent of the cost of electricity in Europe (Pegel, 2009). This figure, however, ignores environmental externalities which Spalding-Fecher and Matibe (2003) estimate to add roughly 30 per cent (R0.05 per kWh) in South Africa. Environmental costs are real costs, however, and not charging energy utilities for them is simply poor economics (Stiglitz, 2004). Efforts to calculate, impute and charge the environmental impact of different types of energy are improving. The Stern Review valued the social and economic damage caused by a ton of atmospheric CO_2 at R840. At this price even the more expensive renewable energy options such as CSP become viable (CSP currently requires a carbon price of R860 per ton to become economically competitive with coal, WRI & Goldman Sachs, 2008). Seen differently, at the global scale the financial case for renewable energy is unambiguous. As cap-and-trade systems expand their reach and the price of greenhouse gas emissions increases, so renewable energy will become increasingly attractive from a cost perspective.

Applying the IEA approach to energy cost comparisons it is possible to compile the indicative data in Table 3.

Given the lead times between investments and energy flows and the lifespan of utility scale energy plants, the manner in which costs are likely to change should form an important component of energy investment decisions. Coal fired electricity is unavoidably becoming more expensive – particularly in South Africa while the cost of renewable energy is coming down as innovation and economies of scale manifest. Looking forward, the scope for innovation and cost reductions in renewable energy is far greater than in the fossil fuel or nuclear sector.

Table 3: Global cost estimates and variability for energy types, and cost estimates for energy types in South Africa (ignoring externalities)

	Global Mean (R/kWh)	Global Standard deviation (R/kWh)	South African estimates (R/kWh)
New coal	0.41	0.12	0.42
Gas	0.39	0.11	n/a
Nuclear	0.41	0.14	0.15
Wind	0.50	0.21	0.94
Offshore wind	0.60	0.25	0.85
PV (CdT)	1.50	0.75	0.93
Solar thermal CSP with storage	0.53	0.60	1.58
Solar thermal	0.49	0.26	0.60
Small hydro	0.86	0.26	0.71
Tide	0.34	0.26	n/a
Geothermal	n/a	n/a	n/a
Landfill methane	0.45	n/a	0.89

Source: UKERC (2007), UNDP et al (2000), NERSA (2009)

Historically the Western Cape has been a passive beneficiary of South Africa's energy programme

White Paper on Energy Policy (DME, 1998) guides national energy policy but progress against goals has been varied

The cost of producing electricity in South Africa varies between 17 cents and R2.10 per kWh.

Costs ignore environmental externalities which amount to at least 5 cents per kWh.

. The Western Cape's energy sector

Historically the Western Cape has been a passive beneficiary of South Africa's energy programme: a programme that lacks supply, is under-funded and extremely carbon intensive. Reducing the Western Cape's dependence on the national energy regime and nurturing a provincial energy sector represents an economic priority. This priority involves more than simply reconciling supply and demand to ensure energy security, but includes structural reform of the entire economy so as to make it more competitive, labour intensive and equitable.

The Western Cape has the natural resources and institutional and human capacity to become one of sub-Saharan Africa's renewable energy centres and an exporter of energy, technology and services. This status is unlikely to emerge spontaneously, however. Planning and deliberate interventions will be required. This in turn requires an understanding of the national energy regime.

South Africa's energy sector was designed to support the country's mining interests, and resulted in the national economy being defined by what Fine and Rustomjee (1996) termed the "minerals-energy complex" – a system to supply the cheapest possible energy to mines and mineral beneficiation plants. Mining and minerals beneficiation now account for 52 per cent of all electricity consumption and ESKOM the State Owned Enterprise generates over 95 per cent of this electricity (Breddell, 2008). The revenue returns on this allocation are poor, contributing only 6.4 per cent to GDP.

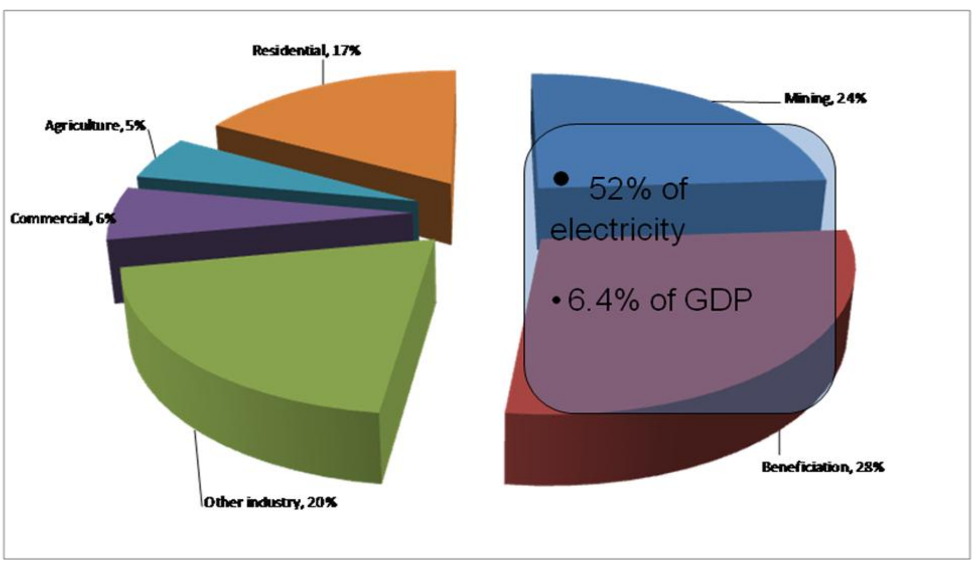

Figure 5: South Africa's energy consumption by sector. Source: Adapted from Pinpoint Energy

ESKOM continues to define South Africa's energy sector.

ESKOM holds the conflicting role of monopoly supplier and monopsony buyer of electricity in South Africa

In spite of this ministry and energy regulator (NERSA), ESKOM continues to define South Africa's energy sector, and real change continues to fall well short of policy utterances.

Fostering a favourable environment for renewable energy providers is not part of ESKOM's strategy

ESKOM assumes that the country will need 70 MW of electricity by 2025. Peak demand in 2009 was in the order of 36 MW and to keep track of demand ESKOM requires a 55 per cent extension of capacity. How it will achieve this, and whether this will be ESKOM's responsibility exclusively, is less clear but officially the energy strategy of South Africa's first democratic government is contained in the White Paper on Energy Policy (DME, 1998). The White Paper contains five key objectives:

i. Increasing access to affordable energy services

ii. Improving energy governance

iii. Stimulating economic development

iv. Managing energy-related environmental impacts

v. Securing supply through diversity

Progress against these objectives has varied, as described below.

Access to affordable energy services: "Electricity for all" was one of the Reconstruction and Development Programme's (RDP's) sub-programmes in 1994. The sub-programme focussed on grid connections and resulted in the proportion of households with grid connection increasing from 36 per cent in 1993 to 85 per cent in 2009. Between 1994 and 2000 the average cost of a new connection declined (Borchers, 2001), but the subsequent effort involved extending the grid to increasingly remote households and necessitated increases from R3,000 per connection in 2005 to R11,000 in 2009 (Mokghoto, pers. comms.[4]).

The cost of producing electricity in South Africa is linked to ESKOM's daily efforts to reconcile demand with supply from different sources. Baseload demand amounts to 25 GW (2009). This power is supplied by coal at a cost to ESKOM of roughly R0.17/ kWh. During peak demand (mornings, evenings and winter) roughly 37 GW is required, although this figure is increasing annually. To meet peak demand ESKOM draws sequentially on nuclear energy (R0.17/ kWh), pumped storage and hydro (an additional R0.15/ kWh) and then gas and diesel turbines at R2.10/ kWh (NERSA, 2009). As demand grows the increasing reliance on

[4] Loyd Mokghoto is ESKOM's Customer Services Regional Manager for the "Northern Region" and was interviewed by Anton Cartwright in June 2009 as part of HSRC's Limpopo Innovation Strategy formulation.

expensive forms of contingency electricity, in conjunction with the rising cost of extending the grid, has pushed the cost of producing ESKOM power from R7.50 per watt to R18.75 per watt between 2006 and 2009. This translated into an average cost of electricity in South Africa of R0.33/ kWh in 2008/9 (Nersa 2008), but is set to increase by 25 per cent a year over the next three years. The rapidly rising electricity prices have introduced inflationary pressures and seen poor households persist with coal, paraffin and wood as alternative fuel sources. Further inflationary pressure has been created by the collapse of South Africa's rail capacity, a problem that has necessitated a shift to road-freight and required ESKOM to budget R10 billion for road repairs by 2015.

Large, energy intensive companies in South Africa tend to negotiate industrial discounts for electricity directly from ESKOM, but households and smaller companies purchase their electricity from their local municipality. In 2009 the City of Cape Town paid ESKOM R0.22 per kWh (R0.33 if all administration costs are included) for its electricity. The on-selling of bulk energy by municipalities to end-users has historically been a major source of revenue for these local governments – roughly R3 billion in profit per annum for the City of Cape Town. National guidelines encourage municipalities to offer 50 kWh of free electricity to poor households, but local application of this guideline varies between 20 kWh and 100 kWhs and no standardisation of "poor households" exists.

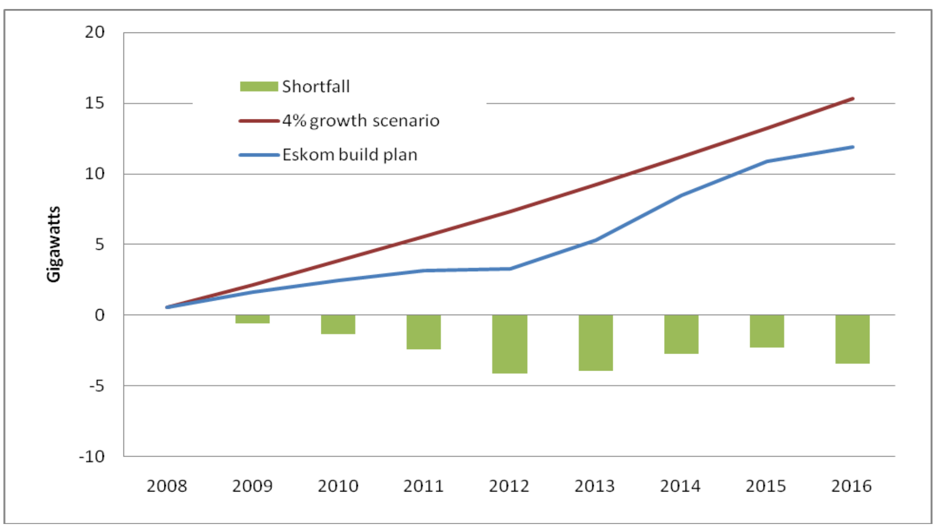

Figure 6: Projected peak energy demand (in excess of baseload) at 4% economic growth (red line) and ESKOM supply (blue line) with the shortfall shown in green. The projected deficit was originally illustrated by Anton Eberhard, but has been granted temporary relief by the economic recession of 2009 that has seen ESKOM revise its demand forecast for 2025 down by some 21 per cent.

Energy Governance: Governance reform since 1998 has seen ESKOM forego its status as a parastatal and become a tax-paying public company required to pay dividends to government when it generates a profit. The ESKOM Conversion Act (2001) created the possibility of

The supply of abundant low-cost electricity has, however, proven unsustainable.

South Africa has failed to reconcile the country's progressive National Environmental Management Act (1998) and National Water Act (1998) with its energy planning

The REFITs has not been complemented by power purchase contracts. .

When confronted by supply shortages and the need for new capital ESKOM regressed to dated coal-fired technologies

Independent Power Producers (IPPs) supplying energy into the grid but to date ESKOM, which holds the conflicting role of monopoly supplier and monopsony buyer of electricity, has obfuscated IPP attempts to supply this energy and protected its market position; "Fostering a favourable environment for renewable energy providers is certainly not part of this strategy." (Pegel, 2009).

The formation of a bespoke Ministry of Energy in 2009 provided some hope for a greater focus on national energy priorities and an end to the subordination of energy policy to mining interests. In spite of this ministry and energy regulator (NERSA), ESKOM continues to define South Africa's energy sector, and real change continues to fall well short of policy utterances.

Calls to privatise ESKOM are inconsistent with prevailing policy commitment to a "developmental state" in which public companies play a strategic role. ESKOM has, however, mooted the idea of selling 30 per cent equity to BEE companies and integrating its distribution networks with the distribution assets of municipal distributors to form six regional electricity distributors (REDs). Under the proposal, Eskom will not hold a stake in the REDs; rather they will come under the umbrella of a Department of Energy controlled holding structure called Electricity Distribution Holdings Industry (EDI Holdings). In July 2005, "RED 1" commenced control of the electricity distribution previously controlled by the Cape Town municipal authorities and Eskom, but in January 2007 the Supply and Distribution licence that had been given to RED 1 was returned to the City of Cape Town. In general municipalities have resisted the formation of REDs so as to protect the revenue that they currently generate from on-selling bulk electricity.

If the South African energy sector is to remain competitive, it needs to innovate. The governance culture of ESKOM, however, continues to militate against innovation, by reflecting apartheid era tendencies to be inward-looking, autonomous and very poor on collecting and sharing data or public accountability. In this sense the predominance of ESKOM is a governance problem for the Western Cape's energy sector.

Stimulating economic development: South Africa's relatively cheap electricity (UKERC, 1998) has been a component of the country's competitive advantage and has stimulated economic development in energy intensive sectors: mining, iron and steel and heavy manufacturing

(SANEA, 2003). Cheap electricity has also allowed for the relatively low-cost pumping and transporting of water which has benefited the agricultural sector. The supply of abundant low-cost electricity has, however, proven unsustainable. The power outages of January/ February 2008 cost the country an estimated R1,898 - R2,115 billion (IEA, 2009) and the need to increase supply has seen ESKOM trying to raise R400 billion for a capital investment programme further entrenching higher electricity prices.[5]

Mining, the chief beneficiary of South Africa's cheap energy has provided the historical backbone of the South African economy but has equally failed to create the extent and type of employment that could advance the country's development aspirations. The mining of coal and generation of electricity employed 155,000 people in 1986, but only 49,000 by 2001 in spite of increasing demand (SANEA, 2003). Mining has also generated significant environmental degradation, most notably air and water pollution, which in turn has impacted upon some of the country's poorest people (Turton, 2010).

Environmental impacts: South Africa has failed to reconcile the country's progressive National Environmental Management Act (1998) and National Water Act (1998) with its energy planning, and in terms of "managing energy related environmental impacts" has performed poorly. Coal supplies 94 per cent of the feedstock for the national grid and ESKOM alone consumes 95 million tonnes of coal a year, which will increase to 141 million tonnes by 2018 under recent projections (Dames, 2010)[6]. This coal has low calorie value, high ash content and fortunately a low sulphur content, although sulphur dioxide pollution remains a problem at South Africa's coal fired power stations. ESKOM has purchased the equipment and filters required to ensure "flue gas desulphurisation" at its coal fired power stations, but has apparently never installed these (Winkler, 2008, p.59). As a result, the greenhouse gas intensity of South Africa's economy (0.75 kgCO2e/ $GDP PPP)[7] is significantly higher than the world average (0.56 kgCO2e/ $GDP PPP) and unlike other countries has not improved over the past decade (WRI, 2003). In the context of mounting concern about climate change and global pressure to cost and pay for the emissions, the carbon intensity of the South African economy represents an economic liability. The extraction and burning of coal makes demands on the country's limited water resource. Conventional coal-fired power stations required 1.8-2.0 litres per kWh, although new dry cooled systems have improved this to 0.1 litres per kWh (Winkler, 2008).

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[5] ESKOM's ability to raise capital is restricted by its +BBB credit rating. The South African Government as the single shareholder pledged R60 billion over 3 years in 2009, and issued R176 billion worth of government guarantees to assist in the raising of finance.

[6] Brian Dames is the chief Business Officer for Eskom and was quoted in Engineering News 27/01/2010.

[7] Other estimates put this figure at 1.81 kgCO2e/ $GDP.

Supply through diversity: It is the fifth White Paper objective – securing supply through diversity – that is most relevant to this study. South Africa plans to make use of "every energy source optimally: coal, gas, oil, nuclear and renewable energy" (Mlambo-Ngcuka, 2003), but has not acknowledged the contradictions and opportunity costs between these fuel sources. The 2003 White Paper on Renewable Energy (DME, 2003) set a target of 10,000 GWh (roughly 4 per cent) of renewable energy supplied into the grid by 2013. The target is un-ambitious relative to global standards, but South Africa will struggle to attain it (Alfstad, 2004), which in turn will make it difficult to meet the ambitious target of reducing greenhouse gas emissions by 34 per cent relative to business as usual in 2030 that was tabled prior to COP-15.

In March 2010 the Minster of Energy insisted that the country would draw on new and diversified energy sources including industrial cogeneration sources, but as with preceding policy announcements (the 1998 intention to install 50,000 solar water heaters and develop prototypes for solar, wind and tide energy and the National Integrate Resource Plan of 2009, for example) this has not been supported by practical measures to enable supply. Neither has there been any effort to tackle the vested (and corrupt) interests that currently resist change. The Renewable Energy Feed-in Tariffs (REFITs) provides a case in point. The REFITs are well-crafted and provide adequate incentives to private sector investors. They have not, however, been complemented by power purchase contracts or volume stipulations that would allow investors to know how much energy they will be able to sell, and have fallen foul of the underlying flaw that sees ESKOM as the monopoly supplier and monopsony buyer of electricity.

When confronted with supply shortages and the need for new capital in 2006, ESKOM mandated power conservation on large users and returned to out-dated technologies, including two new coal fired stations at a combined cost of R270 billion. Medupi will be a dry-cooled system and Kusile will be fitted with flue-gas desulphurisation, but the construction of these power plants represents the 30-year lock of a technology that is proven not be labour un-intensive (Austin et al, 2004; NERSA,2009) will emit considerable greenhouse gases and will render energy subject to international coal price variations. ESKOM also re-commissioned three coal-fired power stations (DME 2008, p.7). This was in spite of the potential economic liability of these plants and the global trends towards renewable energy. In addition gas has been piped from Pande and Temane in Mozambique for consumption by SASOL using infrastructure that cost South Africa R9 billion, hydro-electric power has been sourced from the Gariep system and South Africa's neighbours and the Pebble Bed Modular Reactor at Koeberg was to have been – and may still be - a R25 billion source of nuclear power.

National reticence towards renewable energy is in spite of documented comparative advantage

The lock-in of problematic technology to the national energy supply is both a challenge and an opportunity for the Western Cape.

The Province has managed to distinguish itself as a regional leader in the renewable energy sector, and has the institutional and human capacity to develop this role

The Western Cape set the target of producing 15 per cent of the province's energy from renewable sources by 2014.

National reticence towards renewable energy is in spite of documented comparative advantage in solar, wind and wave energy (ERC, 2009). Much of the country receives more than 6,000 MJ/ m^2/ annum of solar irradiation that is required to make existing solar technologies highly effective. Large stretches of the South African coast receive wind at strengths that exceed the critical 4m per second and tide, current and wave characteristics are favourable for ocean energy.

Real diversification requires innovation, but ESKOM has revealed itself to be an un-innovative and un-transparent institution (Reddy, 2010), structured internally in silos of "generation", distribution", "connection" that is not conducive to the collection and flow of information or the assimilation of new technologies. The diversification that has taken place has not relied on renewable energy.

The lock-in of problematic technology to the national energy supply is both a challenge and an opportunity for the Western Cape. The province consumes roughly 28 per cent of the country's energy (250 million GJ), most of which is derived from ESKOM and as such the Western Cape shares ESKOM's energy challenges. In spite of this the Province has managed to distinguish itself as a regional leader in the renewable energy sector, and has the institutional and human capacity to develop this role.

The Western Cape economy, unlike the national economy, is not dominated by mining and other energy intensive sectors, but energy remains crucial to the province's horticultural sector (water pumping and cold storage), manufacturing, the growing service sector and the mobility (including export) of goods and people. Industry (46.9 per cent) and transport (34.9 per cent) were the chief energy consumers in 2004 (see Figure 7). Electricity (25 per cent), petrol (24 per cent), diesel (17 per cent) and coal (17 per cent) represent the main sources of energy, but paraffin is a significant fuel for poor households. The province is home to the 1,800 MW Koeberg nuclear plant, but this is owned and run by ESKOM.

Solar and wind are likely to constitute the dominant renewable energy sub-sectors in the Western Cape

Within wind and solar, the transition to renewable energy will involve a range of technologies each with its own merits and challenges

The Western Cape should aim to become the regional leader in renewable energy technologies and services.

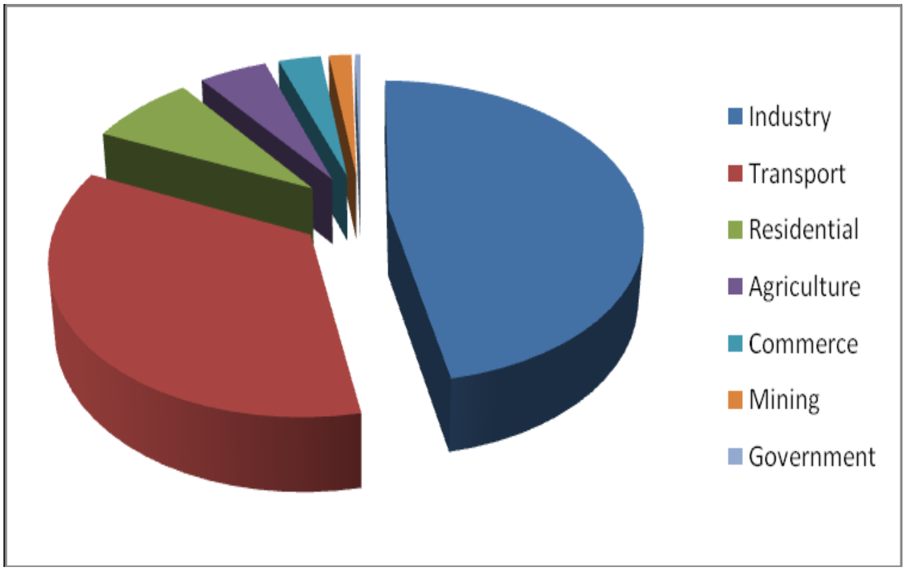

Figure 7: Sectoral distribution of the Western Cape's energy consumption

The Western Cape has developed a "Sustainable Energy Policy", of which the Renewable Energy Plan of Action is an integral component. The policy sets the target of producing 15 per cent of the province's energy from renewable sources by 2014. 2,800 MW of potential wind power and a mass roll-out of solar water heaters (which it estimated to produce energy at R 0.09/ kWh) are envisaged as being the chief contributors toward the target, although opportunities for photovoltaic energy, biomass energy from sawmills and pulp plants, energy from landfill methane combustion, small-scale hydro and wave energy are listed. The Western Cape already has pump-storage capacity at the Palmiet Scheme that enables the province to shape its supply of renewable energy so as to off-set peak demand.

In the Western Cape Renewable Energy Action Plan supply options are complemented by energy efficiency measures. Energy efficiency technologies, including the latest lighting, heating and transport technologies, can reduce demand further often at very low costs (R0.05 kWh-0.15kWh). Some of the best energy efficiency measures are behavioural and have no cost, or even save money.

Annex 1 of this document outlines the various renewable energy options available to the Western Cape and provides some analysis on their inherent viability and scope for implementation.

Whilst solar and wind are likely to constitute the dominant renewable energy sub-sectors in the Western Cape, for the time being, no single technology is able to deliver the energy solution that would transform the

Western Cape's economy. As Shell Plc points out in its most recent scenario planning: "There are no ideal answers – TANIA"[8]. Even within wind and solar, the transition to renewable energy will involve a range of technologies each with its own merits and challenges. Renewable energy is best used when it is available. For solar this means more energy in summer than winter and no energy during darkness. For wind (in the Western Cape) the supply is greater in summer than winter and usually stronger during the day. Tide energy is reasonably predictable, but non-existent four times every day as the tides change. Biofuel energy is dependent on the availability of feedstocks and indirectly dependent on rainfall. The generation of energy from landfill methane flaring is greater during periods of low pressure when the methane gas escapes the landfill more readily. Wave energy (in the Western Cape) is typically greater in winter than summer, but highly variable. Hydro-electric power is dependent on precipitation. Combining and developing a suitable and complementary mix of renewable energy technologies and locations in the Western Cape will require planning and some support.

The goal for the Western Cape should be identified up-front. The region has the collection of policies, targets, university departments, NGOs and companies that could see it becoming the southern African hub for renewable energy technologies and services. At the same time the adoption of these technologies could, in the medium term, contribute to lower cost energy supply, a more stable and labour intensive economy and an attractive place for investors that exported both services and technologies. Precedents for this type of regional differentiation can be found in the State of California, which distinguished itself from the United States' generally poor commitment to renewable energy under the Bush Administration by installing a range of renewable energy technologies and environmental legislations. This strategy has seen California emerge as the North American centre for renewable energy under the Obama Government.

Achieving an appropriate mix of technologies is only possible if decision makers have an extensive understanding of the different options, their proponents and respective challenges.

4. Renewable energy sub-sectors and institutions

For each of the technologies available to the Western Cape, Section 4 maps the key technological attributes, international market leaders, recent innovations and scope for development in the province.

[8] This scenario profile emerged from a Shell scenario developed in the 1990s called "TINA – There is no alternative".

4.1 Wind energy

At the end of 2008, wind energy accounted for roughly 1.5 per cent of global energy supply and represented the greatest source of renewable energy (WWEIA, 2009). The industry reported a turn-over of R 450 billion.

It is anticipated that 1,500 GW of wind energy will have been installed globally by 2020 (WWEA, 2009), roughly 12 per cent of global electricity supply, although the Energy Watch Group believes that capacity could be as high as 7,500 MW by 2025.

Off-shore wind has the benefit of higher wind speeds and no land purchase costs, but requires more costly transmission and maintenance, represented just 1 per cent of the global wind industry in 2008 (26 projects, all in Europe). Due to land constraints, off-shore wind projects are expected to grow more rapidly than land-based projects over the next 10 years (United States DOE, 2008), but maintenance of off-shore plants is roughly ten times more expensive than land-based plants, placing a premium on equipment reliability. For the Horns Rev II project in the North Sea, Siemens have offered a 20 year repair guarantee on each of the 91 turbines, so as to address this problem.

In 2008 the United States overtook longstanding industry leader, Germany, as the country with the most wind capacity. Bulgaria, Turkey and China have (of the countries that have more than 100MW installed) all doubled their capacity in the last two years.

Denmark pioneered the wind energy sector and is still a major player. The off-shore wind farm at Middelgrunden in Denmark (twenty 2 MW turbines) was constructed in 2000 but remains a flagship of the industry. Spain's wind energy capacity reached 20,000 MW in 2009 (Stewart, 2006). Navarra, a land-locked region laying in the north-east of Spain imported energy until it installed its first wind turbine in 1996. The region is currently meets 70 per cent of its energy needs from wind energy and is Spain´s most successful regional economy.

The China Energy Conservation Investment Corporation (which employs 11,000 people) has been responsible for the installation of 1,500 MW of wind capacity in China and is building a further 1,000 MW. The Chinese Government's involvement has facilitated investments by the private sector, as was demonstrated by the floating of China Longyuan Power in 2009.

Wind energy represents the greatest source of global renewable energy.

Lighter material, more efficient central cogs aerodynamics, better positioning of the turbine, higher turbines and large rotors define wind energy innovation

Modern turbines only begin to produce power at wind speeds of 4m-5m per second, and reach their optimal power rating at wind speeds of 12m per second.

Off-shore wind has the benefit of higher wind speeds and no land purchase costs, but is more expensive to maintain

Innovation in the wind energy sector is focused on the “capacity factor” – the proportion of wind energy that is harvested.[9] Improvements rely on lighter material, more efficient central cogs, aerodynamics, better positioning of the turbine, higher turbines (wind shear determines that wind speeds increase with altitude at low altitudes) and large rotors (United States DOE, 2008). Modern turbines only begin to produce power at wind speeds of 4m-5m per second, and reach their optimal power rating at wind speeds of 12m per second. At very high wind speeds, modern turbines change their pitch to spill wind and prevent damage. The largest current turbines are able to generate 3.6 MW, but the Danish firm Dong Energy are working on a 8-10 MW turbine that will harvest over 40 per cent of the wind energy available. Other innovations under development include variable length rotors (EUI, 2003) advanced material blades, improved blade shapes, hydraulic systems that eliminate gearboxes that are expensive to maintain (Enercon GmbH, 2009) and transformers that deliver wind energy in grid compatible ways.

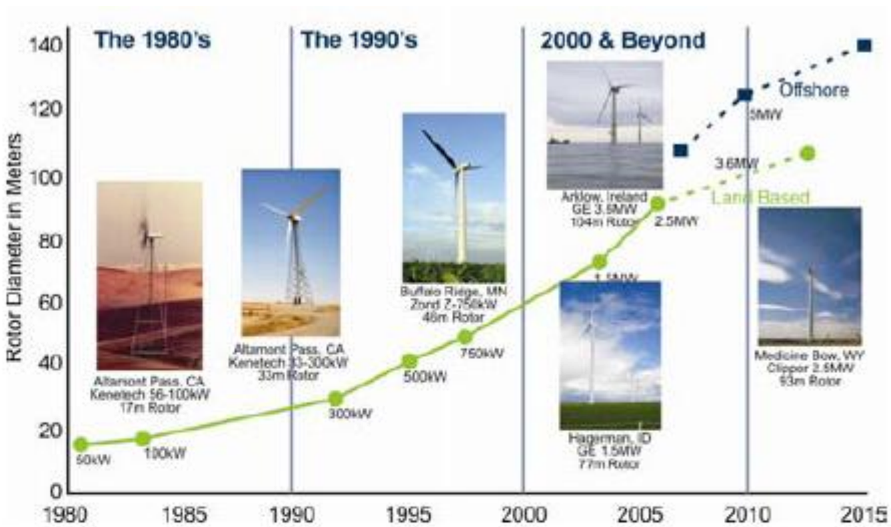

Figure 9: Development path of wind energy in the US (DOE, 2008)

In 2008 the global wind sector employed more than 440,000 people (WWEA, 2009). The energy used (and greenhouse gas emissions produced) to build and erect wind turbines is typically off-set by the energy that is saved by the turbine within two months of its operation.

Table 6: Wind energy - Country leaders, and South Africa peer country performance

Country	Existing capacity (2008)	Planned capacity

[9] Betz’ Law dictates that the maximum energy that can be extracted from a wind stream without preventing the flow of wind is 59 per cent - “the Betz Limit”.

United States	25.2 GW	
Germany	23.9 GW	
Spain	16.7 GW	
China	12.2 GW	30.0 GW
India	9.8 GW	17.5 GW
Japan	1.9 GW	
Brazil	0.36 GW	1.5 GW

Whilst windmills have long provided a means of abstracting borehole water in South Africa's rural areas, the Western Cape is currently the only province in South Africa with large-scale wind capacity. The Western Cape has excellent wind power potential, with all of the coastline exposed to wind speeds above the critical 4m per second, and some coastal areas receiving much more than this (DME at al, 2001). The Province's Sustainable Energy Action Plan identified 2,800 MW of wind potential, but currently only 10 MW of wind energy is installed.

The ESKOM funded trial project at Klipheuwel in the Western Cape tested three different turbines (Vestas 660 kW, Jeumont 750 kW and Vestas 1,750 kW), but it is not clear if or how findings from this experiment informed national energy policy. The Darling Wind Farm currently consists of four 1.3 MW turbines, with an additional six turbines planned. The four turbines were installed at a cost of R75 million and supply energy to the City of Cape Town in bilateral "wheeling" agreement. Under this agreement electricity is "wheeled" over ESKOM's grid network to the City. Darling has not, yet, been awarded a contract to supply the national grid.

The solar industry can be divided into PV and solar thermal

Spain leads the CSP market and exports its technologies, services and some its renewable energy - predominantly to Germany.

The scale introduced by CSP has reduced the cost of solar power

Goldman Sachs put the average global levelised cost of CSP electricity at R1.42 per kWh, but significantly a doubling of capacity would see CSP costs fall to R1.05 per kWh, and forecasts are for CSP to cost R 0.90 per kWh by 2015.

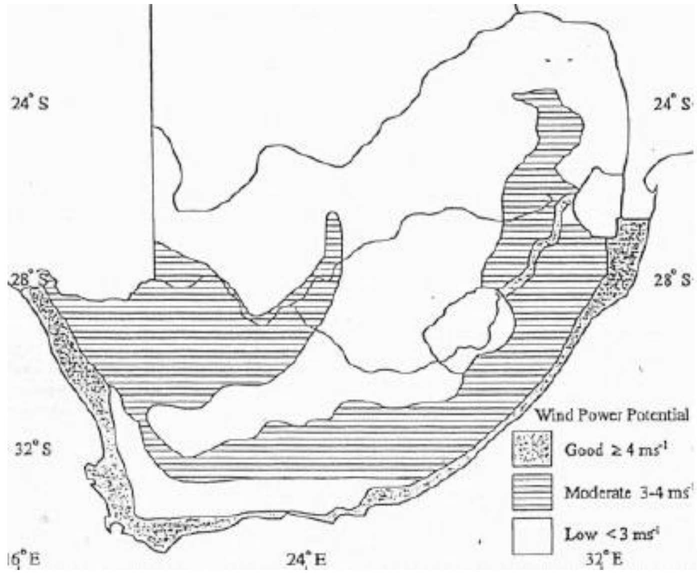

Figure 10: South Africa wind potential map (Diab, 1993)

In 2009 the Cape Town based company Genesis Eco-energy announced a partnership with the Irish company Mainstream Renewable Power (MRSP) in a reported R94 billion investment to construct 18 wind farms in Southern Africa – many of them in the Western Cape. The architects of the project believe wind could supply 70 per cent of South Africa's electricity needs, but their immediate target was to generate 5,000 MW – the 5 per cent of South Africa's electricity demand (2009) that is dependent on expensive gas-turbine and pump-storage schemes to meet peak demand. The MSRP project has however faltered on uncertainty over the volume of energy that it would be able to supply to the grid, with allegations that ESKOM may have played an obfuscating role in hampering the issuing of a power purchase contract. Sere Wind Farm, the R3 billion 100 MW ESKOM planned windfarm that was due to be constructed on the West Coast, appears to have been a casualty of similar institutional and financial uncertainty.

The energy company Kestral, based in the Eastern Cape, produces small turbines with 600W-3kW capacity to predominantly rural clientele for the operating of light, monitoring and telecommunication appliances. The advantage of these systems is that they can operate at wind speeds as low as 2.8 m per second.

4.2 Solar energy

The global solar industry can be divided into photovoltaic (PV) and solar thermal (most commonly associated with solar water heaters) technologies. PV relies on chemicals that convert solar irradiation into direct current electricity, while solar thermal is typically used to substitute the heating function of electricity. PV technology can be further divided into crystalline silicone (Cadmium Telluride which produced energy at R0.95/ kWh), metallurgical silicon (silicon R1.38/ kWh) and thin film technologies (usually Cadmium Telluride based, which provides the cheapest energy at R0.90/ kWh). PV represents a rapidly innovating sector as the energy transfer ability of new materials is continually improved and the strength of photovoltaic material has improved to the point that it is able to replace roof-tiles.

In 2008 the PV industry grew by 10 GW in total. Germany remains the global leader with 5.3 GW of installed PV and twelve utility scale projects. The largest plant, Woldpolenz, at Muldentalkreis has 40 MW of capacity and produces 40,000 kWh of electricity per year. The plant, which cost R1.5 billion, is comprised of 550,000 panels each coated with a thin Cadmium Telluride PV layer. The Woldpolenz plants cost five times more per MW than Medupi Power Station (480 MW) in South Africa, but the difference is that Medupi's functioning will be dependent on the on-going purchase of coal and operations and maintenance costs that are 12 times more expensive per unit of energy than those at Woldpolenz (based on Winkler, 2008, p.94-95). In 2007 two "large scale" PV plants were completed in the United States (14 MW) and Spain (20 MW) respectively.

Different PV technologies perform relatively better or worse under different irradiation conditions (Jardine & Lane, 2002). Amorphous silicon and copper indium diselenide (CIS) receivers give the best results under clear sunny conditions. Amorphous silicon is also better able to handle a wide range of temperatures. Crystalline silicon perform relatively better under cooler, occasionally overcast, conditions.

The solar-thermal sector is capable of producing utility scale energy - "solar walls" in Sweden and Denmark produce 0.8 GW of energy and take up over a hectare of space (EIA SHC, 2008). To date, however, the solar thermal sector has been predominated by solar water heaters. In 2007 the global installed solar-water heater capacity was the equivalent of 154 GW, just under half of which was in China (Weiss et al, 2008). In the United States, which had 19.6 GW of installed capacity in 2006, the most common application of solar-thermal capacity is for pool heating (Weiss, et al. 2008).

Concentrated solar power (CSP) can be applied to PV or solar thermal technologies amd represents an important innovation strand within the solar industry (WRI & Goldman Sachs, 2009). A range of CSP technologies is available but although parabolic dishes represent the most "commercially viable solar technology" (Edkins et al. 2010) and 600 MW is installed globally. Panels that track the sun's movement (heliostats) and reflect irradiation onto a concentrated point or tower and central receiving towers are also used. Most

CSP plants operate at high temperatures (650°C - 750°C) and require the cooling. Where water is scarce more expensive "dry-cool" systems are necessary and it is possible that this cooling is provided with desalinised sea-water. The world's most intensive solar irradiation regions tend to be in deserts and affordable transmission of CSP to industrial hubs and cities requires parallel research.

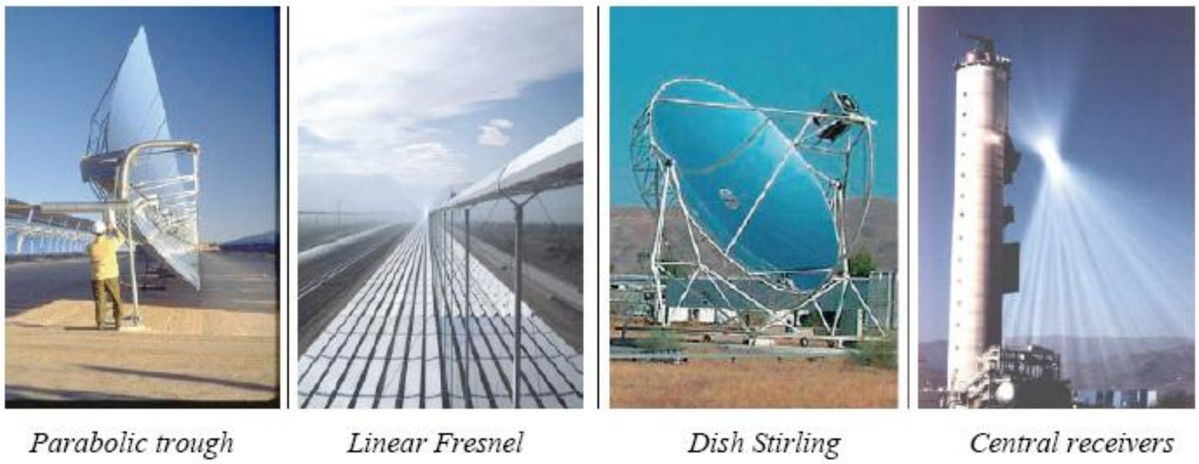

Figure 11: The four major CSP technologies. Parabolic troughs involve sophisticated mirrors that track the sun and reflect the sun's rays towards onto an absorption tube that contains oil which absorbs and retains heat before being used to generate steam. Linear Fresnel uses long flat mirrors (sometimes rotating) to reflect liggt onto a central fluid filled absorber. Can be relatively low cost. Stirling dishes, produced by Stirling Energy Systems, are most commonly used off-grid and focus irradiation on a point suspended above the dish. Do not require water for cooling although water is used to clan the dish. Central receivers use heliostats to track the sun and focus energy onto a central tower (Source: Appears in Edkins et al, 2009).

Spain leads the CSP market and exports its technologies, services and some its renewable energy (predominantly to Germany). The PS10 solar-power tower near Seville uses 624 flat rotating mirrors each with a surface area of 120 m^2 and produces 11 MW of power. Energy from the system is stored as steam in pressurised tanks. The success of PS10 allowed Abengoa Solar, the company that installed the mirrors at the project, to initiate PS20 (20 MW) at an adjacent site in 2009. These are not, however, the largest solar projects in Spain or the world. A PV plant near Madrid, Parque Fotovoltaico Olmedilla de Alarcon, has 60 MW capacity. Whilst China followed an experimental 7 MW trial project in Shangai with a 100 MW CSP project in Ningxai which it plans to extend to 500 MW. In the United States, which began its PV–CSP programme in the mid-1980s in the Mojave Desert, a number of projects in the Nevada desert now exceed 60 MW.

Figure 12: CSP plants in Seville, Spain. (Source: www.abengoa.com)

The scale introduced by CSP has reduced the cost of solar power, and the scope for further cost reductions appears to be greater than other renewable technologies. At the moment, however, solar power is currently expensive. Goldman Sachs (citing WRI, 2009) put the average global levelised cost of CSP electricity at R1.42 per kWh compared to global coal at R0.59 per kWh, but significantly a doubling of capacity would see CSP costs fall to R1.05 per kWh, and forecasts are for CSP to cost R 0.90 per kWh by 2015 (Reuters, 2009). Economies of scale aside, developing storage technologies that retain energy for more than six hours is one of the innovation priorities for the industry. Salt mixtures (sodium nitrate and potassium nitrate, calcium nitrate) are the most common storage medium but oil, steam and water are also used. United States companies have pioneered the use of saline solutions to store solar energy for up to 18 hours which allows for the displacement of peak demand periods when expensive options are otherwise required. The efficiency of solar energy to electricity (usually measured over the course of a year) represents the other innovation focus; conversion rates of 13 per cent are considered good in this regard. A solar tower planned for Mafikeng South Africa, aimed for 14.7 per cent solar-to-electric efficiency (Mbeleko, 2009).

Solar ponds, which were considered for applications in South Africa, Israel and the United States in the 1980's (Scholtz and Eberhard, 1998) use solar irradiation to alter the saline gradient in water columns. Solar ponds are no longer considered an efficient solar technology.

The Desertec Industrial Initiative seeks to supply solar energy from north Africa to Europe, and is under planning.

South Africa has 556 MW of installed solar capacity, but lags its potential and its peer countries in this sector.

The scale introduced by CSP has reduced the cost of solar power

A combination of imported parabolic mirrors and locally manufactured flat mirrors might serve the Western Cape best in terms of solar energy

CSP could produce jobs per 5.9 MW in South Africa.

The massive Desertec Industrial Initiative, an ambitious project to build a CSP plant in the Sahara that could supply North Africa and Europe with electricity, is attracting significant attention within the solar sector. The Swiss engineering group ABB (manufacturers of a specialist in high-voltage, direct-current transmission grids), German engineering giant Siemens, Spanish engineering firm Abengoa, Deutsche Bank, German utilities E.ON and RWE, MAN Solar Millennium (a joint venture of MAN Ferrostaal and Solar Millennium (which makes CSP equipment) and Munich Re are all reported to be involved in the project planning, but as yet no investment decision have been taken (Edkins et al, 2009).

Other leading PV companies include Ausra (United States), BP Solar, Conergy (Germany), eSolar (California, USA), Sharp Solar (Japan), Solar City (California, USA), SunRun (California, USA), Mirror Manufacturer (P.A. USA). Solar companies tend to be smaller and more labour intensive than coal, nuclear and even wind power companies, and a growing solar energy sector has the potential to contribute positively to economic development.

A more complete list of global leaders in the solar industry is contained in Annex 1. From an innovation perspective, the ancestry of these companies is interesting. In Europe solar leaders tend to have emerged from large European Union funded research programmes aimed at diversifying industrial juggernauts and telecoms businesses. In the United States the State of California represents a hub, and companies tend to be linked to large energy utilities many of which face public pressure to diversify away from fossil fuels. The Japanese company Sharp Solar represents one of that country's (and company's) many electrical innovation success stories. The solar thermal energy sector, which is less technically sophisticated and more labour intensive than the PV sector, tends to be increasingly based in India and China due to labour costs considerations.

South Africa had 556 MW of installed solar capacity at the end of 2006 (Weiss et al, 2008). Among South Africa's peer countries, China, Brazil, Turkey, Greece and Israel all have at least ten times more solar-thermal capacity, whilst Cyprus, Israel, Barbados, Greece and Brazil all have higher installed capacity per capita. South Africa's laggard status is in spite of comparative advantage in solar energy. Winkler (2008) concurs with Eberhard and Williams (1988) in claiming that South Africa's "overwhelming[ly]" renewable energy potential lies with solar energy, and cites the scope for 280,000 GW nationally, but as with the rest of the country, the Western Cape does not have PV capacity on any significant scale. There is currently insufficient trial-project data to know the exact cost of solar energy in the Western Cape, but estimates range between R2.00 – R10.00 per kWh for PV and R1.00-R1.50 for solar thermal. The expectation is that these costs could eventually reach R0.40 and R0.30 respectively based on current innovation trajectories (UNDP et al, 2000). A 100 MW solar tower project is planned for Uppington, Northern Cape, but investors have remained on the sidelines until they can be guaranteed electricity sale volumes. Significantly the REFIT for CSP is the highest of all feed in tariffs R2.10.

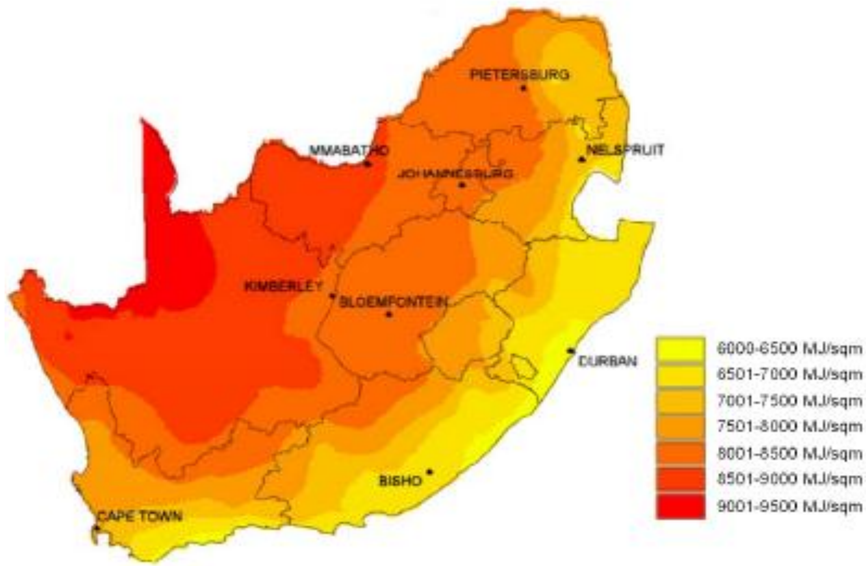

Figure 13: Annual solar irradiation in South Africa (Source CSIR et al., 2007)

Edkins et al (2010) suggest that central receivers and linear Fresnel technologies, neither of which require the specialised parabolic mirrors could be manufactured in South Africa and contribute towards a local CSP sector, employing an estimated 5.9 people per MW of power. The same authors assume that imported technologies will be required to complement locally manufactured solar capacity.

The Western Cape has a growing solar water heater capacity, and the City of Cape Town is considering a statutory roll-out of this technology that could include 300,000 households – 40 per cent of rate paying households. Installed SWH units range in cost from R6,000- R40,000. The Western Cape's Kuyasa Project outside Cape Town, which includes SWHs on low-cost government built houses, became the first Gold Standard[10] registered CDM project in the

[10] In carbon trading parlance "Gold Standard" denotes a project of exceptional environmental and social integrity.

world. The project has assisted in the creation of an internationally recognised service industry that includes Western Cape based institutions such as SouthSouthNorth, REEEP, the Energy Research Centre, the Centre for Renewable and Sustainable Energy Studies (CRSES) at the University of Stellenbosch, Agama Energy, the Promoting Access to Carbon Equity (PACE) Centre and the City of Cape Town.

Local suppliers of SWHs tend to import their SWHs from China and India before modifying them, although locally designed and manufactured models (such as Xstream) are available. South Africa's nascent SWH industry has been boosted by an ESKOM rebate to homeowners that install SWHs. The rebate was doubled in January 2010 and affords the average homeowner a discount of R6,000 provided they use registered service providers.

4.3 Biomass energy

Biomass energy refers to the use of organic matter to make heat which can be used to generate electricity. Biomass feedstocks includes cultivated wood and cleared vegetation, sawdust from sawmills, bagasse from sugar refineries, organic solid waste that would otherwise be turned to landfill and animal waste.

Globally three broad categories of biomass are being developed:

- Anaerobic digesters producing combustible biogas from organic waste (plant material, animal waste, sewerage plants) or from landfills.
- Use of calorific material (sawdust, bagasse, timber, bamboo) for direct combustion or thermo-chemical combustion in processes of boiler combustion, pyrolysis, gasification and torrefaction. While combustion is simple, the other three processes involve burning the gases that are emitted when biomass is exposed to high temperatures, and produce energy more efficiently than combustion.
- Biofuels include starch based bioethanol and plant oil based biodiesel.

In eastern China urban landfill sites and livestock farms have fuelled utility scale biomass to electricity projects. In Denmark, State owned Dong Energy and Inbicon Company (Integrated Biomass Conversion) is developing a project that converts 30,000 tons of wheat straw and raw material into 5.4 million litres of ethanol and 13,000 tons lignin bio-pellets for use in local energy generation.

In 2007 global production of biofuel reached 65 billion litres - 1.3% of liquid fuels

Where modifications to coal-fired boilers permit the use of biomass and avoid a complete lock-in to coal as a fuel source, then biomass could yet provide a reprieve from the full consequences of the poor energy planning.

The Bellville landfill methane project displaces roughly 94,000 tons of CO_2 per annum - the equivalent of 100,000 MWh of ESKOM electricity

In South Africa biomass accounts for roughly 30 per cent of total energy use, but this is the result of wood burning in poor households (Winkler, 2008). When fuelwood is harvested and not replaced it does not represent a sustainable energy source. Domestic dependence on biomass is likely to persist as electricity costs increase, and for this reason sustainable fuelwood cultivation and harvesting projects have an important role to play, as do waste-to-fuel projects that displace wood burning.

On a different scale there is financial and environmental merit in using industrial residues from the paper, sawmill and sugar industry to generate electricity. Most sugar refineries already use their bagasse in cogeneration for local use, but are unable to supply this electricity into the national grid under current legislation. NERSA (2009) estimate that industrial waste alone could generate 12,900 GWh of electricity per annum and is considering the implementation of a co-generation feed-in tariff (Cofit) to incentivise these projects. Where modifications to coal-fired boilers permit the use of biomass such as waste, bamboo or eucalyptus and avoid a complete lock-in to coal as a fuel source, then biomass could yet provide a reprieve from the full consequences of the poor energy planning that has characterised the past two decades in South Africa. Similarly where utility scale biomass burning power stations are constructed, this would allow for a spatial diversification of baseload power supply away from the regions where coal is mined. The ability to generate biomass energy on demand distinguishes it from wind, solar and wave energy. Western Cape companies such as Envirovest BioProducts (Pty) Ltd have been talking to the country's mining houses about using locally grown bamboo as a feedstock.

Landfill methane is a particular type of "biomass" that when flared can generate energy. The flaring of landfill methane to turn it back into CO_2 - a less noxious greenhouse gas – has proven popular as a source of carbon credits, but can also be used to generate electricity. The Durban Solid Waste projects at the Bisasar Road, Marrianhill and LaMercy represent a regional pioneer in this field, and has been replicated in the Western Cape at Bellville South. The Bellville project which displaces roughly 94,000 tons of CO_2 per annum - the equivalent of 100 GWh of ESKOM electricity. The original plan was for the Bellville project to sell generated energy to local industries, including a glass factory, but in light of the REFIT (R0.90 per kWh) offered to energy from landfill sites, the project may seek to acquire a power purchase agreement from ESKOM.

Global production of biofuel totals 65 billion litres, 1.3 per cent of liquid fuels (Steenblik, 2007) and double the production of 2004. The growth in biofuel production slowed in 2008 and 2009 on the back of oil price decreases and concerns over food security, but global production continues to expand. Brazil is the largest biofuel producer (over 30 million litres per annum) and exporter of biofuel. The USA and China rank second and third respectively in terms of production production (Steenblik, 2007). South Africa's biodiesel industry has progressed in fits and starts. Initially looking to government for support in the form of a fuel levy, the industry faltered in 2007 when this levy did not materialise. Under the co-ordination of the South African Biofuel Association (SABA) and in the context of high oil prices, the industry has re-emerged with three companies currently producing biofuel from soy, sugarbeet, sugarcane and maize feedstocks. The industry has set itself a target of 8 per cent of the national petrol mix and 2 per cent of the national diesel mix (SABA, 2007).

Biomass energy tends to be highly labour intensive, and has the potential to provide employment in rural areas. In South Africa, biomass energy is estimated to create 16 to 23 jobs per GWh (Austin et al, 2003; WC RE Plan, 2007).

4.4 Geothermal energy

Geothermal energy uses heat and steam from the earth's core to drive turbines or supply space heating. More modern techniques pump water through hot rock fissures to create steam for power generation. Geothermal energy is available on demand, unlike wind and solar, making it easier to plan its use.

In 2008 10 GW (roughly 70 GWh) of geothermal capacity existed across 24 countries, globally. The United States remains the world leader in geothermal with over 120 projects under development in 2009 representing a total of 5 GW of capacity (UNEP, 2009). The United States is also responsible for most of the research and innovation in this field. Only Kenya in Africa has developed significant geothermal capacity production – 1,088 GWh in 2005 (Lund 2005; Bertani 2005). Other countries with significant recent growth in geothermal include Australia, El Salvador, Guatemala, Iceland, Indonesia, Mexico, Nicaragua, Papua New Guinea, and Turkey. In Africa, it is only Kenya that has developed significant geothermal production - 1,088 GWh in 2005 (Lund 2005; Bertani 2005). The Western Cape has limited geothermal capacity in regions such as Tulbagh and Montague, and the Breed River Valley, but as yet has not considered developing these for electricity purposes Eberhard and Williams (1998).

4.5 Ocean energy – wave, tide

Hydro-energy, includes wave, tide and current energy.

Wave power has been utilised for over a 100 years, but still represents a small component of the global renewable energy mix (WEC, 1993). Appendix 1 draws on a study by Stellenbosch

University to list companies and their technologies active in the wave energy sector. Various wave technologies exist, but all either use waves to exert vertical or horizontal pressure on a piston or a fluid column. Most remain in experimental or prototype phase. The United Kingdom and Scotland, which have particularly energetic wave climates, had a bespoke wave energy programme, but this was closed down in the 1980s when oil prices dropped. Innovation, especially in small-scale devices, continued and some time ago Thorpe (1999) believed wave energy could supply electricity at R0.60 per kWh. Currently Europe, India, Japan, South Korea all have wave energy programmes, whilst universities in Denmark, Norway and the USA have research programmes looking at wave power technologies. Some of the most promising technologies link off-shore wind energy with wave power technologies, so as to ensure that electricity is transmitted to the main-land through the same cables.

The Western Cape has reasonable wave energy potential (estimated at 35 kW - 50kW per metre of wave front, Thorpe, 1999) a strong marine engineering sector and some of the human and institutional capacity to develop this sector locally. The Stellenbosch University has, since the 1970s, had an Ocean Energy Research group that has been working on wave technology prototypes but no Western Cape company is, as yet, operational in this sector. The same that developed the Darling Wind Farm is reported to be exploring R 15 billion 770 MW wave energy project off the west Coast through a company called "Wave Energy Generation" (Engineering News, 18 September 2009). The project proposes to use a technology called the SWEC – Stellenbosch Wave Energy Converter – and involves numerous 5 MW units.

Ocean-energy, includes wave, tide and current energy.

The Western Cape has reasonable wave energy potential (estimated at 35 kW - 50kW per metre of wave front.

Commercial ocean technologies are not yet proven in South Africa in spite of a strong marine engineering presence

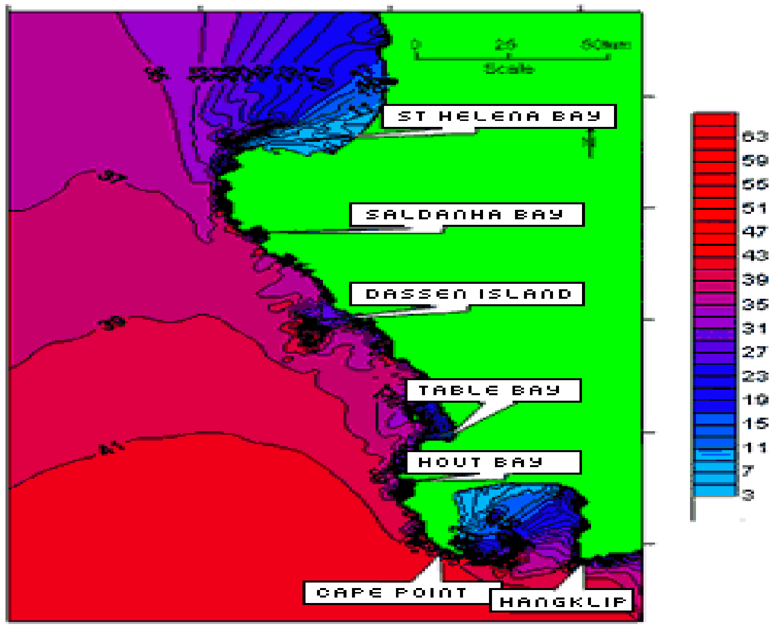

Figure 14: wave energy contours for the Western Cape coast showing reasonable potential along the west and south coast especially at off-shore locations (Source: Joubert 2008)

The best tide-energy sites occur where the tide energy is focussed by the surrounding topography, such as in the English Channel. Tide energy offers the great advantage of being predictable and staggered – by positioning turbines at different locations around a coast a smooth supply curve can be attained. The most recent turbines are constructed with a void in the centre to prevent damage to marine life. Major companies in the tide-energy market include OpenHydro, which has developed and installed a 6m (1 MW) in diameter turbine that sits on the ocean floor off the Scottish Coast, and is developing a 10 and 16 metre turbine. OpenHydro sources some of its turbine equipment from South Africa, a testimony to the country's marine engineering capacity and a suggestion that this form of energy could find greater application in this country.

The Canadian based Finavera Renewables proposed the idea of a R300 million, 20 MW wave energy power plant off the coast of South Africa, but as yet no progress has been made on this project.

4.6 Hydro-power

Hydro power is no classically renewable (UNEP, 2009) as it relies on dams, turbines and usually disrupted hydrological flows. Dams become net sources methane – a noxious greenhouse gas. Hydro dies, however, have an important role to play in storing renewable energy and releasing it during periods of peak demand.

Off-stream hydro, where rivers are diverted over turbines, is typically smaller scale but less environmentally disruptive and may have a contributing role to play in the Western Cape's energy mix.

In large, modern, dam-fed hydro plants an energy conversion rate of 90 per cent is considered possible, but the methane emissions from large dams and the CO_2 emissions released from the cement with which these dams are constructed, off-sets some of the environmental benefits of this energy source. The global hydro accounts for 15 per cent of global electricity supply, can supply relatively cheap power. In Canada, the states of British Columbia, Manitoba and Quebec obtain over three quarters of their energy from dam-fed hydro-sources. The largest dam-fed hydro plants are in China, which has a number of projects in excess of 10 GW. Smaller-scale, off-stream hydro represents an increasingly popular and environmentally recognised source of local energy supply and China, New Zealand, Canada, Australia and Nepal all have growing small-hydro sectors.

The Western Cape has the Palmiet hydro-scheme which is currently used for pump storage to meet peak demands and could be similarly deployed in the context of renewable energy.

5. The role of DEDAT in the Western Cape's Renewable Energy Sector

The analysis so far has shown that the global renewable energy sector is large, growing and part of a global reconfiguration of sectoral and regional competitive advantage. It has also shown that while South Africa lags the world and its peer countries in developing renewable energy, the Western Cape is well placed to distinguish itself from the national energy regime by developing and applying renewable energy and exporting products and services to the African sub-continent.

There are many reasons why the Western Cape might want take up this role: employment creation, energy security, competition policy, support for new businesses, attracting foreign direct investment, using existing water resources more effectively and identifying with the global effort to combat climate change and securing positive location marketing in the process, are all closely associated with the emerging renewable energy sector. More fundamentally being able to support local economies and communities with renewable energy is likely to become a key component of competitive advantage, if not survival. Just as energy intensive companies such as aluminum smelters now seek to establish themselves in countries where electricity is cheap, in a future where climate change is a defining threat and greenhouse gas emissions are either taxed or traded, companies will move to those locations where energy can be accessed with very low associated emissions.

Table 7: Western Cape Renewable energy targets

Energy source	Target
Wind	3,000 MW
Ocean	1,000 MW
Solar-PV	247 MW
Hydro	15 MW
Solar thermal	14,000 MW
Pumped storage	18,000 MW
TOTAL	7,452 MW

Source: Renewable Energy Action Plan, Western Cape (2007)

How then does the Western Cape, and specifically the DEDAT, bring about the necessary change?

The general answer, given the mandate of the department, has to be identifying and communicating the economic risks linked to the evolving renewable energy economy. This in turn will require governance, planning, finance and research and development and under each of these headings DEDAT has responsibility for specific interventions and general programmes (See table 7).

Table 8: Interventions and programmes for DEDAT in pursuit of a provincial energy sector

SPECIFIC INTERVENTIONS	GENERAL INTERVENTIONS/ PROGRAMMES
GOVERNANCE	
• Lobby for a share of the NIRP to be awarded to Western Cape companies • Address the City of Cape Town's fear that establishing a RED and reducing demand for ESKOM energy will reduce their revenue.	• Expose the economic implications of ESKOM's lock-in to coal and fossil fuel. • Communicate and market the intent to pursue a roll-out of renewable energy. • Activate the RED in tandem with the City of Cape Town, so as to manage the revenue loss.
• Model technology and geographical permutations and their contribution to addressing intermittency • Identify and promote "wheeling" agreements	• Support research and development
PLANNING	
• Establish links between provincial renewable energy targets and actual projects. • Formulate a framework for evaluating energy	• Establish the provincial governance criteria that can support a Western Cape renewable energy sector.

technology options. • Establish a provincial Special Purpose Vehicle (SPV) that can facilitate interaction and the spread of information between stakeholders in the provincial renewable energy sector.	
FINANCE	
• Apply REFIT in province • Introduce flex pricing at the margin • Network of local financial institutions and developers • Import support	• Calculate LCOE for various technologies once all environmental externalities have been included
RESEARCH AND DEVELOPMENT	
• Identify carbon sinks and sources on the province and quantify their respective contributions. • Quantify the opportunity cost of pursuing fossil fuel and nuclear energy options • Acknowledge and support "free-wheeling agreements" • Local application of the LTMS	• Interact with the universities in the province that have renewable energy research programmes. • Distinguish between rural and urban technological needs

5.1 DEDAT and Governance

Governance reform is a prerequisite for technology development, the flow of funding and finance and effective planning. With regards to renewable energy, it is essential that the Province addresses the institutional impediments that currently hinder the commercialisation of renewable energy. Most critical in this regard is the need for enforced power purchase agreements to IPPs from the Single Purchase Office within ESKOM and a challenge to the vested interests seeking to prevent the diversification of energy supply in line with national policies.

If governance is understood to be the "rules of the game" then DEDAT's responsibility involves establishing the rules that will favour the emergence of renewable energy. This includes:

There is a role for public sector intervention in ensuring the roll-out of the Western Cape renewable energy sector.

The need is both for specific interventions and general programmes.

Activities include governance reform, planning, finance and research and development

- Raising awareness of the benefits of renewable energy, the costs and risks of not developing renewable energy and the mechanisms and precedents for successful transitions to renewable energy.

- Gaining clarity on how the National Integrated Resource plan (NIRP) will be compiled from different sources and how power purchases agreements will be allocated. NERSA has published criteria that will be taken into consideration when procuring energy, but it is not yet clear how these will be combined. The criteria include: network compatibility, low transmission losses, raising of finance, environmental impact assessments complete, short commissioning periods, local economic development, broad-based black economic empowerment.

- Mediation between ESKOM, NERSA, ESKOM's single buyer office and aspirant power producers. At the moment investments in South Africa's energy sector are considered risky precisely because the institutional environment is clouded with uncertainty and information is poor. Mediating between the leading players and the communication of precise information represents an important component of local governance.

- Activating the RED. For the Western Cape to become more energy autonomous, a functioning RED is necessary. This in turn requires agreements between ESKOM, the province and the City of Cape Town over who will own, pay for and maintain distribution networks (including the Steenbrass Power Station on the Palmiet pumped storage scheme that is critical to load management) and who will be able to secure revenue for the sale of energy through the grid. In the short-term, compensation for lost revenue to local municipalities may have to be provided by project developers. The type of discussions and settlements that are required to establish an independent RED capable of buying and selling energy can only be facilitated by the provincial government. This is not a straight forward agreement. The City of Cape Town has over 30 intake points on different ESKOM tariffs, and reconciling local supply and demand while ensuring financial compensation for lost revenue would require province-wide facilitation.

- Support for “wheeling agreements”. Given the inertia in the issuing of PPAs and the development of renewable energy in the national energy regime, many of the Western Cape’s best options involve bilateral agreements between suppliers and consumers. Consumers choose these agreements to ensure energy security in an unstable national grid and to qualify for the finance and markets that require carbon reporting and management and reducing liability under future scenarios in which carbon is priced. It is these agreements that has seen Consol glass procure energy from Durbanville landfill, the City of Cape Town purchase energy from Darling Wind and many of the country’s mines develop their own energy sources. Such bilateral are to be encouraged. Once they constitute a critical mass they could form the basis of a renewable energy sector. To distribute this energy, suppliers are required to “wheel” electricity across the grid to consumers or lay their own distribution cables. “Wheeling” agreement require negotiation and DEDAT has a role to play in these negotiations. Similarly DEDAT would do well to establish the extent of these agreements and to encourage their development. Bilateral “wheeling agreements” are precisely what Shell plc envisage (on a larger scale) with their proposed energy “blueprint” scenario: “Partnerships between suppliers and consumers looking to diversify their energy procurement, reduce their exposure to climate change levies and secure their supply through diversity sees a critical mass of business enterprises, energy sectors and countries collaborate around opportunities to profit from comprehensive climate change policies.” The envisaged outcome is, “.....overall higher energy security extrapolates into a more secure economic global environment where equity has increased and cooperation has become the norm”.

5.2 DEDAT and planning

In late March 2010, South Africa’s Finance Minister issued a plea to the World bank to ignore its environmental and climate change policies and issue a R28 billion loan for the financing of what will become the world’s fourth most carbon intensive power plant. "If there were any other way to meet our power needs as quickly or as affordably as our circumstances demand, we would obviously prefer technologies — wind, solar, hydropower, nuclear — that leave little or no carbon footprint. But we do not have that luxury if we are to meet our obligations both to our own people and to our broader region whose prospects are closely tied to our own.

The Minister has a point; South Africa is in a desperate situation in which its options are suddenly limited, and decisions that will have dire economic and environmental consequences become unavoidable. For the Western Cape, entering the renewable energy economy requires the type of decisions that South Africa should have been taking ten years ago.

The province has a raft of legislation that differentiates it from the rest of the country and supports and enables effective energy planning. The Sustainable Energy Strategy and

Programme of Action (November 2007) the Western Cape Sustainable Development Implementation Plan (August 2007), the Renewable Energy Resource Assessment, Scenarios, Proposed Objective and Actions (May 2007), a Climate Change Strategy and Action Plan for the Western Cape (March, 2008), and a White Paper on Sustainable Energy (October 2008). Perhaps most crucially the province has established:

- a renewable energy target – 15 per cent of locally used energy by 2015, 12 per cent of which would be locally generated.
- an energy efficiency target – 15 per cent reduction by 2015 relative to 2006
- a CO_2 reduction target of 10 per cent by 2014 relative 2000 emissions levels.

There are many good reasons to pursue these targets: an estimated 16,000 additional jobs (WC DEADAP, 2008), foreign direct investment would be attracted, the regional balance of payment would be improved (even without considering the potential to export products and services), the cost of energy would be reduced, and the province would become an easier and cheaper place in which to conduct business. Perhaps most importantly, pursuing these targets would assist in establishing the institutional and human competence required to deliver future programmes. However, linking targets with actions will require planning and a commitment to "learning by doing". Whilst the bulk of the Western Cape's renewable energy will undoubtedly come from solar and wind, a standardised system for evaluating technology decisions systems is required. Necessarily this system needs to take into account more parameters than energy decisions have had to consider in the past, and it is doubtable whether a simple cost-benefit analysis could adequately serve this purpose. Evaluations could be made in various ways, but coherence with the National Renewable Energy White Paper's 5 salient objectives (DME, 1998, DME, 2003) is important. Certainly decisions based on single criterion run a greater risk of producing unforeseen and perverse outcomes. A multiple criteria assessment (Van Ierland, 2007) of renewable energy options should, as start, consider the following:

- **Comparative advantage and competitive advantage:** Comparative advantage remains the foundation of economic advantage. Whilst South Africa has comparative advantage in coal, the Western Cape has comparative advantage in wind, solar, wave and tide energy. The province's agricultural sector could provide the basis of comparative advantage in biomass, biogas and biofuel energy, while the municipal capacity could establish the basis for a landfill gas to energy comparative advantage.

  Converting comparative advantage into competitive advantage (as measured by market share) requires human and institutional capacity, and while the Western Cape leads the rest of the country in this regard, it remains in deficit relative to its peer countries and the world.

Necessarily the financial evaluation of energy decisions needs to take into account more parameters than in the past

Western Cape has comparative advantage in wind, solar, wave and tide energy

Given the urgency, priority should be given to those technologies that can be scaled up quickly

Renewable energy technologies could deliver employment and a more equal distribution of benefits than the relatively labour un-intensive and highly concentrated fossil fuel industry.

Renewable energy technologies are more water efficient than fossil fuel technologies

- **Cost per kilowatt hour:** Whilst some mitigation options, most notably energy efficiency, are cost saving most renewable energy is currently more expensive than coal fired electricity, especially if the cost of environmental externalities is ignored.

Costs come down with innovation and scale, but at different rates (see Figure 12). Strategic priority should be given to those technologies that are both low cost and in which the Western Cape has the ability to innovate to reduce costs. Solar, wind and coastal hydro (based on the regional marine engineering capacity) are candidates in this regard.

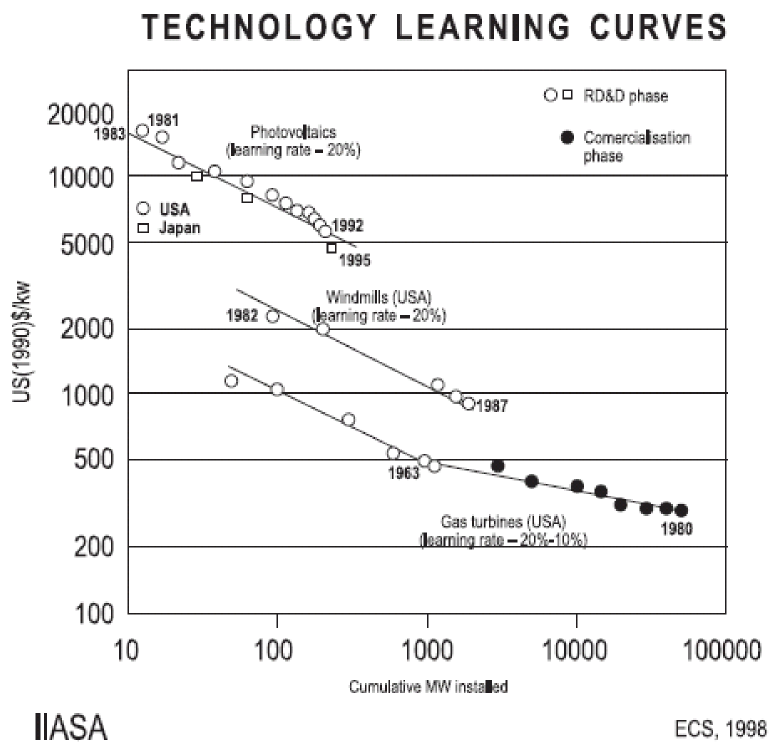

Figure 15: History and scope for learning to reduce costs in different energy options

The LTMS research seeks to guide South stated intention to "peak, plateau and decrease" its emissions of greenhouse gases by 2050. The LTMS introduces the idea of emission reduction "wedges" that could be aggregated to meet the national target. The LTMS findings should not be viewed as definitive and are the subject of ongoing work. What they do identify clearly is a range of energy efficiency measures (vehicle efficiency, industrial efficiency) that are cost-saving or relatively low cost and which both reduce greenhouse gas emissions and the quantum of fossil fuel energy that has to be replaced by renewable energy.

A summary of LTMS findings that relate to Western Cape technologies is provided in Annex 4.

- **Macro-economic implications:** South Africa has committed to increasing its budget deficit through the period 2010 to 2012, principally as a result of increased allocations to State Owned Enterprises and public infrastructure, and will target a deficit of 9.8 per cent of GDP in 2001/12 (IPAP2, 2010). There is a strong case for this expansion, as South Africa seeks to stimulate growth in support of its much-needed development. Running a budget deficit will, however, place additional pressure on South Africa's balance of trade and payments. Under ESKOM's plan to meet its energy targets for 2025, which relies heavily on coal, nuclear, industrial energy savings and some solar water heaters, the country would experience an estimated R345 billion net outflow of capital due to foreign purchase of equipment and fuel (Pinpoint Energy, 2009; Greyling, 2009).

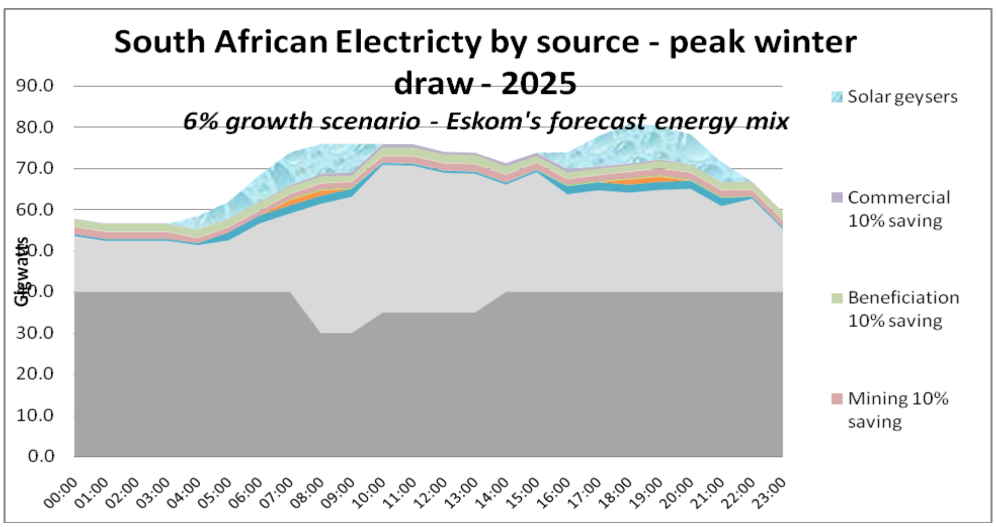

Figure 16: ESKOM 2025 energy mix for 6 per cent economic growth (Source: Pinpoint Energy, 2009)

Under an aggressive commitment to utility scale renewable energy (see below) net outflows would be limited to R15 billion in spite of the need to import technology and services. South Africa's choice of energy technology, then, influences the balance of trade and payments.

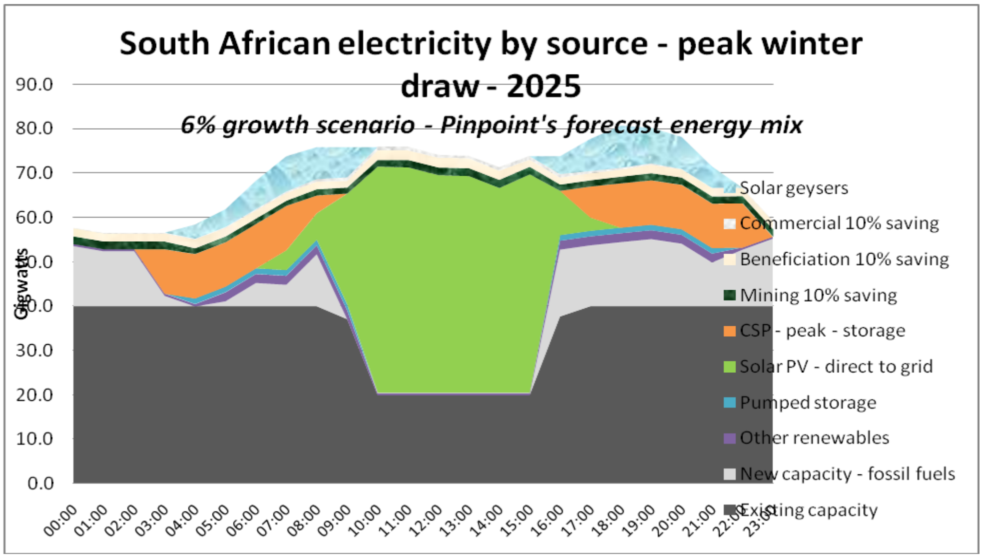

Figure 17: Alternative 2025 energy mix for 6 per cent growth. (Source: Pinpoint Energy, 2009)

- **Equity Implications:** South Africa is an unequal society and one of the articulated aims of the post-apartheid government has been to reduce inequality. The type of renewable energy and energy efficient technologies envisaged in second Industrial Policy Action Plan (IPAP2) – even though the targets are modest - would see a massive redistribution of revenue away from the country's centralised suppliers of coal, oil and electricity. The creation of IPPs and REDs would also see provinces other than Gauteng, Mpumalanga and Limpopo associated with energy revenues.

- **Ease of doubling time:** If South Africa is to navigate its current energy crisis and emerge as a competitive economy in a low-carbon world, then it needs to give consideration to how it can generate local energy as quickly as possible. Not all renewable energy sub-sectors can be developed at the same pace and given the urgency, priority should be given to those technologies that can be scaled up quickly. Winkler (2008) lists the time taken to double installed capacity of various renewable energy technologies based on historic global rates. The rate of growth can be affected by political commitments and public and private investments, and should not be considered universal or constant. Development rates will be influenced by local human and industrial capacity, as well as the lead times on imported content. The important principle is that the rate of development between options differs and given the need, and the potential for lock-in and path dependent learning, consideration should be given to speed with which the required generation capacity can be created

Table 9: Ability of different energy technologies to scale up

	Global operating capacity (GW)	Years for doubling
Biomass	40	23
Wind	10	3
Photovoltaic	0.5	3
Solar-thermal (parabolic)	0.4	14
Solar thermal (tower)	0.4	14
Small hydro	23	23
Geothermal	8	17
Tidal	0.3	N/A

- **Greenhouse gas emissions:** Reducing run-away climate change is one important component of securing the Western Cape's energy balance and the future competitiveness of the regional economy. Not all energy options, or renewable energy options, reduce the emission of greenhouse gases to the same extent. Technologies that emit the lowest level of CO_2e per unit of energy should be prioritised as these technologies are likely to be increasingly attractive as climate change risks increase.

- **Employment:** There is a growing acknowledgement that renewable energy technologies could deliver employment and a more equal distribution of benefits than the relatively labour un-intensive and highly concentrated fossil fuel industry. It is this acknowledgment that has seen renewable energy form a central component of government bailout packages. Figures for employment intensity differ (see Table 10 for a comparison of the Western Cape Renewable Energy Action Plan's (2007) and Austin *et al's* (2003) estimates). What does not differ is the grater intensity of the renewable energy sector. Given the rates of unemployment in the Western Cape, and the ability of employment to address a number of social and economies ills, the potential contribution of renewable energy towards economic development through employment creation should be included in considerations of the appropriate energy mix.

Table 10: Jobs per energy source

Fossil fuel Technology	Jobs/ GWh		Renewable Technology	Jobs/ GWh	
	WC RE Plan (2007)	Austin et al (2003)		WC RE Plan (2007)	Austin et al (2003)
Coal (current)	0.3	0.7	Solar thermal	10.4	8.7
Coal (future)	0.7		Photovoltaics	62	
Nuclear	0.1	0.08		12.6	
Nuclear (PBMR)	0.2		Wind	5.6	
Gas	0.1	0.13	Biomass	23	16.3
Liquid fuel (diesel and paraffin)	0.1		Landfill	23	1.34
			Ocean energy	1 (not empirical)	
			Hydro	1	
			Bioethanol		3.8

- **Water:** Many existing sources of energy require water in the mineral extraction and combustion phase. New coal fired power stations are "dry-cooled" but still consume some water and nuclear and CSP renewable technologies differ in the extent to which they require water. Given the aridity of the Western Cape and the increasingly high opportunity cost of water in the province, energy technologies that save water should be prioritised.[11]

- **Technological and institutional capacity to deliver:** Related to competitive advantage, the institutional complexity of delivering a renewable energy project should inform

[11] An interesting aside to the water-energy consideration is the potential for renewable energy to support desalinisation as a solution to the provincial water crisis and a support to agriculture. The chief barrier to desalinisation is the energy demands of industrial scale plants (and the brine discharge that results as a by-product). Where energy can be provided through coastal solar and wind technologies, it increases the appeal of desalination and can contribute to the alleviation of water shortages – as has been the case on the Spanish south coast.

which technologies are adopted first. It took the Darling wind arm seven years to receive IPP status and longer for it to begin selling its power. Complexity relates to ESKOM's position as the sole utility and the purchaser of all energy, the sophistication of certain renewable technologies, the acquisition of land for generation and transmission (possibly across provinces and across public and private land), accessing a water permit, the need for an EIA and the need for finance. Given the urgency with which renewable energy is required, less complex projects should be favoured above more complex projects.

- **Complementarity with demand requirements:** Projects should be evaluated in accordance with their ability to alleviate critical demand constraints in terms of the timing and location of supply. This is a function of the timing of the energy supply, the storage capacity and the location. Projects that displace the need for high cost energy (such as that supplied by pump-storage schemes during peak demand periods) deserve to be favoured over those that supply base demand, even though a combination is ultimately required. While technologies should be chosen and located so as to best match demand, it should be noted that storage techniques are being improved in parallel with renewable energy innovation.

  One of the recent lines of research involves storing renewable energy in the batteries of electric vehicles that are linked to the grid. Vehicles would be charged overnight, but could release electricity back into the grid while parked at homes and office blocks during the day.

Table 11: Hypothetical assessment of the Western Cape's energy options in terms of multiple significant criteria

	Comparative advantage	Cost	Cost reduction potential	GHG emissions	Macro-economic	Employment	Water	Technological and institutional complexity	Demand relief	Equity	TOTAL
Coal	3	3	0	0	1	1	1	2	3	0	**14**
Nuclear PBMR	1	1	0	3	1	0	2	2	3	0	**13**
Gas	0	2	0	1	1	2	2	1	3	1	**13**
PV-CSP	3	1	3	3	2	3	2	2	1	1	**21**
Solar thermal	3	2	3	3	2	3	3	2	1	3	**25**
Wind	3	2	3	3	2	3	3	2	0	2	**23**
Geothermal	1	1	2	3	2	2	2	1	3	1	**18**
Hydro	2	2	1	2	1	2	2	3	2	2	**19**
Biomass	2	2	3	1	3	3	2	2	3	3	**24**

Following Hallegatte (2007), Von Ierland et al. (2007), Constable and Cartwright (2009).

Table 9 illustrates a multi-criteria assessment of energy technology options in the Western Cape context.

5.3 Finance

In the medium to long run, a low carbon economy will result in cheaper energy, save fiscal and private resources and make a contribution to the reduction of climate change costs. This does not remove the need for immediate investments in the transition or the need to overcome the perverse incentives faced by local municipalities to continue selling as much ESKOM energy as possible so as to generate revenue for municipal coffers. To reach the provincial targets for renewable energy, greenhouse gas mitigation and energy efficiency an estimated R8.8 billion investment in renewable energy and energy efficient technology would be required by 2014 (WC DEAT, 2007). This is money that the provincial government does not have in its MTEF. To secure local municipality buy-in for this roll-out, some compensation would have to be made for the revenue that municipalities would lose by displacing sales of ESKOM electricity. Based on 11,627 GWh per annum (Winkler et al 2006) and a R0.20 margin per kWh the city makes roughly R2 billion per annum from electricity sales – more than 2 per cent of its GDP.

Given the market failure that characterises climate change (Levitt and Dubner, 2009) the pace and scale at which renewable energy innovation needs to take place and the need for some co-ordination of renewable energy technologies so as to address the intermittency challenge, there is a case for public funding of this technology development. Revenue from the carbon market could, if accessed, provide an estimated R500 million per annum toward the renewable energy technology required in the province, but as is normal for the carbon market this money is difficult to access and would, at best, make a small contribution to the required finances.

Annex 3 includes a range of financing options and examples, covering public, private and hybrid finance. Some of the best financing options involve hybrid of public and private finance. Under these arrangements the public sector enters into an entrepreneurial relationship with the private sector with the intention of using the fiscus to crowd-in private sector investment for worthy causes.

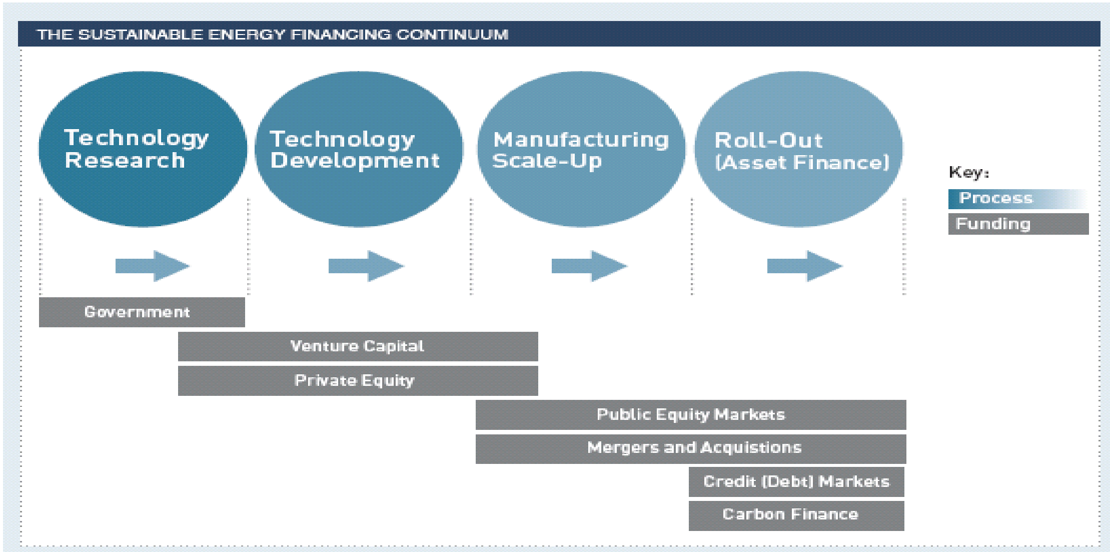

Figure 18: Stylised model of financing combinations in the development of renewable technologies.

The other clear finding to emerge from a review of financing options is that REFIT policies have an excellent track record. In 2009 64 of the 73 countries with renewable energy targets had tailored support schemes in place. Fourty of these countries had publicly funded feed-in tariffs (Mendonca, 2007). The incentives offered by South Africa's REFIT, simply highlight the imperative of issuing contracts in which these prices are paid to project developers.

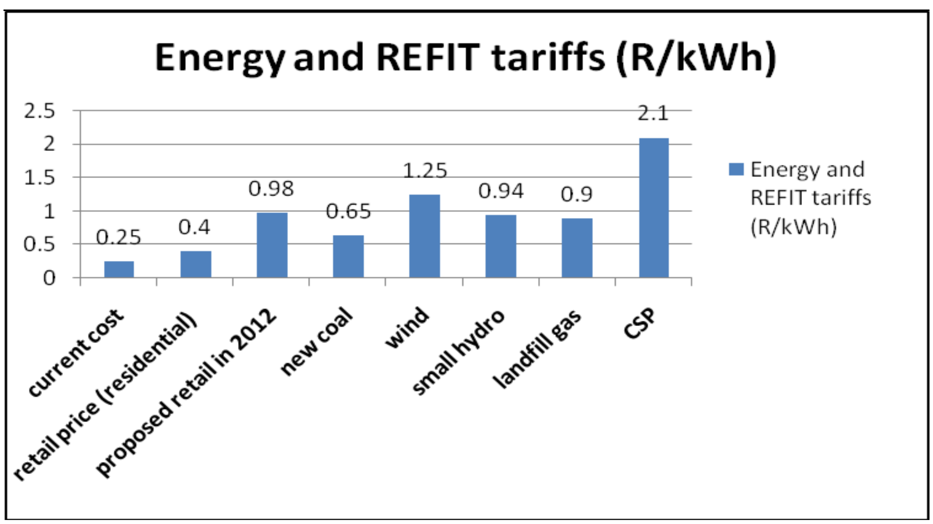

Figure 19: The tariffs are guaranteed for 20 years without digression. Source NERSA (2009)

There are certain financing tasks that the DEDAT is specifically well place to complete:

- **Create an imperative:** A Western Cape municipal CFO is on record as having said, "I have no mandate to spend one cent more on anything because it is green"(Cited by Brian Jones in presentation to the City of Cape Town). The CFO is no doubt correct. Decision makers in the Western Cape and the rest of the South Africa have very little rationale or resources for spending on "green" issues. Creating this mandate, supported by the kind of research contained in this document, and making it an imperative that is supported by budgeted fiscal resources is part of DEDAT's financial responsibility. An important component of this imperative involves creating the budget allocations in the MTEF for the type of renewable energy support outlined in this document.

- **Applying the REFIT in the province:** The REFIT represents the key financial instrument for supporting renewable energy in South Africa. Its application – paying REFIT prices to APPS contracted in power purchase agreements (PPAs) – is essential to the transformation of the provincial energy sector. Individual companies, however, have weak negotiating power with ESKOM's single buyer office when it comes to securing PPAs and there is a danger that the issuing of PPAs will be used to support political ends. Assisting Western Cape companies to access PPAs at REFIT prices represents one of the roles that DEDAT could play in supporting the regional economy. to sisting Insisting on the inclusion

- **Flex pricing at margin:** Municipalities in the Western Cape currently have discretion over energy pricing and should be encouraged to use this pricing discretion to support renewable energy.

  Regulated energy prices can introduce stability, but the current approach to electricity pricing and recent price hikes in South Africa places an undue burden on the poor and small businesses and undermines the development of a flexible price-signal for the development of suitable energy alternatives. Brazil, which confronted similar energy issues to those currently experienced by South Africa, in 2000, provide one possible solution to energy price regulation. In Brazil large corporate consumers of energy were able to purchase more or less the same quantum of energy they had required the previous year at regulated prices that increased predictably and stably. Additional energy requirements, however, had to be purchase don the open market from independent power producers. The approach, which admittedly requires significant institutional capacity and data to administer, strikes a balance between regulated and free market prices by restricting free market principles to the margin.

- **Import support**: Given South Africa's laggard status in the renewable energy sector, and the pace with which innovation in this sector is progressing at an international level, it is not possible to nurture a renewable energy sector (or meet provincial targets) without the importing of technologies. In this regard DEDAT has a role to play in negotiating the terms of trade and supporting the adoption of appropriate technology and the assimilation of this technology into the Province's human capital stock through learning. Appropriate in this context refers to capital: labour ratios and, crucially, the ability to contribute to a technological and spatial mix of renewable energy that has the maximum impact on baseload coal requirements.

5.4 Research and development

The switch to renewable energy requires change. Change is dependent on innovation – the adoption of "new" or "new to you" technologies or processes. As a sign of this change, between 1975 and 2007 the IEA was involved in 21 new large research energy technology collaborations ("Implementing Agreements") related to fossil fuels within its 28 participating countries, and only 16 for renewable energy, but by 2007 the number of agreements was tilted in favour of renewable energy (10) over fossil fuels (6) (IEA, 2007). South Africa's Medium Term Strategic Framework states that "Science and technological innovation and development are important sources of industrial competitiveness and sustaining growth" (Presidency, 2009), but energy innovation in South Africa has not tracked the global change. South Africa currently spends 0.9 per cent of its GDP on R&D, with an unknown but very small component of this going to renewable energy (CeSTii, 2010). Capacity to deliver renewable energy, "Is lacking at every stage of the technology cycle, from research and development to installation and maintenance" (Pegels, 2009). In China the equivalent R&D figure is 1.4 per cent, while in India it is 0.69 per cent. The OECD average is 2.3 per cent (OECD, 2009) and the world average was 1.9 per cent in 2007 (ABM, 2008). ESKOM's R&D proposals (contained in NERSA 2009) are vague and un-strategic and private sector innovation has, to date, struggled to break the institutional constraints on the commercialization of renewable energy technologies.

There are certain financing tasks that DEDAT is particularly well placed to deliver on. Creating certainty. Drawing down the REFIT. Import support. Securing some of NIRP2

The gap between the innovation frontier in renewable energy and South Africa's current position represents an economic liability

The Western Cape cannot rely on the national innovation system if it is going to realize its renewable energy potential

The South African energy innovation system has its origins in the apartheid goal of independence from external energy supplies and innovation since democracy has remained path-dependent. The two leading players, ESKOM (electricity) and SASOL (oil) bias to R&D and the innovation pathway of the energy sector (Pegel, 2009).

None of ESKOM's 1998 South African Bulk Renewable Energy Generation (SABRE-Gen), the Central Energy Fund's (CEF's) sustainability arm, CEF's subsidiary the SA National Energy Research Institute or the more recent Clean Technology Fund have been able to overcome the country's lock-in to fossil fuels and deliver meaningful change in spite of abundant resources. The resulting gap between the innovation frontier in renewable energy and South Africa's current position – whether measured in terms of patents or the greenhouse gas intensity of the economy – represents an economic liability.

It is possible to exploit "late mover advantage" to leapfrog to the forefront of the low carbon global economy, but it is more likely (as demonstrated by Spain) that benefits will accrue with the customary lags between public and private investment in R&D, domestic applications and the creation of an export industry.

The Western Cape cannot rely on the national innovation system if it is going to realize its renewable energy potential and while the provincial innovation system is unavoidably nested within national human capital and innovation effort, the province needs to shape its innovation efforts to support its renewable energy ambitions. Without innovation the Western Cape will remain dependent on the national energy regime.

It is not the province's role to pick technology winners, but rather to create the type of environment in which potential winners can develop. In R&D terms the DEDAT could achieve this by supporting the following R&D efforts:

- An analysis of the opportunity cost of not switching to renewable energy. Such analysis should adopt a dynamic perspective and include, for example, the longer term economic consequences of carbon emissions under a carbon constrained world, the employment and water resource prospects of a continued minerals and energy focus and the consequences of technological lock-in. These "counterfactual risks" risks are seldom factored into energy decisions and this is why South Africa now, for example, finds itself in a desperate plea to the World Bank Group for R 28 billion finance for a technology that they admit will be polluting and which will allow the World Bank Group the type of influence over the South African economy that has proven so disastrous elsewhere in Africa.

- Cape Town is the financial, business and environmental services capital of South Africa and is home to three leading universities and international (WWF, Conservation International) and national (ERM, SEA, REEP, PACE) leaders in the renewable energy and climate change industry. Co-ordinating and supporting (including with financial support) interaction between industry stakeholders in the private sector, universities and government. The Western Cape's Innovation Strategy identifies the need for this "triple helix" partnership as the bedrock of effective innovation. As the need for energy system change at the global becomes more acute, competitive advantage will be bestowed on those economies that are best equipped to change and established innovation capacity will be rewarded. In China, the fact that thirty five of the 70 companies involved in off-grid wind power generation in 2007, are affiliated to universities, "colleges" or research institutes (Junfeng et al., 2007) reveals the importance of learning research in this sector.

- Shaping of university level research. The Western Cape is home to the bullk of South Africa's renewable energy research. (1) The University of Stellenbosch's Centre for Renewable and Sustainable Energy Studies was central to the apartheid government's search for alternative energy sources during isolation and continues with its work. (2) The City of Cape Town has, in conjunction with the University of Cape Town's African Centre for Cities, established a Climate Change Reference group that has, to date, proven effective in advancing research, co-ordinating climate change related activities and reviewing and disseminating knowledge to a variety of public, private and civil society institutions. (3) The University of Cape Town's Energy Research Centre and Environmental and Geographical Sciences Department are internationally acclaimed. Under apartheid isolation the government made effective use of university research capacity to advance its economic and technological needs. The obvious outcome of this focus has been companies such as SASOL, but it is plausible for this capacity to deliver renewable energy solutions to the Western Cape.

6. Conclusion

The Western Cape has committed itself to growth and development. Whilst growth is possible through replication, development implies a form of qualitative change. One central aspect of this change relates to the flux that is taking place in the international energy sector. This is not a flux that the South African energy regime, to is detriment, is tracking.

The economic competiveness of the Western Cape will, to an increasing degree, be determined by the extent to which it can distinguish itself from South Africa's energy regime and assimilate renewable energy technologies. Whilst energy decision used to be about reconciling supply and demand for least cost to utilities, they are now informed by employment considerations, water availability, international investment, status in the global economy and regional brands.

There are some natural barriers to the uptake of renewable energy at the provincial level such as the limited water available for biofuel cultivation, the lack of geothermal capacity and the difficulty of water cooled CSP given water restrictions, but the Western Cape has comparative advantage in renewable energy and most barriers are institutional, technical and financial. For the Western Cape to fulfil its renewable energy potential it will be required to overcome these barriers. The institutional nature of these barriers necessitates a role for public entities, such as DEDAT, in the advancing the provincial energy regime.

The shift to renewable energy is not easy. It involves moving from the "tried and tested" to the "new, uncertain and variable". DEDAT has an important role to play in removing the institutional barriers, shaping the collection of renewable energy technologies that emerges so as to best meet demand, enabling finance and supporting research and development, as part of its effort overcome the market failures and vested interests that have seen the entrenchment of coal and oil fired energy.

By registering the country's first RED the province has positioned itself at the forefront of this process nationally, but activating this RED and the needs to be complemented by the registration of local IPPs (which were affirmed as being essential in State of the Nation Address of 11-02-2010) and the securing of PPAs from ESKOM's Single Buyer Office for Western Cape based companies under future "Integrated Resource Plans". The goal for the Western Cape is sustained competitive advantage and the development of competitiveness in new industries and markets.

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8. Annex 1: Summary of Western Cape Renewable Energy Options as presented in the RE Plan of Action for the Western Cape and SABRE-Gen research

Energy source		Potential	Cost estimates	Comment
Solar power		Much of the province receives between 6,500-7,000 MJ/m2 per annum of solar irradiation	R25/W	
	Photovoltaic	Two track potential with imported parabolic dishes and locally manufactured flat mirrors. CSP for large scale.		Can be used on site, no need for transmission. Has utility scale potential under CSP. CSP technology progressing quickly. Sun-tracking parabolic dishes commercially available.
	Solar thermal (SWH)			Excellent job creation potential. SWHs do not require transmission. Has potential for large-scale.
Wind		2800 MW of available potential. Experimental turbines at Klipheuwel turbines (750 kW, 660, kW and 1.75 kW respectively).	Local estimates suggest R 22 million per MW of capacity, which translates to R1.10-R2.75/ kWh depending on utilisation. US $2,400 – 5,000 kWh. European estimates suggest R1.65 is required for first twenty year followed by R 0.44 thereafter to ensure	Planning is currently based on a 1993 wind-map (Diab, 1993), which needs to be updated. No high temperatures or high pressures make technology relatively safe. Reasonably labour intensive, but imported components for large turbines. Darling wind farm has set precedent. Klipheuwel trial project provides valuable information on “Vestas” and “Jeumont” turbines.

			viability.	
Methane flaring		All landfill sites and sewerage works present potential.		High repliciability at solid waste sites. Prevents emission of noxious methane gas. Economic viability is dependent on revenue for carbon saving. Durban Solid waste project provides useful learning. Bellville landfill under construction.
Biomass	Three technologies: Pyrolysis, gasifucation, torrefication	Were dependent on timber feedstocks it will be water constrained. Massive potential in the use of waste cellulosic material.		Able to supply on demand. Offers decentralisation potential. May offer flexibility as an alternative feedstock in coal fired power stations.
	Biofuel (bioethanol and biodiesel)	4%-10% of liquid fuels could be displaced. Water is the major constraint. Dryland wheat and canola are possible feedstocks in the Western Cape.	Bioethanol production costs estimated R3.08-R3.45 per litre. Biodiesel typically 10% more expensive.	Highly tariff protected global trade. Brazil lead global industry and produce bioethanol at R1.35 per litre. True potential lies in 2nd (cellulosic) and 3rd generation biofuel, but involvement in 1st generation may be a prerequisite for involvement later on. Food security impacts need not follow, where biofuel investment can be used to increase production in poor rural areas. High potential when linked to agrarian reform programme.
Hydro	Steenbrass/ Palmiet Power Station			Essential in reconciling supply and demand. Limited. Small-scale applications is expected to be mainly for sites remote from the grid. Not considered renewable by UNEP, but off-stream plants limit environmental impact.
Wave		120 MW of power is considered feasible. South African average is favourable – 17 kW/m of wave length.		Wave energy capacity is concentrated on the West and Southern Cape coast where 30-50 kW/m of wave length is common off-shore.

Annex 2: Lead companies in the international renewable energy sector

The wind energy sub sector is overseen by the Global Wind Energy Council (GWEG), but major corporate players in the international wind energy sector include:

- Dong Energy: Dong was founded in 1972 around North Sea gas interests. It was then a State owned company and remains 73 per cent owned by the Danish Government. The Danish Government has long recognised the need to promote energy innovation and diversification and with the assistance of its state-funded innovation centre, Dong managed to transition into a wind energy market leader. The latest developments have seen Dong Energy (which employs 6,000 people) partner with Siemens Energy to advance their development of turbines.

- Vestas: Originally Danish, now a multi-national company, is the world's leading manufacturer of turbines and producers turbines with 850 kW - 3.0 MW of capacity. In terms of innovation, the company has pioneered means of connecting renewable energy sources to a variety of different energy grids.

- Siemens Energy: Based in Munich, Germany, generated Euro 23 billion worth of sales in the 2009 financial year, the majority of which came from wind technologies (Engineering News, 11 December 2009).

- Enercon GmbH: Leader in the German market. Enercon has driven innovation in rotor blade technology. In 2009/10 Enercon exported over 60 per cent of its product.

- Clipper Windpower: Based in Iowa, Clipper designs advanced wind turbines, manufactures its 2.5 MW Liberty® wind turbine and actively develops wind power generating projects in the Americas and Europe.

- Peregrine Power: Peregrine Power LLC is an Oregon-based company that focuses on the provision of services. The company carries out research and development in power systems, power electronics, and controls. It is currently focusing its research on the application of semiconductors, improvements to power electronics and power systems and inverters for PV systems.

- China Longyuan Power

SOLAR ENERGY COMPANIES:

- ABB (manufacturers of a specialist in high-voltage, direct-current transmission grids),
- Siemens, German engineering giant.
- Anengoa, Spanish engineering firm.

- German utilities E.ON and RWE, MAN Solar Millennium (a joint venture of MAN Ferrostaal and Solar Millennium (which makes CSP equipment
- Ausra (United States),
- BP Solar,
- Conergy (Germany),
- eSolar (California, USA),
- Sharp Solar (Japan),
- Solar City (California, USA),
- SunRun (California, USA),
- Mirror Manufacturer (P.A. USA)

WAVE

In 2009 Stellenbosch University conducted a review of wave energy technologes that might be applied on South Africa. The following information is, largely, a summary of their findings.

- **Wave Dragon LTD (Denmark):** Wave Dragon Ltd took first major step to deploy the Worlds Largest Wave Energy Converter (WEC) by submitting their Environmental Impact Statement. Plans are to deploy a 7MW device off the Dale and Marloes Peninsula (Pembrokeshire, Wales) during the summer of 2008. Through this application, the Wave Dragon is taking the first step in establishing a 70MW wave power plant in the Celtic Sea by 2010. The Wave Dragon Project is part funded by European Objective 1 funds through the Welsh Assembly Government (NexusExchnage, 2009).

- **Pelamis Wave Power LTD (Scotland):** September, 2007 - The UK Government has given permitting permission for the Wave Hub project - Pelamis is one of the four (4) wave device developers chosen to work with the Wave Hub project. March 2007 - completed work-up trials in the North Sea. New trials of the first machine to be complete in Orkney will be followed by installation of commercial wave farm in Portugal. The wave farm will be installed 5 km (3 miles) off the Portuguese coast, near Póvoa de Varim. The project will have an installed capacity of 2.25MW and is expected to meet the average electricity demand of more than 1500 Portuguese households. March, 2009 - Pelamis project has been pulled indefinitely after a series of technical (buoyancy tank leaks) and financial setbacks (NexusExchnage, 2009).

- **Wavebob (Ireland):** In March 2006, a one quarter scale prototype was installed in Galway Bay. Developers have an ongoing test program of development at the test site. In April 2007 it was announced that Wavebob has partnered with US energy company Chevron to provide technical consulting services. The partnership will look at converting ocean wave energy into useful power. In October 2007, Wavebob announced that their prototype device is producing electricity.

- **Embley Energy and Sperboy (United Kingdom):** From 2003-2005, Sperboy completed the Marine Energy Challenge, where independent consultants investigated its performance in terms of power capture as well as carrying out a detailed study of both capital and maintenance costings to arrive at their prediction for the cost of delivered power. In 2007, Sperboy announced project work with the Universities of Bristol and The West of England.

- **Float Inc. (USA):** The company has have a number of projects under active consideration involving various uses of the PSP which include oil and gas industry applications, floating yacht harbors, and ocean wave energy conversion.

- **Seavolt technologies (USA):** Wave tank tested and now participating in a UK wave research study called the Marine Energy Challenge.
- **Checkmate SeaEnergy (UK)**
- **Finavera Inc.**
- **Baek Jae (South Korea)**
- **Aquamarine Power, Ocean Energy and Oceanlinx (Australia)**

Annex 3: Financing options for renewable energy

Public finding: In 2009 64 of the 73 countries with renewable energy targets had tailored support schemes in place. Fourty of these countries had publicly funded feed-in tarrifs (Mendonca, 2007). The energy sector tends to be highly regulated and the potential “up-side” of becoming a leading supplier and exporter of a labour intensive technology experiencing growing demand has provided a further incentive for governments to commit fiscal resources in support of renewable energy research and commercialisation. Certainly most of the successful, large scale, renewable energy projects and companies to date have received government support. China’s march to the forefront of the global renewable energy sector is often cited as a replicable model of how government funding can be used to foster development. Yet the reality of the “infant industry”, “technology incubator”, “picking winners” rationales for fiscal funding of new technologies is, at best, patchy in terms of success and usually expensive when successful.

How governments fund renewable energy roll-out without promoting moral hazard or lock-in of inappropriate technologies, is difficult but a number of examples and funding sources are available.

- **UNEP's Sustainable Energy Finance Initiative (SEFI)** Governments often focus on legislation and tax when approaching the development of new technologies, although these financial mechanism are seldom enough to support the emergence of the large scale-scale development needed for the sector. This is especially true in the case of South Africa as energy policy is set at the national level. UNEP (2009) suggests that the focus should be placed on public finance mechanisms that support the sustainable energy industry by filling the financing gaps a technology encounters as it proceeds from R&D through to commercialisation and full-scale development.

  SEFI outlines a technological innovation financing continuum formed of four parts: R&D, demonstration, pre-commercialisation, and commercialisation. Public finance mechanisms that are currently in use in this area and throw light into the right direction to support emerging technological sectors include integrated links that use technology innovation stages and necessities along the innovation chain, including pure and applied research, feasibility studies and demonstration. Useful examples are SenternNovem´s grant programmes in the Netherlands (DEN and EOS) and the Austrian Technologies for Sustainable Development, which apply to a broad range of SE sectors. This approach aids to ensure that financial mechanisms are in line within and across the different stages of the sector development.

- **The Canadian Green Municipal Funds:** The Green Municipal Enabling Fund (GMEF) offers grants up to CDN$ 350,000 to municipalities and their private sector partners for cost-shared planned initiatives, feasibility studies and on-site tests for the pre-feasibility and feasibility stages of the commercialisation process. It is run by the federation of Canadian Municipalities.

- **Guarantees:** Focus on large industrial projects and are usually implemented together with private financial institutions. These focus on projects that banks perceive as risky. Conventionally, the institution divides the risk into either partial risk guarantees offered to selected lenders which ensure debt-servicing payments for concrete time periods or exposure levels, or partial credits guarantees which extend loan repayment periods, in order to improve the project's cash flows. The rationale is that buying down the risk usually leads to lower costs of financing for the borrower and or decreased assurance requirements. In developing countries, the World Bank has been offering through the Global Environmental Facility some guarantees, such as for geothermal projects exploration risks. In developed counties, guarantees are uncommon, excluding a few examples from small to mid-size instruments such as the French FOGIME, the USDE

(United States Department for Agriculture) and the Canadian GMIF RE and EE programmes.

- **REFIT:** South Africa's tabling of REFITs is consistent with international experience as the best way of financing renewable energy (Mendonça 2007, p.8). For the REFIT to be effective, however, it has to be complemented by volume specific purchase agreements with surety of payment on supply. It is PPAs that will provide private investors with the confidence to raise capital and invest in South Africa.

For the Western Cape this may prove difficult. The province currently has little influence over the Integrated Renewable Programme that will determine the composition of renewable energy purchases into the grid, and is not well placed to push for the required urgency in finalising the IRP and issuing contracts. Uniquely, however, the province is a registered RED and so can begin entering into bilateral agreements with suppliers independently of ESKOM. This will see the province paying the premium, rates that were meant to be financed from the national fiscus, may prove crucial in expediting investment in the region and distinguishing the region from the rest of the country. A precedent for this type of approach has been created at the Darling Wind Farm, which sells electricity directly to the City of Cape Town.

Certainly the ability to attract private foreign direct investment for renewable energy into the Western Cape should be given high priority as a means of capturing some of the revenue and jobs (and creating additional jobs) that are currently concentrated in the energy producing region of the Highveld. Considerable private and quasi-private finance is available.

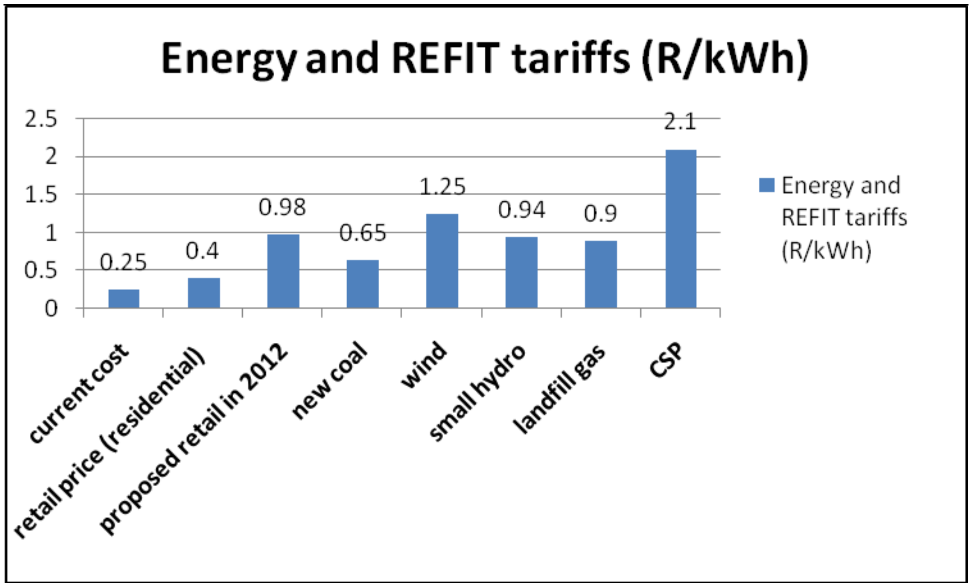

Figure 16: The tariffs are guaranteed for 20 years without digression. Source NERSA (2009)

- **Technology Innovation Agency**:
- **Incubators**: Public funded (or in part government funded) incubators
- **CaBEERE:** A joint project between the Governments of South Africa and Denmark. CaBEERE aimed at building capacity in energy efficiency and renewable energy.

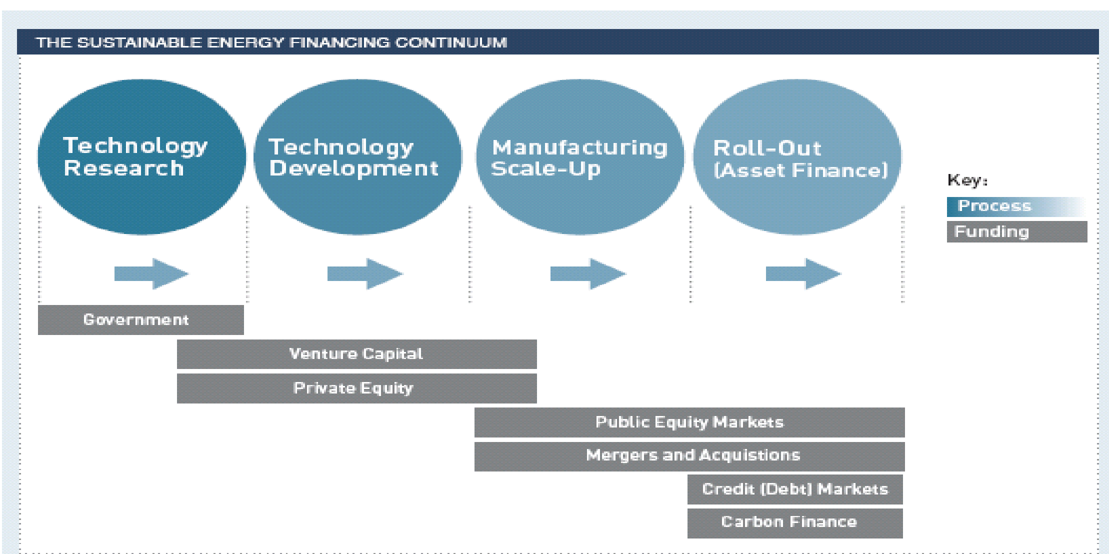

Figure 15: Stylised model of financing combinations in the development of renewable technologies.

Private finance: Straight loan finance for renewable energy remains problematic unless supported by REFIT or polluter pays type legislation. As most technologies are in early stages of development, they have not yet realized their full cost digression potential and continue to entail a higher risk than established technologies.

- **Corporate lending:** The bank sets general conditions but places few restrictions on how the company can use the funds.

- **Project Finance**: or Limited Recourse Finance: debt amount is borrowed for a certain project linked to the revenue the project will generate.

- **Insurance finance:** The insurance industry is exposed to climate change but also has long term contracts with households and companies to provide cover against disasters and liabilities. It is within the insurance industries interests, for example, to replace burst electric geysers with solar water heaters when it replaces the geysers that it is required to every year.

- **Venture Capital:** A specific form of the more conventional equity capital. Focused on 'early stage´ or ´growth stage`, of technological companies and markets. Money is raised from a wide range of sources with high risk appetite to include insurance companies, pension funds, mutual funds, or high net worth individuals. George Soros declared prior to the COP-15 in Copenhaguen in December of 2009 that he will invest R7.5 billion in clean-energy technology. There is a high risk of failure in each venture and an investment horizon of 4 to 7 years. The return requirement can widely range from 50 to 500 per cent of original investment. Given the risks and returns available in renewable energy projects, venture capital is unlikely to be attracted without a REFIT, guarantee or polluter pays policy in place.

- **ROCs:** Renewable obligation certificates (ROCs) involve customers that purchase green energy receiving acknowledgement for their purchase. Suppliers are encouraged to offer an increasing proportion of their electricity from renewable energy sources.

- **Carbon finance:** Transaction value in the global carbon during 2008, reached R900 billion. The number of registered CDM projects and projects issuing CERs increased 48 per cent and 57 per cent respectively for the same period (UNEP 2009). In 2008, the EU Emissions Trading Scheme represented 79 per cent of the global carbon market in terms of value. Total allowances and credits in the US, covering the Chicago Climate Exchange (CCX) and Regional Greenhouse Gas Initiative, represented 3 per cent of value of the global carbon market. New Carbon Finance calculates that trading in the carbon market accounted for about 1per cent of the world´s derivatives markets in 2008. The United Nations and Australia are respectively putting in place legislation on cap-and-trade extending to 2020. If the US introduced a similar scheme, New Carbon Finance Expects the global carbon market to increase to R15.75 trillion annually up to 2020.As a province in an Annex 2 country, the Western Cape stands to benefit from carbon trading. It should be noted though that carbon revenue typically contributes 5-12 per cent of the capital required for renewable energy technology. In addition the UNFCCC controlled carbon market, operating through the CDM, has proven a blunt instrument for accessing technology funding (Pace, 2009). The voluntary carbon market, which mimics the UNFCCC market has grown rapidly and was valued at R 10 billion in 2008 and grew by 87 per cent in that year.

Carbon finance tends not to cover the ful capital cost, but can be used increase returns and attract other forms of finance.

- **Hybrid finance:** Some of the best financing mechanisms involve a hybrid of public and private finance. Under these arrangements the public sector enters into an entrepreneurial relationship with the private sector with the intention of using the fiscus to crowd-in private sector investment for worthy causes.

- **Household investment:** ESKOM's SWH rebate represents an incentive to homeowners to install this technology, but in the United States a more innovative and complete system is in operation aimed at achieving the same result. Securing investment in residential renewable energy and energy efficiency is one important component of most national mitigation strategies and presents the potential for the spread of carbon revenue benefits to households. Houses contribute between 15 per cent and 30 per cent of most country's emissions (more in poorer countries) and technologies or measures that reduce residential emissions can simultaneously reducing domestic expenditure on energy. The usual impediment for households wanting to invest to reduce their consumption of fossil fuels is the high up-front capital costs for the installation of renewable energy end energy efficiency technologies. Households may want the lower marginal energy costs associated with renewable energy and energy efficiency but typically don't have the capital required to access it. This is true of solar water heaters, compact fluorescent lightbulbs, insulation and photovoltaic cells. Even where households have the money, the assumption that these capital investments only save money over a 7-12 year period acts as a deterrent for most residents who think that they may move before then. The evidence from the United States shows that most people stay in their houses for an average of 12 years, but when questioned assume they will stay only an average of 7 years. The assumption of a shorter period dissuades people from making an investment that they may not recoup in full. A raft of financing approaches from subsidies, to loans and tax rebates and straight grants have all met with mixed results and proven costly to administer.

  In the United States the Federal Government began rolling out a financing scheme to address this impediment that was piloted in San Diego in 2009. Under the scheme the companies that install residential renewable energy and energy efficiency technologies are paid by the local municipality or city. The owner of the house then pays the municipality a monthly addition to their property tax for the duration of the period that they are in the house. If they sell the house, the tax is transferred to the new owner. The municipality, because it has a liability secured against the home owner's assets, is able to issue bonds (treasury or private sector bonds) against the money that is owed to it, thereby obviating any cashflow shortfall it might have as a result of the scheme. In many instances the local energy utility is only too willing to be the financier of the bonds, whilst municipalities benefit further from the scheme by expanding their tax base.

SunEdison's business model tackled the problem of financing head-on. Instead of selling panels to companies such as Wal-Mart, Walgreens and Staples, it leased the panels to them – under 20-year contracts – and armed with blue chip lease agreements as sureties it was able to secure financing. The company had effectively created corporate green bonds for its clients and in the process cracked the solar financing conundrum, at least for its select group of "tenants".

Annex 4: LTMS findings

The Long-Term Mitigation Scenario (LTMS) energy model assumes a renewable electricity share of 15 per cent in 2020 and 27 per cent by 2030 (Hughes et al. 2007, 37). However, it is unclear if and how this share needed for the LTMS will be reached, as South Africa has made little progress towards achieving its 10,000 GWh target in the first half of the period (DME RED 2009, 12). To date, only about 3 per cent (296 GWh) has been installed (DME RED 2009, 13).

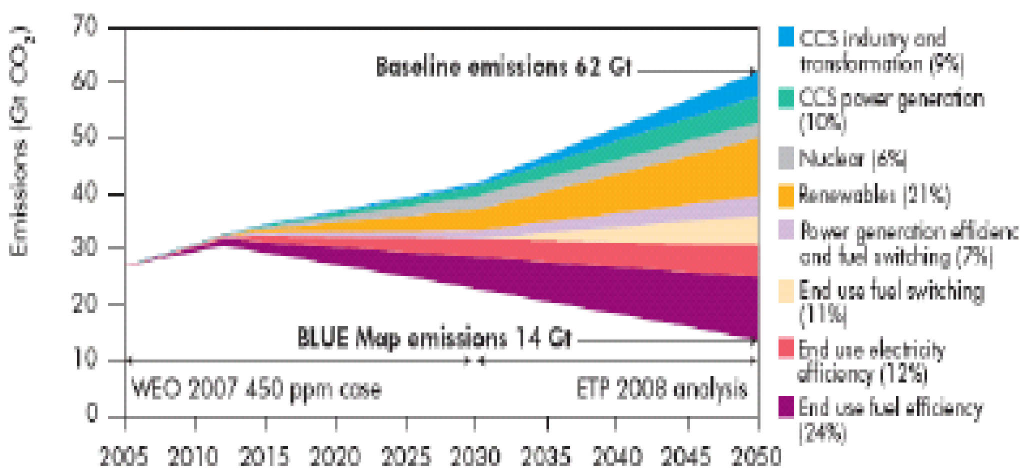

Figure 8: Illustration of the "wedge" approach to greenhouse gas emissions reduction modelling. Source: IEA, Energy Technology perspective (2008).

Table 5: Select LTMS carbon reduction technologies and cost per reduced ton of CO_2e ($/ton$CO_2e$).

Technology/ policy intervention	CO_2 reduction potential	R/ ton of CO_2 saved impact on GDP
CO_2 tax	12,287	R42
Electric vehicles charged with nuclear energy	6,255	R102
Vehicle efficiency	758	-R269
Subsidy for SWH	307	R125
Industrial efficiency	4,572	R-34
Nuclear (no decommissioning costs)	1,660	-R18
Carbon capture and storage (20Mt)	449	R72
SWH subsidy	307	-R208

Annex 5: Associations and lobby groups

The regions, cities and companies that are active in the renewable energy sector have aligned themselves in a variety of ways to advance, protect and sometimes force their interest. An understanding of these affiliations is a prerequisite for effective engagement in the rapidly evolving renewable energy sect. Align takes place according to views on the extent and pace of renewable energy adoption, as well as on the technology mix and financing mechanisms that should be adopted. Broadly speaking businesses request for greater pricing and trading of carbon, while NGOs lobby for stricter regulation and policing.

Advocacy groups and "facilitators" greatly outnumber companies that are actually developing technologies and generating renewable energy, an observation that adds to the complexity of this sector especially as advocacy groups do not always concur and sometimes compete for resources.

International Renewable Energy Association: is an inter-governmental organisation mandated to promote the sustainable use of renewable energy. The agency, which was formed in January 2009, has 140 member states. IRENA aims to collate and distribute information and provide a platform for member country interactions through its bi-annual conferences.

The International Chamber of Commerce (ICC): members contain intense polluters, but has access to G8 and WTO, and has spoken out for a global agreement on climate change that includes all major emitter countries, active carbon markets and government funding for new technologies.

The Climate Group: A member association that brings large corporate including British Petroleum and Duke Energy with western governments. It promotes CCS, nuclear power and biomass as crucial technologies for low carbon economies.

The International Energy Agency (IEA): acts as energy policy advisor to 26 Member countries in their effort to ensure reliable, affordable and clean energy for their citizens. Founded during the oil crisis of 1973-74, the IEA's initial role was to co-ordinate measures in times of oil supply emergencies. As energy markets have changed, so has the IEA. Its mandate has broadened to incorporate the "Three E's" of balanced energy policy making: energy security, economic development and environmental protection

IETA: IETA works for the establishment and promotion of a global market-based trading system for greenhouse gas emissions by businesses. It also aims at maintaining social equity and environmental equity.

World Economic Forum (WEF): WEF has an Initiative on Climate Change" that is nominally supported by industrial giants BP, Shell, IETA and Vattenfall. To transition to a lower carbon economy, WEF supports nuclear power, CCS and greater use of the Clean Development Mechanism.

Brazilian Climate Alliance: Created in September 2009 by fourteen of the main Brazilian entities in agribusiness, planted forests and bioenergy. It represents 28 per cent of the entire Brazilian energetic matrix and 16 per cent of the country's exports. During COP 15 the alliance concentrated on the reform of the CDM and the restructuring of REDD. It also focused on development a business model for Brazil based on the principles of a low intensity carbon economy, such as using public policy to favour trade mechanisms that tap carbon credits (namely through the large scale production of ethanol). The body also stands for environmental services payments to avoid deforestation.

ISES is a multi-faceted, global membership organisation. With its long history and extensive technical and scientific expertise provided by its members, the Society is a modern, future-oriented non-governmental organisation (NGO). Clearly defined goals, extensive communication networks and practical, real-world projects are the hallmarks of ISES.

South African National Energy Research Institute (SANERI): SANERI is the public entity entrusted with the coordination and undertaking of public interest energy research, development and demonstration. SANERI is a relatively new body, established by the then Minister of Minerals and Energy in October 2004, as a subsidiary of CEF (Pty) Ltd. The

Department of Science and Technology, together with the Department of Minerals and Energy, are joint custodians of SANERI and assist in providing political and strategic focus for the company.

African Wind Energy Association: WEA is a non-profit organisation formed in 2002 to encourage manufacturers, developers, governments, renewable energy owners and individuals to promote and support wind energy development on the African continent. It is based in Darlin, South Africa, and it is a member of the World Wind Energy Association.

The Sustainable Energy Society of Southern Africa: SESSA is a non profit organisation and is dedicated to the use of renewable energy and energy efficiency. The inter-disciplinary nature of SESSA attracts the membership of industry, scientists, researchers, developers and the general public – the only qualification is a keen interest in renewable energy and its utilization to ensure a sustainable energy future.

Renewable Energy & Energy Efficiency Partnership: REEEP is a Public-Private partnership and was launched by the United Kingdom along with other partners at the Johannesburg World Summit on Sustainable Development in August 2002. It has been developed via an intensive consultation process in 2003 covering a wide range of stakeholders at the national and regional levels. It is an active global partnership that structures policy initiatives for clean energy markets and facilitates financing for sustainable energy projects.

Southern African Biofuels Association: It is a non-profit organization committed to the development and implementation of a sustainable biofuel industry in Southern Africa, a comprehensive structure to market the product as well as laws and regulations to support it. SABA lobbied government for a fuel levy and for blends in all diesel and petrol. It was consulted in the development of a draft Biofuels Strategy in 2007.