Final Report:

A CATALOGUE OF RENEWABLE ENERGY SOURCES FIT FOR ETHEKWINI

Submitted by

Marbek Resource Consultants Ltd.

Submitted to

Ms Jessica Rich
Manager, Policy Coordination and Implementation,
Environmental Management Department
eThekwini Municipality

June 2007

Marbek Resource Consultants (Pty) Limited

10 May 2007

Ms Jessica Rich
Environmental Management Division
eThekwini Municipality
Durban

Dear Jessica:

Re: Final Report / Renewable Energy Study / Catalogue

Please find attached the final draft of our Renewable Energy Study for the Municipality of eThekwini. This incorporates changes suggested by you and your staff, and well as additional text which we discussed with you.

As with the earlier draft version, the report is provided only in PDF format, to ensure proper formatting of this fairly complex document. If you require a Word version for editing, please let me know.

We look forward to presenting the report to stakeholders in July.

Sincerely

Geoff Stiles
Managing Director

PO Box 898, Parklands,
Johannesburg, South Africa 2121
Phone: +27 (0) 11 447 7879
Cell: +27 (0) 82 347 0032
Fax: +27 (0) 11 327-7207
Email: geoff@cbla.org.za

Executive Summary

Background: objectives and outputs. The *immediate objective* of this project is to provide eThekwini Municipality decision makers and officials with the proper technical guidance on the potentials of today's renewable energy (RE) technologies as well as guidelines for implementation.

The *development objective* is to ensure that the eThekwini Energy Strategy will include the development and the implementation of these RE technologies.

The project was to provide "…a Catalogue of the sources of RE which are fit for eThekwini" and also to "…focus on the technical and financial aspects only (leaving the policy issues to the politicians)" and would ultimately include the following items:

1. A preamble describing the technical–not political—content
2. A list of 10-20 potential technologies development proposals
3. A set of criteria for the prioritisation of these. The set will include but not be limited to
    - Potential to contribute to the comprehensive energy supply of eThekwini with a focus on energy security
    - Potential to reduce environmental, economic, social strains to informal settlements
    - Potential to create jobs
    - Sustainability
    - Implementability and development costs in relation to the eThekwini Municipality
4. A selection + prioritisation of between 4 and 8 of the technology developments which are technically most feasible to pursue for the eThekwini Municipal Area
5. An analysis and a development scenario for each of the selected (4-8) technologies.

Resource Assessment. The project team developed a list of --- technologies for assessment, divided into 3 main categories: wind, solar and biomass. The latter category was in turn divided into 7 categories, s follows:

1. Sugar cane and cane residue, i.e. bagasse, from the sugar industry.
2. Waste of several kinds from the paper industry.
3. Wood waste from the saw milling industry.
4. Waste water and sewage effluent.
5. Organic waste for landfills
6. Oil-producing crops such as soya, sunflower, maize, jatropha and possibly algae, which can be used in the production of bio-fuels

7. Charcoal production from waste wood.

The analysis of wind and solar resources is fairly straightforward, and produced the following conclusions:

- Based on available data, the wind resource in eThekwini is sub-economic, with an average wind speed from 2 to 4 m/s depending on location. No developments based on this resource should proceed unless a thorough analysis of micro-sites over at least a year and preferably two years is completed first.

- The solar resource of eThekwini is suitable for significant development. Although relatively low by South African standards, due to a combination of local factors, it is still sufficient to provide a major source of thermal energy, e.g. through domestic hot water heating.

The analysis of biomass resources is more complex, due to the diversity of options. The conclusions reached are as follows:

- Substantial opportunities exist to generate electricity from bagasse, both through expansion of own-generation capacity in raw sugar mills, and through greenfield plants generating electricity as part of ethanol production.
- Woody biomass waste, primarily from the lumber industry and the pulp/paper industry, also constitute a large untapped resource, though precise breakdowns for eThekwini were not available and proximity to point of final use will be a problem.
- Sewage effluent is a major potential source of energy, from use both of the methane gas generated and the dry solids, some of which are already being pelletised.
- Landfill gas (for electricity generationp or direct thermal use) resents another major opportunity, primarily from the expanded Buffelsdrei landfill, which will eventually become the major landfill for the municipality as current landfill are closed.
- Production of biofuels—both bio-ethanol and bio-diesel—represents another major opportunity, thanks to the municipality's proximity to sugar producers on the ethanol side, and availability of industrial land for development of algae-based biodiesel.

Preliminary Assessment of RE Technology Opportunities. Following the review of renewable resources the consultants prepared a " long list" of 27 technologies which were then assessed on the basis of a scoring system as follows:

Two key factors were considered first:
1. Availability/reliability of the resource.
2. Maturity of the technology

On this basis, one technology—production of ethanol from cellulose—was eliminated due primarily to lack of technological maturity.

Five additional major factors were then reviewed:

1. Potential to contribute to the comprehensive energy supply of eThekwini with a focus on energy security
2. Potential to reduce environmental, economic, social strains to informal settlement
3. Potential to create jobs
4. Sustainability

5. Implementability and development costs in relation to the eThekwini Municipality

Finally, a further 6 minor factors were considered:

6. Environmental impact (overall)
7. Availability of commercial financing
8. Eligibility for CDM or other non-commercial financing (TRECS/ RE Subsidy)
9. Regulatory constraints
10. Availability of SA or international standards
11. Local content in manufacture

Priority List of RE Technologies. An overall priority ranking was then established, using a weighting system based on the 13 factors noted above. This resulted in a shortlist of 6 technologies (encompassing 9 different applications) as follows:

1. Solar thermal: low- and medium-income housing
2. Solar thermal: commercial buildings
3. Biofuels: bioethanol from cane and bio-diesel from algae
4. Sewage/wastewater: electricity generation and/or pelletised solids.
5. Bagasse to electricity
6. Charcoal from retorts

Detailed Review and Recommendations (Proposals). The six short-listed technologies were then reviewed in detail resulting in specific recommendations (proposals) for implementation. In cases 1 and 2, the technology was subjected to a detailed technical and financial assessment using the RETSCREEN programme The following were the recommended actions:

- *Implement separate low-income and middle-income solar hot water projects,* the former to be based primarily on applications to new (RDP) housing, and the latter primarily on retrofits of existing housing; use programmatic CDM and the newly-announced Eskom DSM programme for solar to reduce costs to the municipality and the end-user.

- *Implement a solar hot water project for commercial/institutional buildings*, starting with the municipality's own building stock and treating this as part of an overall energy audit process to ensure that solar is implemented rationally as part of an overall savings package.

- *Develop a procurement programme for transformation of the municipal petrol-fuelled vehicle fleet to a 10% bio-ethanol blend,* taking advantage of the proximity of bio-ethanol production in KZN.

- *Develop a procurement programme for transformation of the municipal diesel-fuelled vehicle fleet to 100% bio-diesel,* using only bio-diesel from sustainable sources such as algae (once it becomes commercially established) or other sources that do not compete with food production.
- *Institute a feasibility assessment of opportunities for the use of sewage gas and sewage solids as energy sources,* including particularly the expanded use of methane to produce electricity and the potential of dried solids to either (a) produce charcoal for use as a transitional fuel for rural/peri-urban households or (b) substitute for coal in industrial uses such as cement kilns.
- *Institute a feasibility assessment to compare opportunities for using landfill gas from Buffelsdrei* to either (a) generate electricity as per established programmes in eThekwini or (b) generate

higher calorific-value gas from the direct conversion of organic waste at this site to methane using pyrolysis, which can then be used for electricity generation.

Institutional Changes Required. The development of the projects described in this report will require major institutional changes in the planning and implementation of RE in eThekwini. This can take three possible forms:

1. Expanding the capacity of the Environmental Management Department to meet the need for accelerated development of renewable energy within the municipality's overall environmental mandate;

2. Mandating another department such as Durban Electricity to undertake this work, also requiring expanded specialist capacity; or

3. Developing a special-purpose vehicle or vehicles to implement the projects.

On balance and taking into account experience in other jurisdictions, the consultants strongly favour option 3, and propose that eThekwini urgently undertake a review to determine the finanicial and capacity requirements for establishing a Renewable Energy Corporation which would act both to promote RE in the municipality and develop and manage RE projects, including the possible use of independent public/private entities to undertake the actual implementation.

Table of Contents

1 Introduction

1.1 *Objectives*

The *immediate objective* of this project is to provide eThekwini Municipality decision makers and officials with the proper technical guidance on the potentials of today's renewable energy (RE) technologies as well as guidelines for implementation.

The *development objective* is to ensure that the eThekwini Energy Strategy will include the development and the implementation of these RE technologies.

1.2 *Expected Outputs*

The main output of the project has been described as

> "…a Catalogue of the sources of RE which are fit for eThekwini."

The catalogue was expected to

> "…focus on the technical and financial aspects only (leaving the policy issues to the politicians)."

However in discussion with the client it was agreed that while recommendations regarding broad national policy issues should not be a part of the analysis, some consideration must be given both to national policy as it influences local policy, to local policy itself and in particular the institutional frameworks required to implement effective RE policies in eThekwini.

The "Catalogue" (a term which we took to refer to a listing of information) was to include:

6. A preamble describing the technical–not political—content
7. A list of 10-20 potential technologies development proposals
8. A set of criteria for the prioritisation of these. The set will include but not be limited to
    - Potential to contribute to the comprehensive energy supply of eThekwini with a focus on energy security
    - Potential to reduce environmental, economic, social strains to informal settlements
    - Potential to create jobs
    - Sustainability
    - Implementability and development costs in relation to the eThekwini Municipality
9. A selection + prioritisation of between 4 and 8 of the technology developments which are technically most feasible to pursue for the eThekwini Municipal Area
10. An analysis and a development scenario for each of the selected (4-8) technologies.

In practice, all of the contents described above have been incorporated in the report.

1.3 *General approach*

As agreed with the client, the consultant's approach to this project is based on the following:

- An understanding of the national White Paper for RE and relevant updates of this document.
- The physical, technical and socio-dynamic situations of the eThekwini Municipality Area
- International strategies and know-how for development of RE sources, including the most recent technical information on the effectiveness of various RE technologies.

In addition, it was agreed that the project should include an overview of the availability of specific RE resources within the eThekwini Municipality and adjacent areas, including particularly wind, solar and biomass resources.[1] This is particularly important because at present, there is no up-to-date and reliable information on resource availability to guide decision-makers in the municipality in screening potential RE projects. Combined with the technical assessment and socio-economic assessment provided by this report, the resource availability assessment should enable decision-makers to better understand the opportunities for RE implementation in the municipality and to optimise key institutional and policy factors affecting the decision to adopt RE technologies as part of the Energy Strategy.

[1] It is noted that one potential renewable resource has not been included in this report, for lack of consistent and reliable local data: small-scale hydro. The authors are aware that feasibility work on small-scale hydro for the Western Bypass Aqueduct is ongoing, but aside from this and a national study on the subject, there was insufficient information available to permit an assessment of local opportunities.

2 Background Studies and Materials

The recommendations of this report have been influenced by a number of key policy and strategy documents, local, national and international. These include the following

2.1 *Local*

2.1.1 The State of Energy Report

Completed in 2006, the eThekwini Municipality State of Energy Report (SOER) is a comprehensive and detailed document outlining the municipalities major energy carriers, breaking consumption down by energy carrier type and sector. It is an important precursor to, and basis for, an eThekwini Energy and Climate Change Strategy, currently in preparation.

Because of time and information limitations, the SOER did not include a detailed section on RE supply, but it did provide a comprehensive list and preliminary evaluation of a wide range of renewable energy sources and technologies. Its major conclusion was that,

> "(Renewable energy) has the potential to provide the population of the EMA, as well as South Africa as a Nation, with a substantial proportion of its future energy needs in a sustainable manner. This potential has hardly begun to be realised.
>
> Barriers to the uptake of proven renewable technologies must be fully grasped and overcome. This will almost certainly involve a paradigm shift in the way that many organisations and individuals view their energy supply, and will likely require a *critical mass* of applications before ongoing success is guaranteed."

This final conclusion of the SOER is really the starting point for the present effort: viz, helping eThekwini to achieve a paradigm shift in thinking about RE, by first developing a systematic approach to RE development, then developing or incentivising a critical mass of projects that can in turn demonstrate the benefits of RE to key decision-makers.

2.1.2 The Energy Strategy

The eThekwini Energy Strategy is still in preparation, and the consultants have seen only a few of the initial preparatory documents. Possible objectives of the Strategy are also incorporated in the SOER, in particular, Table 3.4.6 on pages 116-17. As a basis for discussion, this table (which outlines the potential contribution of RE to sustainable energy use in eThekwini) is reproduced below.

Renewable Energy Sustainability Objectives	
	Environmental
1	**Mitigation of local and global pollutants through the enhanced usage of renewable energy sources.** As described in earlier sections.
	Economic
1	**Encourage job creation via the expansion of the renewable energy sector** As described in earlier sections. The Municipality should encourage the development of Durban as a Global Centre for Sustainable Industries, thereby attracting sustainable growth and job creation. The RET industry has the potential to absorb many of those employees who have lost jobs in the traditional manufacturing sectors.

	Social
1	**Improved health and quality of life** As described in earlier sections.
	Institutional Issues
1	**Development of formal mechanisms for consideration of external costs when establishing energy supply alternatives** Without consideration of the environmental, health and safety costs associated with coal-based power generation, the financial viability of renewable alternatives can appear uncompetitive. It is vital, therefore, that formalised methodologies are developed and adopted which take account of all external costs when evaluating energy supply options.
2	**Greater understanding of the municipal fuelwood usage statistics** Data on rural fuelwood use is extremely sketchy. More background research is required in order for the scale of use of this energy source to be confirmed. Only then can strategies be formulated to ensure sustainable use of this precious resource.
3	**Development of novel finance initiatives, and other instruments, to encourage uptake renewable energy technologies In the absence of suitable financial interventions, the uptake of SWHs and other renewable energy technologies may remain jeopardised due to high outlay costs, despite their being a cost-effective solution in the medium-term. Financial incentives, or subsidies, could be developed to assist in removing these perceived barriers, together with regulatory interventions such as obligatory renewable energy uptake in new build situations.**
4	**Continued use of alternative funding options to further renewable energy uptake for eThekwini Municipality The Municipality will continue to explore all possible finance options including CDM, REFSO and international donor funds to assist, where appropriate, with the roll-out of renewable technologies.**
5	**Establish a target and timeline for medium-term and long-term renewable use This is considered necessary in order to give impetus to a renewable energy programme. Whilst remaining challenging, the targets should be realistic and be based upon a mix of renewable energy technologies appropriate to the topography and prevailing climatic conditions of the EMA.**

The purpose of the table is to outline the various ways in which RE can contribute to the achievement of sustainability objectives for eThekwini. A few of these are of particular importance to the present task:

- Encourage job creation via the expansion of the renewable energy sector
- Develop formal mechanisms for consideration of external costs when establishing energy supply alternatives
- Develop novel finance initiatives, and other instruments, to encourage uptake renewable energy technologies
- Continue use of alternative funding options to further renewable energy uptake for eThekwini Municipality
- Establish a target and timeline for medium-term and long-term renewable use

As this list suggests, the role of RE in the implementation of the eThekwini Energy Strategy should emphasise its sustainability value and the possibility of using alternative and novel financing sources (unavailable or less available than for conventional energy technologies) to ensure early adoption of priority RE technologies. This is effectively the approach we have taken in the recommendations provided in this report, with one important exception: We believe that existing municipal financing mechanisms can be applied to some kinds of renewable energy implementation, particularly in the liquid fuels area. For others (e.g. solar and biomass), more innovative approaches may be required.

A final point on the integration of national strategy objectives into the eThekwini Energy Strategy: The national White Paper on Renewable Energy (which substitutes for a full national strategy at present; see section 2.2.1 below) includes a specific target for RE supply by 2013. It is certainly important for eThekwini to consider incorporating a supply target proportional to the national target into its own planning, as an acknowledgement of the importance of supporting the national strategy. However we believe that the national target is actually very conservative, and that this target can easily be exceeded by eThekwini at very low cost to the municipality.

2.1.3 The Integrated Development Plan

The eThekwini Integrated Development Plan: 2010 and Beyond (IDP) is in an effort to translate the City's Vision into action. The IDP is divided into eight unique Plans, and the RE Catalogue study is understood to be a response to Plan Two: *Economic Development and Job Creation*, which stipulates the following activities in its Core Value Matrix:[2]

- *Sustainability*: Developing Renewable Energy Sources
- *Smart city*: Renewable Energies Investigation

This study could also arguably be situated within Plan One: *Sustaining our Natural and Built Environment*, where one of the major sustainability "values" is defined as "Focus on renewable energies." Ideally, of course, this focus would evolve from the process of investigation and development, and the emphasis on economic development and job creation as the primary motivators behind renewable energy development seems appropriate both to the eThekwini economic situation and to the realities of the municipality's very challenging environmental mandate.

2.1.4 Other relevant eThekwini studies and documentation

The eThekwini Municipality Environmental Management Policy, the eThekwini Environmental Services Management Plan (EESMP) and the eThekwini Biodiversity Strategy and Action Plan (EBSAP) will all be supported by the development of RE in the eThekwini Municipality. Details of the "fit" between the consultant's recommendations and these documents is further elaborated in the final section of this report.

2.2 *National*

2.2.1 Policy context

The White Paper on Renewable Energy is perhaps the most important document reviewed by the project team. The objectives and goals of this document, launched in 2002 and revised in 2003, were summarized as follows:

> "Government's long-term goal is the establishment of a renewable energy industry producing modern energy carriers that will offer in future years a sustainable, fully non-subsidised alternative to fossil fuels. The proportion of final energy consumption currently provided by renewable energy has come about largely as a result of poverty (e.g. fuelwood and animal

[2] *eThekwini Municipality Integrated Development Plan: 2006-2011*, July 2006, p. 107.

waste used for cooking and heating). To get started on a deliberate path towards this goal, the Government's medium-term (10-year) target is:

10 000 GWh (0.8 Mtoe) renewable energy contribution to final energy consumption by 2013, to be produced mainly from biomass, wind, solar and small-scale hydro. The renewable energy is to be utilised for power generation and non-electric technologies such as solar water heating and bio-fuels. This is approximately 4% (1667 MW) of the projected electricity demand for 2013 (41539 MW)… equivalent to replacing two (2x 660 MW) units of Eskom's combined coal fired power stations.. and is in addition to the estimated existing (in 2000) renewable energy contribution of 115 278 GWh/annum (mainly from fuel wood and waste)."

It is interesting to note that the RE White Paper targets electricity use rather than energy use in general. This is due to a combination of two things: (i) the government's emphasis on reducing emissions from coal-fired power generation, and (ii) its desire to offset current and future power shortages, which have become a major political and economic issue in the country. Nevertheless, the White Paper does include specific reference to bio-fuels and biomass, although the implication is that they are to be used primarily for power generation.

The White Paper target is not overly-ambitious, representing less than a 9% increase in total RE use over a 10-year period (although the increase is intended to come mainly from new forms of RE rather than from an expansion of RE from fuel wood and waste). By comparison, the United Kingdom's renewable energy targets is a 10% increase in the contribution of renewables to electricity supply by 2010, compared to 4% now.[3] The EU has also recently set a target of a 20% boost overall in renewable fuel use (not just for electricity) by 2020. Although it is unfair to compare South Africa or eThekwini's targets with those set by highly industrialised nations, it is also important to remember that for many renewable energy sources—e.g. solar—South Africa is far better endowed than the countries of the north.

For eThekwini, it is interesting to note that the municipality's current electricity use (2004 data) is almost exactly equal to the supply target for the RE White Paper. If eThekwini simply adopted the national target and gave RE a 9% share of total electricity use, this would amount to 972.6 GWh of supply per year by 2013.

The Draft National Biofuels Strategy, tabled in late 2006, is another important and relatively recent national policy document.[4] This document sets out a preliminary framework for the use of biofuels as energy sources for both transport and stationary uses. It is based on a previous document which outlined the economic potential for developing a biofuels industry in South Africa,[5] and provides recommendations for both regulatory and pricing issues which might incentivise the use of biofuels in South Africa. Importantly, the Biofuels Strategy attempts to quantify the "fit" between the White Paper goals and the availability and practicality of using biofuels to meet these goals.

The RE White Paper is at this point the most advanced and comprehensive policy document available in South Africa on the subject, although it is already somewhat outdated (as the Biofuels Strategy demonstrates). Unlike its work on energy efficiency or biofuels, government

---

[3] Renewable energy industry groups such as the British Wind Energy Association have called for a 25% contribution by 2025.
[4] *White Paper On Renewable Energy*, Department of Minerals and Energy of South Africa, November 2003.
[5] *An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa*: *Final Report to the National Biofuels Task Team*, November 2006, The DTI.

has so far not updated the White Paper or developed a comprehensive national strategy for renewables.

2.2.2 Regulatory issues (NERSA, MFMA, Eskom)

The regulation of renewable energy on the national level is the responsibility of the National Energy Regulator of South Africa (NERSA). NERSA's mandate was originally limited to electricity, but was expanded in 2005 to include all energy sources. NERSA has a separate department dealing with RE, and has promised to include a least-cost renewable energy scenario in its upcoming national integrated resource plan (NIRP).[6] More recently, they have issued a terms of reference for a study to determine an appropriate feed-in tariff for renewable energy suppliers (see section 2.2.3 below for more on this issue).

NERSA is a critical factor in the development of energy projects in that power producers are required to obtain a license from NERSA to trade in energy of any kind. In this regard NERSA do not regulate tariffs which could be charged by IPPs. However, in terms of the NERSA regulations a tariff which is higher than an existing tariff cannot be imposed on a captive market which means that a municipality may not subsidise a RE producer by means of a tariff increase or force any section of the users, e.g. industry, to buy energy at a higher price to offset the higher cost of RE.

However, it is acceptable to market green energy as a special commodity at a premium, to users who may want to benefit from the status of being a green energy user—in other words, on a voluntary basis. We believe this is an important opportunity for eThekwini, and will return to it later in the report.

The Municipal Finance Management Act (MFMA) of 2003 is important primarily because it spells out the areas where municipalities in South Africa may engage in capital investments, and the mechanisms they may use to finance such investments. It also imposes strict controls on reporting and accounting for all municipal structures and activities.

The MFMA attracted attention in 2006 primarily because of concerns over the role that municipalities are increasingly playing in developing projects to reduce greenhouse gas emissions, and particularly projects that are targeted for financing through the Clean Development Mechanism (CDM). As Durban already has a registered CDM project under its landfill gas-to-electricity programme, this issue appears to be of little importance to the municipality's future development, though it is important to note that there may be changes to the MFMA specifically to accommodate CDM investments and other types of investments which do not immediately fit the MFMA's asset categories.

Another national issue which impinges on eThekwini's energy planning is the proposed development of Regional Electricity Distributors (REDs), which was initiated by NERSA in 2003-4 and piloted in the Western Cape. This programme has recently suffered serious setbacks as the City of Cape Town has opted out of the local pilot RED, and a number of municipalities have objected to the plan on the grounds that it deprives them of a major source of revenue without adequate compensation. As the present study was being completed, the future of REDs was in serious doubt and several commentators have suggested that the concept itself will be dropped.

2.2.3 Incentives: RE subsidies, TRECs.

In its present state of development, RE invariably requires some form of incentive to ensure that it is both cost-competitive with conventional energy sources as well as technically reliable. This is true in the

---

[6] *"National integrated resource plan under review*", **Creamer's Engineering News**, 21 April 2006.

industrial as well as the developing world, and has spawned a wide range of solutions—beginning in the 1980s with a US government programme called PURPRA to compel utilities to purchase electricity from renewable sources at a cost-competitive rate or tariff.[7] Since that time, a wide variety of RE incentives have emerged, including *inter alia*:

- Tax incentives, such as accelerated depreciation allowances
- Feed-in tariffs, which (like PURPRA) ensure that RE is sold into the national grid at a rate which is sufficient to repay the long-term investments incurred by RE developers.
- Long-run marginal cost pricing of electricity tariffs, which ensures that the long-term socio-economic and environmental costs of conventional energy developments are priced into the tariff, thus indirectly making RE more competitive.
- Subsidy programmes for targeted RE resources, e.g. wind or solar, reducing risks for developers by reducing their initial capital costs.
- "Green Power" purchasing programmes, involving payments by users at a premium rate for green (renewable) energy in one jurisdiction or grid system, to offset purchase of non-green energy in one's own system.
- Tradable Renewable Energy Certificates (TRECs), which provide a common denominator for purchase of green energy, e.g. by setting standards and providing a system of monitoring and verification.
- Carbon emissions reduction credits, which are governed largely by the Clean Development Mechanism of the Kyoto Protocol, and which of course apply to projects using any emissions-reducing technology, not just those using RE technologies (see more in the next section).

South Africa has already provided a set of incentives for RE development, and others should soon be in place. For example:

1. The DME has recently established the Renewable Energy Subsidy Office (REFSO) whose mandate includes:

    - The management of renewable energy subsidies in such a way as to keep transaction costs at a minimum, whilst supporting the Government's renewable energy targets;
    - The provision of advice to developers and other stakeholders on renewable energy finance and subsidies. Information on local and international funding sources is provided. This includes details on the services and products offered by development finance institutions, as well as donor agencies and commercial banks;[8]
    - The Subsidy Governance Committee (SGC) is responsible for decision making regarding the award of subsidies. The SGC is accountable to the Director General of the DME.

The salient features of the 2005 – 2006 subsidy scheme are:

- Grants are only eligible to projects with capital costs less than R100million, and are capped at 20% of project capital cost;
- Projects must use commercially proven renewable technologies;

[7] This Congressional initiative was called PURPRA (Public Utility Regulatory Policies Act) and required utility companies to purchase electricity from renewable energy plants at the rate by which the RE plants generate their own power, i.e. at real cost.

[8] http://www.dme.gov.za/energy/renew_finnace.stm (sic)

- Grants are made on a once-off basis, and are applicable to new projects only. The available grant amounts, as stated by the DME are:
    - For electricity: R250 per kW
    - For bioethanol: R167 per kl/year
    - For Bio-diesel: R273 per kl/year

In short, the scheme is primarily intended to facilitate RE fairly small-scale developments and to encourage use of RE technologies that are commercially-proven. The operation of this scheme is still in early days, but the REFSO has setup an application process consisting of an expression-of-interest form (downloadable from the website), followed by a "letter of registration" awarding the grant. It appears that the SGC had approved and issued a total of 29 letters of registration up to January 2006, but no information on grants since that time is available, nor are the amounts granted available as most such transactions are confidential.

2. The DME has also sponsored a study of TRECs, which has just been completed and is available on the DME website.[9] The study involves both a feasibility assessment and a very detailed treatment of alternative mechanisms for managing and operating a TREC system. Although not conclusive in its recommendations, the report is expected to stimulate more active discussion of TRECs, which as noted above are an important pre-requisite to operating a robust and verifiable system of purchasing green energy.

3. Green energy buyers are already actively developing portfolios in South Africa, the two main players being Agama Energy in Cape Town and Amatola Green Power, based in Port Elizabeth. According to industry information, these buyers have yet to complete a sale, but it is know that Amatola, for example, is actively seeking to obtain power purchase agreements from a number of the larger sugar mills in both KZN and Mpumulanga.

4. Carbon emissions credits represent a major opportunity for RE financing, although there is potential redundancy with the TREC system.[10] The development of Clean Development Mechanism projects is clearly on the increase, with more than 40 projects now listed by the South African Designated National Authority (DNA).

5. Accelerated rebates from the national fuel levy are being considered as an incentive for RE fuel producers, e.g. producers of bio-ethanol and bio-diesel. Also under review is the possibility of using the equalisation fund to further subsidise RE fuel producer costs. This is dealt with in the draft National Biofuels Strategy (see section 2.2.1 above), but most greenfield project developers feel the Strategy's proposals are inadequate to make their investments profitable and are lobbying government to increase the subsidy. If successful, this will lead to a substantial surge of activity in this sector.

2.3 *International*

2.3.1 Trends in RE development

The international renewable energy scene is a dynamic and complex one, and the time limitations of this report do not permit a detailed examination of either policies or incentive programmes in other

[9] *Tradable Renewable Energy Certificate System Feasibility: Final Report*, March 2007, www.dme.gov.za.
[10] The redundancy stems from the fact that in Europe, the value of TRECs is based in part on the fact that they offset carbon emissions; thus selling TRECs for a RE project while also selling carbon emissions credits from the same project, could be construed as "double counting".

jurisdictions. However it is clear that a great deal of the current and growing interest in RE is a function of concerns over climate change and the role which conventional fossil fuel-based energy technologies have played in raising global temperatures. The Kyoto Protocol and the Clean Development Mechanism in particular have provided a major incentive for RE projects, evidenced by the fact that of 138 projects registered with the CDM Executive Board by the end of February 2007, 105 or 76% are renewable energy projects. Of the 1727 projects in the "pipeline", 1132 or just under 67% are renewable energy projects.[11] In this case, renewable energy includes the following categories:

- Biogas
- Biomass energy
- Landfill gas
- Hydro
- Solar
- Tidal
- Ocean current
- Wind

The impact of climate change has been to change the methodology by which governments assess their future energy needs. Whereas in the 1980s and 1990s, this process was driven by efforts to promote "integrated energy planning" in which the full environmental and social costs of energy investments was included in the costing exercise, making renewable energy and energy efficiency options more attractive than they would be using a standard economic analysis with no provision for externalities. More recently, pressure has been exerted to ensure that the complete "life-cycle costs" of energy technologies are fully examined at the planning stage, both to ensure that the best possible investment is made for the users of energy, and that taxpayers are not burdened in future with unexpected costs for decommissioning and adverse environmental or social impacts. This approach has been further strengthened by the realisation that energy technologies which utilise fossil fuels are contributing disproportionately to global warming, thus amplifying the life-cycle costs of these technologies.[12]

In South Africa, an IEP plan has been in place since 2003 and is actively used by NERSA in its planning work, as well as by government itself[13]. South Africa is thus in the position—unique among African countries—of having a fully developed and modern energy planning system. Yet despite this, RE technologies remain vastly underutilized and public knowledge about their cost-effectiveness is still very poor.

2.3.2 Other policy and financing issues

Kyoto Protocol. South Africa's (and hence Durban's) role within the Kyoto Protocol is that of a "non-Annex 1" country, which means that they are eligible to generate CDM projects and sell the credits from these projects to entities in developed (Annex 1) countries, but are not required to meet any limits or targets for emissions reductions of their own. It is widely recognised that this status may change once negotiations for the next phase of Kyoto (post-2012) are concluded, but it is highly unlikely that South Africa will be targeted for major emissions caps and rather more likely that pressure will be exerted on China, India and perhaps Brazil.

---

[11] The "pipeline" is the total number of CDM projects known to be in various stages of development. The source of this information is a monthly update issued by the UNEP-Risoe Energy & Climate Change Centre, www.uneprisoe.org.
[12] Although in fact, the costs of greenhouse gas emissions are usually not considered in the life-cycle cost analysis, primarily because it is remains difficult to quantify them.
[13] *Integrated Energy Plan For The Republic Of South Africa*, Department Of Minerals & Energy, 19 March 2003.

Nevertheless, the national government is strongly committed to reducing greenhouse gas emissions as well as regulating local atmospheric pollutants more aggressively. The Clean Air Act of 2004-5 spells out new conditions for the granting of permits to polluters and specifies minimal levels of pollution for a wide variety of substances. More stringent accounting of permit compliance and more effective monitoring procedures are expected to follow soon. This will indirectly incentivise the use of renewable energy technologies as industry and other sectors are compelled to seek cost-effective means of meeting pollution standards.

Independent Power Production. Another major force affecting the prospects for renewable energy is the government's call for independent power production, coupled with the probable introduction of feed-in tariffs (as noted above). In 2003, Cabinet approved private-sector participation in the electricity industry and decided that future power generation capacity will be divided between Eskom (70 percent) and independent power producers, or IPPs (30 percent). The DME was mandated with the responsibility of ensuring private-sector participation in power generation through a competitive bidding process and that diversified primary energy sources be developed within the electricity sector without hindrance.

A power generation investment plan was drawn up to take into account this 30 percent private-sector participation in power generation. The planning and development of transmission systems were to be undertaken by the transmission company, subject to the government's policy guidelines.

So far, this process has not had a major impact on IPP development, though this may change soon. The DME called for expressions of interest for "peaking power plants" in 2006, specifying two subprojects with a 300-MW to 600-MW plant in the Eastern Cape and a 750-MW to 830-MW plant in Natal. Independent Power South Africa (IPSA), a private company, has already constructed a natural gas-fired plant in Newcastle, which was due to be operational in late February of this year. They are planning a much larger plant for the Coega industrial development in Port Elizabeth (PE), and several other cogeneration facilities are also planned for PE.

As well, two wind farms are planned for PE and Jeffrey's Bay, and a small pilot wind facility is now operational at Klipheuwel in the western Cape; another is under development at Darling, also in the Western Cape; and a small-scale hydroelectric project has been built in Bethlehem in the Free State, which has also qualified as a CDM project.

Although the status of IPPs in South Africa is still somewhat clouded, it is certain that they will play a major role in meeting South Africa's electricity supply needs in future. As we explain later, they should also play a key role in helping eThekwini to move renewable energy forward on the municipal agenda.

Financing Options. The resurgent interest in IPPs and renewable energy in particular has created comparable interest in the financial sector. Several South African banks—notably ABSA, Nedbank and Standard Bank—are actively pursuing financing deals with CDM components, and renewable energy is high on the list of potential project opportunities. Nedbank already has a declared interest in IPPs, having financed the private takeover of the Kelvin Power Station in Johannesburg, and is involved in financing of several of the new peaking plants. Standard Bank has had a long-standing agreement with a major CDM broker/developer, which includes providing more attractive conventional financing to projects which are CDM-eligible.

The Development Bank of Southern Africa (DBSA) is another source of funding for renewable energy as well as for IPPs. DBSA has provided grant funding for the environmental assessment of the Jeffrey's Bay windfarm project, and is expected to be involved as a lender in the project implementation phase. DBSA has also been involved in renewable projects such as the Durban Landfill to Gas project and the Bethlehem small-scale hydro project, in both cases in their capacity as the local agency for the World Bank's various carbon funds.

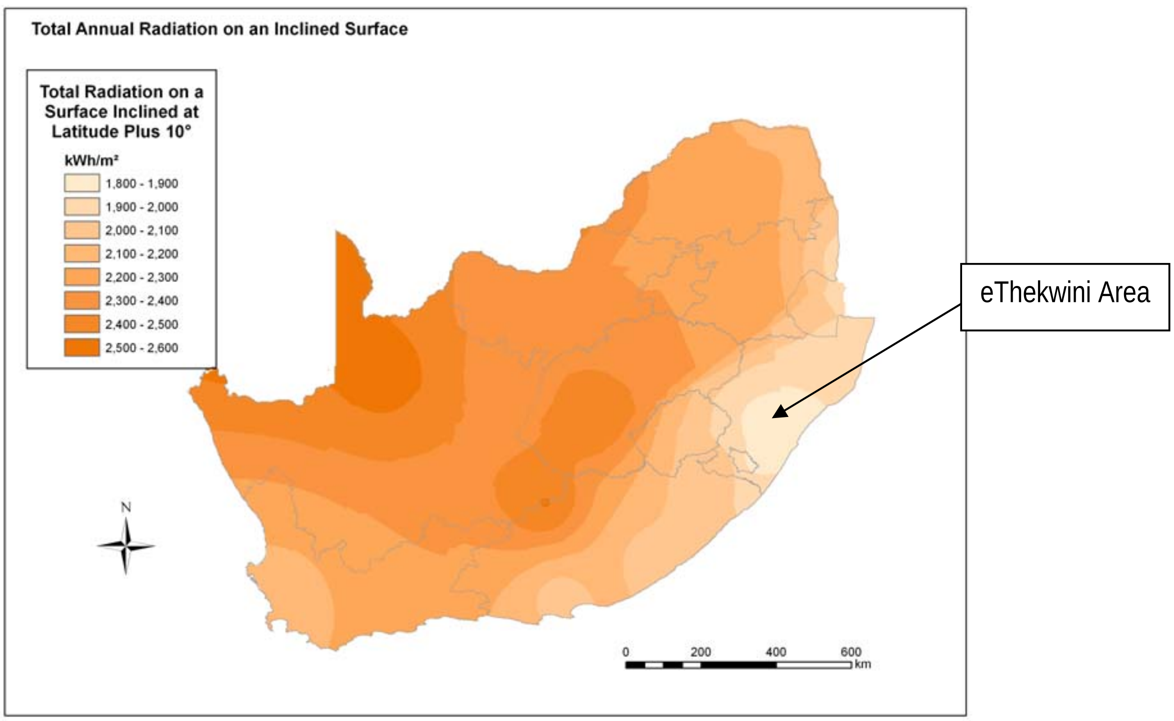
South Africa's Central Energy Fund (CEF) is also a major player in this field. CEF provides an equity stake of up to 49% in renewable energy projects, and is already involved in a major bio-ethanol project, a windfarm (the Darling project) and several conventional IPPs. CEF's financial capabilities are substantial, and their mandate is to incentivise energy supplies by supporting both private and public developers.

It is useful to note the approach followed by another municipality in South Africa—Port Elizabeth. PE issued an invitation for RE proposals on a no-cost basis to the municipality. In this case all the projects are to be self financed through debt and equity finance instruments by the developers while the municipality agrees to purchase the energy at a financially attractive rate. This resulted in a number of projects being planned with no shortage of debt financing as well as investor financing. The CEF has already taken an equity stake in several of these projects, and is participating in the planning process. A high percentage of the projects in PE are renewable energy-based, e.g. a large wind farm, a landfill gas to electricity project, a solar hot water project, and a gas to electricity project using methane from the municipality's sewage and wastewater plant.

3 Resource Assessment

3.1 *Solar Resources*

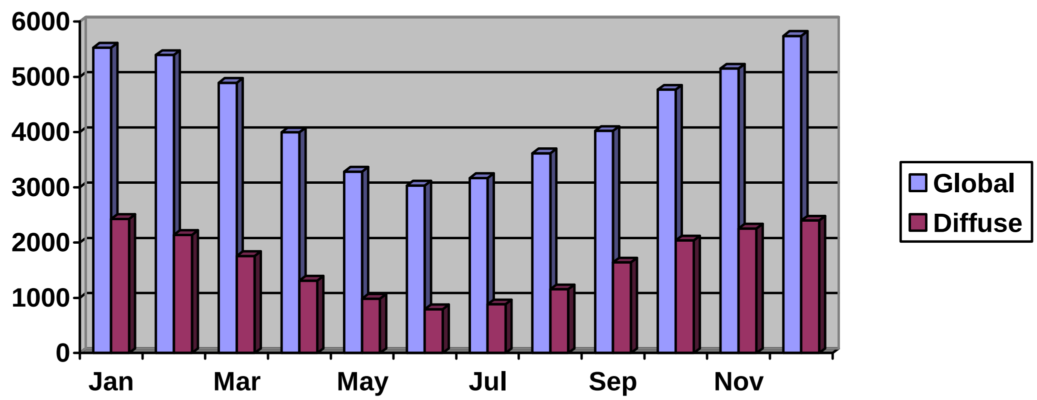
The evaluation of the solar resource in the eThekwini area shows a somewhat unusual trend as compared to the rest of South Africa. For several months of the year the available hours of full sunlight in this region are significantly lower than the rest of the country. As a result, the summary data (see following chart) shows a clear reduction in total solar radiation for the specific area around eThekwini. The explanation for this appears to be a unique combination of pollution, high humidity levels and the topography of the area, combining to create a higher degree of cloud cover in the summer period than is normal for South African cities. For example, the percentage of clear days in January (which can be treated as typical for the summer period) is 42%, while the percentage for winter is 72%. The implication of this is that when the sun is at its highest in the summer, the eThekwini area has the highest percentage of cloudy days, while when the sun is at its lowest level on the northern horizon it has less cloud cover.



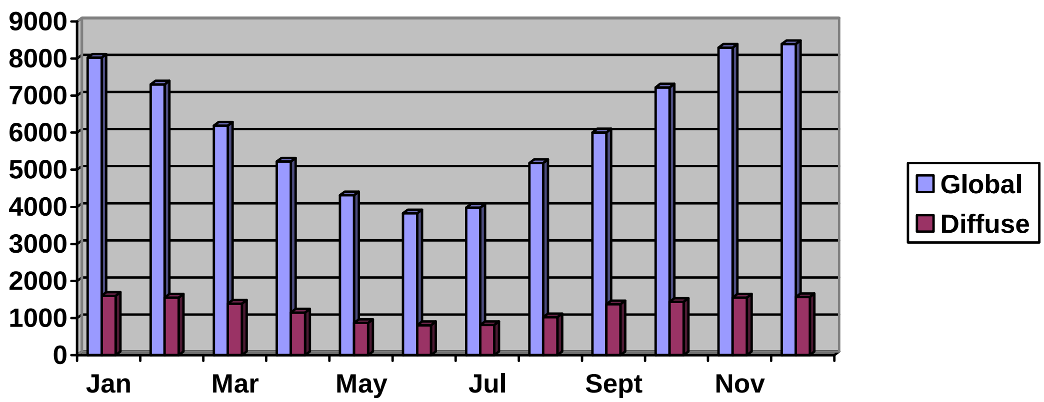
As the chart shows, the average annual available solar energy in eThekwini is still in excess of 1800 kWh/m², which is adequate for the economic production of hot water and/or electricity. However there is a clear difference between the potential for production of hot water and that for electricity, a fact which is partly independent of the level of solar radiation.

Note: As solar radiation passes through the earth's atmosphere, some of it is absorbed or scattered by air molecules, water vapor, aerosols, and clouds. The solar radiation that passes through directly to the earth's surface is called Direct Solar Radiation. The radiation that has been scattered out of the direct beam is called Diffuse Solar Radiation. The direct component of sunlight and the diffuse component of skylight falling together on a horizontal surface make up Global Solar Radiation.

The following two graphs illustrate the striking differences between solar radiation in eThekwini and Upington in the Northern Cape, the area with the best solar profile in South Africa.



Mean Daily Radiation Durban (Watt-hours per m² per day)



Mean Daily Radiation Upington (Watt-hours per m² per day)

The comparison shows that the mean annual radiation for Durban is 1598 kWh/m² and for Upington is 2244 kWh/m². This is a difference of approximately 646 kWh/m² between a best case scenario and a worst case scenario in South Africa, which actually compares very well with, for example, the US which has a solar radiation range between 1460 kWh/m² and 2190 kWh/m². (NREL)

Regardless of the solar resource, the final assessment of the viability of solar in eThekwini must be based on a comprehensive analysis of actual projects using a desktop model such as RETSCREEN. We deal with this issue below through assessment of specific technology alternatives.

Solar Electricity / Photovoltaics

Electricity-producing solar panels are usually referred to as “photovoltaic” or PV panels. This is basically a set of treated silicon cells arranged in a series string that produces electric power when exposed to light. There are three common types of solar panels manufactured. Briefly, they are:

- *Monocrystalline solar panels* - made from a single large crystal, cut from ingots. Most efficient, but also the most expensive and functions slightly better in low light conditions.
- *Polycrystalline solar panels*- basically, cast in ingots of silicon which contain many small crystals. This is the most common type right now. They are slightly less efficient than single crystal, but once set into a frame with other cells, the actual difference in watts per square meter is not much.
- *Amorphous solar panels* - "thin film", here the silicon is spread directly on large metal sheets, usually stainless steel. It is cheaper to produce, but often less efficient, which means larger panels for the same power.

The current cost of photovoltaic modules is such that when measured against the very low Eskom tariffs, this technology fails to pass the threshold for basic economic viability. This was confirmed using a RETSCREEN analysis, assuming a monocrystalline panel and no battery back-up (that is, the panel is connected directly to the grid, which requires an inverter but no storage). Using the same avoided electricity cost of R0.36/kWh as for solar thermal systems (see next sections), the system fails to achieve positive cashflow over its entire 20-year life (see Annexure 4 for full details). Although this assessment was done on the basis of a single panel operating in central eThekwini (Durban Airport), the picture would not be much different for large-scale PV applications. Such “solar utilities” would also require vast areas of inexpensive land, and high levels of security to offset possible vandalism.

Despite the poor economic returns, there are small scale niche applications for PV where the cost of a power line or electrical connections from the grid make the technology marginally viable.

Photovoltaic prices have generally shown a downward trend, and although they still cannot compete with grid connected power, there may be room for subsidies to recover the difference for some applications.

As the table below illustrates, there are large variations in the price of PV systems, depending on the manufacturer and the country of manufacture.

Manufacturer	Rating	Price
Photon	20 watt	R 1 070
Kyocera	43 watt	R 1 860
Kyocera	54 watt	R 2 190
Kyocera	65 watt	R 2 735
Kyocera	70 watt	R 3 480
Kyocera	85 watt	R 4 865
Sharp	80 watt	R 3 185
Sharp	125 watt	R 6 445

A typical example of a monocrystalline PV panel is shown on the following page.

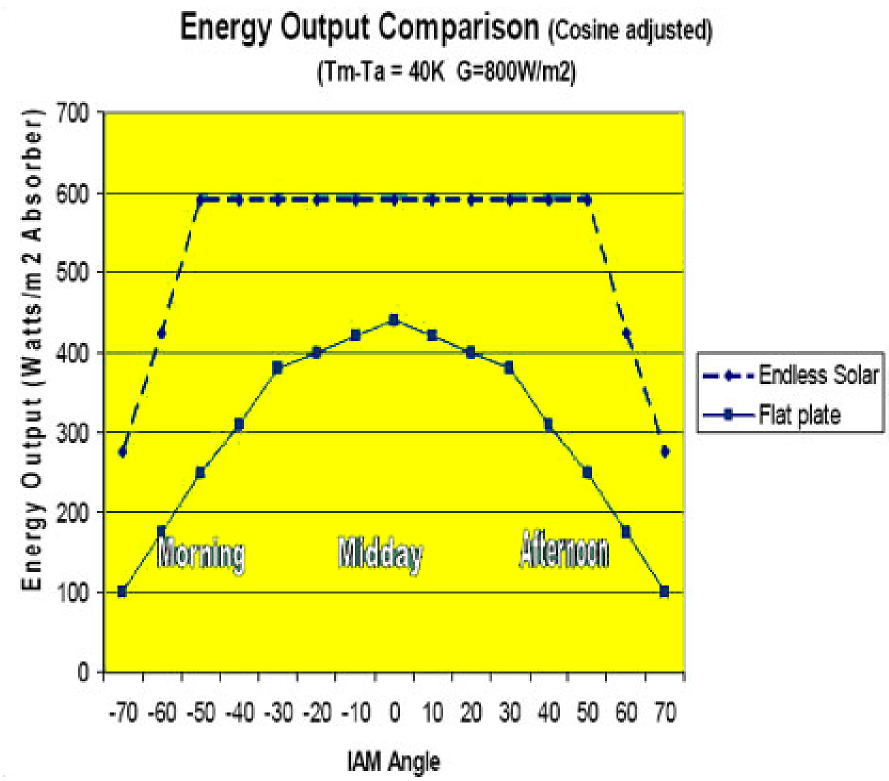
Solar Hot Water

The production of hot water is a very different story. The cost of solar hot water systems is much lower than PV modules and at the same time they operate at much higher levels of efficiency. Locally produced solar hot water systems can be purchased for as little as R2 500 for a 50 litre unit and the prices are still coming down; 150-250 litre units (appropriate for middle-income households) are also likely to be price-competitive as Eskom introduces subsidies through their DSM programme.

At efficiencies of above 60%, solar hot water provides direct savings to the consumer as well as having a positive impact on demand side management for the utility. Solar hot water systems are therefore a very useful contributor to the overall energy basket of any municipality.

A solar hot water system needs to *absorb, retain, transfer* and *store* energy as efficiently as possible. The main component in a solar water heating system is the collector. The two basic types of solar hot water collectors are *flat plate collectors* and *evacuated tube collectors*. Many *flat plate collectors* use an absorber plate with a specially developed black coating to maximize the collection of solar energy whilst simultaneously limiting re-radiation of energy back to the atmosphere. *Evacuated tube collectors* use an evacuated glass tube to enclose each pipe and its associated absorber plate. Convection losses are almost eliminated by the vacuum in the tube, making this type of collector more efficient than the flat plate type, especially at high temperatures. A translucent sheet covering the absorber, plus insulation at the back, minimize heat loss. Transfer of heat to the domestic hot water system may be via solar fluid flowing through a tube attached to the absorber plate, or heat pipes integral with the solar plates to fluid contained in a manifold at the top of the collector, connected in turn to the storage cylinder by a heat exchanger. The solar fluid usually contains a non-toxic anti-freeze solution.

Prices for typical evacuated tube solar hot water systems are shown in the Annexure 3, based on imports from Dubai. On the following page is a graphic demonstrating the higher efficiencies typical of these collectors, compared with flat plate collectors.



NOTE: "Endless Solar" is a proprietary evacuated-tube collector (not available in South Africa), but is comparable to systems which are available here.

Government as well as Eskom are already planning major initiatives towards the mass implementation of solar hot water systems throughout South Africa, and it is therefore crucial that eThekwini begin to develop programmes to take advantage of this opportunity. A more detailed description of possible programmes is provided in section 5.1 below.

The Eskom position on solar hot water has been summarised as follows:

> "South Africa's water heating load is primarily electricity and there would be great benefits in freeing up electrical capacity if electric geysers could be replaced with solar equivalents.
>
> Solar water heating is by far the most cost effective renewable technology which could be introduced in South Africa, the cost/kW could easily be as low as R 22,500/kW compared to other renewable technologies which could be as much as R 100,000/kW.
>
> Target market . The hot water market constitutes approximately 30% of the South African energy consumption in the combined domestic, commercial and industrial sectors. In the commercial sector the following can greatly benefit from installing solar water heating equipment:
>
> - government and private hospitals

- tertiary institutions
- hotels
- schools
- office complexes

In industry any client that uses hot water in their process can benefit from installing solar water heating equipment."

The Department of Minerals & Energy have taken a similarly proactive stance on solar hot water. They are initiating a roll-out programme of solar heaters, with the focus on middle- to high-income households in Gauteng, the Western Cape and KwaZulu-Natal. The initiative is spearheaded by CEF.

The DME-CEF initiative also includes efforts to:

- Produce national standards for solar water heaters;
- Write a code of practice;
- Provide a nationally-accredited training programme for installers
- Enhance market awareness to determine savings when using a solar water heater;
- Buy a test rig to allow the South African Bureau of Standards (SABS) to certify the systems;
- Determine models for financial aid in helping this industry in South Africa.

The revised South African National Standard (SANS 1307) for solar hot water is now available and the code of practise has been finalised as SANS 10106. The project will see in total 500 SABS certified systems installed in Cape Town, Durban and Johannesburg. The systems will be monitored for one year and thereafter the DME will determine which financial aid model to adopt.

The City of Cape Town is also drafting of by-laws to support the drive for solar water heating. According to these by-laws, the City will enforce the installation of these solar heaters to all newly built houses to help manage peak demand on the national Eskom grid. The by-law should be enforced later in 2007.[14]

As an example of the economic benefits derived from solar hot water systems, Sustainable Energy Africa in 2004 undertook an analysis for the City of Tshwane, using the LEAP energy modelling programme and comparing two options for solar hot water:

11. A roll-out for low-income houses
12. A roll-out for middle-income houses

The results are useful: Based on an assumed roll-out by 2020 of solar hot water in 50% of Tshwane housing in all sectors, the most cost-effective option was a roll-out in middle-income housing, which would achieve payback within approximately 7 years without subsidies (3-4 with subsidy). By comparison, solar hot water for low-income housing would require a 50% subsidy to achieve viability, and even then would only meet costs by year 10—due primarily to the much lower usage levels in low-income housing, and to the fact that smaller units are more costly per litre of water delivered.

[14] From the DME website, www.dme.gov.za.

The Tshwane study did not include the option of installing solar hot water in commercial buildings, but did include an analysis of the impact of installing high-efficiency heating/ventilation/airconditioning systems in new commercial and local authority buildings, which shows a 10% per annum cost saving.[15]

As discussed further in section 5.1 below, the Tshwane study was based on a very broad set of parameters and did not include technology-specific scenarios. Our analysis, based on the RETSCREEN Tool, includes specific assumptions on solar technologies (for both low- and middle-income SWH systems) and results in a much more conservative estimate of paybacks.

Demand Side Management

As indicated above, Eskom is now considering extending its Demand Side Management (DSM) programme to include residential and commercial solar water heating, which can potentially incentivise major roll-outs of this technology in municipalities such as eThekwini. To understand this better, we need to review briefly the characteristics of DSM and consider how it might assist the development of solar hot water programmes in eThekwini.

DSM means the planning implementation, and monitoring of end-user's activities designed to encourage consumers to modify patterns of electricity usage, including the timing and level of electricity demand. Electricity demand is the amount of electricity required by all electric equipment operating at one time in a building, an area or a city. The prime objective of DSM is providing constant, efficient use of electricity thus resulting in lesser amounts of electricity during peak times, thus managing the demand effectively.

If electricity is managed in this way, the demand is more consistent and consequently electricity suppliers are more able to meet the requirements of all of its consumers. The key benefit of DSM is efficient use of electricity, without influencing the customer production and satisfaction levels, resulting in significant cost savings for the provider and thus the consumer as well.

In this regard, Eskom has developed a number of case studies which are published on the Eskom website. Some of these are:

- Municipal Water Pump Rescheduling
- Variable Speed Drives on Air Conditioning System
- Residential Load Management
- Mine Pump Scheduling
- Lighting Projects -Commercial
- Lighting Projects - Controlled Switching

Demand side management is approached in two ways: energy efficiency and load shifting.

The efficient use of energy

The efficient use of energy has the effect of reducing the overall use of energy on a 24 hour basis although it may have most of its impact during peak demand times. The main objective in this instance is

[15] Personal communication, M Borchers, Sustainable Energy Africa.

to replace inefficient equipment with more efficient equipment e.g. incandescent lamps with energy efficient lamps or to improve the duty cycle or operation of equipment e.g. variable speed drives on air-conditioning systems.

Load shifting or peak lopping

Load shifting refers to switching certain loads off during peak demand times and on during off-peak times e.g. timers for geysers or rescheduling process and/or operations from peak demand times to off-peak times (such as the rescheduling of municipal water pump operations).

Alternatively the replacement of equipment and appliances which are normally grid supplied with stand-alone renewable energy devices can very effectively be introduced for peak lopping purposes. A typical example of this is solar hot water systems. Studies have shown that solar hot water systems will have a significant impact on demand reduction and/or control.

DSM and Solar WH

The proposed DSM programme for solar water heating has been based on a detailed analysis by Eskom of installed and operating costs for solar and its possible impact on electricity demand. The status of SWH has been summarised by Eskom as follows:

- The current market for SWH is ~15,000m2/annum, i.e. approx 7,500 SWH systems/annum
- The market for electric geysers is estimated at 3.3m with annual sales ~400,000
- SWH and electric heaters are substitute products, i.e. for low-income houses at least, SWH is a direct replacement for electric geysers.

Eskom's subsidy will be on a sliding scale based on a detailed evaluation of the impact on demand. As a rule of thumb, a typical 150-litre system, with a 2.1 m^2 area and costing R8050 and will receive a subsidy of up to R2500.[16]

The municipal perspective

Municipalities suffer the same pressures as Eskom when it comes to meeting increased load demand. In this regard they can benefit from a DSM programme involving more efficient use of energy or reduction in loads. Significantly, solar hot water systems are able to achieve both aims: Reducing the inefficient use of electricity to heat water for the consumer while reducing peak loads for the utility. This is achieved primarily because solar hot water systems, when properly sized for their end-use and of high technical quality, store energy efficiently during the low-use daytime hours and release it during the peak hours, particularly the early evening peaks. For the householder, this means a significant reduction in water heating costs, which comprise 50-60% of the average home electricity bill.

3.2 *Wind Resources*

South Africa has generally been seen as a country with an adequate though not exceptional wind resource. For example, wind maps produced by Diab (2000) show that the whole of the South African coast has a wind resource in excess of 4m/s, measured at 10 meters above ground. This has generally

[16] This figure is based on discussion at an industry workshop in January, and is being updated constantly. More recent information (unsubstantiated) suggests up to a 50% subsidy.

been extrapolated to wind speeds of 6 m/s or greater, on the assumption that higher wind turbine heights (a hub height of 40-50 metres is typical of most modern utility-grade wind turbines) would produce higher wind speeds. However there is little hard evidence of these higher speeds, though most wind studies to date have used the extrapolated figures uncritically.

Recorded average wind speeds in the eThekwini area, according to 3 different sources, are summarised in the following table:

	Anemometer Height	Diab Wind Atlas	Nat Weather Service	Eskom Wind Atlas
Durban Airport	13 m	3.2m/s	3.5m/s	4.1m/s
Margate	10m			3.8m/s
Greytown	10m			2.2m/s
Shaka's Kraal	10m	2.3m/s	3.1m/s	
Mount Edgecombe	10m	2.4m/s	2.5m/s	
Virginia	10m		2.7m/s	

Wind speeds of 4 m/s at 10-metre height are generally marginal with respect to economic viability. As well, wind is very site-specific and as a result dramatic changes can be encountered from one site to the next. In fact, it is difficult to develop a sound business case for wind where wind speeds are below 6m/s at 10 meters above ground, even if other conditions (e.g. local obstructions) are ideal.

Many different factors must be considered in siting a wind turbine, including local logistics, strength of foundations, proximity of grid connections etc. Because the present study does not include site assessments, our conclusions are necessarily very general.

To provide a clearer understanding of how the wind energy data for the eThekwini area translates into recommendations for specific technology programmes, we have completed a trial assessment using the RETSCREEN programme for one location: Durban airport. In order to understand the outputs of RETSCREEN and their impact on viability, it is necessary to explain some of the underlying assumptions of the programme and our use of it:

1. Wind data is specified as 4.1 m/s at 13 metres hub height, based on Durban airport actual data. The programme recalculates for a 49-metre hub height based on an internationally accepted algorithm. Durban airport is generally considered to have the highest wind speeds in the region, so we have assumed this is a “best-case” example.

2. The turbine type and rating is fairly standard; we have used a typical product manufactured by Vestas Wind Systems, with 850 KW output per turbine and a total of 18 turbines having a total capacity of 15.3 MW.

3. Default figures are used for various kinds of efficiency and site-specific losses.

4. A financial analysis is performed using construction, maintenance and operating costs similar to wind turbines being installed at other South African locations, e.g. Port Elizabeth. Costs for feasibility studies and EIA work are also included.

5. An avoided cost of electricity of ZAR 0.36/kWh is used, based on information from Eskom.

The result of this analysis are provided in section 4.3 below, where we assess the potential for wind farms and other forms of wind energy in eThekwini.

3.3 *Biomass Resources*

In the case of biomass resources, our assessment centres not on the availability of resources within eThekwini (although this is covered indirectly) but rather on the overall economic availability of these resources, i.e. their availability for eThekwini users subject to transport and other constraints. As a result, this section is much longer than the previous two, a function also of the great variety of biomass resources and technologies.

Biomass resources include not only the primary resource—e.g. forests and agricultural crops—but also secondary sources such as biomass waste from pulp and paper mills, wastewater and sewage effluent, and organic wastes from households and industry, including those currently sent to landfills. It also includes tertiary or derivative resources, e.g. liquid biofuels derived from various crops, intended for use either in transport or industry and charcoal from waste biomass.

The use of biomass resources for energy is often contentious, for a variety of reasons:

- If the resource is grown specifically for energy use, its production (or the use of land for its production) may compete with other uses, e.g. for food crops.
- If the resource in question is industrial waste, there may be issues around contamination of the waste stream by toxic substances (e.g. pulp waste may contain certain chemical residues which are not easily destroyed or abated by the proposed new use).
- In either of the above cases, the use of a biomass resource may have to be justified against other possible uses of the same resource, or the user may have to establish that there is a surplus of the resource and that its proposed use does not reduce its availability for more benign or productive uses.
- In the case of charcoal production, the source of the biomass material and the method of production are both contentious. Production of charcoal is only sustainable if it (a) uses only waste materials that have no effective alternative use, (b) uses the most efficient possible means of production (with least emissions), and (c) provides a low-emissions alternative to current fuel use in the relevant sector.

For practical purposes, we have limited the assessment of biomass resources to a few important categories, which we feel are the most likely to offer a reasonable potential for use in eThekwini's future renewable energy mix. These are:

1. Sugar cane and cane residue, i.e. bagasse, from the sugar industry.

2. Waste of several kinds from the paper industry.

3. Wood waste from the saw milling industry.

4. Waste water and sewage effluent.

5. Organic waste for landfills

6. Oil-producing crops such as soya, sunflower, maize, jatropha and possibly algae, which can be used in the production of bio-fuels

7. Charcoal production from waste wood, which is technically a use rather the resource itself but requires separate consderation.

We have not included several other minor sources which could be used, for example, to produce ethanol or bio-diesel, such as sorghum[17], wheat and canola; nor have we included the use of pulp or wood waste as a source of ethanol, which as we note elsewhere is theoretically possible but as yet unproven in the commercial realm.[18]

The assessment of these resources is based largely on two national studies: A 2004 study of biomass resources in South Africa, and a 2006 study of biofuels potential—both conducted for the Department of Minerals & Energy.[19] To this we have added our own research on certain specific processes, e.g. the use of algae for bio-diesel production.

Sugar cane residue. The harvesting and milling of sugar cane produces two kinds of waste material: bagasse, the residue left after milling of the cane, which has significant potential for energy use; and "tops and trash", the material left behind from the harvesting and usually burned on the fields. Apart from its energy potential, bagasse is also used by the pulp/paper industry as a component of linerboard, i.e. the material used in production of storage cartons. It has been estimated that the a total of 11.47 mT of bagasse are produced annually by the sugar industry, of which 83% is produced in Kwazulu Natal (the remainder being produced in Mpumulanga). In addition, 5.34 mT of tops & trash are produced, with KZN again producing 83%.

Bagasse is used as a source of heat for processing and for generating electricity in the sugar industry worldwide, and because of the large volumes of raw material involved, it is often possible for the sugar mills to generate electricity from bagasse surplus to their needs, which is then sold to the utility through power purchase agreements. In South Africa, by contrast with neighbouring countries such as Zimbabwe, Zambia, Malawi and Mozambique, the percentage of mills generating surplus electricity is still very low. In the 2004 survey, only 6 mills out of 14 surveyed were found to be selling electricity to the grid; but significantly the largest of these was Tongaat Hulett's Maidstone mill, which is the only mill within the eThekwini metro area and which makes 5 MW of capacity available (out of 29 MW total capacity) for sale as "green power."[20] This mill generates 67.4 GWh, although more than 85% of this is used by the mill itself.[21]

As the 2004 study points out, the potential for generating additional electricity from bagasse as well as other cane residues is significant, but there are important qualifications:

> "…(in order) to export significant amounts of electricity to the grid, (the industry)… requires a reduction in power and process steam requirements and an increase in power generation efficiency i.e. high pressure boilers and a combination of efficient back pressure and condensing turbo-alternators. At an anticipated conversion rate of 25% power to fuel, the

[17] Sorghum is often used as a rotational crop with sugar cane in KZN, and in fact can be substituted for cane as source stock for ethanol, thus improving the viability of ethanol production in traditional sugar-growing areas.
[18] The use of pulp and wood waste is usually referred to as "cellulosic ethanol", and is currently a major focus of research & development efforts worldwide as it greatly expands the potential for ethanol production from waste.
[19] *An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa*, Dept of Minerals & Energy, October 2006; and Assessment of Commercially Exploitable Biomass Resources: Bagasse, Wood & Sawmill Waste and Pulp in South Africa, DME December 2004.
[20] All other sugar mills in both KZN and Mpumulanga only have the option of selling to Eskom, and due to the low feed-in tariff offered Eskom, there is little incentive to sell.
[21] *Sustainable Energy: Towards Productive Cities*, page 61.

estimated total potential electricity from sugarcane biomass is about 5 500 GWh, from bagasse alone it is roughly 3 000 GWh and the in-house requirements are 700 GWh.

In short, there is a generation potential of between 2 100 GWh and 4 800 GWh additional to what is being generated now. However, this figure is somewhat misleading, in that it assumes major technological changes in the processing of sugar, the ability (and willingness) to use cane residues now routinely burned in the fields, and significant improvements in power generation technology over the current standard.

There is no question that there is room for improvement in technologies. For example, at Maidstone the electricity exported yields 106 kWh/tonne of bagasse, significantly lower than levels achieved with newer technologies, such as gasification of cane residues and use of modern back-pressure turbines, which typically yield 185-200 kWh/tonne or even more. However, were Tongaat-Hulett to introduce newer technologies, they would first need to have eThekwini Electricity upgrade the main bus-bar to allow for additional power supply, and would also need to find new uses for the excess steam generated.

Since Maidstone is the only mill within eThekwini's boundaries, expansion and modernization of power generation at the mill is the only option available to increase the contribution of electricity from sugar cane to the municipality. Because Tongaat-Hulett is a private company, the City would have to provide a strong incentive in terms of a higher feed-in tariff than presently offered, and upgrading of the distribution system. However it is also possible to consider the purchase of power directly from other mills, through Green Power arrangements or special wheeling agreements. In these cases, eThekwini could incentivise investment in the necessary technologies by developing power purchase agreements directly with the developer.

It is worth noting that Tongaat-Hulett is already engaged in negotiations for sale of surplus electricity to a green energy buyer, Amatola (see section 2.2.3 above). EThekwini could in theory work through Amatola to purchase this energy, providing that the price is realisitic.

Paper/pulp waste. There are basically three sources of biomass produced by pulp and paper mills namely black liquor, sludge and bark.[22]

Black liquor: Black liquor is a residue from the chemical pulping process. This liquor is concentrated through evaporation and subsequently burnt in boilers to recover valuable process chemicals. The combustible substance is mainly lignin. At 50% moisture the estimated liquor quantity available in South Africa is over 5.2 million tons per annum.

Bark: The quantity of bark is roughly 9% of softwood pulpwood and 0.5% of hardwood pulpwood intake. This gives a total amount of bark produced by the industry in South Africa in 2003 of 345 000 tons at an average moisture content of 50%.

Sludge: The quantity and quality of the sludge varies considerably and depends on mill configuration and type of paper produced. The amount of sludge also depends on its moisture content. At 50% moisture the total amount of fibre and bark sludge produced by the SA industry in 2003 is estimated at 234 000 tons. Sludge usually has a dry solids content of 20 to 40%. This high liquid content is often reduced by mechanical dewatering.

[22] This section is taken substantially from *Assessment of Commercially Exploitable Biomass Resources*, DME 2004.

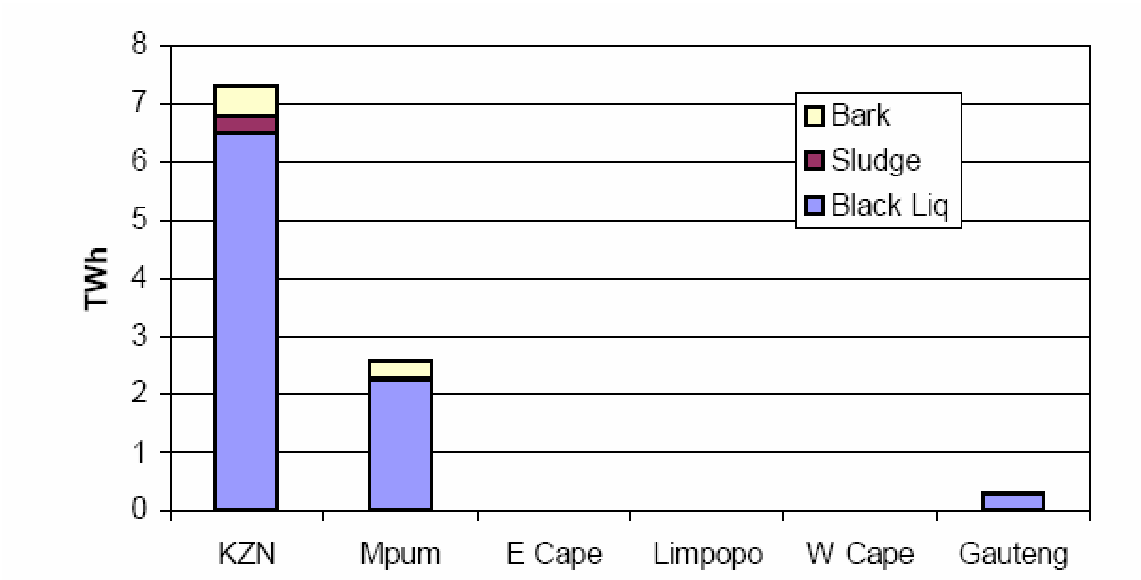
All 3 of these sources are technically available for use as a renewable, alternative fuel for boilers, furnaces and kilns. The industry itself uses black liquor and bark to fire its own boilers, but typically produces in excess of its own needs. The capacity of conventional boilers to burn waste efficiently is extremely variable, but Mondi's recent installation of a fluidised-bed boiler at Merebank in eThekwini shows that it is possible to convert most pulp and wood waste to heat and steam at a very high level of efficiency—notwithstanding the environmental concerns expressed during the EIA for this particular project. Mondi is also utilising wood chips to fire boilers at its Felixton Plant (outside of eThekwini) and has experimented with use of black liquor at the same plant. A natural gas-fired co-generation facility is being installed at Mondi's plant in Richard's Bay.

The cement industry has also shown an interest in substituting some forms of pulp and wood waste—particularly pulp sludge—for coal in their kilns. This could substantially reduce industry GHG emissions from coal, but the use of alternative fuels in kilns is still under national environmental review and not all such fuels may pass muster. Natal Portland Cement operates a large kiln in Port Shepstone—outside of the eThekwini boundary—and has been experimenting with a variety of alternative fuels in the past 3-4 years; the same company operates a large grinding mill in eThekwini, but most of the energy used at this mill is electrical and there are no realistic options for power generation from renewable sources at present.

The total South African pulp and paper industry biomass waste is about 5.78 million tons with an energy content of 10.17 TWh. About 90% of this biomass is black liquor with an energy content of 9.03 TWh while the remainder consists of sludge and bark. Black liquor is only produced by the chemical pulping process and is usu-ally burnt to recover chemicals. The total biomass has a potential electricity capacity of about 2 542 GWh.

Significantly, a very high proportion of waste from the pulp/paper industry is found in KZN, as the following graphic illustrates:

Energy Content of Pulp & Paper
Residue by Province, 2004



DME 2004

Wood waste from the saw milling industry. Just over 4% of eThekwini is covered by indigenous forest, and under 1% by commercial plantations (non indigeneous) and wood lots.[23] The amount of wood waste available in the municipal area is not known, but there is detailed information available for KZN and South Africa as a whole.

Nationwide, the sawmilling industry yield on softwood in 2003 was about 47.6% and on hardwood 42%. This resulted in a total sawmill biomass waste of about 2.95 million tons mainly from softwood. This biomass waste consisted of 55% chips, 28% sawdust and 17% bark.

The energy value of all sawmill waste in South Africa is summarised in the following table:

Type of Waste	Mass 1000 t	Fibre %	Moisture %	Ash %	NCV MJ/t	Energy TWh
Chips	1 622	59.20	40.00	0.80	10 316	4.65
Dust	826	59.50	40.00	0.50	10 611	2.43
Bark	501	58.00	40.00	2.00	10 135	1.41
Total	2 948	59.08	40.00	0.92	10 368	8.49

DME 2004

Although no independent statistics for sawmill waste in eThekwini could be found, approximately 29% of the national figure, or 846,000 tonnes, is produced in KZN. At 40% moisture content, this has an energy value of 2,462 GWh. The provincial breakdown is presented in the following table:

Type of Waste	**KZN 1000 t**	**Mpum 1000 t**	**E Cape 1000 t**	**Limpopo 1000 t**	**W Cape 1000 t**	**Gauteng 1000 t**
Chips	465	793	193	68	102	0
Sawdust	237	404	98	34	52	0
Bark	144	245	60	21	32	0
Total	846	1 443	351	123	186	0

DME 2004

In principle, waste wood materials provide a useful substitute for solid wood in a variety of applications, including commercial and industrial heating and domestic cooking. They can be compressed to form bricquets or pellets (which reduces transport costs), or burned directly in multi-fuel boilers and furnaces. They can also be carbonised through pyrolysis to form charcoal, which again can be utilised in a variety of applications but is typically used for cooking. Because wood waste tends to burn more efficiently in compressed or carbonised form than in round-wood form, it is in theory more energy-efficient.

Unfortunately, none of these uses is commercially practical unless the point of end-use is reasonably close to the point of production—as a rule, less than 50 km. Beyond this point, the energy cost of transportation outweighs any possible energy benefits. As well, the efficiency of wood combustion

[23] Jessica Rich, personal communication.

depends in large part on the technology used, i.e. whether it is suited to use of chips or pellets and whether it incorporates energy-efficient design features.

Wastewater and sewage effluent. eThekwini produces significant amounts of waste water, including sewage and grey water from the city's central collection systems. Because of the high organic content of this liquid effluent, it is highly suitable for processing through digesters, and a major end product of digestion is methane gas—a significant greenhouse gas.

The quantities of effluent available and their estimated methane production are summarised in the following table:

Ethekwini Water and Sanitation
Calculated Gas Production for the Wastewater Treatment Works with Anaerobic Digestors

Works	Flow in Ml/d	Approximate Sludge Gas in cubic meters per day	Approximate Methane Gas in cubic meters per day	Details
Kwa Mashu	58	3,619	2,413	Heated with sludge gas, excess used on plant or flared
Northern	51	3,182	2,121	Heated with sludge gas, excess used on plant or flared
Amanzimtoti	20	1,248	832	Unheated all gas produced vented to atmosphere
Umbilo	15	936	624	Heated with sludge gas, excess vented to atmosphere
Phoenix	13	2,000	1,333	Heated with sludge gas, excess flared to atmosphere
Isipingo	12	750	500	Unheated all gas produced vented to atmosphere
Verulam	6	375	250	Unheated all gas produced vented to atmosphere
Kwa Ndengez	2	125	83	Unheated all gas produced vented to atmosphere
Mpumalanga	2	125	83	Unheated all gas produced vented to atmosphere

Ethekwini Water & Sanitation 2007

As this table illustrates, four of the nine plants presently use the sludge gas to re-heat the digesters (thus improving the efficiency of digestion); the balance are unheated and all of their gas (methane plus sludge gas) is vented to atmosphere. Two of the four plants (Kwa Mashu and Northern) which use sludge gas for re-heating either flare all the unused methane gas or use it for other plant functions; the other two either flare or vent and do not re-use the methane.

Since flaring and use for heating of some kind appears to be the status quo for several plants, the opportunities for improvement are limited, but there may be opportunities to capitalise on destruction of methane for carbon credits where it is not flared. If flared, this would be taken as the baseline activity, and the only opportunity for carbon credits would be through use of methane for electricity generation (as in the landfill projects). However, experience elsewhere suggests that if methane destruction cannot be used for credits, the incremental credits from use of methane to generate electricity are of marginal benefit to project finances.

Another important opportunity for energy production comes from the solid sludge itself. Ethekwini has already experimented with production of pellets from the sludge at a few locations, but so far has had little success in selling or otherwise disposing of these. According to department staff, substantial quantities of pellets and dried sludge are accumulating with no clear plan for disposal. Details of the total amount of wet and dried sludge available are provided in the table below, indicating that approximately 84.3 tonnes per day (dry weight) are accumulated. In the consultants' view, this presents an excellent opportunity to use a waste product for energy generation either through (i) charcoal production using retorts, which in turn can provide an alternative or transitional fuel for use in cooking and heating in those rural/peri-urban areas in eThekwini which presently have a high reliance on wood and charcoal, or (ii) through substitution of dry waste (in pelletised form) for coal in cement kilns, providing that the current concerns around the environmental impacts of alternative fuel use in the cement industry are resolved.[24]

WWTW SLUDGE INFORMATION							
	WWTW	Nature of Sludge	Digester Available? Yes/No	Extended Aeration Yes/No	Dewatering Mechanism if any	Destination of Sludge	Estimated amount of Sludge Production ton(DS)/d
Lower Umgeni Area	Northern	Digested Sludge	Yes	No	Belt Press	Stockpiled on site	10.61
	Kwa Mashu	Waste Activated Sludge & Sludge from Biofilters	Yes	No	Belt Press	Stockpiled on site	12.07
	New Germany	Waste Activated Sludge	No	Yes	None	Piped to Northern HOW	0.00
Southern Coastal Area	Kingsburgh	Waste Activated Sludge	No	Yes	None	Tankered to Southern WWTW	1.52
	Umkomaas	Waste Activated Sludge	No	Yes	Drying Beds	Tankered to BulBul drivetip site	0.70
	Craigeburn	Waste Activated Sludge	No	Yes	Drying Beds	Tankered to BulBul drivetip site	2.10
	Amazimtoti	Digested Sludge	Yes	No	None	Tankered to Southern WWTW	8.41
	Isipingo	Sludge from Biofilters	Yes	No	Drying Beds	Stockpiled on site	0.03
Inland Area	Hammersdale	Waste Activated Sludge	No	Yes	Centrifuge	Sent to Sludge Farm	6.06
	Mpumalanga	Digested Sludge	Yes	Yes	Drying Beds	Stockpiled on site	1.35
	Hillcrest	Waste Activated Sludge	No	Yes	Drying Beds	Tankered to tip site	0.10
	Kwandengezi	Sludge from biofilters	No	No	Drying Beds	Stockpiled on site	0.03
	Dassenhoek	Waste Activated Sludge	No	Yes	None	Sludge Lagoon	0.30
	Fredville	Waste Activated Sludge	No	Yes	Drying Beds	Remains in the drying bed	0.01
Northern Coastal Area	Phoenix	Raw Sludge & WAS (digested)	Yes	No	Centrifuge	WAS-tankered to Shongweni Digested Sludge- stockpiled on site	14.04
	Umhlanga	Waste Activated Sludge	No	Yes	Centrifuge	Stockpiled on site	1.11
	Umdloti	Waste Activated Sludge	No	Yes	None	Stockpiled on site	0.08
	Verulam	Waste Activated Sludge	No	Yes	Centrifuge	Stockpiled on site	2.27
	Tongaat Central	Waste Activated Sludge	No	Yes	Centrifuge	Tankered to Shongweni landfill site	1.97
	Genazzano	Waste Activated Sludge	No	Yes	None	Stockpiled on site	0.03
Central Coastal Area	Central	Raw Sludge	No	No	None	Piped to Sea Outfall	
	Umhlatuzana	Waste Activated Sludge	No	Yes	None	Piped to Southern WWTW	
	Umbilo	Waste Activated Sludge & Sludge from Biofilters	Yes	No	Belt Press	Stockpiled on site	21.54
	Southern	Raw Sludge	Yes	No	None	Piped to Sea Outfall	
						Total for all WWTW tonnes/day	**84.30**

Ethekwini Water & Sanitation 2007

[24] The use of alternative fuels in cement is currently the subject of a national Environmental Impact Assessment, the results of which should be available in July or August 2007.

There is a clear need to undertake a more detailed study of the potential for using excess methane, sludge gas and dried sludge for various energy requirements. Although a detailed assessment of this issue is beyond the scope of the present study, we have included this option in our short-list because of the ready availability of materials and their high energy potential. We provide a brief assessment of options for their use in section 5.

Organic Waste for Landfills. This is a major source of potential renewable energy for eThekwini, and is already being exploited for electricity production through two Clean Development Mechanism projects: the LaMercy/Marianhill combined project, and the Bisasar Road Project. Of the two, Bisasar Road is by far the largest, involving projected greenhouse gas emissions (including electricity production) of 350,000 tonnes of CO2-equivalent per year. Total production from the two projects is slightlu over 400,000 tonnes per year.

Although these three landfills are now largely developed and will be generating electricity from methane for at least 20+ years, the municipality is expecting to close Marianhill in 5 years and Bisasar road in about two years (La Mercy is already closed). Thereafter, solid waste presently being taken to these landfills will gradually be shifted to a new and much larger landfill: Buffelsdrei at Hillcrest. The Buffelsdrei landfill site has an ability to absorb over m3 of waste a year. The City has decided that it will not open any further landfill sites for at least another 15-20 years.

It is clear that the success of the power generation/CDM projects at LaMercy/Marianhill and Bisasar Road will favour a similar development at Buffelsdrei. However, before proceeding to duplicate the approach used in the first two projects, we suggest considering alternative technologies which may prove more efficient and cost-effective in producing renewable electricity. These are discussed further in sections 4 and 5.

Oil-producing crops/biofuel. The potential for replacing hydrocarbon fuels with biofuels has attracted a great deal of attention of late, both internationally and nationally. Most of the effort in this sector has been directed towards finding replacements for the main transport fuels, viz. petrol and diesel, since transport represents approximately 30% of South African final energy demand. The situation in eThekwini is if anything more extreme than the national situation, with transport responsible for 42% of final demand, compared with 47% for industry and commerce (according to the SOER). Reducing dependence on fossil fuels for transport and substituting biofuels should therefore be an important element in the eThekwini Energy Strategy, and will also serve to substantially reduce greenhouse gas and other emissions. Even if the alternative fuels are not sourced locally, increased use of renewable or biofuels means there will be a substantial improvement in carbon dioxide and other emissions.[25] The mechanisms for doing this will be in part policy-based and in part economic, as explained further in section 6.

In principle, biofuels can also be used as a substitute for some or all of the current mix of hydrocarbon fuels. However, there are limits to this statement: For example, assuming existing South African engine technology, bio-ethanol can only be substituted for petrol up to a 20% blend, and the South African government has now mandated a more conservative figure of 10%.[26] Beyond the 20% level, major changes are required to engine design, although Brazil has long demonstrated that this can be achieved quickly and effectively if there is a national consensus.

[25] As a rule of thumb, bioethanol emits 60% less carbon dioxide than petroleum fuels, and 80% less than liquid fuels derived from coal (*Creamer's Engineering News*, 02 December 2005).
[26] *National Biofuels Strategy*, December 2004, DME.

By contrast, bio-diesel can in theory be directly substituted for hydrocarbon diesel, though this is usually done by the major oil refiners and blenders to avoid voiding of warranties and ensure that the final product is appropriate for local use (e.g. contains additives for altitude differences).

The major constraint on biofuel development is resource availability. Most sources of bio-diesel are also food crops: for example soybean, sunflower and maize. Some of these, particularly maize, can also be used to produce bio-ethanol. Bio-diesel can also be produced from jatropha, palm oil (which would have to be imported) and even from used cooking oil. All of these uses (with the exception of used oil) either compete directly with use of the same crop for food, or utilise land that could otherwise be used for food production. This is a major issue for both bio-diesel and bio-ethanol, and has resulted in a major international campaign to restrict biofuel production.[27]

As part of its efforts to develop a biofuels strategy, the South African government has evaluated the potential for a local biofuels industry, and has concluded that,

> *Based on international targets by developed countries, with Kyoto commitments, and given South Africa's limited agricultural capacity, a biofuels target of 3.4 % of liquid fuels (by energy) by 2013 – equating to 50 % (by energy) of the total Renewable Energy target (of 10 000 GWh by 2013) – seems reasonable."*[28]

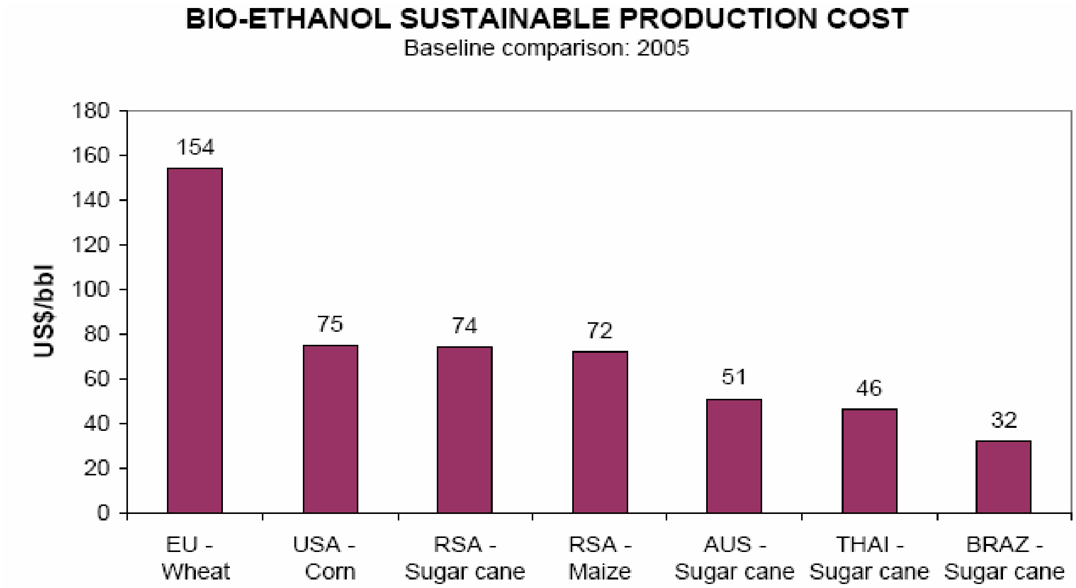
This study goes on to propose a 2% share of the total diesel market for bio-diesel and a 10% blend of bio-ethanol to petrol, based on an economic assessment that suggests that bio-diesel from soy and ethanol from maize and sugar cane are both viable at the equivalent oil price of US$65/barrel. The draft National Biofuels Strategy, now under review, effectively repeats these assumptions and proposes subsidies to sustain this level of market penetration.[29] The Strategy is expected to be finalised later this year.

The relative cost of biofuel production in South Africa and internationally is summarised in the following graphic, re-produced from the national study:

[27] See for example *"Diversion Of U.S. Grain To Fuel Is Raising World Food Prices",* Lester R. Brown, Earth Policy Institute, March 21, 2007.

[28] *An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa*, Dept of Minerals & Energy, October 2006, pages ii-iii.

[29] The subsidies in this case involve a 40% rebate on the fuel levy and possible use of the Equalization Fund to offset oil price fluctuations.



The graph shows that the cost production of ethanol from either sugar cane or maize in South Africa is roughly comparable, but well above the cost of production in Australia, Thailand or Brazil. Production of ethanol from sugar cane is slightly higher than from maize, while both soybean and sunflower oil are substantially more expensive, as the following table shows:

Comparison of Production Costs for Ethanol		Sugar Cane	Maize	Soybean oil	Sunflower oil
Net crop feed price	cent/litre	231	254	310	493
Net biofuel production price	cent/litre	375	367	364	548

These economic arguments aside, the major finding of the national study is that production of maize, soya and possibly sunflower for food purposes will not be sacrificed by the growing of these same crops for biofuel. The study however recommends that,

> *"Given South Africa's limited agricultural land and water availability, it is important to guard against an over-investment in biofuel production. Rather, a healthy balance between the production of food and fuel is needed, and this should guide the level of incentives provided."*

Beyond this somewhat bland statement, neither the Strategy nor the study upon which it was based say much about the capacity of South African agriculture to produce sufficient fuel crops without sacrificing food production. They do however agree that,

> *"…to ensure indigenous food security, no more than about 5 mil ha (3 mil ha underutilised land; and 2 mil ha of existing farmland) can be set aside for energy crops. This is enough for 50 plants, or enough to meet*

about 50 % of South African liquid fuel needs."[30]

One possible way out of the food-fuel conflict is to select oil sources which do not compete with food production. There are 3 possibilities of this kind:

- Use of waste oils, particularly discarded vegetable oils from restaurants and the food industry.
- Use of non-field crops which also have no food value such as jatropha.
- Use of algae, produced in high-intensity factory environments.

Of the three, use of waste oils is the least-cost and most practical, since it involves recycling of a waste product that is otherwise valueless. However there are serious and unresolved issues around the quantities available and the potential carcinogenic qualities of oils exposed to high temperatures during cooking.[31]

The use of jatropha is still extremely contentious because it is an alien species (though not necessarily invasive), and is perennial and therefore more difficult to control. Jatropha also potentially displaces food crops, even though it is not a food crop itself. Examples of jatropha cultivation and use for bio-diesel production can be found in West Africa, and there are limited examples from South Africa itself, though these are still in early stages of development.[32]

The most promising of the three non-food sources is algae. Currently in early stages of development in South Africa by two separate firms[33], algae promises to have the least impact on both food production and competing land-uses, and is also a more efficient means of producing biofuels. The algae is grown in a closed environment (typically large glass tubes or plastic "curtains") on land zoned industrial or in some cases on reclaimed mining land, and uses a combination of waste water and stack emissions to produce an effective growth medium.

Algae plants are typically located close to major emitters such as power stations or pulp and paper plants, and utilise the NO_x and CO_2 emissions from these plants to stimulate algal growth. The algae thus acts simultaneously as an absorber of airborne pollutants, a carbon sink and a new source of energy.[34] After the oils in the algae are extracted (typically through centrifuges), they are sent to bio-diesel refineries, of which more than 100 are expected to be set up around the country, taking the output from up to 8-10 algae production plants. The process is claimed to be between 10 and 20 times as efficient as oil production from crop-based agriculture, producing 40,000 litres per acre of algae facility per year. The carbonaceous residue from the extraction process can also be densified and used directly as a solid fuel or used to generate biogas which can in turn produce heat or electricity.

The advent of algae-based oil production would appear to solve most of the problems associated with oil production from food crops, and is highly efficient and environmentally beneficial. However, the technology has yet to be implemented on a commercial scale anywhere, and the investment required is substantial. It is unlikely to be a major source of bio-diesel (or bio-ethanol, which can also be produced

---

[30] *An Investigation into the Feasibility of Establishing a Biofuels Industry in the Republic of South Africa*, Dept of Minerals & Energy, October 2006, page 9.

[31] Bio-diesel can also be produced from animal fats, but the problems are similar to use of used cooking oils: availability, distribution costs, health issues and quality control.

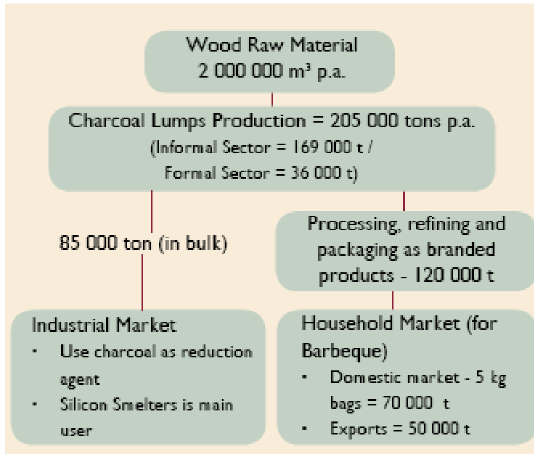
[32] There is allegedly a pilot jatropha project at Owen Sithole Agricultural College in Empangeni. There is also a jatropha nursery project in Mafeking, though this appears to be on hold due to delays in developing the bio-diesel processing facilities and a major kill-off of the jatropha (*R850m bio-diesel undertaking put on hold, Busniess Report,* March 11, 2007).

[33] Since the first draft of this report was completed, one of these companies has ceased operations, leaving the prospects for biodiesel production from algae in a state of uncertainty, although interest in this option remains high.

[34] For more details, see www.greenfuels.com.

by this process) for at least 3-4 years. However, as we will demonstrate later, encouraging indirect investments by private investors in this form of liquid fuels production would make eminent good sense, as would mandating the use of biodiesel in the eTheikwini diesel fleet.

Charcoal Production. The carbonisation of wood for the recreational market, barbeques etc, is well established in South Africa and Silicon Smelters, a local company, uses large quantities of charcoal for their processes. Carbonization as a process can be used to dispose of a multitude of waste products by turning it into useful charcoal. We have included this option here because although the source raw material is the same as for several other technological options, we believe this option provides the most appropriate use for eThekwini.



The normal approach for carbonising wood is the batch kiln technique. A batch kiln can take the form of anything from a hole in the ground to a custom built brick or steel and fire brick structure.

A batch kiln cannot handle all forms of waste, and would definitely not be suitable for waste products such as pelletized sewage sludge or landfill materials. In these instances a retort would be the most suitable approach for the following reasons:

- Continuous feed of waste materials of any size depending on the retort design
- Temperature and feed rate control
- High levels of efficiency
- Compact models possible
- Self sustaining through methane produced as a by-product
- Co-generation possible from heat generated
- Drying of waste material feed stock using waste heat
- Clean and smoke free allowing for use within built-up areas.

The photo at the end of this section shows what a retort can look like as well as give an indication of how clean and pollutant free the environment around a retort can be.

Retort feedstock

Retorts have been used extensively for the production of charcoal from wood as well as activated carbon from among other sources cocoanut shells and macadamia nut shells. It is a well developed and understood technology which can readily be adapted to carbonise a range of feedstock products. It is foreseen that in this instance the feedstock for retort may include landfill, wood and sewage sludge/pellets.

Emissions: Kilns and retorts

Emissions from kilns or retorts are largely dependant on the type of feedstock and the moisture content thereof.

In a kiln, the feedstock, such as wood, is packed into the kiln and lit. All the openings are then closed in order to shut of all oxygen—a process called pyrolysis. Pyrolisis is an exothermic process which takes place in the absence of oxygen whereby the feedstock is carbonised without it being burned. The result is that it is a completely uncontrolled process which produces a number of emissions namely, carbon monoxide, carbon dioxide, methane, ethane, pyroacids such as acetic acid and methanol, tars, heavy oils and water. All these are emitted as black smoky flue gas. Product constituents and the distribution of these constituents vary, depending on the raw materials and the carbonization parameters. Organics and CO may naturally be combusted to CO_2 and water. However, the extent of combustion also varies dramatically from plant to plant and as a result the emissions can be quite variable. Some of the specific organic compounds that may be encountered in a kiln may include ethane, methane, and polycyclic organic matter. If these are not combusted, tars may solidify to form polycyclic matter emissions and pyroacids may form aerosol emissions.

Retorts operate on a principle where the feedstock is heated either from an external heat source or by lighting it, to drive off the volatile organic compounds (VOCs) which then become the fuel source supporting the exothermic process. The VOCs are burned at temperatures of between 900°C to 1000°C and the heat from that flame either radiates the feedstock or alternatively the hot gas is fed back through the material to be carbonised.

This is where the main difference between the retort and the kiln approach shows some clear advantages. By controlling the air/oxygen needed for the combustion process it is possible to control the temperature inside the retort as well as the feedstock feed rate. By doing this the four most important components required for quality charcoal can be regulated namely the fixed carbon content, the volatile content, the moisture content and the ash content i.e. the charcoal quality. This control also allows for all VOCs to be combusted to CO_2 which is a much preferred option to the methane and other potential ground water and sea water-polluting substances found in landfill and sewage sludge. Stack emissions of a well regulated retort are clear with no smoke showing except at start-up. Ideally this is a 24 hour continuous process which only requires shutdown for cleaning once a month or longer.

The result is that retorts are ideal for placement anywhere in that they are not only clean "burning" devices but that they can also be designed and built in any size.

Efficiency

The typical yield of a kiln is less than 20% by mass. Most of the mass loss is as a result of the volatiles and moisture, i.e. moisture content plays a role but ideally should not be more than 25%. However, a significant percentage of the mass is also lost as a result of some of the material having to burn, or rather smoulder, to sustain the process. Should too much air accidentally be introduced the whole batch can go up in smoke with a 0% yield.

A retort on the other hand can have yields as high as 45% by mass because the process takes place in the total absence of oxygen and because the burning volatiles sustain the process.

Other retort advantages

The waste heat produced by a retort can be used for a number of applications. In this instance it can be used as a heat source to dry sewage sludge or wet landfill or if wood is used for drying wood to the most efficient moisture content level.

Waste heat could also be used to generate steam or hot water should there be a need.
Depending on the material carbonised, there could be an over-production of VOCs. These could either be flared or alternatively used in an internal combustion engine depending on the quality and composition of the VOCs.

The fixed carbon content of retort produced charcoal can be in excess of 90% depending on the temperature and the feed rate whereas kiln produced charcoal may be lower than 50% and because there is no control this figure could be anything but seldom higher than 60%.

Uses for charcoal

No matter what the origins of the feed stock are, the end result is carbon of a high level of purity, and a high energy value. Charcoal can be briquetted for the recreational market or used for industrial processes, e.g. Silicon Smelters; or the process could even be taken further to produce activated carbon should the raw material allow it.

More significantly, charcoal manufactured in a retort can be substituted for wood, dung or coal for cooking and heating in low-income communities. Although the economic viability of this option depends in part on the availability of inexpensive wood wastes and must be subjected to a more detailed feasibility assessment, we believe that charcoal of this kind could serve as a useful transitional fuel for low-income and informal eThekwini settlements.

Figure 1: Example of a Retort

4 Preliminary Assessment of RE Technology Opportunities

4.1 *Methodology for selection of short-list*

The Terms of Reference for this project call for the consultant to develop a short list of 4-8 RE technologies, based on a review and assessment of a long list of "10-20 potential technologies." During the initial consultations for this project in March, and following our own basic review of RE potential, we prepared a long list of some 27 technologies, including a number of variations on specific technologies such as wind, solar and biofuels. The technologies included in this "very-long-list" are summarised table on the following page.

Our initial assessment of these technologies was based on two major factors:

- Availability/reliability of the resource.
- Maturity of the technology.

Resource availability/reliability refers to the technical limitations placed on the technology by the major input source, e.g. wind (both speed and constancy) in the case of wind farm projects, or available solar radiation in the case of solar projects, or availability of specific forms of biomass in the case of biomass energy projects. This is a fairly rational and quantitative exercise, in that the required resource is either available in sufficient quantities and qualities, or it is not. Section 3 has included some preliminary information on the key renewable resources as well as on technological applications of these resources.

Maturity of the technology refers to a more subjective factor: the current status of the technology in terms of both available scientific information on performance and cost, and the availability of feasibility or pre-feasibility studies which support the viability of the technology in locations similar to eThekwini.

In principle, looking at these two factors allows us to eliminate those technologies which can be easily proven to be uneconomic given resource constraints or technical immaturity at current stage of development. The subsequent analysis would then concentrate on a smaller number of technologies and more easily reduce these to a shortlist.

However in practice it has proven difficult to do this. As a result, only one technology was completely eliminated on grounds of technological immaturity: *cellulosic ethanol*, which is still in early stages of research development with no proven commercial applications. This potential source of biofuels is however an important one for future consideration, as it enables the use of waste wood and pulp as a source of ethanol, and hence incurs no risk of competition with food crops.

The technology long-list, including cellulosic ethanol, is presented on the following page.

Following the application of the first two factors, each technology was evaluated on the basis of 5 major factors and 6 minor factors. The 5 major factors were provided in the TOR, as follows:

- Potential to contribute to the comprehensive energy supply of eThekwini with a focus on energy security
- Potential to reduce environmental, economic, social strains to informal settlements
- Potential to create jobs
- Sustainability

- Implementability and development costs in relation to the eThekwini Municipality

Technology Long-List
Wind
-Wind farms-coastal
-Wind farms-escarpment
Solar
Solar H/W
-Low-income housing
-Middle-income housing
-Commercial buildings
-Utility approach
Solar PV
-Large arrays (central)
-Distributed (household)
Municipal Waste
-Landfill-to-electricity
-Landfill to heat
Industrial Waste
-Waste to electricity
-Waste to heat/steam
Sewage Waste
-Sewage waste to heat
-Sewage waste to electricity
-Sewage solids to energy
Wave/Ocean
-Wave Power to electricity
-Sea current power/electricity
Biomass
-Bagasse to electricity
-Wood/pulp waste to power
-Sawmill waste to power
-Charcoal production using retorts
Biofuels for transport
-Bio-ethanol from cane
-Bio-ethanol from maize
-Cellulosic ethanol from pulp/wood waste
-Bio-diesel from seed oils
-Bio-diesel from algae
-Bio-diesel from waste oil
Biofuels/other
-Ethanol gel for cooking

The last of these is really two factors , but we have interpreted it to mean simply an assessment of the practical options for development of the technology by the municipality itself.

In the analysis, the two primary factors were accorded a weighting of 2 and the 5 “major factors” a weighting of 1.5, i.e. 150% and 200% more respectively than the minor factors.

The 6 minor factors are:

1. Environmental impact (overall)
2. Availability of commercial financing
3. Eligibility for CDM or other non-commercial financing (TRECS/ RE Subsidy)
4. Regulatory constraints
5. Availability of SA or international standards
6. Local content in manufacture

As the following sections will show, this second-level assessment produced a short-list of 6 technologies which were then evaluated again in order to obtain a final priority ranking. This involved 3 steps:

1. Some of the short-listed technologies were analysed using the international assessment programme RETSCREEN, to provide detailed information on performance, life-cycle costs and economic viability.(Note: At this stage the results which any desktop modelling such as RETSCREEN would produce can only be seen as an indication of whether further detailed assessment is worthwhile or not, i.e. it should not be seen as a feasibility study.)
2. Where RETSCREEN was not useable (e.g. for biomass), we undertook our own review based on information in the literature and international practice.
3. A re-assessment is then made of the technologies' performance relative to the 5 major and 6 minor factors above, to give a weighted score.

The results of the evaluation for each of the short-list technologies is then presented in a format based on the template approved earlier, for incorporation in the RE Catalogue.

4.2 *Explanation of weighting/scoring/evaluation*

In the following sections, we provide a brief description of each of the eleven second-order factors and how we have evaluated them.

4.2.1 Second-level assessment: Major factors

4.2.1.1 Potential to contribute to the comprehensive energy supply of eThekwini with a focus on energy security

This refers to the need for increased local supply of energy from renewables to offset the current high level of reliance on petroleum and coal-based fuels. Because the focus is on eThekwini, the rating of this factor is primarily a function of availability, i.e. can the resources supporting the technology (wind, biomass, solar) in question be supplied reliably and effectively? In this sense, certain biomass resources and technologies would receive a low rating since they are not available in eThekwini and not economic to supply from outside the area; while others such as solar would be highly rated because their availability is good and supply reliable.

4.2.1.2 Potential to reduce environmental, economic, social strains to informal settlements

This factor is inevitably subjective, since access to energy for informal settlements is problematic because of both cost and accessibility. Energy technologies that have low entry-level costs and are adaptable to community use (e.g. basic solar hot water) will score highest on this factor, while high-tech solutions (e.g. wind farms or wave power) will score low. In effect, this means that most centralised or nonlocal technologies will score very low since they bring no direct benefits to the community in the form of reduced strains.

4.2.1.3 Potential to create jobs

This factor is difficult to assess because it depends in part on where the technology is sourced and the level of sophistication required to manufacture and/or maintain it. Technologies amenable to local manufacture and maintenance will obviously score higher here, although there is a risk of oversimplification because the potential for local involvement does not automatically imply that this involvement will happen. For example, incentives of various kinds may be required to ensure local manufacture, and special training programmes initiated to guarantee a high level of maintenance capability.

4.2.1.4 Sustainability

This refers to a broad array of factors covering environmental, social, and economic concerns. It is thus really a by-product of other factors, but we have endeavoured to provide an overall rating based on the prospects for long-term sustainability of the programmes needed to implement the technology. Technologies which have a small environmental footprint and require little ongoing servicing or upgrading will score high on this factor, while those with questionable environmental impacts and/or requiring frequent and costly maintenance or materials supply will score low.

4.2.1.5 Implementability and development costs in relation to the eThekwini Municipality

As noted above, we have treated this as a single factor: the practical options for development of the technology by the municipality itself, or the indirect costs to the municipality should development by undertaken by a private developer. A high score on this factor means that the City should be able to undertake the development on their own resources, while a low score means that the development should probably be undertaken by a private, or at least external, organisation..

4.2.2 Second-level assessment: Minor factors

4.2.2.1 Environmental impact (overall)

This factor refers specifically to the overall environmental impacts the project might cause, and is related to the sustainability factor in 4.2.1.4 above. In practice, a score for this factor can only be determined through a detailed environmental assessment or EIA, but we have made a preliminary assessment based on local or international experience with the technology in question. Here, a high score means that the technology is expected to have only favourable or neutral impacts, and a low score means that the impacts are likely to be negative.

4.2.2.2 Availability of commercial financing

"Commercial financing" refers either to loans available from commercial banks, or to grants and loans available from specialist financing institutions such as DBSA or IDC. Scoring is based on the probability that the technology in question falls within the eligibility parameters of these institutions. As an example, new and high-risk technologies such as wave power would likely attract less support of this kind than established technologies such as solar hot water or use of biomass to produce heat in industry.

4.2.2.3 Eligibility for CDM or other non-commercial financing (TRECS/ RE Subsidy)

Scores on this factor also reflect eligibility for financing, in this case from mostly non-commercial sources, e.g. government or international subsidy programmes or market-based programmes such as CDM. Eligibility is a complex subject, and in this case we have reduced it to a fairly simple question: Have projects/technologies like this been supported by such programmes in the past? If not, what is the risk associated with trying to obtain funding now?

4.2.2.4 Regulatory constraints

Because most renewable energy technologies are so far unregulated, this factor is difficult to score. Generally speaking, we treat the existence of effective regulation as a positive factor, with the exception of few technologies where we think regulation may impede rapid adoption with no discernable benefits. We interpret the absence of regulation as a negative factor, as it may lead to poor quality control and unmitigated social or environmental impacts.

4.2.2.5 Availability of SA or international standards

Local South African standards for a number of RE technologies are in process of development (e.g. solar hot water and biofuels), and the prospect of such a standard is seen as a generally positive factor, i.e. a higher score. This is because the existence of an appropriate standard can be a market stimulus for some kinds of technology, removing uncertainties regarding efficiency and cost-effectiveness.

4.2.2.6 Local content in manufacture

This factor relates closely to others, such as sustainability and job creation potential. Because many RE technologies are in fairly early stages of development, local manufacture though possible may be quite far down the road. Accordingly, we score a technology high on this factor only if manufacture (or partial local content) is a present reality.

3.6 *Matrix for Short-list Selection*

The results of the scoring for the 27 long-list technologies are provided in the summary matrix following this section. Significantly, two technology choices score very low at the outset due to poor resource availability: *Coastal and Escarpment Wind Farms*.

The reason for this is that our examination of data on wind availability and constancy in both areas (section 3.1 above) shows average wind speeds well below the minimum required for economic operation.

Confirming this, feasibility studies elsewhere in South Africa have shown that for annual average wind speeds below 6m/s at a measured height of 10m to 15m it is very difficult to make a case for wind energy at present Eskom tariffs.[35] Initial indications, based on wind data from the Diab Wind Energy Atlas, the Eskom Wind Energy Atlas as well as data supplied by the Weather Bureau, are that the annual average wind speeds in the eThekwini area ranges from 2.5m/s to 4.5m/s.

This means that an economic case can only be made for wind energy in the eThekwini area if a tariff far in excess of existing tariffs is charged. The possibility of the municipality buying electricity at much higher rates as part of a “Green Energy” policy initiative is not ruled out, but the increase would have to be substantial.

[35] Provide source?

The RETSCREEN study (see annexure 4) confirms this assessment for eThekwini, demonstrating that the annual revenue from both power sales and carbon credits would fall well short of meeting annual operating and amortized capital costs, by a ratio of nearly 4:1. A price sensitivity analysis, also part of the RETSCREEN study, shows that a wind farm could only be financially feasible above an electricity price of R0.90/kWh (assuming no subsidies). Notably, the price negotiated for power purchased from a wind farm in one other South African municipality is R0.50/kWh, but the location in question has average wind speeds in excess of 6 km/h and would therefore deliver much larger amounts of electricity and would do so more reliably, which in turn affects price.

On this basis, we have concluded that wind energy resources in the eThekwini area are insufficient to meet the requirements of a commercially viable wind farm, and for this reason would fail to attract either commercial or non-commercial financing. Further research, including site-specific studies, may reach different conclusions, but we strongly advise against the development of wind farms in eThekwini until such studies are completed. The same argument would apply to small-scale wind projects or to household-sized micro-turbines, since the capital cost per kWh is higher for these technologies than for wind farms.

As noted previously, a third technology was eliminated following initial assessment of technology maturity: *cellulosic ethanol from pulp or wood waste*. This technology is still under development, and while highly touted by scientists around the world (as well as by the Stern Review), has still not reached full commercialisation.[36] A further factor influencing this decision is uncertainty concerning the availability of wood waste resources in the eThekwini municipality and the high cost of transporting waste from more distant sources[37]. An overall discussion of ethanol and other biofuels and the role they might play in eThekwini's RE programme is provided in section 6 of this report.

As the matrix shows, the total scores of the remaining 23 remaining technologies are widely variant. The resulting assessment leads to a short-list of 6 technologies (encompassing 9 different applications) as follows:

1. Solar thermal: low- and medium-income housing
2. Solar thermal: commercial buildings
3. Biofuels: bioethanol from cane and bio-diesel from algae
4. Sewage/wastewater: electricity generation and/or pelletised solids.
5. Bagasse to electricity
6. Charcoal from retorts

The selection of these technologies may be subject to further discussion and analysis but in our view represent the best mix for eThekwini and the most likely to lead to widespread adaptation. Notably, three of the technologies (nos. 3 and 5 above) involve use of resources which are not within the jurisdiction of the municipality, but which may provide opportunities for purchase of Green Power.

The remainder of this report is concerned with outlining the mechanisms and policy actions required to implement these technologies.

[36] Citation on cellulosic ethanol, to be provided.
[37] Reference from DME study to be provided.

eThekwini Renewable Energy Catalogue Project

Scoring Template for RE Technology Long-list

Technology	*Information Sources/ Technical Issues*	Resource Availability/ Reliability	Technical Maturity	Contributes to energy supply/security	Reduces strains to informal settlements	Potential to create jobs	Sustainability	Implementability for eThekwini Municipality	Environmental Impacts	Availability of Commercial Financing	Eligibility for CDM/Non commercial Financing	Regulatory Constraints	Availability of SA or International Standards	Local Content in Manufacture	Average Score	Comments/ Qualifications
Wind	Based on wind atlas + MET & Eskom															
-Wind farms-coastal	Limited site information	0	4	5	2	3	4	0	3	0	0	3	4	2	3.15	Resource availability poor due to low wind speeds in both
-Wind farms-escarpment	Limited site information	0	4	5	2	3	4	0	3	0	0	3	4	2	3.15	coastal and escarpment areas.
Solar	Based on MET data broken down by sub-regions															
Solar H/W																
-Low-income housing	Assumes 50-litre unit	4	3	4	5	4	4	5	5	1	5	3	5	3	5.31	Less cost-effective but excellent social value.
-Middle-income housing	Assumes 200-litre unit	4	3	4	0	3	4	5	5	2	5	3	5	3	4.69	Flagship project, with maximum economic benefits.
-Commercial buildings	Assumes 1000-litre unit	4	3	4	0	3	4	3	5	3	5	3	5	3	4.54	Flagship project, with maximum economic benefits.
-Utility approach	Assumes central units for large numbers	4	2	4	0	2	3	4	3	5	5	5	3	2	4.19	
Solar PV																
-Large arrays (central)	Amorphous technology	4	3	4	3	1	3	3	4	3	5	2	1	1	3.92	Not cost-effective at current tariffs
-Distributed (household)	Amorphous technology	4	3	4	1	3	4	2	4	1	4	2	1	1	3.69	Not cost-effective at current tariffs
Municipal Waste	Based on eThekwini data															
-Landfill-to-electricity	Established, opportunities from new or extended landfills	5	5	5	0	2	4	5	3	5	5	3	3	3	5.08	Established technology but new opportunities for Buffelsdrei landfill need to be explored.
-Landfill to heat	Alternative to electricity if users found			4	0	2	3	5	3	5	5	3	3	4	3.38	
Sewage Waste	Based on eThekwini data															
-Sewage waste to heat	Assumes flaring & heat reclaim	5	5	5	0	2	4	4	4	4	5	3	3	4	5.04	Extend existing practice to other facilities.
-Sewage waste to electricity	Extension of above	5	4	5	2	2	4	4	4	4	5	3	3	3	5.04	Need feasibility study to determine if volumes sufficient.
-Sewage solids to energy	Requires energy for drying of waste	5	3	4	0	2	3	4	4	4	5	3	2	3	4.35	Can be achieved thru carbonisation in retorts.
Wave/Ocean	Based on….?															
-Wave Power to electricity		5	2	3	0	1	4	3	5	4	5	4	2	1	3.96	Unproven: only one wave-power installation (in Spain), no sea
-Sea current power/electricity		5	1	3	0	1	4	3	5	3	5	4	2	1	3.73	current applications.
Biomass	Based on DME study 2004															
-Bagasse to electricity	Established technology but low feed-in tariff a barrier	4	5	4	0	4	4	2	4	5	4	5	4	3	4.92	Can be implemented through purchase of Green Power rather than direct investment.
-Wood/pulp waste to power	Source external to eThekwini	4	4	3	0	3	4	2	3	5	4	5	2	3	4.31	Insufficient data on resource base in eThekwini.
-Sawmill waste to power	Source external to eThekwini	4	3	3	0	3	4	2	3	5	5	5	3	3	4.31	Insufficient data on resource base in eThekwini.
-Charcoal production using retorts	Not a known source of fuel	3	5	3	5	5	4	4	3	2	4	3	2	5	5.12	Requires acceptance of new fuel; should probably be viewed as a transitional solution.
Biofuels for transport	Based on DME study 2006															
-Bio-ethanol from cane	Limited availability in metro area but otherwise ok	3	5	5	0	4	4	2	4	5	5	5	3	4	4.96	Can be implemented through purchase of Green Power rather than direct investment.
-Bio-ethanol from maize	High input energy costs, competition with food uses	0	5	2	0	2	2	1	2	2	1	3	3	2	2.58	Problematic because of high energy usage in production, competition with food crops.
-Cellulosic ethanol from pulp/wood waste	Still in experimental phase/high cost	3	0												0.46	Experimental stage only.
-Bio-diesel from seed oils	Competition with food uses	2	5	4	0	3	3	1	3	5	3	5	2	4	4.04	Competition with food crops a problem.
-Bio-diesel from algae	New technology but now in SA; can be adapted to urban settings, but requires industrial or mining land with no restrictions.	5	3	5	0	3	4	5	5	5	4	5	2	3	5.04	Offers opportunity for investment by City through making land available, possible levy on production.
-Bio-diesel from waste oil	Sources not proven;	3	4	2	3	4	3	3	3	2	5	3	2	4	4.27	Problems with potential carcinogens in used oils.
Biofuels/other																
-Ethanol gel for cooking	Treated separately; source assumed to be bio-ethanol				5	4	2	4	3	1	4	3	2	4	3.04	Promising but needs to be reviewed for safety concerns.

NOTE: All ratings on a 5-point scale, where 5-highest and 1=lowest.

NOTE: Scores highlighted in RED indicate short-list technologies, with score of 4.5 or higher.

5 Detailed Proposals for Short-listed RE Technologies

5.1 Solar Thermal

5.1.1 Low-income housing

The use of solar hot water systems in low-income housing is probably the most cost-effective way of reducing the burden of high electricity bills for South Africa's most vulnerable populations. Studies demonstrate that even low-income families have substantial hot water needs and that heating of water still comprises over 50% of typical monthly costs. The major barriers to acquisition of solar hot water systems for these families in the past have been:

1. The high initial cost of even relatively small (50-75 litre) systems, and the lack of alternative financing structures to reduce these costs.
2. The difficulties and risks of installing such systems on the structures of informal housing, particularly on unsupported roofs or roofs which lack proper fastenings..
3. The risk of damage and/or theft, particularly on low-level structures.

The decision by DME, CEF and Eskom to increase the market penetration of solar hot water systems is an important first step in alleviating barrier no. 1 in particular. Barriers 2 and 3 however remain, and there are no obvious ways to remove these barriers until informal housing is replaced by proper low-income housing under the RDP or other programmes.

Accordingly, we have limited our recommendation to implementing solar hot water systems in low-income (formal) housing, and separately (see next section) to implementing in middle-income housing. This is consistent with the approach being used by both DME and Eskom, and can build on the pilot solar hot water programme already instituted by eThekwini. [38]

Recommendation: Implement a solar water heating programme in formal low-income housing areas, starting with a pilot roll-out of 500 units, followed by a large-scale roll-out of up to 10,000 units. Although previous experience with this technology in the earlier eThekwini pilot of 2002-3 indicated that price was a significant barrier, the opportunity to introduce subsidies through DSM and CDM should alleviate this barrier. Moreover, the implementation can be done both with existing housing and with new housing under the municipality's roll-out, which we understand aims at constructing up to 16,000 units per year.

The proposed programme for low-income housing should have the following characteristics:

1. The proponent/implementing agency should be the municipality itself, using the mechanism of a special-purpose vehicle or SPV (probably Section 21). This is because attracting private finance to such a project would be extremely difficult if not impossible.
2. Financing should be via either amortised paybacks on electricity bills (for customers not on a pre-pay system) or (for the large majority on pre-pay) by a tariff levied on the pre-pay amount.

---

[38] This pilot project, implemented between 2002 and 2003, resulted in installation of approximately 100 solar water heaters in two low-income townships in eThekwini. The results of this pilot project showed that most households were unable to overcome the first-cost barrier (the actual cost was subsidized by a 50% grant), even though the simple payback was 12-24 months. (SOER, p. 105).

3. The SPV should be responsible for overall management, procurement and installation/maintenance, the latter implemented via a competitive tendering process with appropriate quality assurance guarantees.
4. The roll-out should be staggered, starting with a pilot programme of ±500 units in a single location or community, and proceeding to a total roll-out of up to 10 000 units.
5. The programme should initially focus on retrofit of existing formal housing. The roll-out of a similar programme for the municipality's re-housing initiative could also be included, but this would involve a much larger project (roughly 16,000 houses per annum).
6. Partial financing can be obtained from Eskom DSM, probably covering between 25-40% of the installed cost. Grants from REFSO could also be considered, but it is probable that the DSM financing will rule out REFSO financing.
7. Carbon financing should be considered for the balance of funding, using the concept of "programmatic CDM"[39] and with the SPE taking ownership of credits and re-distributing these to the homeowners to reduce their paybacks. Separate financing for the development of the CDM documentation may be required, though it is quite likely that donor assistance would be available to cover this.
8. A specification for the solar hot water units should be developed, preferably a single spec for all low-income houses, though allowances for gross differences in household size could be allowed. For example, spec 1 could be a 50-litre flat-plate unit for households of 4 persons or less; spec 2 would be an 85-litre flat-plate unit for larger households. Both would specify limited end-use capabilities, e.g. one shower and one central hot water faucet per household.
9. A more detailed feasibility assessment including cost estimates for the entire programme should be developed before proceeding further.[40]

Amortizing payment for solar installations through the pre-payment system might be complicated and will be more difficult to administer than payment for account customers; but we believe it is a workable solution which will solve the problem of the high front-end costs of solar for low-income customers.

To gain a better appreciation of how such a programme would work, the consultants developed an analysis of a 10,000 unit low-cost housing retrofit programme using RETSCREEN's solar hot water module. This resulted in the following outputs:

Low-Income Solar Hot Water Project	
Total number of units	10,000
Average unit size (in litres)	50
Avoided cost of heating energy	R0.36/kWh
Discount rate	10%
Total cost of installation	R 14,693,750
Subsidies (CDM/DSM)	R4,848,937
Net Cost	R9,844,813
Payback period (years)	13.2
MWh Saved (15 years)	16,111
Carbon credits earned (15 years)	23,852

[39] Programmatic CDM is a new concept, designed for projects where there are many small but relatively uniform activities (e.g. installation of solar systems) taking place over a long period of time, and with a single programme entity managing the project. This concept is expected to receive final approval from the CDM Executive Board in May of 2007. More information can be found at: www.cdm.unfccc.int

[40] In addition to reviewing different options for implementation, the feasibility study could also look at whether the project would qualify for CDM, in view of the impact of DSM financing on the additionality requirement.

The full RETSCREEN analysis is provided in Annexure 4.

To better understand how the programme would operate, the following table provides a proposed implementation schedule, with estimated itemized costs.

Low-Income Solar Programme					
Programme Components	*Elapsed Time (months from start)*	*Primary Responsibility*	*Financing Sources*	*Unit costs*	*Estimated Programme Cost*
Develop SPV	+3	eThekwini	eThekwini		*
Develop financial model	+6	eThekwini	eThekwini		*
Tender pilot	+8	SPV	eThekwini		*
Implement pilot (500 units)	+9-12	Contractors	eThekwini/ Donor?	R5,000	R2,500,000
Evaluate and revise	+13	eThekwini	eThekwini		*
Develop Prog CDM PDD	+14-16	Consultant	Donor or Buyer	R50,000	R50,000
Tender full programme	+18	SPV	Donor?	R50,000	R50,000
Roll-out full programme	+20	SPV	Donor/self-financed	R1,470	R14,700,000
Apply for Eskom DSM grant	?	SPV	Eskom	(R500)	(R500,000)
Inflow of CERS (verified)	Periodic	3rd Party (DOE)	CDM	R64/cer	(R15,265)
Ongoing management	+20-ongoing	SPV	Self-financed		included
Total (Net) cost					**R 16,784,735**
* Assumed to be undertaken by eThekwini staff, therefore no incremental cost.					

5.1.2 Middle-income housing

Solar hot water systems are probably best-suited to middle-income families with fairly high usage patterns and a standard billing (rather than pre-pay) contract with the utility. This would facilitate amortising the higher cost through the billing system, and would encourage families to choose systems that more accurately suited their needs and usage patterns.

Recommendation: Launch a solar hot water retrofit programme for middle-income households in eThekwini. This programme would have the following characteristics:

1. Development and design of the project would remain with the municipality, but implementation would be by turn-key contract awarded to one or more bidders on a competitive basis. This would ensure that the municipality retained control over the effectiveness of the project but did not have to develop a substantial administrative structure to deal with it.
2. The work programme specified for the turn-key contracts would include:
    a. Procurement and installation of systems meeting the project specifications.

    b. Applying for the Eskom DSM grant and using that source of funding to pay down part of the final cost to the consumer (this might require the bidder to demonstrate that they are registered as an ESCO with Eskom).
    c. Ongoing maintenance for a period of 5 years, possibly exercised through a warranty system from the manufacturer.
3. CDM credits might be applied for as part of the programmatic project developed for low-income housing, but this would have to be examined and if implemented, would probably be the responsibility of the municipality, who could provide proportional rebates for the credits through the electricity billing system.
4. Payment for the installed systems could also be amortised through the billing system, in which case the municipality (on behalf Durban Electricity) would pay the contractor directly for systems installed and recover the cost from the consumer over 10 years or longer.
5. This project would apply primarily to retrofit of existing housing, since there is nothing comparable in middle-income housing to the municipality's programme for construction of low-income housing. As well, most new middle-income developments are built by private contractors and privately financed. Ethekwini could however investigate the possibility of managing a solar hot water programme for new housing, as an extension to the low-income programme. This would be an incentive to developers who could offer this as an option to prospective buyers and perhaps tie the incremental costs into the bond.
6. As an initial target, the project would implement ±500 units and then roll out on the basis of 1000 units per year for up to 10 years. Units would be sized to family water usage requirements based on past records from the water department, but would generally be for 150-litres and up. All units would be evacuated-tube solar panels with integral pressurized and insulated tanks, feeding into the existing geyser system for the house. All would be roof-mounted.
7. As with the low-income project, a detailed feasibility study resulting in a business plan should precede approval of the concept.

As with the low-income programme, the consultants developed an analysis of a 10,000 unit programme using RETSCREEN's solar hot water module. This resulted in the following outputs:

Middle-Income Solar Hot Water Project	
Total number of units	10,000
Average unit size (in litres)	200
Avoided cost of heating energy	R0.36/kWh
Discount rate	10%
Total cost of installation	R84,939,400
Subsidies (CDM/DSM)	R25,481,820
Net Cost	R59,457,580
Payback period (years)	10.6
MWh Saved (15 years)	129,960
Carbon credits earned (15 years)	128,265

This analysis confirms that solar systems in middle-income housing have better paybacks than those for low-income housing. This is a function of household usage patterns, middle-income households generally having much higher usage per person than low-income. Indeed, using the RETSCREEN model, a sensitivity analysis would show that the payback for middle-income reduces significantly with increased usage.

It should also be noted the consultants have assumed a 30% subsidy from Eskom DSM, and a fairly low price for CERs (approximately US$10/CER). Both of these figures may be substantially increased, and if so the paybacks would reduce significantly.

The full RETSCREEN analysis for middle-income housing is provided in Annexure 4.

A proposed schedule for a middle-income solar roll-out, with estimated costs, is given in the following table:

Middle-Income Solar Programme					
Programme Components	*Elapsed Time (months from start)*	*Primary Responsibility*	*Financing Sources*	*Unit costs*	*Estimated Programme Cost*
Develop financial & management model	+6	eThekwini or consultant	eThekwini		*
Tender pilot	+8	eThekwini	eThekwini		*
Implement pilot (500 units)	+9-12	Contractors	eThekwini	R5,000	R4,500,000
Evaluate and revise	+13	eThekwini	eThekwini		*
Develop Prog CDM PDD	+14-16	Consultant	Buyer of credits	R50,000	R50,000
Tender full programme	+18	eThekwini	eThekwini	R50,000	R50,000
Roll-out full programme	+20	eThekwini	eThekwini or self-financed	R8,500	R85,000,000
Apply for Eskom DSM grant	?	eThekwini	Eskom	(R2,550)	(R25,550,000)
Inflow of CERS (verified)	Periodic	eThekwini	CDM	R64/cer	(R82,090)
Total (Net) Cost					**R 64,050,000**
* Assumed to be undertaken by eThekwini staff, therefore no incremental cost.					

It is important to note that although solar hot water systems are an important device for replacing fossil fuel usage and mitigating green house gas emissions, they should not be seen as a solution on their own. Other energy saving measures should be considered in tandem and incorporated if feasible. Examples of these are: geyser blankets and demand reduction measures such as ripple control.

5.1.3 Commercial buildings applications

Commercial buildings ideally should be broken down into a number of categories in that hot water requirements vary significantly among different types of building. For example the hot water usage in office buildings is minimal as compared to hotels and hospitals. However, even within each category there could be significant variations.

In addition, some categories of commercial buildings, e.g. hotels and hospitals, require a guaranteed supply of hot water and will therefore require backup in the form of electric geysers. Because geysers in such installations typically provide for the peak supply needs which solar cannot provide, solar hot water systems in commercial buildings are usually viewed solely as energy savings devices rather than as load-reduction technologies. This fact may in turn affect their eligibility for Eskom DSM grants, although the Eskom programme does allow for energy efficiency improvements as well as load reduction.[41]

Because of these unique features, implementation of a solar hot water programme in commercial or institutional buildings can only be undertaken following a detailed energy audit with the objective of identifying the full range of energy savings opportunities and including solar options within these recommendations. Putting solar hot water systems into buildings as a first-order improvement is risky and could lead to uneconomic decisions if the usage of hot water and the current supply costs are not fully understood.

Ideally, audits would also include evaluation of the possibility of using heat pumps, which are extremely efficient for bulk water heating and which can be used alongside solar systems to reduce peaks at a much lower cost to the end-user.

Recommendation: EThekwini Municipality should consider developing an audit-based programme for improving the energy efficiency of commercial/institutional buildings. The use of solar hot water systems in the city's existing building stock can be promoted indirectly by including solar hot water systems as one retrofit option, but would also ensure that the recommendations were tailored to each building's unique energy usage and locational features.

To ensure that this programme is implemented effectively and aggressively, it would be most appropriate to begin by undertaking a complete energy evaluation of the city's own building stock, and then identifying buildings (or types of buildings) where solar hot water systems would be most cost-effective. A gradual roll-out using an ESCO accredited by Eskom could then take place, utilizing the DSM programme to recover up to 50% of the project costs for both energy efficiency and solar improvements.

As a second option, the municipality should consider revising its building codes to stipulate that solar hot water must be included as an option in new commercial and local authority buildings, and that architects/engineers must demonstrate that they have considered this and included or excluded it on the basis of a realistic analysis including subsidy options.

5.2 Biofuels

5.2.1 Bioethanol from sugar cane/bagass to electricity

This section includes two projects from the short-list: (i) Production of bioethanol from cane and (ii) generation of electricity from bagasse (waste). The two are presented as one linked project because bagasse is an inevitable byproduct either of sugar milling or of the direct use of cane for ethanol production. As indicated earlier, cane-based ethanol is being developed in KZN and this production will be in addition to existing (and expanded) production of ethanol from molasses as a by-product of sugar production. In either of the two cases, generating surplus electricity from bagasse is technically possible (depending on the internal needs of the plant) and could significantly improve the profitability of ethanol production.

As noted previously, sugar cane is not a major resource in eThekwini itself, but rather in areas surrounding the municipality. The main reasons for looking to sugar for increased renewable energy

---

[41] However, the Eskom subsidy will be based on a diversity factor applied to demand for each type of unit; commercial buildings may fare poorly in this analysis, since their peak use periods tend to be different from the system peak.

supplies is (i) the opportunity provided to eThekwini to purchase "green electricity" from sugar or ethanol producers, and (ii) the opportunities for incentivising the use of bio-ethanol through a demonstration project involving the municipal vehicle fleets and possibly municipal employees.

Several developers in KZN are currently considering development of large-scale ethanol production from sugar cane, in some cases coupled with use of the bagasse waste to generate electricity both for plant use and for sale to the grid. At least one developer is planning a greenfields project using the cane directly, while several other projects involve use of waste molasses from the sugar production process in existing plants. As noted previously, a number of the major sugar producers (e.g. Tongaat Hulett) are reviewing options for sale of their surplus electricity to Green Power buyers. These developments offer unique opportunities for eThekwini participation in Renewable Energy.

Recommendations:

1. *eThekwini can participate in bio-ethanol production by developing agreements to purchase ethanol or ethanol blend in bulk from the major oil companies,* converting their (petrol-fuelled) municipal fleets either to ethanol use, or to use of the mandated 10% blend. The latter is by far the easiest option since it would involve no changes to the vehicle fleet: a 10% ethanol blend will run efficiently in existing engines. By mandating this change on behalf of the entire vehicle fleet—involving annual consumption of 5.8 million litres of petrol—eThekwini may be able to gain a price advantage and will also ensure that there is a key market driver for ethanol use. Further discussion of some of the constraints and opportunities around this recommendation is provided below. A similar proposal for bio-diesel is provided in the next section.

2. *eThekwini can mandate the purchase of green electricity from sugar or ethanol producers*. The municipality presently purchases 100% of its electricity from Eskom[42], although we understand that historically a small amount of surplus electricity was purchased from Tongaat-Hulett's Maidstone plant. To our knowledge, no other private PPAs have ever been utilized by the municipality in meeting its electricity needs. We therefore propose that the municipality attempt to re-establish the Maidstone arrangement either directly or through a Green Electricity buyer such as Amatola or Agama, and that they should simultaneously investigate the possibility of similar power purchase agreements with other sugar producers.

It is possible in principle for eThekwini to invest directly in bio-ethanol production or green power developments and thereby participate in the larger potential benefits as shareholders. We do not recommend this option because of the high risks involved and the limitations placed on the municipality's financial role by the MMFA. It would be both more appropriate and less risky to participate in these opportunities as contractual buyers of renewable energy through bulk purchase agreements.

There are several constraints of which the municipality should be aware if it embarks on either of these two initiatives:

For bio-ethanol, there may be slight decreases in the fuel efficiency of vehicles due to the lower calorific value of ethanol vs petrol[43]. This is partly offset by the very substantial reductions in greenhouse gas

---

[42] In addition, a total of 85 business and 28,499 domestic users fall outside the municipal supply arrangement and buy directly from Eskom.

[42] The total supplied to eThekwini is 11,000GWh. (Ethekwini Municipality State of Energy Report 2006, p. 80). Power is purchased at 275KV, and all reticulation is done by the municipality.

[43] Estimates of the amount of efficiency loss (for ethanol alone) vary, from 11% to 33%. This is compensated to some degree by the fact that ethanol has a higher flash point than petrol and thus marginally improves combustion.

emissions. Bio-ethanol will only be procurable from the existing fuel blenders, i.e. from the major petroleum companies, since the blending has to be done locally under strict quality controls and adjusted for local climatic conditions. This means in effect that even bulk buyers such as eThekwini could be purchasing blend which contains ethanol from many different sources, including those—e.g. maize and soya—which potentially compete with land used for food crops. Assuming that this is an important issue for eThekwini, it could only be overcome by purchasing ethanol stock directly from the producer and paying the blender to produce a special blend for the municipality's use alone. This is of course highly impractical and would substantially increase costs to the municipality.

On balance, we suggest that eThekwini exercise its considerable purchasing power to set an important example for ethanol/blend use, and then advocate the gradual replacement of any residual maize-based ethanol with local sugar-based ethanol. Since blending of ethanol is done locally, it is probable that the blend produced in KZN will be substantially based on sugar cane and molasses and will not be produced from any of the key food crops.

For green electricity, the major barrier is no longer regulatory but rather a matter of market maturity. Government through NERSA is working to facilitate the development of independent power producers, as noted above, and several sugar producers are actively seeking customers for their surplus power. However this process will only achieve sustainability if major buyers come into the market and commit themselves through firm Power Purchase Agreements with potential producers. There are risks in doing this, and green electricity will certainly be more expensive than electricity from an Eskom six-pack. But such purchases will achieve the dual purpose of helping to create a more stable market for new independent power producers, and (in a few cases) helping ethanol-from-sugar producers to achieve greater financial stability through power sales. And they will ensure that eThekwini is a leader among municipalities developing renewable energy options.

5.2.2 Bio-diesel from algae

This option is both simpler and more practical than the bio-ethanol option; but the technology is also new to South Africa, and according to some sources is still commercially unproven, so there are higher risks as a result.

For bio-diesel from algae, the resource is created by the project and there is no risk of competition with agricultural or forest land or food crops. Indeed, the concept is relatively environmentally benign because (i) it can use industrial or waste land and (ii) it has the parallel benefit of directly absorbing carbon dioxide and nitrogen oxides in the algae cultivation process, while also offsetting emissions from the use of hydrocarbon diesel in transport.[44]

More importantly for eThekwini, bio-diesel can be substituted directly for hydrocarbon diesel (i.e. it does not have to be used as part of a blend), although once again this must be done through established blenders/distributors as otherwise the use of this fuel would invalidate engine warranties.

Recommendations: EThekwini's participation in an algae-to-bio-diesel project can be implemented in two possible ways:

1. Facilitating the use of bio-diesel from this source as a bulk buyer on behalf of the municipality.
2. Incentivising the involvement of local industries in this process by making land available for algae production.

[44] In practice, however, the sequestration value of the algae process cannot be counted for purpose of documenting reduced GHG emissions, if the emissions reductions through offset of hydrocarbon diesel are also counted.

The first of these is the easiest and least costly to the municipality. In 2004, eThekwini's fleets used 26.8 million litres of hydrocarbon diesel per annum.[45] Assuming a 74% reduction in GHG emissions from substitution of bio-diesel at 100% substitution (no blend), this would result in a carbon savings of as much as 54,000 tonnes of CO_2-equivalent per year.[46] The incremental cost to the city would be negligible or zero, since bio-diesel has roughly equivalent calorific value to hydrocarbon diesel and if purchased through existing blenders will be sold at a competitive price and will not affect warranties.

The second is more complex, since the main incentive for algae oil producers to locate in eThekwini is the opportunity to reduce industrial emissions through trading off absorption of CO_2 and NOx, against gaining access to vacant industrial land near the major emitters. In eThekwini, such industries are typically privately rather than publicly-owned. The absence of a large municipal coal-fired power station (such as the Kelvin station in Johannesburg) is a further drawback, since these stations are ideal locations for algae production.

Nevertheless, we feel that the enormous potential of this technology for producing biofuels sustainably dictates that eThekwini make every effort to place itself in the forefront of this activity. The municipality's great advantage is also its greatest current liability: the large number of major emitters and the proximity of two of South Africa's major oil refineries. Ethekwini should therefore promote itself as a location for algae-based bio-diesel production by negotiating with the South African companies licensed to use this new technology and assisting them in identifying appropriate sites. This would also ensure that the sites meet the municipality's own environmental and social criteria for new industrial locations. By developing bulk purchase agreements tied to the introduction of these facilities, eThekwini would both incentivise the investment and ensure that its shares in the benefits by replacing its current diesel consumption with 100% bio-diesel.

The costs to eThekwini of option 1—bulk purchase for the municipal fleet—would be negligible, as noted above. However the municipality would need to establish contracts with the main bio-diesel suppliers or, more likely, with the refineries who will oversee blending and distribution. In this regard it should be noted that production of bio-diesel from algae will be highly decentralized, as the technology is fairly simple and is being implemented as a series of local production facilities by a number of small investors as well as by parastatals such as IDC and CEF.

NOTE: *Recent developments in the algae-based biodiesel industry—including the failure of the first company to enter this market—suggest that commercial implementation of this technology in South Africa may now be at least 3-4 years away. Accordingly, the authors propose that a more detailed assessment of biodiesel options should be made before proceeding with any specific technology.*

5.3 Sewage/wastewater

eThekwini already processes a substantial amount of its sewage and wastewater in digesters, producing sludge and methane gas and using some of this for re-heating the digesters. Although this may suggest that there is little opportunity for additional energy from this source, we believe that the combination of an expanding city population and opportunities to utilize methane for power as well as heating make this a high-priority project—although in the short time available for this project we were unable to do a detailed

[45] eThekwini Municipality Greenhouse Gas Inventory, 2004.

[46] This is an order-of-magnitude "tank to wheel" estimate and would have to be refined to include losses for energy inputs to the production process and leakage for items such as energy used in transport and storage. The reduction is based on IPCC emissions factors, which show that bio-diesel generates only 24% of the CO_2 emissions attributed to hydrocarbon diesel.

feasibility assessment of this option. We have also considered the possible use of sewage sludge from the digesters for charcoal production.

Section 3.3 above demonstrated that all methane produced by eThekwini Water & Sanitation is either vented to atmosphere or flared. While the amounts are fairly small, units with methane production in excess of 1,000 cubic meters per day should be evaluated for their potential to provide additional heat and/or electricity using gas engines. The municipality's familiarity with this technology given their experience with landfill gas-to-electricity production should make the evaluation process fairly simple and straightforward. If the current heating requirements are already being met by sludge gas (as at KwaMashu, Amazimtoti, Umbilo, Phoenix and Northern), the methane could be used exclusively for power generation.

The amount of electricity generated from this activity would be relatively small but could be designed to accommodate future expansion at each facility or, if this is impractical, would serve as a model for new facilities to be developed to accommodate wastewater/sewage requirements of eThekwini's growing population. Using the concept of programmatic CDM, eThekwini could initiate a new project which allowed for counting of carbon emissions reductions for any new project which arises from the development of methane utilization for energy at either current or future facilities—providing that they can establish that the project would be financially marginal without carbon credits, or that it was not already planned by the City.

If the amount of methane is found to be too small to warrant electricity generation, then consideration should be given to installing a small compression facility to provide bottled methane to nearby low-income populations as an alternative to use of wood and coal for cooking/heating.

Recommendation: Undertake a feasibility study[47] to assess the energy potential of excess sewage sludge, methane and sludge gas for power generation and other uses.

5.4 Use of sewage sludge

During the preparation of the final version of this report, additional information received from eThekwini made it clear that the potential for use of dried sewage solids/sludge was significant, given the substantial daily production of this waste material and the fact that it is accumulating rapidly without any obvious means of disposal. There are a number of options for use of dried sludge which require further investigation, including on-site use of the sludge for power generation and/or heat production, and sale of the sludge to industrial users, notably to the major cement producer in the region, Natal Portland Cement, as a substitute for coal in their kiln at Port Shepstone.

Recommendation: Undertake a feasibility assessment of alternative commercial uses of the dried sludge, comparing the cost/benefits of using it on-site with off-site sale or transfer.

The use of sludge solids for charcoal production is covered later in this section.

[47] This would be a more detailed feasibility study than has already been done in-house, and would include evaluation of both heat and electricity options.

5.5 Landfill gas

The use of landfill gas for electricity generation is an established technology of which eThekwini already has extensive experience. Develoment of the Buffelsdrei Landfill for this purpose would be a logical and appropriate extension of the municipality's previous work in this area, and should gain approval as a CDM project with minimal difficulty. However as the practice of utilising existing landfills for power generation is becoming common practice in South Africa (at least 5 other municipalities are pursuing projects of this kind), issues may arise around the additionality of such a project—particularly since this is already the standard for eThekwini.

To minimise this risk, we suggest that the municipality could use the Buffelsdrei site as a pilot for newer gas generation technologies, in particular pyrolysis—a technology currently in use in Europe but new to Africa. Using this technololgy would require a re-organisation of the current landfill practices at Buffelsdrei, since organic waste would have to be separated at the landfill and re-directed to a pyrolysis converter; the converter is the linked to a reciprocating gas engine and generator, much as with the current landfill-to-electricity projects in eThekwini.

If Buffelsdrei site is already generating some landfill gas, the higher calorific value gas generated by the pyrolysis unit could be blended with the lower calorific value gas from the landfill, to increase the overall energy (and carbon) value of the project.

The advantage to eThekwini would derive from the fact that this is a new technology and not common practice in South Africa, hence would easily pass the additionality test for CDM. As well, the project would produce a higher energy-value gas and avoid problems arising from gas leakage at the landfill site.

Further information on the pyrolysis technology as developed by one UK company, ENER-G Group, is available at www.energ.co.uk. Other examples can be provided from Denmark and Germany.

Recommendation: Undertake a feasibility study to compare the benefits of using existing landfill gas-to-electricity technology at the Buffelsdrei site with those from a pyrolysis-based system with organic materials separation. Include in the feasibility study the potential for increased benefits from CDM registration of the project and increased energy yield form the pyrolysis option.

5.6 Charcoal as a transitional fuel (from retorts)

Charcoal production from retorts can serve as a method for converting sewage and organic landfill waste into a useful energy source. Referring to section 3.3, retorts are ideal for this purpose. "Small" fit-for-purpose retorts can be placed at selected sewage treatment and landfill sites to convert sewage pellets and organic matter into charcoal. Retorts, as part of their operation produces large amounts of waste heat which can in turn be used to dry sewage pellets or sludge and organic matters to 25% moisture content, which would be suitable for carbonisation.

Referring to the table on the next page, it can be noted that a large number of eThekwini households use paraffin, wood, coal and animal dung for cooking and heating. Although they represent less than a quarter of total households (thanks to the municipality's ambitious electrification programme), the numbers are still significant and represent an important opportunity to introduce transitional fuels for heating and cooking.

Table 3.2.2.1: Breakdown of energy source for heating, cooking and lighting in households in 2001[19]

Energy Carrier/Source	Cooking		Heating		Lighting	
	Households	%	Households	%	Households	%
Electricity	566,333	72	562,725	72	627,305	80
Gas, LPG	12,666	2	6,255	<1	2,072	<1
Paraffin	179,778	23	113,215	14	22,531	3
Wood	17,930	2	55,389	7	-	-
Coal	2,501	<1	4,514	<1	-	-
Animal Dung	2,872	<1	1,531	<1	-	-
Solar	2,604	<1	2,686	<1	1,298	<1
Candles	-	-	-	-	132,464	17
Other	2,061	<1	40,430	5	1,075	<1
Total	**788,745**	**100**	**788,746**	**100**	**788,746**	**100**

The main reason rural and peri-urban populations use coal or wood or dung is because they are either free resources or can be bought in small quantities, appropriate for persons having low disposable incomes. Also any container large enough can be used to make a fire in. However, the health risks associated with these fuel sources are a major concern and several South African municipalities are actively seeking alternatives to the use of solid fuels, including propane and ethanol gel

Although paraffin does not produce the same amount of pollutants as coal, it is a volatile liquid and is considered to be a major fire risk, particularly in “shack” settlements.

More critically, the Free Basic Electricity subsidy has had little impact on the use of these fuels for cooking and heating because 50 KWh/month is barely adequate to meet lighting requirements and a small amount of water heating.

Charcoal as a Low Smoke Fuel and Transitional Fuel

The regulated introduction of charcoal--a “low smoke fuel”—to rural and peri-urban residents for cooking and heating purposes will result in significant reduction in the incidence of lung diseases, including tuberculosis among existing coal, wood, dung and paraffin users. It will also provide the eThekwini Municipality with an ideal opportunity to convert waste products such as organic landfill materials and pellets from sewage sludge into charcoal using specially designed retorts. The raw material for charcoal need not be limited to the above feedstock but can include any substance which can be carbonised such as wood, wood waste from saw mills, and paper waste.

We have estimated that if 50% of the households presently using coal, wood, dung or paraffin for heating and cooking instead use charcoal as a fuel source the net requirement for charcoal will be approximately 1 250 tonnes. This could easily be accommodated by carbonising the solid and pelletised waste from existing sewage processing in eThekwini, plus some wood waste from sawmills and paper production.

The major constraint to implementing a programme of this kind would be marketing. As most of the rural and peri-urban communities in eThekwini are not familiar with charcoal as a fuel, a significant education programme would be required, and the municipality would need to ensure that current retailers of coal and paraffin are included in the marketing and distribution process.

Recommendation: We suggest that a detailed feasibility study should be undertaken first, including both the production of charcoal from retorts at various sewage/wastewater processing sites, as well as from sawmill and other wood waste. The study should also include implementation of a marketing and distribution system to bring the new fuel to the rural/peri-urban user base.

6. Conclusions

6.1 General "Fit" with the eThekwini Energy Strategy

The eThekwini Energy Strategy is still under development, but it is expected that renewables will feature as a significant part of the final strategy. Elements of the strategy-in-progress were reviewed in section 2.1.2 above, and five key objectives singled out for further consideration:

1. Encourage job creation via the expansion of the renewable energy sector
2. Develop formal mechanisms for consideration of external costs when establishing energy supply alternatives
3. Develop novel finance initiatives, and other instruments, to encourage uptake renewable energy technologies
4. Continue use of alternative funding options to further renewable energy uptake for eThekwini Municipality
5. Establish a target and timeline for medium-term and long-term renewable use

Within the time and financial constraints of this assignment, we have only been able to consider the last 3 objectives. Further discussion with stakeholders and more detailed feasibility studies of some of the recommended options should lead to a more complete understanding and implementation plan for the first two objectives.

Realisation of the remaining 3 objectives is discussed in the following subsections.

Develop novel financing initiatives

Four of the major recommendations of this report—low-income and middle-income solar hot water programmes, and bio-ethanol and bio-diesel utilisation—require novel approaches to financing, although not necessarily new sources of finance.

To explain, all 4 of the recommended programmes are likely to be eligible for registration as Clean Development Mechanism projects and two will also certainly qualify for DSM support from Eskom. The CDM process is familiar to eThekwini as a result of its two landfill gas-to-electricity projects. DSM is less familiar, but there are numerous companies in the municipality who are qualified for DSM work as registered Energy Service Companies (ESCOs) and many more who will be seeking registration with Eskom as DSM incorporates solar water heating as a target area.

CDM can probably best be implemented through what is now referred to as "programmatic CDM", in essence a project activity that uses a single baseline (in this case, current electricity consumption for geysers) but permits a large number of households or other entities to adopt the technology over time and in many different locations. Programmatic CDM is explained further in section 6.1.4 below.

The two solar projects also require financing by the municipality, as the combination of DSM and CDM will not be sufficient to incentivise adoption of SWH for low-income families, and possibly not for middle-income families either. This is evident from the two RETSCREEN analyses, which that even with DSM and CDM, paybacks may be as long as 14 years for low-income families and for the lowest-income segments may still be unaffordable.

One approach to removing this barrier is to initiate a structured loan programme delivered by the municipal utility (Durban Electricity). For low-income households, this would probably have to operate through the pre-pay system, with a percentage levy deducted from each pre-payment. Because this system is already computerised, the percentage could vary according to the historic purchase levels of the card holder/household head. For middle-income households, the levy would be a simple monthly deduction from the utility bill. All levies would have to reflect the interest costs to the municipality of advancing this money, and would probably require that a commercial bank be involved to underwrite the programme.

The financing of the biofuels programmes is more straightforward. For bio-ethanol, our proposal concerns only a change in procurement strategy, as a means of incentivising bio-ethanol production. This could be done through direct contracts with the ethanol producers, but in the more likely event that eThekwini opts for purchasing blend to minimise the need for technical changes in their fleet, the contracts can be made directly with the blenders or bulk retailers, with the municipality stipulating the blend level.

For bio-diesel, there is the option to facilitate the introduction of an algae production facility in the eThekwini area, by making appropriate industrial or degraded land available (directly or through re-zoning) and situating the facility near a major source of NOx and CO_2 emissions. The municipality could also become an investor in the facility, though this would probably not be allowable under the conditions of the MMFA. A more appropriate path is to lock in the facility's production through a purchase contract for eThekwini's diesel fleet. Since the producers of bio-diesel may be a separate entity from the producers of the algae oil feedstock, it would also make good sense for the municipality to make this a condition of awarding licenses for local production. The existence of a major purchase contract will also provide the developer with additional leverage in obtaining project financing.

Continue use of alternative funding options

The immediate sense of this objective was to continue options that were already known to the city—CDM being one of these, as well as donor funding from key organisations such as DANIDA, who have provided support in the past. However, the CDM methodology we are suggesting for the solar water heating projects (i.e. programmatic CDM) is a novel one, and will require support for development both of the programme itself and the accompanying technical documentation. This could conceivably come from a number of sources, including (again) DANIDA, but also internally from SANERI or CEF. If the project is large enough, support from private buyers of carbon credits may also be possible.

CDM will also be an option for both the bio-ethanol and bio-diesel projects, but in both cases, the current developers are well aware of this and are pursuing it on their own, with the intention of using the CERs to offset their own investment costs. The RE grants from REFSA could also be obtained by these entities (as by developers of the other projects), but it is our understanding that the REFSA grant precludes use of the DSM grant, and vice versa.

Establish a target and timeline

The timeline for these initiatives depends largely on the ability of eThekwini management to get approval and provide budgets for the early implementation activities, e.g. funding of pre-feasibility and feasibility studies, negotiation with private partners, development of programme management structures, and pursuit of financing. For some of the projects proposed—e.g. bioethanol and bio-diesel—rapid implementation is essential, since some developers are already planning these projects and are identifying financing options and selecting locations. For solar water heating, the announcement of the full Eskom DSM programme is likely to happen at any time, and it would be well for the municipality to prepare the background studies to ensure that they are ready to apply for this funding as soon as it is available. Funding from CDM will take longer, but the basic methodology development can begin now based on a preliminary concept of each programme.

The setting of targets for Renewable Energy supply for eThekwini should ideally be done as part of a stakeholder-drive process, with different sectors identifying opportunities and assigning levels of market penetration. However there are at least 3 targets which can be identified immediately:

1. *Reducing electricity use for hot water heating in the domestic sector.* Based on an assumed 10,000-household target for each of the low- and middle-income sectors, the total amount of renewable energy delivered when the implementation is fully realised would be 10.2 GWh/annum for the two programmes. CO_2 reductions would be just under 11,000 tonnes.

2. *Using bio-ethanol from the municipal fleet at a 10% ratio*. This would result in a replacement of 580,000 litres of petrol assuming a 10% blend as proposed by the national government. Though small in total impact, the adoption of a bio-ethanol blend purchasing programme by the city would stimulate ethanol development in the KZN region and would probably result in much higher levels of savings in the long run. As a municipal target (including private users incentivised by the city policy), we suggest that 10 million litres of petrol replaced would be realistic. This would provide the benefit of reducing CO_2 emissions by approximately 25,000 tonnes per year, in addition to significant reductions in SOx and NOx emission from vehicles using this fuel.

3. *Displacing diesel with bio-diesel*. As noted, 100% replacement of hydrocarbon diesel with bio-diesel in the municipal fleet would result in a savings of approximately 54,000 tonnes of CO_2-equivalent per year, and a direct replacement of 26.8 million litres of hydrocarbon diesel with a renewable fuel having generally positive environmental impacts. There would be no financial benefit, and depending on the quality of the bio-diesel produced, there might be small efficiency losses resulting in marginally higher consumption. The value of this option is therefore limited to its sustainability or "green" impacts, i.e. its value in placing eThekwini in the forefront of national efforts to strengthen sustainable energy options.

Using Programmatic CDM

During the period of this study, a new approach to developing projects under the Clean Development Mechanism has finally been approved by the CDM Executive Board—so-called *Programmatic CDM*. This form of CDM is well-suited to the needs of municipalities, since it permits development of a *programme of project activities* rather than a single project activity, enabling individual projects to be added to the programme from time to time and over a potentially wide geographic area. The procedures for registration of programmes of activities have now been finalised, and a number of pilot projects are now being developed in South Africa.[48] As a general rule, programmatic CDM projects—like regular CDM projects—have to use approved baseline and monitoring methodologies and establish the additionality of the programme; but because they can apply to a large number of similar project activities, they tend to incur lower transaction costs for the participants.

To give a pertinent example: Under programmatic CDM, a solar hot water programme could be implemented for low-income housing which would permit similar activities—e.g. solar hot water for new housing In different locations and at different times—to be added as the municipality is able to afford them. The programme would be approved at the outset as a single CDM project, including a standard baseline and monitoring methodology, and individual housing projects meeting the programme's

[48] One of the authors of this study is currently preparing a background study on programmatic CDM for the SA National Energy Research Institute, which will include guidelines for development of programmatic CDM for various types of project.

eligibility requirements could be added to the programme from time to time, with credits accumulating from their individual start-up dates.

Programmatic CDM projects can last for up to 28 years, though the "crediting period" for individual project activities within the programme is limited to either 10 years or 3 x 7 years (21 years), as with regular CDM.

Further information on programmatic CDM and its potential application to renewable energy technologies can be made available to eThekwini as required.

6.2 Total Programme Costs

Total costs of the proposed RE programme for eThekwini are difficult to determine, since the approach we have suggested is conditional on certain policy decisions at both the national and local levels. For example, if the final biofuels strategy implemented by the national government provides a strong incentive for private investment in this sector (e.g. by maximizing returns on the fuel levy or using the equalization fund to further subsidise biofuels production costs), then production could rise fairly rapidly and both bio-ethanol and bio-diesel could be available for large-scale purchase within the current year.[49] A failure of government to meet the private sector's expectations would result in cancellation of a number of such projects and resulting higher prices for biofuels overall.

At the same time, realistic cost estimates for other biofuels and biogas developments (e.g. use of methane from digesters and landfills, use of sewage sludge for charcoal production or for fuel substitution in cement kilns) cannot be developed without more detailed feasibility studies.

Of the recommendations made in this report, only the 2 solar hot water projects for the domestic sector are sufficiently well-researched and market-ready to make a realistic estimate of costs. The cost of these two projects is estimated at R80,784,000, net to the municipality.

6.3 Institutional Changes Required

Experience in other jurisdictions suggests that ramping up a major RE programme as proposed here will invariably require key organisational and institutional changes. At present, responsibility for RE development is vested exclusively in the Environmental Management Department of the City Engineers' Office. Involvement of Durban Electricity and other key departments such as DSW has been channelled through the Environment Department and indications are that these other departments are not willing to take on primary responsibility for RE work at present.

The alternatives to the present arrangement are basically three:

1. Maintain responsibility within the Department of Environmental Management, creating additional specialist capacities and budget;

2. Create a special department, or sub-department, of the municipal government to deal with RE; or

3. Create a Special Purpose Vehicle (SPVs) for this purpose.

---

[49] As of 30 June 2007, the date of submission of this report, there were no public announcements concerning the final Biofuels Strategy, although Cabinet had been scheduled to meet and finalise the Strategy by mid-June.

The alternative of developing SPVs has already been suggested for specific projects, e.g. the low-income solar hot water programme. The rationale behind this suggestion is as much managerial as financial: By insulating the programme from normal departmental management, the municipality can hire staff more quickly, target specialist skills and ensure that programme results are monitored independently of overall department performance. As well, the risks arising from these projects can be ring-fenced, each project or its SPV having an independent business plan and independent sources of financing.

In our view, this strategy is superior to either implementing through the Environmental Management Department or re-allocating responsibilities to other departments of municipal government, e.g. giving Durban Electricity responsibility for solar water heating, because it minimises financial risk but also because it allows for the SPV to have more focused objectives and yet to be responsive to the municipality's needs. It is our view that electricity distributors or transmitters are inappropriate hosts for RE programmes, since their main concern is often to reduce peak demand rather than to achieve specific targets for renewable energy production.

Admittedly, this approach may not be appropriate for all of the projects we have recommended in this study. For example, it may be possible for DSW to oversee development of alternative uses for methane and also sewage sludge, since they already have substantial experience in working with landfill gas-to-electricity projects. On the other hand, a substantial expansion of this activity might overload the department's resources and reduce the effectiveness of programme delivery.

We therefore recommend that serious consideration be given to development of an SPV to both plan and implement RE activities in the municipality, possibly using a corporate model similar to that of the Central Energy Fund—i.e. a private company mandated by government (in this case, municipal government) to achieve certain goals with maximum efficiency. The alternative of a non-profit corporate entity should also be considered, though on balance, there is little advantage to this option if the SPV intends to stimulate involvement of private sector developers.

Annexure 1

List of acronyms

List of Acronyms and Abbreviations

CDM	Clean Development Mechanism
CEF	Central energy Fund
CO_2	Carbon dioxide
DANIDA	Danish International Development Agency
DBSA	Development Bank of Southern Africa
DEAT	Department of Environment and Tourism
DME	Department of Minerals & Energy
DNA	Designated National Authority (for CDM)
DSM	Demandside management
EBSAP	eThekwini Biodiversity Strategy and Action Plan
EESMP	eThekwini Environmental Services Management Plan
EU	European Union
FBE	Free Basic Electricity
GHG	Greenhouse Gases
GWh	Gigawatt-hours
IDC	Industrial Development Corporation
IDP	eThekwini Integrated Development Plan”
IPSA	Independent Power South Africa
IPPs	Independent Power Producers
KWh	Kilowatt-hours
KZN	Kwazulu Natal
MFMA	Municipal Finance Management Act
MW	Megawatts

KW	Kilowatts
Mtoe	Million tons of oil-equivalent
MWh	Megawatt-hours
NERSA	National Energy Regulator of South Africa
NIRP	National Integrated Resource Plan
NO_x	Nitrogen oxides
NREL	National Renewable Energy Laboratory (US)
PURPRA	Public Utility Regulatory Policies Act
PV	Photovoltaic
RDP	Reconstruction Development Programme
RE	Renewable Energy
REDS	Regional Electricity Distributors
REFSO	Renewable Energy Subsidy Office
SABS	South African Bureau of Standards
SANERI	South African National Energy Research Institute
SANS	South African National Standard
SGC	Subsidy Governance Committee
SOER	eThekwini State of Energy Report 2006
SPV	Special Purpose Vehicle
TRECS	Tradable Renewable Energy Certificates
VOCs	Volatile organic compounds

Annexure 2

Contact list

Will Cawood	Durban Alternative Energy Company
Mohammed Dildar	Manager : Works/eThekwini Water and Sanitation Unit
Rafig Gafoor	Environmental Manager Mondi Business Paper
Julia Glenday	Environmental Management/eThekwini
Colin Hawith	DSW/eThekwini
Quentin Hurt	Eco-Serv
Muna Lakhani	Institute of Zero Waste in Africa
Manisha Maganlal	Environmental Management/eThekwini
David Mercer	Enviros
Alan Munn	Engen Refineries
Gladys Naylor	Mondi Business Paper
Richard Pocock	Independent consultant
Jessica Rich	Environmental Management/eThekwini
Linsey Strachan	Landfill Manager/eThekwini
Roy Wienand	Durban Electricity
Arnaud Wienese	Sugar Research Institute

Annexure 3:

Pricing Information on Evacuated-Tube Solar Hot Water Systems

Model NO	Volum (L)	No.of Tube(pcs)	Price (Rand)
HW15A	115	15	3377.5
HW18A	140	18	3895
HW21A	160	21	4378
HW24A	180	24	4878.25
HW30A	220	30	5844.25
HW12B	125	12	3826
HW15B	155	15	4533.25
HW18B	185	18	5257.75
HW21B	215	21	5947.75
HW24B	240	24	6672.25
HW30B	300	30	8104
TW15A	115	15	3222.25
TW18A	140	18	3670.75
TW21A	160	21	4119.25
TW24A	180	24	4567.75
TW30A	220	30	5464.75
JX15B	155	15	4429.75
JX18B	185	18	5119.75
JX21B	215	21	5568.25
JX15B	130	15	3670.75
JX18B	155	18	4205.5
JX21B	180	21	4740.25

Model NO	Volum (L)	No.of Tube(pcs)	Price (Rand)
JX24B	205	24	5292.25
BJ15A	85	15	2946.25
BJ18A	100	18	3343
BJ21A	115	21	3757
BJ24A	130	24	4153.75
XF15A	85	15	3101.5
XF18A	100	18	3532.75
XF21A	115	21	3946.75
XF15B	130	15	4343.5
XF18B	155	18	4981.75
XF21B	180	21	5689
XT16E	240	16	7483
XT20E	300	20	8983.75
XT24E	360	24	10484.5

Annexure 4

RETSCREEN SUMMARIES

Wind Energy Results

RETScreen® Energy Model - Wind Energy Project

Training & Support

Units: Metric

Site Conditions		Estimate	Notes/Range
Project name		**eThekwini**	See Online Manual
Project location		**Durban**	
Wind data source		Wind speed	
Nearest location for weather data		Airport	See Weather Database
Annual average wind speed	m/s	4.1	
Height of wind measurement	m	13.0	3.0 to 100.0 m
Wind shear exponent	-	0.14	0.10 to 0.40
Wind speed at 10 m	m/s	4.0	
Average atmospheric pressure	kPa	101.3	60.0 to 103.0 kPa
Annual average temperature	°C	18	-20 to 30 °C

System Characteristics		Estimate	Notes/Range
Grid type	-	Central-grid	
Wind turbine rated power	kW	850	Complete Equipment Data sheet
Number of turbines	-	18	
Wind plant capacity	kW	15,300	
Hub height	m	49.0	6.0 to 100.0 m
Wind speed at hub height	m/s	4.9	
Wind power density at hub height	W/m²	142	
Array losses	%	3%	0% to 20%
Airfoil soiling and/or icing losses	%	2%	1% to 10%
Other downtime losses	%	2%	2% to 7%
Miscellaneous losses	%	3%	2% to 6%

Annual Energy Production		Estimate Per Turbine	Estimate Total	Notes/Range
Wind plant capacity	kW	850	15,300	
	MW	0.850	15.300	
Unadjusted energy production	MWh	1,064	19,158	
Pressure adjustment coefficient	-	1.00	1.00	0.59 to 1.02
Temperature adjustment coefficient	-	0.99	0.99	0.98 to 1.15
Gross energy production	MWh	1,054	18,966	
Losses coefficient	-	0.90	0.90	0.75 to 1.00
Specific yield	kWh/m²	448	448	150 to 1,500 kWh/m²
Wind plant capacity factor	%	13%	13%	20% to 40%
Renewable energy delivered	MWh	952	**17,139**	
	GJ	3,428	61,700	
				Complete Cost Analysis sheet

RETScreen® Cost Analysis - Wind Energy Project

Search Marketplace

Type of project:	Custom	Currency:	South Africa
		Second currency:	Euro symbol
Cost references:	Second currency	Rate: ZAR/€	0.17900

Initial Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	% Foreign	Foreign Amount
Feasibility Study							
Site investigation	p-d	8.0	ZAR 3,000	ZAR 24,000		0%	€ -
Wind resource assessment	met tower	1	ZAR 75,000	ZAR 75,000		0%	€ -
Environmental assessment	p-d	1.0	ZAR 380,000	ZAR 380,000		0%	€ -
Preliminary design	p-d	5.0	ZAR 3,000	ZAR 15,000		0%	€ -
Detailed cost estimate	p-d	5.0	ZAR 3,000	ZAR 15,000		0%	€ -
GHG baseline study and MP	project	1	ZAR 120,000	ZAR 120,000		0%	€ -
Report preparation	p-d	4.0	ZAR 3,000	ZAR 12,000		0%	€ -
Project management	p-d	10.0	ZAR 3,000	ZAR 30,000		0%	€ -
Travel and accommodation	p-trip	4	ZAR 3,000	ZAR 12,000		0%	€ -
Other - Feasibility study	Cost	1	ZAR 15,000	ZAR 15,000		0%	€ -
Sub-total:				**ZAR 698,000**	0.5%	0%	€ -
Development							
PPA negotiation	p-d	10.0	ZAR 3,000	ZAR 30,000		0%	€ -
Permits and approvals	p-d	10.0	ZAR 3,000	ZAR 30,000		0%	€ -
Land rights	project	1	ZAR 20,000	ZAR 20,000		180%	€ 201,117
Land survey	p-d	5.0	ZAR 3,000	ZAR 15,000		0%	€ -
GHG validation and registration	project	1	ZAR 65,000	ZAR 65,000		0%	€ -
Project financing	p-d	10.0	ZAR 3,000	ZAR 30,000		0%	€ -
Legal and accounting	p-d	15.0	ZAR 3,000	ZAR 45,000		0%	€ -
Project management	p-yr	1.00	ZAR 180,000	ZAR 180,000		0%	€ -
Travel and accommodation	p-trip	8	ZAR 3,000	ZAR 24,000		0%	€ -
Other - Development	Cost	0	ZAR -	ZAR -		0%	€ -
Sub-total:				**ZAR 439,000**	0.3%	8%	€ 201,117
Engineering							
Wind turbine(s) micro-siting	p-d	2.0	ZAR 3,000	ZAR 6,000		0%	€ -
Mechanical design	p-d	5.0	ZAR 3,000	ZAR 15,000		0%	€ -
Electrical design	p-d	4.0	ZAR 3,000	ZAR 12,000		0%	€ -
Civil design	p-d	5.0	ZAR 3,000	ZAR 15,000		0%	€ -
Tenders and contracting	p-d	15.0	ZAR 2,500	ZAR 37,500		0%	€ -
Construction supervision	p-yr	0.50	ZAR 220,000	ZAR 110,000		0%	€ -
Other - Engineering	Cost	0	ZAR -	ZAR -		0%	€ -
Sub-total:				**ZAR 195,500**	0.1%	0%	€ -
Energy Equipment							
Wind turbine(s)	kW	15,300	ZAR 7,000	ZAR 107,100,000		100%	€ 598,324,022
Spare parts	%	1.5%	ZAR 107,100,000	ZAR 1,606,500		100%	€ 8,974,860
Transportation	turbine	18	ZAR 128,000	ZAR 2,304,000		50%	€ 6,435,754
Other - Energy equipment	Cost	0	ZAR -	ZAR -		100%	€ -
Sub-total:				**ZAR 111,010,500**	78.6%	99%	€ 613,734,637
Balance of Plant							
Wind turbine(s) foundation(s)	turbine	18	ZAR 300,000	ZAR 5,400,000		0%	€ -
Wind turbine(s) erection	turbine	18	ZAR 100,000	ZAR 1,800,000		20%	€ 2,011,173
Road construction	km	3.50	ZAR 30,000	ZAR 105,000		0%	€ -
Transmission line	km	1.00	ZAR 1,800,000	ZAR 1,800,000		0%	€ -
Substation	project	1	ZAR 1,500,000	ZAR 1,500,000		0%	€ -
Control and O&M building(s)	building	1	ZAR 300,000	ZAR 300,000		20%	€ 335,196
Transportation	project	1	ZAR 153,600	ZAR 153,600		0%	€ -
Other - Balance of plant	Cost	0	ZAR -	ZAR -		0%	€ -
Sub-total:				**ZAR 11,058,600**	7.8%	4%	€ 2,346,369
Miscellaneous							
Training	p-d	5.0	ZAR 3,000	ZAR 15,000		50%	€ 41,899
Commissioning	p-d	10.0	ZAR 3,000	ZAR 30,000		50%	€ 83,799
Contingencies	%	10%	ZAR 123,446,600	ZAR 12,344,660		50%	€ 34,482,291
Interest during construction	8.0%	12 month(s)	ZAR 135,791,260	ZAR 5,431,650		0%	€ -
Sub-total:				**ZAR 17,821,310**	12.6%	35%	€ 34,607,989
Initial Costs - Total				**ZAR 141,222,910**	100.0%	83%	€ 650,890,112

Annual Costs (Credits)	Unit	Quantity	Unit Cost	Amount	Relative Costs	% Foreign	Foreign Amount
O&M							
Land lease	project	1	ZAR 40,000	ZAR 40,000		0%	€ -
Property taxes	project	1	ZAR 20,000	ZAR 20,000		0%	€ -
Insurance premium	project	1	ZAR 250,000	ZAR 250,000		0%	€ -
Transmission line maintenance	%	1.5%	ZAR 3,300,000	ZAR 49,500		0%	€ -
Parts and labour	kWh	17,138,889	ZAR 0.005	ZAR 85,694		0%	€ -
GHG monitoring and verification	project	1	ZAR 85,000	ZAR 85,000		0%	€ -
Community benefits	-	1	ZAR 220,000	ZAR 220,000		0%	€ -
Travel and accommodation	p-trip	12	ZAR 4,000	ZAR 48,000		0%	€ -
General and administrative	%	6%	ZAR 798,194	ZAR 47,892		0%	€ -
Other - O&M	Cost	0	ZAR -	ZAR -		0%	€ -

RETScreen® Financial Summary - Wind Energy Project

Annual Energy Balance

Project name		eThekwini			
Project location		Durban			
Renewable energy delivered	MWh	17,139	Net GHG reduction	t_{CO2}/yr	17,216
Excess RE available	MWh	-			
Firm RE capacity	kW	-	Net GHG emission reduction - 6 yrs	t_{CO2}	103,298
Grid type		Central-grid	Net GHG emission reduction - 20 yrs	t_{CO2}	344,327

Financial Parameters

Avoided cost of energy	ZAR/kWh	0.3500	Debt ratio	%	100.0%
RE production credit	ZAR/kWh	-	Debt interest rate	%	10.0%
			Debt term	yr	10
GHG emission reduction credit	ZAR/t_{CO2}	35.0	Income tax analysis?	yes/no	Yes
GHG reduction credit duration	yr	6	Effective income tax rate	%	30.0%
GHG credit escalation rate	%	0.0%	Loss carryforward?	yes/no	Yes
			Depreciation method	-	Straight-line
			Depreciation tax basis	%	50.0%
Energy cost escalation rate	%	0.0%			
Inflation	%	0.0%	Depreciation period	yr	3
Discount rate	%	0.0%	Tax holiday available?	yes/no	No
Project life	yr	20			

Project Costs and Savings

Initial Costs			
Feasibility study	0.5%	ZAR	698,000
Development	0.3%	ZAR	439,000
Engineering	0.1%	ZAR	195,500
Energy equipment	78.6%	ZAR	111,010,500
Balance of plant	7.8%	ZAR	11,058,600
Miscellaneous	12.6%	ZAR	17,821,310
Initial Costs - Total	100.0%	**ZAR**	**141,222,910**
Incentives/Grants		ZAR	-
Periodic Costs (Credits)			
Drive train		ZAR	150,000
Blades		ZAR	50,000
		ZAR	-
End of project life - Credit		ZAR	-

Annual Costs and Debt		
O&M	ZAR	930,695
Debt payments - 10 yrs	ZAR	22,983,378
Annual Costs and Debt - Total	**ZAR**	**23,914,073**
Annual Savings or Income		
Energy savings/income	ZAR	5,998,611
Capacity savings/income	ZAR	-
GHG reduction income - 6 yrs	ZAR	602,572
Annual Savings - Total	**ZAR**	**6,601,183**
Schedule yr # 10,20		
Schedule yr # 15		

Financial Feasibility

			Calculate energy production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	-11.8%	Energy production cost	ZAR/kWh	0.7153
After-tax IRR and ROI	%	-11.8%	Calculate GHG reduction cost?	yes/no	Yes
Simple Payback	yr	24.9	GHG emission reduction cost	ZAR/t_{CO2}	364
Year-to-positive cash flow	yr	immediate	Project equity	ZAR	-
Net Present Value - NPV	ZAR	(125,210,019)	Project debt	ZAR	141,222,910
Annual Life Cycle Savings	ZAR	(6,260,501)	Debt payments	ZAR/yr	22,983,378
Benefit-Cost (B-C) ratio	-	#DIV/0!	Debt service coverage	-	0.21

RETScreen® Equipment Data - Wind Energy Project

Wind Turbine Characteristics		Estimate	Notes/Range
Wind turbine rated power	kW	850	*See Product Database*
Hub height	m	49.0	6.0 to 100.0 m
Rotor diameter	m	52	7 to 80 m
Swept area	m²	2,124	35 to 5,027 m²
Wind turbine manufacturer		Vestas Wind Systems	
Wind turbine model		VESTAS V52/850kW	
Energy curve data source	-	Standard	Rayleigh wind distribution
Shape factor	-	2.0	

Wind Turbine Production Data

Wind speed (m/s)	Power curve data (kW)	Energy curve data (MWh/yr)
0	0.0	-
1	0.0	-
2	0.0	-
3	0.0	201.5
4	25.5	564.4
5	67.4	1,098.0
6	125.0	1,731.6
7	203.0	2,384.9
8	304.0	3,000.3
9	425.0	3,544.0
10	554.0	3,996.7
11	671.0	4,348.6
12	759.0	4,598.7
13	811.0	4,753.3
14	836.0	4,824.3
15	846.0	4,825.7
16	849.0	-
17	850.0	-
18	850.0	-
19	850.0	-
20	850.0	-
21	850.0	-
22	850.0	-
23	850.0	-
24	850.0	-
25	850.0	-

Yearly Cash Flows			
Year	**Pre-tax**	**After-tax**	**Cumulative**
#	**ZAR**	**ZAR**	**ZAR**
0	-	-	-
1	(17,312,890)	(17,312,890)	(17,312,890)
2	(17,312,890)	(17,312,890)	(34,625,779)
3	(17,312,890)	(17,312,890)	(51,938,669)
4	(17,312,890)	(17,312,890)	(69,251,559)
5	(17,312,890)	(17,312,890)	(86,564,448)
6	(17,312,890)	(17,312,890)	(103,877,338)
7	(17,915,462)	(17,915,462)	(121,792,800)
8	(17,915,462)	(17,915,462)	(139,708,261)
9	(17,915,462)	(17,915,462)	(157,623,723)
10	(18,065,462)	(18,065,462)	(175,689,185)
11	5,067,917	5,067,917	(170,621,268)
12	5,067,917	5,067,917	(165,553,352)
13	5,067,917	5,067,917	(160,485,435)
14	5,067,917	5,067,917	(155,417,519)
15	5,017,917	5,017,917	(150,399,602)
16	5,067,917	5,067,917	(145,331,686)
17	5,067,917	5,067,917	(140,263,769)
18	5,067,917	5,067,917	(135,195,852)
19	5,067,917	5,067,917	(130,127,936)
20	4,917,917	4,917,917	(125,210,019)

Photovoltaics Results

RETScreen® Energy Model - Photovoltaic Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		**Domestic**	See Online Manual
Project location		**Durban**	
Nearest location for weather data	-	Durban/Louis Botha	Complete SR&SL sheet
Latitude of project location	°N	-30.0	-90.0 to 90.0
Annual solar radiation (tilted surface)	MWh/m²	1.19	
Annual average temperature	°C	20.6	-20.0 to 30.0

System Characteristics		Estimate	Notes/Range
Application type	-	**On-grid**	
Grid type	-	Central-grid	
PV energy absorption rate	%	100.0%	
Minimum battery temperature	°C	15.0	0.0 to 15.0
PV Array			
PV module type	-	mono-Si	
PV module manufacturer / model #		XXXXXXX	See Product Database
Nominal PV module efficiency	%	11.4%	4.0% to 15.0%
NOCT	°C	45	40 to 55
PV temperature coefficient	% / °C	0.40%	0.10% to 0.50%
Miscellaneous PV array losses	%	5.0%	0.0% to 20.0%
Nominal PV array power	kWp	**5.00**	
PV array area	m²	43.9	
Genset			
Charger (AC to DC) efficiency	%	95%	80% to 95%
Suggested genset capacity	kW	6.6	
Genset capacity	kW	**7.5**	
Fuel type	-	Diesel (#2 oil) - L	
Specific fuel consumption	L/kWh	0.46	
Power Conditioning			
Miscellaneous power conditioning losses	%	5%	0% to 10%

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
Energy from genset (Diesel (#2 oil) - L)	MWh	**1.136**	
Specific yield	kWh/m²	91.9	
Overall PV system efficiency	%	7.7%	
PV system capacity factor	%	9.2%	
Renewable energy collected	MWh	5.040	
Renewable energy delivered	MWh	**4.032**	
	kWh	4,032	
Excess RE available	MWh	**0.000**	
			Complete Cost Analysis sheet

Version 3.2

NRCan/CETC - Varennes

RETScreen® Solar Resource and System Load Calculation - Photovoltaic Project

Site Latitude and PV Array Orientation		Estimate	Notes/Range
Nearest location for weather data		Durban/Louis Botha	*See Weather Database*
Latitude of project location	°N	-30.0	-90.0 to 90.0
PV array tracking mode	-	Fixed	
Slope of PV array	°	30.0	0.0 to 90.0
Azimuth of PV array	°	0.0	0.0 to 180.0

Monthly Inputs

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average daily radiation in plane of PV array (kWh/m²/d)	Monthly solar fraction (%)
January	1.00	5.56	24.1	5.09	-
February	1.00	5.47	24.3	4.68	-
March	1.00	4.92	23.7	3.74	-
April	1.00	3.97	21.6	2.53	-
May	1.00	3.31	19.1	1.57	-
June	1.00	3.03	16.6	1.19	-
July	1.00	3.17	16.5	1.36	-
August	1.00	3.72	17.7	2.15	-
September	1.00	4.06	19.2	2.98	-
October	1.00	4.75	20.1	3.95	-
November	1.00	5.11	21.4	4.61	-
December	1.00	5.81	23.1	5.40	-

		Annual	Season of use
Solar radiation (horizontal)	MWh/m²	1.61	1.61
Solar radiation (tilted surface)	MWh/m²	1.19	1.19
Average temperature	°C	20.6	20.6

Load Characteristics		Estimate	Notes/Range
Application type	-	On-grid	

Return to Energy Model sheet

RETScreen® Financial Summary - Photovoltaic Project

Annual Energy Balance

Project name		Domestic			
Project location		Durban	Nominal PV array power	kWp	5.00
Renewable energy delivered	MWh	4.032	Net GHG reduction	t_{CO2}/yr	3.82
Firm RE capacity	kW	3.000	Net GHG emission reduction - 20 yrs	t_{CO2}	76.34
Application type		On-grid			

Financial Parameters

Avoided cost of energy	Rs/kWh	0.360	Debt ratio	%	15.0%
RE production credit	Rs/kWh	-	Debt interest rate	%	11.0%
			Debt term	yr	20
GHG emission reduction credit	Rs/t_{CO2}	-	Income tax analysis?	yes/no	No
Avoided cost of capacity	Rs/kW-yr	120			
Energy cost escalation rate	%	5.0%			
Inflation	%	2.5%			
Discount rate	%	9.0%			
Project life	yr	20			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	4.4%	Rs	2,500	O&M	Rs	3,200
Development	4.4%	Rs	2,500	Fuel	Rs	1,295
Engineering	2.6%	Rs	1,500	Debt payments - 20 yrs	Rs	1,069
Energy equipment	40.0%	Rs	22,695	**Annual Costs and Debt - Total**	**Rs**	**5,564**
Balance of equipment	40.1%	Rs	22,761			
Miscellaneous	8.5%	Rs	4,803	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**Rs**	**56,759**	Energy savings/income	Rs	1,452
				Capacity savings/income	Rs	360
Incentives/Grants		Rs	16,500			
				Annual Savings - Total	**Rs**	**1,812**
Periodic Costs (Credits)						
Inverter Repair/Replacement		Rs	2,000	Schedule yr # 10,20		
		Rs	-			
		Rs	-			
End of project life -		Rs	-			

Financial Feasibility

			Calculate energy production cost?	yes/no	Yes
Pre-tax IRR and ROI	%	negative	Energy production cost	Rs/kWh	1.33
After-tax IRR and ROI	%	negative	Calculate GHG reduction cost?	yes/no	Yes
Simple Payback	yr	(15.0)	GHG emission reduction cost	Rs/t_{CO2}	2,086
Year-to-positive cash flow	yr	more than 20	Project equity	Rs	48,245
Net Present Value - NPV	Rs	(72,691)	Project debt	Rs	8,514
Annual Life Cycle Savings	Rs	(7,963)	Debt payments	Rs/yr	1,069
Benefit-Cost (B-C) ratio	-	(0.51)	Debt service coverage	-	(7.03)

Version 3.2

Yearly Cash Flows			
Year	Pre-tax	After-tax	Cumulative
#	Rs	Rs	Rs
0	(31,745)	(31,745)	(31,745)
1	(3,815)	(3,815)	(35,560)
2	(3,880)	(3,880)	(39,440)
3	(3,946)	(3,946)	(43,386)
4	(4,013)	(4,013)	(47,399)
5	(4,082)	(4,082)	(51,481)
6	(4,152)	(4,152)	(55,633)
7	(4,224)	(4,224)	(59,857)
8	(4,297)	(4,297)	(64,154)
9	(4,372)	(4,372)	(68,527)
10	(7,009)	(7,009)	(75,536)
11	(4,527)	(4,527)	(80,063)
12	(4,607)	(4,607)	(84,669)
13	(4,688)	(4,688)	(89,357)
14	(4,771)	(4,771)	(94,128)
15	(4,856)	(4,856)	(98,984)
16	(4,942)	(4,942)	(103,927)
17	(5,031)	(5,031)	(108,957)
18	(5,121)	(5,121)	(114,078)
19	(5,213)	(5,213)	(119,290)
20	(8,583)	(8,583)	(127,874)

Low-Income Solar WH Results

RETScreen® Energy Model - Solar Water Heating Project

Training & Support

Site Conditions		Estimate	Notes/Range
Project name		**Low Income Housing**	*See Online Manual*
Project location		**eThikweni**	
Nearest location for weather data		Durban/Louis Botha	*Complete SR&HL sheet*
Annual solar radiation (tilted surface)	MWh/m²	1.28	
Annual average temperature	°C	20.6	-20.0 to 30.0
Annual average wind speed	m/s	#DIV/0!	
Desired load temperature	°C	60	
Hot water use	L/d	1,500,000	
Number of months analysed	month	12.00	
Energy demand for months analysed	MWh	25,161.36	

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	**Electricity**	
Water heating system seasonal efficiency	%	100%	50% to 190%
Solar Collector			
Collector type	-	Evacuated	*See Technical Note 1*
Solar water heating collector manufacturer		XXXXXXXX	*See Product Database*
Solar water heating collector model		XXXXXXXX	
Gross area of one collector	m²	0.65	1.00 to 5.00
Aperture area of one collector	m²	0.56	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.76	0.40 to 0.80
Fr UL coefficient	(W/m²)/°C	5.93	0.30 to 3.00
Temperature coefficient for Fr UL	(W/(m·°C)²)	0.01	0.000 to 0.010
Suggested number of collectors		26661	
Number of collectors		5000	
Total gross collector area	m²	3250.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	90.0	37.5 to 100.0
Storage capacity	L	252,000	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	No	
Suggested pipe diameter	mm	N/A	8 to 25 or PVC 35 to 50
Pipe diameter	mm	38	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m²	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	1	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
SWH system capacity	kW_{th}	1,960	
	MWth	1.960	
Pumping energy (electricity)	MWh	**0.00**	
Specific yield	kWh/m²	496	
System efficiency	%	39%	
Solar fraction	%	6%	
Renewable energy delivered	MWh	**1,611.12**	
	GJ	5,800.03	
			Complete Cost Analysis sheet

RETScreen® Solar Resource and Heating Load Calculation - Solar Water Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Durban/Louis Botha	*See Weather Database*
Latitude of project location	°N	-30.0	-90.0 to 90.0
Slope of solar collector	°	25.0	0.0 to 90.0
Azimuth of solar collector	°	0.0	0.0 to 180.0

Monthly Inputs

(Note: 1. Cells in grey are not used for energy calculations; 2. Revisit this table to check that all required inputs are filled if you change system type or solar collector type or pool type, or method for calculating cold water temperature).

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average relative humidity (%)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	5.56	24.1	80.0		5.32
February	1.00	5.47	24.3	80.0		4.92
March	1.00	4.92	23.7	80.0		4.00
April	1.00	3.97	21.6	78.0		2.77
May	1.00	3.31	19.1	76.0		1.83
June	1.00	3.03	16.6	72.0		1.44
July	1.00	3.17	16.5	72.0		1.61
August	1.00	3.72	17.7	75.0		2.40
September	1.00	4.06	19.2	77.0		3.19
October	1.00	4.75	20.1	78.0		4.19
November	1.00	5.11	21.4	79.0		4.83
December	1.00	5.81	23.1	79.0		5.65

		Annual	Season of Use
Solar radiation (horizontal)	MWh/m²	1.61	1.61
Solar radiation (tilted surface)	MWh/m²	1.28	1.28
Average temperature	°C	20.6	20.6
Average wind speed	m/s	#DIV/0!	0.0

Water Heating Load Calculation		Estimate	Notes/Range
Application type	-	Service hot water	
System configuration	-	With storage	
Building or load type	-	House	
Number of units	Occupant	20000	
Rate of occupancy	%	80%	50% to 100%
Estimated hot water use (at ~60 °C)	L/d	960,000	
Hot water use	L/d	1,500,000	
Desired water temperature	°C	60	
Days per week system is used	d	7	1 to 7
Cold water temperature	-	Auto	
Minimum	°C	19.2	1.0 to 10.0
Maximum	°C	21.9	5.0 to 15.0
Months SWH system in use	month	12.00	
Energy demand for months analysed	MWh	25,161.36	
	GJ	90,580.90	

Return to Energy Model sheet

RETScreen® Financial Summary - Solar Water Heating Project

Annual Energy Balance

Project name		Low Income Housing	Electricity required	MWh	-
Project location		eThikweni			
Renewable energy delivered	MWh	1,611.12	Net GHG reduction	t_{CO2}/yr	1,590.13
Heating fuel displaced	-	Electricity	Net GHG emission reduction - 15 yrs	t_{CO2}	23,851.98

Financial Parameters

Avoided cost of heating energy	Rs/kWh	0.360	Debt ratio	%	1.5%
			Debt interest rate	%	11.0%
			Debt term	yr	15
GHG emission reduction credit	Rs/t_{CO2}	64.0	Income tax analysis?	yes/no	No
GHG reduction credit duration	yr	15			
GHG credit escalation rate	%	2.0%			
Retail price of electricity	Rs/kWh	-			
Energy cost escalation rate	%	8.0%			
Inflation	%	6.0%			
Discount rate	%	10.0%			
Project life	yr	15			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	Rs	5,000	O&M	Rs	255,000
Development	0.0%	Rs	-	Electricity	Rs	-
Engineering	0.0%	Rs	-	Debt payments - 15 yrs	Rs	30,651
Energy equipment	71.0%	Rs	10,438,750	**Annual Costs and Debt - Total**	**Rs**	**285,651**
Balance of system	28.9%	Rs	4,250,000			
Miscellaneous	0.0%	Rs	-	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**Rs**	**14,693,750**	Heating energy savings/income	Rs	580,003
Incentives/Grants		Rs	4,848,937			
				GHG reduction income - 15 yrs	Rs	101,768
				Annual Savings - Total	**Rs**	**681,771**
Periodic Costs (Credits)						
Valves and fittings		Rs	-			
Pool heat pump compressor		Rs	-			
		Rs	-			
End of project life -		Rs	-			

Financial Feasibility

Pre-tax IRR and ROI	%	2.5%	Calculate GHG reduction cost?	yes/no	Yes
After-tax IRR and ROI	%	2.5%	GHG emission reduction cost	Rs/t_{CO2}	357
Simple Payback	yr	23.1	Project equity	Rs	14,473,344
Year-to-positive cash flow	yr	13.1	Project debt	Rs	220,406
Net Present Value - NPV	Rs	(4,322,783)	Debt payments	Rs/yr	30,651
Annual Life Cycle Savings	Rs	(568,333)	Debt service coverage	-	15.00
Benefit-Cost (B-C) ratio	-	0.70			

Version 3.1

Yearly Cash Flows			
Year	Pre-tax	After-tax	Cumulative
#	Rs	Rs	Rs
0	(9,624,407)	(9,624,407)	(9,624,407)
1	429,256	429,256	(9,195,151)
2	465,226	465,226	(8,729,925)
3	504,274	504,274	(8,225,651)
4	546,662	546,662	(7,678,989)
5	592,676	592,676	(7,086,313)
6	642,626	642,626	(6,443,687)
7	696,846	696,846	(5,746,841)
8	755,700	755,700	(4,991,141)
9	819,583	819,583	(4,171,559)
10	888,920	888,920	(3,282,638)
11	964,176	964,176	(2,318,462)
12	1,045,851	1,045,851	(1,272,611)
13	1,134,490	1,134,490	(138,122)
14	1,230,680	1,230,680	1,092,558
15	1,335,060	1,335,060	2,427,618

Middle Income Solar WH Results

RETScreen® Energy Model - Solar Water Heating Project

Training & Support

Site Conditions		Estimate		Notes/Range
Project name		**Middle Income Housing**		See Online Manual
Project location		**eThikweni**		
Nearest location for weather data		Durban/Louis Botha	➡	Complete SR&HL sheet
Annual solar radiation (tilted surface)	MWh/m²	1.28		
Annual average temperature	°C	20.6		-20.0 to 30.0
Annual average wind speed	m/s	#DIV/0!		
Desired load temperature	°C	60		
Hot water use	L/d	1,500,000		
Number of months analysed	month	12.00		
Energy demand for months analysed	MWh	25,161.36		

System Characteristics		Estimate	Notes/Range
Application type		Service hot water (with storage)	
Base Case Water Heating System			
Heating fuel type	-	**Electricity**	
Water heating system seasonal efficiency	%	100%	50% to 190%
Solar Collector			
Collector type	-	Evacuated	See Technical Note 1
Solar water heating collector manufacturer		XXXXXXXX	See Product Database
Solar water heating collector model		XXXXXXXX	
Gross area of one collector	m²	2.22	1.00 to 5.00
Aperture area of one collector	m²	1.92	1.00 to 5.00
Fr (tau alpha) coefficient	-	0.76	0.40 to 0.80
Fr UL coefficient	(W/m²)/°C	5.93	0.30 to 3.00
Temperature coefficient for Fr UL	(W/(m·°C)²)	0.01	0.000 to 0.010
Suggested number of collectors		7806	
Number of collectors		10000	
Total gross collector area	m²	22200.0	
Storage			
Ratio of storage capacity to coll. area	L/m²	90.0	37.5 to 100.0
Storage capacity	L	1,728,000	
Balance of System			
Heat exchanger/antifreeze protection	yes/no	No	
Suggested pipe diameter	mm	N/A	8 to 25 or PVC 35 to 50
Pipe diameter	mm	38	8 to 25 or PVC 35 to 50
Pumping power per collector area	W/m²	0	3 to 22, or 0
Piping and solar tank losses	%	1%	1% to 10%
Losses due to snow and/or dirt	%	3%	2% to 10%
Horz. dist. from mech. room to collector	m	5	5 to 20
# of floors from mech. room to collector	-	1	0 to 20

Annual Energy Production (12.00 months analysed)		Estimate	Notes/Range
SWH system capacity	kW_{th}	13,440	
	MWth	13.440	
Pumping energy (electricity)	MWh	**0.00**	
Specific yield	kWh/m²	390	
System efficiency	%	30%	
Solar fraction	%	34%	
Renewable energy delivered	MWh	**8,663.85**	
	GJ	31,189.87	
			Complete Cost Analysis sheet

RETScreen® Solar Resource and Heating Load Calculation - Solar Water Heating Project

Site Latitude and Collector Orientation		Estimate	Notes/Range
Nearest location for weather data		Durban/Louis Botha	*See Weather Database*
Latitude of project location	°N	-30.0	-90.0 to 90.0
Slope of solar collector	°	25.0	0.0 to 90.0
Azimuth of solar collector	°	0.0	0.0 to 180.0

Monthly Inputs

(Note: 1. Cells in grey are not used for energy calculations; 2. Revisit this table to check that all required inputs are filled if you change system type or solar collector type or pool type, or method for calculating cold water temperature).

Month	Fraction of month used (0 - 1)	Monthly average daily radiation on horizontal surface (kWh/m²/d)	Monthly average temperature (°C)	Monthly average relative humidity (%)	Monthly average wind speed (m/s)	Monthly average daily radiation in plane of solar collector (kWh/m²/d)
January	1.00	5.56	24.1	80.0		5.32
February	1.00	5.47	24.3	80.0		4.92
March	1.00	4.92	23.7	80.0		4.00
April	1.00	3.97	21.6	78.0		2.77
May	1.00	3.31	19.1	76.0		1.83
June	1.00	3.03	16.6	72.0		1.44
July	1.00	3.17	16.5	72.0		1.61
August	1.00	3.72	17.7	75.0		2.40
September	1.00	4.06	19.2	77.0		3.19
October	1.00	4.75	20.1	78.0		4.19
November	1.00	5.11	21.4	79.0		4.83
December	1.00	5.81	23.1	79.0		5.65

		Annual	Season of Use
Solar radiation (horizontal)	MWh/m²	1.61	1.61
Solar radiation (tilted surface)	MWh/m²	1.28	1.28
Average temperature	°C	20.6	20.6
Average wind speed	m/s	#DIV/0!	0.0

Water Heating Load Calculation		Estimate	Notes/Range
Application type	-	Service hot water	
System configuration	-	With storage	
Building or load type	-	House	
Number of units	Occupant	40000	
Rate of occupancy	%	80%	50% to 100%
Estimated hot water use (at ~60 °C)	L/d	1,920,000	
Hot water use	L/d	1,500,000	
Desired water temperature	°C	60	
Days per week system is used	d	7	1 to 7
Cold water temperature	-	Auto	
Minimum	°C	19.2	1.0 to 10.0
Maximum	°C	21.9	5.0 to 15.0
Months SWH system in use	month	12.00	
Energy demand for months analysed	MWh	25,161.36	
	GJ	90,580.90	

Return to Energy Model sheet

RETScreen® Financial Summary - Solar Water Heating Project

Annual Energy Balance

Project name		Middle Income Housing	Electricity required	MWh	-
Project location		eThikweni	Net GHG reduction	t_{CO2}/yr	8,551.00
Renewable energy delivered	MWh	8,663.85			
Heating fuel displaced	-	Electricity	Net GHG emission reduction - 15 yrs	t_{CO2}	128,264.99

Financial Parameters

Avoided cost of heating energy	Rs/kWh	0.360	Debt ratio	%	1.5%
			Debt interest rate	%	11.0%
			Debt term	yr	15
GHG emission reduction credit	Rs/t_{CO2}	64.0	Income tax analysis?	yes/no	No
GHG reduction credit duration	yr	15			
GHG credit escalation rate	%	2.0%			
Retail price of electricity	Rs/kWh	-			
Energy cost escalation rate	%	8.0%			
Inflation	%	6.0%			
Discount rate	%	10.0%			
Project life	yr	15			

Project Costs and Savings

Initial Costs				**Annual Costs and Debt**		
Feasibility study	0.0%	Rs	15,000	O&M	Rs	505,000
Development	0.0%	Rs	-	Electricity	Rs	-
Engineering	0.0%	Rs	-	Debt payments - 15 yrs	Rs	177,182
Energy equipment	76.4%	Rs	64,924,400	**Annual Costs and Debt - Total**	**Rs**	**682,182**
Balance of system	23.5%	Rs	20,000,000			
Miscellaneous	0.0%	Rs	-	**Annual Savings or Income**		
Initial Costs - Total	100.0%	**Rs**	**84,939,400**	Heating energy savings/income	Rs	3,118,987
Incentives/Grants		Rs	25,481,820			
				GHG reduction income - 15 yrs	Rs	547,264
				Annual Savings - Total	**Rs**	**3,666,251**
Periodic Costs (Credits)						
Valves and fittings		Rs	-			
Pool heat pump compressor		Rs	-			
		Rs	-			
End of project life -		Rs	-			

Yearly Cash Flows			
Year	Pre-tax	After-tax	Cumulative
#	Rs	Rs	Rs
0	(58,183,489)	(58,183,489)	(58,183,489)
1	3,214,233	3,214,233	(54,969,256)
2	3,462,760	3,462,760	(51,506,496)
3	3,731,141	3,731,141	(47,775,354)
4	4,020,991	4,020,991	(43,754,363)
5	4,334,053	4,334,053	(39,420,310)
6	4,672,215	4,672,215	(34,748,096)
7	5,037,515	5,037,515	(29,710,581)
8	5,432,159	5,432,159	(24,278,422)
9	5,858,532	5,858,532	(18,419,890)
10	6,319,211	6,319,211	(12,100,679)
11	6,816,983	6,816,983	(5,283,696)
12	7,354,862	7,354,862	2,071,166
13	7,936,105	7,936,105	10,007,271
14	8,564,234	8,564,234	18,571,504
15	9,243,056	9,243,056	27,814,560