3.4.1 Solar Water Heating

Solar water heaters have been discussed in some detail in the Energy Strategy Report, and in the Demand Side and Energy Efficiency Strategy (Borchers 2007). They are modelled primarily as an energy efficiency intervention (reducing current demand for electricity and in some case for LPG and other fuels). However, their contribution in energy terms can legitimately be included, as they provide a net energy input. Solar Water Heaters have been excluded from renewable *electricity* contributions, but they should be included in total energy models (as a contributor). Tradable Renewable Energy Certificates (TRECs) provide an auditable method for monitoring and accounting for this energy.

3.4.2 Solar thermal energy as a use for process heat

There is some potential for solar energy to be used in industrial and commercial facilities as a source of process heat (using technologies similar to SWH, or in some cases using solar concentrators). For example, in Switzerland, 25% of total industrial energy demand is for thermal process heat in the sub 300°C range. More than half of this energy is for applications with temperatures below 150°C (Brunold et al, un dated).

These temperatures are easily achievable with solar concentrators, and in same cases with flat plate collectors. Such applications would obviously require hybridization with more conventional heating options, to ensure production in periods of inclement weather or at night (if required). However, the potential market has not been documented in South Africa. This is an area that merits further investigation.

3.5 Solar Electricity from Photovoltaic technology

Photovoltaic (PV) panels convert solar radiation directly into electricity using the photovoltaic effect. Modules have no moving parts and existing products have manufacturers' warranties of the order of 20 years. PV panels are primarily used to provide electricity for telecommunications, lighting and electronic media in areas that are remote from the grid. There are already approximately two hundred thousand 'off-grid' installations in the country. A recent review found only ten grid-connected installations in the entire country (Cawood & Morris ,2002, p. 29).

However, in countries such as Germany, Japan and the United States (in particular California), incentive programmes have promoted the interconnection of PV panels with the national grid, and the grid market is now far larger than the off-grid market. With our more favourable climate, we could surpass their achievements, given supportive government policies. The international market continues to grow very strongly, with sustained growth rates in the high 20% range. Short-term demand growth rates are currently so high that demand for PV modules has exceeded supply, affecting module availability for South African projects. International incentive programmes have been able to steadily reduce the subsidies paid per kW installed, mainly because the markets, particularly in Japan, are gradually approaching full commercial viability. PV technology is considered by many to be the most promising long-term option for energy supply, with some international scenarios indicating that 50 percent of energy could come from PV by 2100.

The current PV market in South Africa is relatively small (about 12 MWp installed). In 2002, the overall sales volume (including exports) was estimated at 3 to 3.5 MWp, with a market turnover of approximately R200 million to R225 million (Cawood & Morris, 2002, p. 38). At that time, a manufacturer indicated expected production of 8 MWp for 2003. By the end of 2004, one manufacturer had exported approximately 25 MWp during the year, and was targeting a production of 40 MWp for 2005. This manufacturer alone has thus reached nearly ten times the 2001-2002 production figure. (Banks & Schäffler, 2005, p 15)

From a Western Cape perspective, it must be noted that there is a large scale (>30 MW) module assembly facility located in the Western Cape, that has been producing for the export market, and supplying locally (Tenesol). Discussions are also underway regarding the possible establishment of a thin film cell and module production facility in the Western Cape (Project developer, Personal communication).

Thus the opportunity for investment into these facilities, given the overall increasing demand both locally and internationally, needs to be further stimulated. The 'Environmental Economy Programme' as well as the Province as a whole will benefit from the stimulation of a local industry that is able to price product at more reasonable levels and thus further stimulate local uptake of the technology.

3.5.1 Cost indications

The price of PV modules is naturally highly dependent on volume. There is also a current shortage of material on the international market as a result of the huge expansion in grid-connected markets. As a result prices have not decreased in the last few years, and have at times increased. In the longer term, new silicone and alternative material supply infrastructure is expected to improve.

South African off-grid concession companies have paid as little as R18 000/kWp for modules (uninstalled), with prices of R26 000/kWp being more common. Current (early 2007) prices are around R31 000/kWp.The additional costs of the grid connection interface and installation would add perhaps a further 50 percent to the overall cost, yielding achievable capital costs in the range R27 000 to R46 500 per installed kW. These price ranges correspond to energy prices of between R1.22 and R2.16/kWh[2]. Bekker (in press) has calculated the cost of energy from PV for a range of locations in South Africa, and comes up with prices of R1.66 to R1.72 for De Aar, and R1.77 and R1.93 for Cape Town (using a maximum power point tracking inverter – MPPT)

Off-grid systems tend to be more expensive as storage is often required (unless energy is only required in the day, or an output such as pumped water can be stored), and systems are usually smaller. Off-grid systems have costs of the order of R60 000/kW (excluding loads) and energy costs around R3.35/kWh or higher (again depending significantly on maintenance cost accounting)..

Figure 11 illustrates historical and anticipated cost reductions for several renewable energy technologies, including PV. It will be noted that, by 2020, the production costs of PV generated electricity are anticipated to be less than half the current costs, although the cost estimates are still of the order of US 8 cents/kWh (about R0.56 at R7/USD). The German Advisory Council on Global Change (WBGU, 2003) anticipates that, for an 'exemplary

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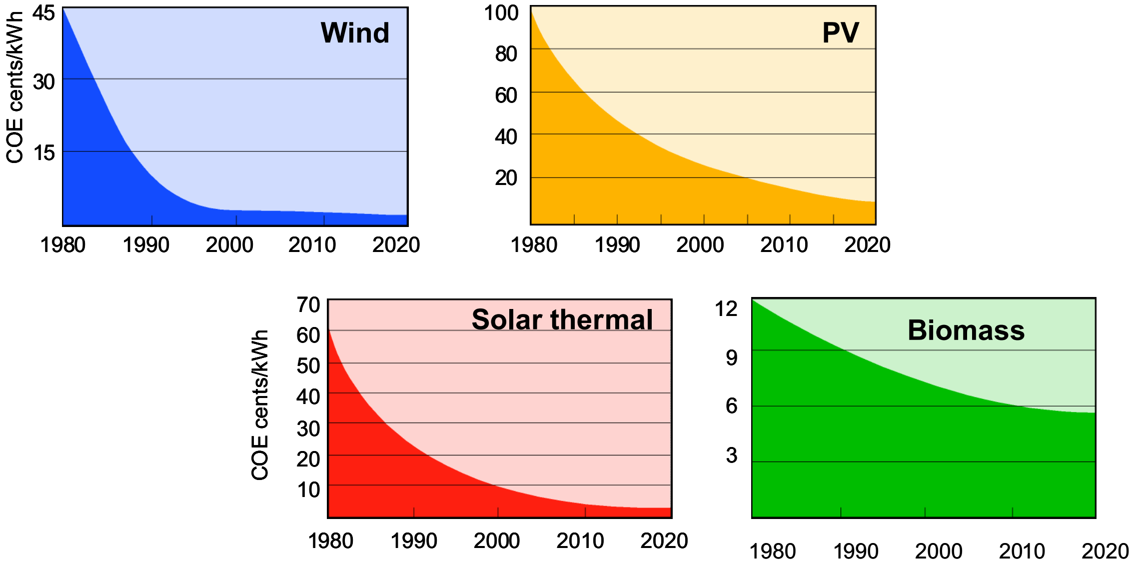
[2] R32 500/kWp, amortised over 20 years:, assume installation falls in medium radiation band of 7800 MJ/year, 8% discount rate, 20 year life.

scenario', the installed cost of grid-connected PV systems (with associated system components) would be €1/Wp by 2020, resulting in an electricity cost of €0.12 per kWh *in Europe*. In high-sunshine regions, the cost would decline to €0.06 per KWh (R0.60 at R10/€).



Source: NREL Energy Analysis Office
Updated: June 2002

Figure 11 Cost reduction curves for renewable energy technologies

An International Energy Agency publication anticipates a reduction in solar technology costs of the order of 30 to 50 percent per decade for each of the next two decades as a result of learning and market growth (IEA, 2003, p. 18). For example, trial production is currently underway at the Johannesburg University of Technology of a novel PV cell manufacturing process that may help reduce the costs of modules by a further 20 to 50 percent in the next few years. A factory employing this technology is under construction in Germany. This innovation would create a more rapid cost reduction than those indicated in Figure 11 and, if the venture is successful, it is likely to have major implications on the development of PV technology in South Africa.

As with other electricity generation devices, PV modules require energy to manufacture. Grid connection systems in Europe currently have an energy payback time of about three years. The payback time would be about 50 percent shorter in the high radiation areas of South Africa, and there is also room for further optimisation or the technology to reduce the payback time further (WPGU, 2003, p. 65)

For the scenarios below, costs as listed in Table 16 have been used.

3.5.2 Photovoltaic system application potential in the Western Cape

The potential contribution of PV to the electricity market is *not* limited by the solar resource availability. Available roof space is a limitation, but it should be noted that if solar PV (or more likely CSP) farms are established on virgin land, then Banks & Schäffler (2005) estimate that an area of only 730 km^2 is required to meet the current electricity needs of South Africa, at a 13% conversion efficiency.

In the medium term, the main limitation is likely to be the ability of global (and local) industry to supply the materials and components required to manufacture cells on the scale demanded. Although some technologies rely on small amounts of potentially scarce materials (indium and tellurium), for most PV cells the main ingredient required is silicon which is the second most common element in the earth's crust. Current technical developments are also achieving a reduction in material usage.

As PV becomes a more significant component of the total grid supply (say 10 percent), it will become necessary to ensure that there are adequate energy storage systems in place (or alternative peak power supply options) to accommodate the variability of PV generation (Section 3.12).

The primary limiting factor for PV technology implementation remains cost. There are, however, several important reasons why PV is expected to play a highly significant role (as discussed by Banks & Schäffler 2005):

- Ease of use: PV modules represent one of the easiest ways to implement renewable energy. The power source itself is extremely robust, requires no maintenance apart from occasional cleaning, and is one of the few products in the world that regularly carries a 20-year warranty. As has already been illustrated in the international market, it is relatively simple to install thousands of grid-integrated systems on domestic and commercial building rooftops (once grid interconnect codes and technologies have been established). PV technology is also extremely well suited to off-grid applications;
- Electricity is generated at point of use: PV systems can be installed almost anywhere, and can be readily integrated into the grid distribution system. PV provides an opportunity for individuals, commercial enterprises and other parties to take steps at their own premises to contribute directly to a more sustainable energy future;
- Technologies are rapidly being developed that allow the integration of PV cells or modules into dual-purpose coverings and fabrics such as:
  - Roof tiles and roofing membranes for flat roofs;
  - Durable building cladding;
  - Fabrics for clothing and tents;
  - Portable product surfaces (watches, cell phones, radios, etc.);
  - Noise barriers on highways;
- The resource is well distributed and it is relatively easy to estimate how much energy will be produced at particular locations (See Bekker, in Press for South African simulations).

For the purposes of the scenarios discussed below, the following potential PV market growth for the progressive renewables is assumed, and the high renewables scenarios (see section 5 for scenario explanations.). Note that just one factory with an output of 50 MW/year would provide more than enough modules for the scenarios below. As such, a module production facility established in the Western Cape is likely to export most of its product. In this context, it is recommended that a full economic analysis be conducted to investigate the effective net cost of energy from PV modules, if one assumes that the modules are sourced from local manufacturing facilities – taking into account the job creation and other interlinked economic benefits.

Table 8 PV market projection used for Progressive Renewable Scenario (by 2035)

	No. inst	Average size	Total	Energy	Note
		kW	MW	GWh	
Large scale	2	1,500	3	7	Large scale grid connect is already on the agenda for the Green Point stadium
Decentralized	166,100	400	66	109	This could be achieved if 10% of households in the province installed a PV system. There are several other grid connect opportunities
Off-grid hh and other	30,000	50	1.5	2.5	There are already more than 20 000 off-grid households in KZN that use 50Wp systems. Although WC has higher grid penetration, market is still significant
Totals			**71**	**118**	

Table 9 PV Market projections used for the High Renewables Scenario (by 2035)

	No. inst	Average size	Total	Energy	Notes
		kW	MW	GWh	
Large scale	15	5,000	75	164	
Decentralized	332,200	500	166	273	This represents a 40% installation rate on hh (less if other applications are used)
Off-grid hh and other	30,000	200	6.0	9.9	It is anticipated that off-grid hh would over time gain access to larger systems
Totals			**247**	**447**	

In the scenarios below, possible roll out rates are modelled (see Table 19 for a 'progressive' and Table 21 for a 'high' scenario.)

3.6 Solar Thermal Electricity Generation or CSP

Solar energy, if concentrated, can be used to heat a working fluid (such as water) to drive turbines or reciprocating Stirling engines. The following material is primarily drawn from Banks & Schäffler (2005). At present, 'Concentrator Solar Power' (CSP) technology has the lowest costs for large-scale solar power generation (Solar Paces, 2005). Several plants exist with a capacity of more than 350 MW, with the bulk of production being from plants in California, which have operated for more than 10 years. For many years, these plants represented 90 percent of the world's installed solar electricity generation capacity, and have only recently been overshadowed by PV.

There are three main CSP technologies that are currently in use and under further development:

1) **Parabolic trough:** A reflective parabolic trough concentrates sunlight onto a tube located along the trough's focal line, heating a fluid in the tube which is then pumped to a steam turbine / generator or can be used to provide process heat. The troughs are normally designed to track the sun to maintain the focus point on the tube. Fluid temperatures range up to 400°C. This technology is used for the California SEGS plants. Although it can be applied on a small scale (for process heat) in electricity generation configurations, plant size would typically be in the multi-megawatt range (50 to 200 MW or even more).
2) **Power tower systems:** Mirrors or heliostats reflect and concentrate sunlight onto a central tower-mounted receiver where the energy is transferred to air or some other

heat transfer fluid. This is then used to drive turbine power systems. As with trough systems, power tower units are typically designed to operate in the multi-megawatt range.

3) **Dish concentrator systems:** These are smaller machines (from perhaps 50 watts to 25 or 50 kW). A parabolic dish (or array of dishes) focuses light onto a receiver, where it can be used to generate electricity directly in a small 'heat engine' (typically a Stirling engine). More rarely, the receivers are connected to a central generation plant using a heat transfer fluid. Dish systems are particularly attractive for small-scale distributed generation options. However, they may also compete favourably in large-scale plants, where arrays of several hundred (or thousand) machines would generate power.

A fourth option, the 'solar chimney' or 'Green Tower' concept uses a very tall chimney (1 to 2 km high) with a green house collector surrounding it on the ground. The hot air rises in the chimney, and the resultant draft can be used to drive wind turbines to generate electricity. If appropriately designed, this technology can produce power on a 24-hour basis, while also providing agricultural produce grown in the 'greenhouse'. Feasibility work has been undertaken on this concept in South Africa.

An important advantage of CSP technologies is that thermal energy storage (using molten salts or other heat stores) can be integrated into the system, thereby allowing power generation during short cloudy patches and during the evening. Gas or other fuel burners can also be integrated into the power generation equipment, so that the system can run on solar plus gas, or even on gas alone. This allows the plant to provide guaranteed power, as required by the grid.

The CSP industry is still nascent, and total installations to date are less than 1 GW. However, both the GEF and the World Bank have provided significant support to CSP (for developing countries) A 2006 review concluded that (World Bank/GEF 2006):

> The benefits of a successful industry, particularly for developing countries, are significant. The technology is not new, but stalled in its development path. All required technology elements are essentially already in place. The major outstanding issue is the need for cost reduction, and this study concludes that there is no fundamental reason why the technology could not follow a similar cost reduction curve to wind energy and eventually be cost-competitive. However robust, long term support mechanisms will be required.

Concentrating Solar Power (CSP) plants are currently under investigation as an option for Eskom, with proposals to build a 100 MW facility in the Northern Cape well advanced. Botswana Power Corporation have also recently issued a tender for a pre-feasibility study, and work on CSP has been undertaken in Namibia.

3.6.1 Cost indication

Cost information for CSP built and applied on a large scale in South Africa is not available. A recent Eskom presentation (Van Heerden 2007), used reference capital and operating costs from a Spanish plant (which has similar radiation conditions), and indicates capital costs of R33 500/kW, and energy costs of R1.61/kWh. This does not reflect potential cost reductions that would occur if significant local production was included (assuming a local industry could be developed). Daroll (2004) listed a cost of R0.40 for the South African plant.

The Long Term Mitigation Study uses cost of around 3000$/kW (R21 900/kW @R7.3/USD) installed – which results in a price of around R1.21/kWh.

In the Second National Integrated Resource Plan developed by Eskom and the NER, a levelised power cost in the range R0.33 to R0.96/kWh is indicated, depending on the assumptions used for discount rate, load factor and other costs.

A recent report (Greenpeace, ESTIA, 2005 p. 16) indicates costs in the range 2000$ to 3000$ per kW for 'next plant built' parabolic trough systems. (Rands R14 600 to R21 900 @ 7.3 R/$). WB/GEF (2006, p xix) lists current costs of around 14 USc/kWh (R1.02/kWh) with a reduction to 6 USc/kWh (R0.44 / kWh by 2025)

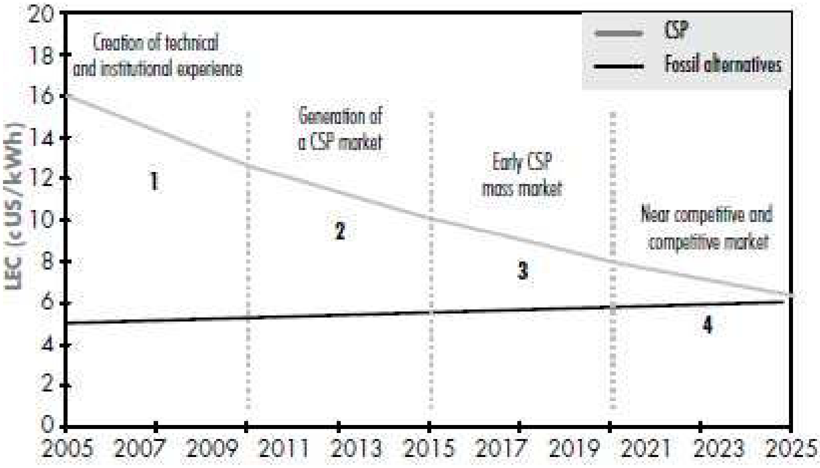


Figure 12 CSP Cost reduction curve (WB/GEF 2006)

In our opinion, the higher end cost figures are over-stated and do not adequately take account of the potential for cost reductions as the technology develops, or for cost reduction that could occur if local industry capacity is developed. Given that South Africa has excellent solar conditions, and reasonably low cost standard engineering construction capability, the scenarios assume a starting cost for a large (100 MW) plant of 3000$/kW or R21 900. If this is combined with fixed and variable operation costs as used for the LTMS study, and a capacity factor of 34%[3], then the cost per kWh would be R0.71 (at an 8% discount rate).

As noted above, certain CSP designs can include thermal storage, and plant can also by hybridized with gas or other fossil fuel options. These options have not been investigated in detail here. However, in anticipation of increased premium on dispatchable power, the scenarios assume that CSP plant with capital costs 50% more than the above figures could offer fully dispatchable power (high availability) and a capacity factor of 50%. Table 16 lists the cost assumptions used.

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[3] A capacity factor of 34% implies that the unit is exposed to 3000 kWh/m^2 of solar radiation per year. This can be achieved with tracking in Cape Town (Bekker in press), and would be exceeded in areas of higher radiation in the North Eastern parts of the province.

3.6.2 Potential Contribution of CSP to Western Cape Energy mix

The above costs are reasonable (for a renewable resource), and could be improved if carbon credits are gained. However, it should also be noted that CSP will perform significantly better in the Northern Cape regions – although in this case longer transmission lines will add to the total cost of power physically delivered to the Western Cape.. For this reason, implementation in the Western Cape may not be the most cost effective in the medium term. However, the power produced elsewhere could be allocated to the Western Cape if appropriate TREC's or similar systems are utilized.

Once CSP technology has been fully proved (and bearing in mind that there are several hundred MW already installed internationally), there are no significant technical, resource and materials limitations to the amount of CSP that could be included in the energy mix. The main constraint would be transmission line construction (if plant is located in the Northern Cape), and matching of demand/supply curves given peak and night time load requirements (see section 3.12.). Our assessments of the potential contribution have thus been based on assumptions regarding growth rate of the emerging industry – and are shown in Table 16

3.7 Wind

Wind energy is currently the fastest growing energy industry in the world, and large wind farms are being established on- and off-shore in several countries. By the end of 2003, cumulative installed capacity reached 40 GW (Jones, 2004), some eight to ten times the Western Cape peak electrical demand.

Wind turbines generating electricity range from battery-charging systems of the order of 100 W up to large multi-megawatt systems supplying power to electrical networks. These larger turbines are usually combined in wind farms with capacities ranging from 10 MW to 100 MW and beyond. Although this study has considered only commercial scale wind farms in the latter category, the potential of off-grid systems is significant.

3.7.1 Potential contribution

The resource at a prospective wind farm site must be accurately known if energy output is to be estimated with any reliability. This is therefore, also crucially important for business plan development.

Wind prospecting is in its infancy in South Africa and descriptions of the resource vary from abundant, to 'significant by international standards upon which wind industries have be built', to merely modest. The two most frequently quoted resource assessments are the Diab (1995) South African Wind Atlas, and a more recent second version of the wind database of the renewable energy resource database prepared by Eskom, CSIR and the Department of Minerals and Energy (DME /CSIR/Eskom 2002).

The Diab study relied on wind speed measurements from weather stations and airports installed at 2 m and 5 m high, with some at 10 m and significant geographical insight. The report prepared in 1995 still contains some of the most useful publicly available information on the resource. The locations of these stations are not however ideal as the masts are too low to reliably extrapolate data to indicate the wind resource in the 80 - 100m level above the ground where the turbine's nacelle (central point) would be located.

The renewable energy resource database (DME/CSIR/Eskom 2002) results were generated through wind modelling calibrated using a select subset of national weather station data. The resource database data covers approximately 88 500 Km^2 or 66% of the land area of the Western Cape (129 500 Km^2). Figure 13 below indicates average annual wind speeds at 10m above ground level for the Western Cape from this database. Although the model clearly requires calibration using suitable measurement masts to correct boundary discontinuities, the information has been used as an input to the Western Cape wind resource analysis as it is the best available.

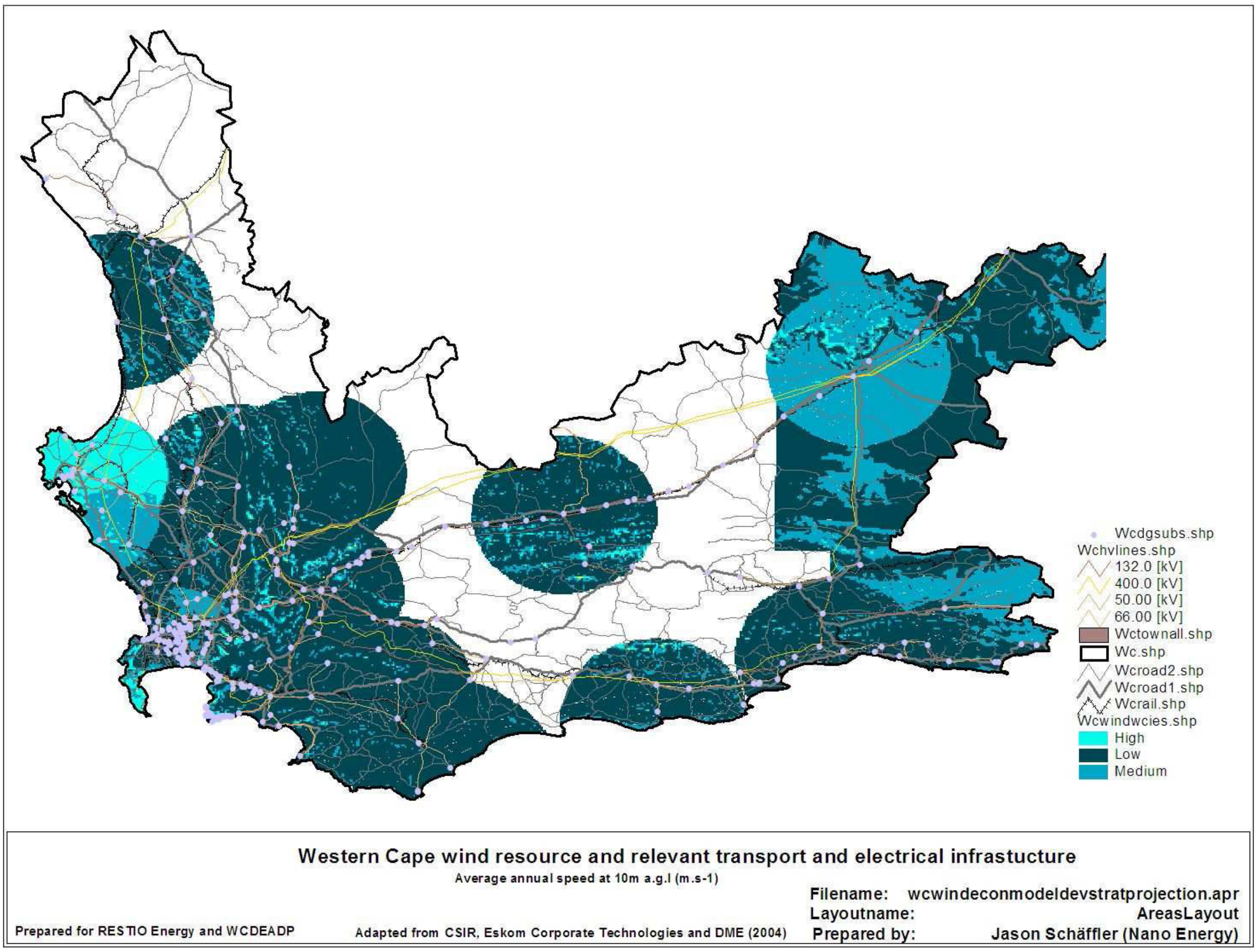

Figure 13 Western Cape wind resource and relevant transport and electrical infrastructure

In 2003, a South African renewable energy strategy formulation team (DME, 2004a) estimated the total national wind generation potential to be 60 TWh per annum. Banks Schäffler (2006) estimated the practically realisable wind resource nationally to be 106 TWh annually.

This strategy development programme has undertaken a more detailed GIS analysis of land available for wind farm development by considering criteria such as the wind resource and proximity of these to relevant transport and electrical infrastructure.