GAUTENG
PROVINCIAL GOVERNMENT

Department of Agriculture, Conservation and Environment

FINAL REPORT: INVESTIGATION OF THE IMPLEMENTATION OF ALTERNATIVE ENERGY OPTIONS IN HOUSEHOLDS AND ASSOCIATED COMMUNITY INSTITUTIONS IN GAUTENG

REPORT 4 OF 4

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Contact: Dr. D.B.K.Rama

Director: Air Quality, GDACE
Tel: 011 355 1989
Email: dhiraj.rama@gauteng.gov.za

Executive summary

The Gauteng Department of Agriculture, Conservation and Environment (GDACE) commissioned this project to have a better understanding of the energy technology options available to inform economic and social development, through sustainable energy provision. This will contribute to enhancing the quality of life and sustainable utilisation of natural resources in the 20 prioritised township programme (20PTP) and other programmes of the Province.

Socio-Economic and Energy Use Assessment

The socio-economic conditions and energy status in a range of different sectors are investigated in this report (details of which can be found in the background report attached at the end of this document (Appendix D: Socio-economic and energy profile). The report specifically looks at conditions within the following sectors;

- Population and households and their socio-economic status
- Infrastructure and Community Facilities

Based on this analysis the report provides an energy demand overview of selected application types of households and institutions which is required in order to define where the technologies need to be applied.

This report focuses mainly on households as it is believed that the other sectors require sector specific interventions such as introduction of cleaner production in industries, review of environmental impacts assessments in terms of energy efficiency for new industrial developments and so forth.

To analyse appropriate energy use interventions, it is necessary to use demand profiles of households which are as close to real households in the study area as possible. We have defined four categories of households – developed from the general household data mentioned above – which will demonstrate and distinguish between the four most significant household energy use scenarios. The energy profile of these are detailed in this report and include:

- Privately built formal electrified households which represent an expanding household type in Gauteng townships
- Formal electrified households (mono-fuel); a government built formal house relying solely on electricity
- Formal electrified households (multiple fuels); a government built formal house relying on a mix of fuels including electricity, paraffin, candles, etc.
- Informal un-electrified household (multiple fuels); these households rely on a range of non-electrical energy sources including paraffin, candles, coal, etc.

Two types of institutions were also selected for the purpose of developing detailed energy use patterns as part of developing application types.

- Schools
- Clinics

Technology Options and Assessment

An overview of available technology options has also been undertaken (see Appendix C: Review of alternative technology options). Alternative energy technologies are defined as those that are cleaner and more sustainable than those which are currently

available and used in the township areas. The focus areas of consideration for energy technology application are residential and institutional (schools and clinics).

The table below shows a list of possible alternative energy technologies grouped as supply-side or demand-side; and as residential, institutional or public. There are also numerous specific technology types available within the identified groupings (such as different sizes and types of solar water heaters).

Possible alternative energy technologies

Supply Side Technologies	
Residential & Institutional	**Public**
Solar water heating	-
Thermal fuels – LPG, biogas, landfill gas, Sasol gas, gelfuel, other clean, smokeless fuels	-
Solar cookers	-
Wind electricity	-
Small hydro electricity	-
Solar PV electricity	Solar PV street lights
Fuel Cell electricity	-
Demand Side Technologies	
Residential & Institutional	**Public**
Plastering (insulation)	-
External painting (reflection)	-
Ceiling and/or insulation	-
Efficient lighting – CFL, LED	Efficient street lighting – CFL, LED
Efficient electrical appliances – refrigerator, stove	-
Efficient design (for new build) – orientation, overhangs, glazing, materials selection, plastering, paints, air changes/hour, etc	-
Efficient cooking – hotbox, paraffin stove swapping, improved coal stoves	-
Geyser & pipe insulation	-

The most appropriate alternate technology, or group of technologies, out of this list will be recommended for piloting. The choice will need to take into account a range of factors including reduced energy demand, impacts on sustainability of energy supply, quality of life improvements through improved health and safety, and improved energy access, affordability and security. The initial technology assessment focuses on the technical pros, cons, risks and impacts for each of the alternative technologies considered.

The technology assessment is supported by a general literature review as well as an assessment of key South African case studies including:

- **Moshoeshoe Eco-village** in Sol Plaatje municipality in the Northern Cape. This project comprises a demonstration phase for a larger project. The municipality is grid connected and the eco-village includes a wide range of innovative housing solutions which advance the state of knowledge and experience in housing delivery in South Africa. The project was formally opened on 12 March 2002.
- **The City Of Cape Town's Low-Cost Urban Housing Upgrade Project in Kuyasa**, **Khayelitsha** in the Western Cape has an initial pilot project of 10 installations which were completed in December 2003. The upgrade as a whole is the first registered CDM gold standard project in the world and the interventions include solar water heaters, energy efficient lighting and insulated ceilings in each unit. The pilot was a demonstration for a similar rollout to about 2 300 houses in Khayelitsha.

- **Folovhodwe Solar Village Project** in Limpopo is at least ten kilometres from the nearest existing power line. It is the first South African demonstration site for the solar electrification of a complete rural community. All 582 households in the village received Solar Home Systems (SHS). Through the Folovhodwe project it is hoped to demonstrate that solar photo-voltaics provide a viable alternative for areas too far from the grid.

In addition to these three case studies the report also sourced information and lessons from a range of other case study examples of alternative energy implementation in similar contexts. These included:

- Cosmo City, City of Johannesburg: solar water heater introduction in a township in Gauteng
- Paranhos Solar Village Pilot Project in Angola: solar PV home systems
- Rosh Pinah Pilot Project, Namibia: small scale anode swapped fuel cells and gelfuel cooking
- Basa Njenjo Magogo, Orange Farm: demonstration of low smoke increased efficiency fires
- The Tata Energy Research Institute (TERI), India: biogas, improved cook-stoves, efficient lighting, and solar PV
- The Khayelitsha Gel Fuel Project, Cape Town: gelfuel cooking

There are many other relevant case studies that give insight into alternative energy options but those listed above cover most of the range of technologies and circumstances anticipated in the townships.

The literature review gives a benchmark for the technology options and provides indicators that will help in the further assessment of these technologies. The most relevant and best covered South African literature has been in the areas of solar water heaters (SWHs) in townships, and solar photovoltaic (solar PV) systems in rural areas. However, technologies such as liquefied petroleum gas (LPG), biogas, gel-fuels, wind power generation, ceiling and insulation installation, efficient lighting and appliances, and efficient cooking methods and appliances were also covered.

Ranking Methodology and Results

In order to determine the most appropriate technologies for townships in Gauteng a decision making framework is required. A standard multi-criteria decision analysis (MCDA) approach was used. This is a well described and internationally accepted method for comparing alternative options against one another based on a set of characteristics of those options [13, 14]. Options are evaluated on the basis of individual criteria, and these scores are aggregated to give overall scores for all options relative to each other.

The MCDA process for this project was developed during initial discussions with the client and subsequent preparatory work, followed by an expert panel workshop amongst the team members. The specific criteria used were then tested and outlined for comment and discussion at the stakeholder workshop. The workshop endorsed the criteria with some comments. These comments were taken into account and a final run of the evaluation was done using the refined criteria, scores and arrangement of alternative options.

Details of how the decision making framework was established and applied to the technology options are provided (see Appendix E: Evaluation of applicable energy options). The process assesses each technology by initially screening them through qualifying criteria and then ranking them using prioritising criteria.

In support of this analysis, as well as the energy use assessment, a number of interviews were held with energy providers. These interviews provided additional information on the availability, security of supply, costs and others characteristics of energy supply options. These included interviews with the following companies as well as a number of academic researchers in the field:

- Egoli Gas
- Sasol Gas
- Eskom
- Central Energy Fund
- Contigas
- Afrox
- BP Gas
- LP Gas Association
- Paraffin Safety Association
- Rentech renewable energy providers
- Universal Energy
- ABSA Bank

To establish a more realistic set of technology options the initial list was screened using certain disqualifying criteria. The disqualifying criteria are a set of parameters that assess whether a technology is suited to the context of the study.

Following this screening the technologies were compared against one another using various prioritising criteria. The prioritising criteria are a set of parameters that score each technology from least to most appropriate allowing the technologies to be ranked. Each technology was scored against each criterion. Each criterion was in turn weighted in importance against the others. The combination of weights and scores gives an overall score for each technology which then allows them to be ranked against one another.

For each type of housing or institution the criteria were separately weighted according to their importance for that application. For some applications certain technologies were also not technically appropriate and were therefore not considered. For example, solar water heaters are not feasible in informal housing where there is no piped water supply.

The disqualifying criteria, and the possible level of control over them, are described below the tables. Each criterion if deemed true can be regarded as a disqualifying parameter for any technology measured against it.

Supply Side Disqualifying Criteria

No.	Criteria	Control	Disqualifier
1	No energy resource	None	Yes
2	Past failure	Very little	Yes
3	Regulatory approval improbable	Very little	Yes
4	EIA approval improbable	Very little	Yes

- **No energy resource** – if the energy resource required by a supply technology is poor or unavailable in the Gauteng area then this criterion will disqualify that technology. There is no control over or possibility of changing this criterion by creating the resource to qualify that technology.
- **Past failure** – if the technology has been tried in similar contexts in South Africa and failed then this criteria will disqualify that technology. There is very little, in the context of this study and timeline, control over or possibility of changing the past experience to qualify that technology.
- **Regulatory approval improbable** – if the technology has regulatory barriers that mean that its implementation is improbable then it will be disqualified. There is very little, in the context of this study and timeline, possibility of changing the regulations or technology to qualify that technology.
- **EIA approval improbable** – if the technology has EIA barriers that mean that its implementation is improbable then it will be disqualified. There is very little, in the context of this study and timeline, possibility of changing the EIA process or technology to qualify that technology.

Demand Side Disqualifying Criteria

No.	Criteria	Control	Disqualifier
1	Past failure	None	Yes
2	No material/component supply	Very little	Yes

- **Past failure** – if the technology has been tried in similar contexts in South Africa and failed then this criterion will disqualify that technology. There is very little, in the context of this study and timeline, control over or possibility of changing the past experience to qualify that technology.
- **No material or component supply** – if the material or component required by a demand technology is unavailable in Gauteng area then this criterion will disqualify that technology. There is very little control over or possibility of changing this criterion and creating the supply, in the context and timeline of this study, to qualify that technology.

The disqualifying criteria were applied to the long list of technologies in order to screen out any technologies that are not suited to the context of this study. The results of the disqualifying process are shown in the tables below:

Supply side technologies

Tech	***Disqualifying Criteria***	***Description of Disqualifier***	***Result***
Solar Water Heaters	None	N/A	Qualifies
Reticulated natural gas	No energy resources	Highly limited reticulation networks and no intention to extend networks to middle and low income residential areas	**REJECT**
LPG	None	N/A	Qualifies
Biogas	None	N/A	Qualifies
Landfill Gas	Past Failure	N/A	Qualifies
Sasol gas	No energy resource	Not available to townships	**REJECT**
Gelfuel	None	N/A	Qualifies
Low Smoke Fuel	No energy resource	Not avail yet in SA	**REJECT**
Solar cookers	Past failure	Roll out to villages in Africa unsuccessful	**REJECT**
Wind	No energy resource	Wind resource in Gauteng is generally low[1]	**REJECT**
Hydro	No energy resource	No volume/pressure-head in townships	**REJECT**
Solar PV	None	N/A	Qualifies
Fuel Cell	None	N/A	Qualifies

Demand side technologies

Tech	***Disqualifying Criteria***	***Description of Disqualifier***	***Result***
Plastering	None	N/A	Qualifies
Extern painting	None	N/A	Qualifies
Ceiling/insulation	None	N/A	Qualifies
Compact Fluorescent Lighting (CFL)	None	N/A	Qualifies
Light Emitting Diodes (LED)	None	N/A	Qualifies
Efficient electrical appliances	No component supply	No SA labelling yet, efficiency unknown	**REJECT**
Efficient design	None	N/A	Qualifies
Low-smoke stoves	None	N/A	Qualifies
Hot box	None	N/A	Qualifies
Geyser/pipe insulation	None	N/A	Qualifies

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[1] The estimated mean annual wind speed in Gauteng is 1-4 m/s. While most small wind turbines will begin generating electricity at wind speeds of approximately 3-4 m/s, the capacity factor would be extremely low and they would only achieve their rated output at a wind speed of 10-12 m/s. See: http://www.csir.co.za/websource/ptl0002/images/environmentek/sarerd/maps/windatlas.jpg

The qualified pool of alternative technologies is therefore:

Qualified alternative technologies

Supply Side Tech's	***Demand Side Tech's***
Solar Water Heaters	Plastering
Liquid Petroleum Gas	External painting
Biogas	Ceiling/insulation
Landfill Gas	Compact Fluorescent Lighting (CFL) and Light Emitting Diode (LED) Lighting
Solar PV Electricity	Efficient design
Fuel Cell Electricity	Low-smoke stoves
Gelfuel	Hot box
	Geyser/pipe insulation

The introduction of diesel generator sets was not included as a qualified supplky side technology as this technology did not meet the initial definition of an alternative energy technology as being cleaner and more sustainable than those which are currently available and used in the township areas.

The qualified technologies are then ranked for application against the six user types developed. This entails scoring and weighting each technology using expert judgement and case study lessons and findings. The prioritisation criteria used are shown below. These criteria were established by the team in discussion with GDACE and confirmed as appropriate at the stakeholder workshop held.

Supply Side Prioritising Criteria

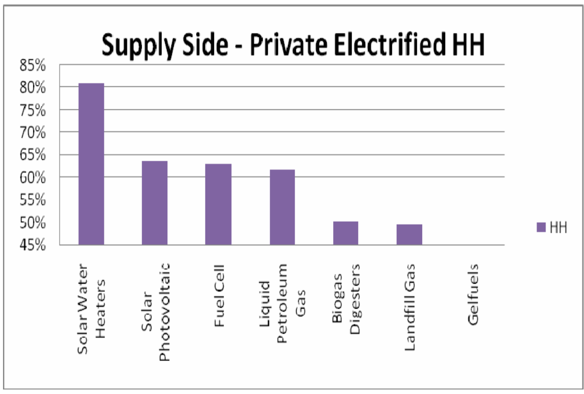
Criteria		**Rating / Score**				
		0	**1**	**2**	**3**	**4**
Security of supply		None	Poor	Neutral	Good	Excellent
Technical constraints		High		Neutral		Minimal
Levelised Costs (R/kWh/yr)		> +25%	> +10%	Neutral (+/- 10%)	< - 10%	< -25%
Environmental Impacts	Air	Negative		Neutral		Positive
	Water	Negative		Neutral		Positive
	Waste	Negative		Neutral		Positive
Employment potential		None	Poor	Neutral	Good	Excellent
Regulatory barriers		High	Moderate	Neutral	Limited	Supportive
Social / user acceptability		Poor	Cautious	Moderate	Good	Excellent
Safety to user		Poor	Moderate	Neutral	Good	Excellent
EIA barriers		High	Moderate	Neutral	Limited	N/A
Replicability potential		Poor	Moderate	Neutral	Good	Excellent
Opportunities for avoided cost		Poor	Moderate	Neutral	Good	Excellent
Security risk (theft proof)		Poor	Moderate	Neutral	Good	Excellent
Tenure		Negative		Neutral		Positive
Public or private investment/subsidies		None	Poor	Neutral	Good	Excellent
Carbon Finance Potential		None	Poor	Neutral	Good	Excellent

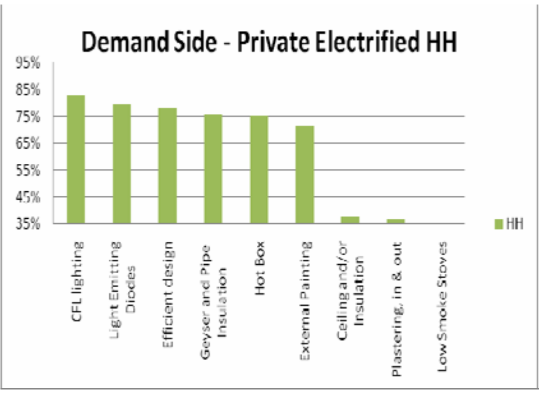
Demand Side Prioritising Criteria

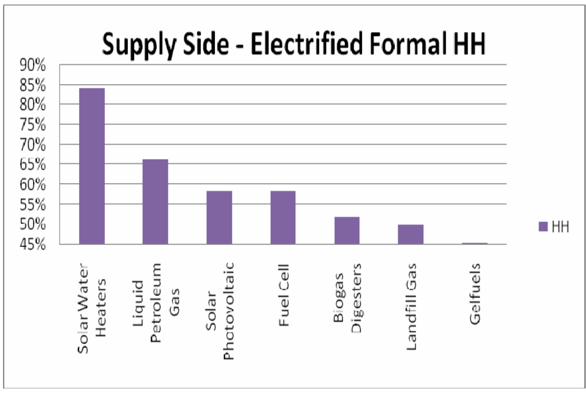
Criteria		**Rating / Score**				
		0	**1**	**2**	**3**	**4**
Technical constraints		High		Neutral		Minimal
Levelised cost (R/kWh.annum)		> +25%	> +10%	Neutral (+/- 10%)	< -10%	< -25%
Environmental Impacts	Air	Negative		Neutral		Positive
	Water	Negative		Neutral		Positive
	Waste	Negative		Neutral		Positive
Employment potential		None	Poor	Neutral	Good	Excellent
Regulatory barriers		High	Moderate	Neutral	Limited	Supportive
Social / user acceptability		Poor	Cautious	Moderate	Good	Excellent
Safety to user		Poor	Moderate	Neutral	Good	Excellent
EIA barriers		High	Moderate	Neutral	Limited	N/A
Replicability potential		Poor	Moderate	Neutral	Good	Excellent
Opportunities for avoided cost		Poor	Moderate	Neutral	Good	Excellent
Security risk (theft proof)		Poor	Moderate	Neutral	Good	Excellent
Tenure		Negative		Neutral		Positive
Public/ private invest/subsidy/DSM		None	Poor	Neutral	Good	Excellent
Carbon Finance Potential		None	Poor	Neutral	Good	Excellent

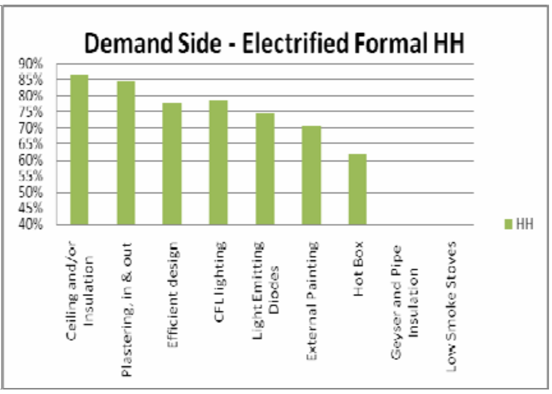
The ranks of the supply and demand technologies are presented for each user type in the bar graphs below:

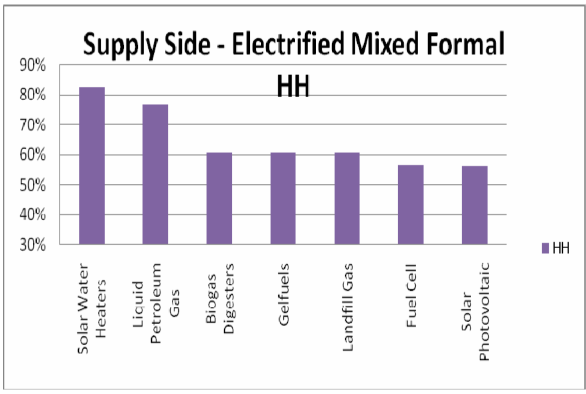
Technology ranking against user type (application)

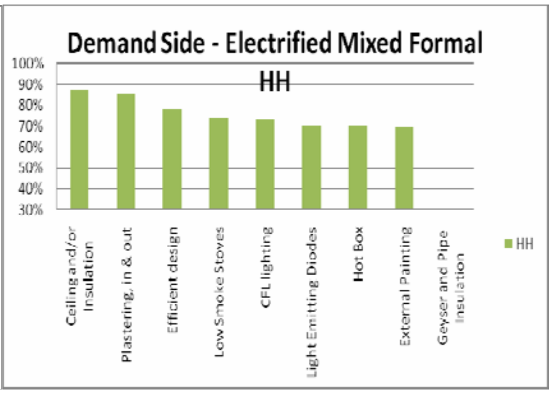


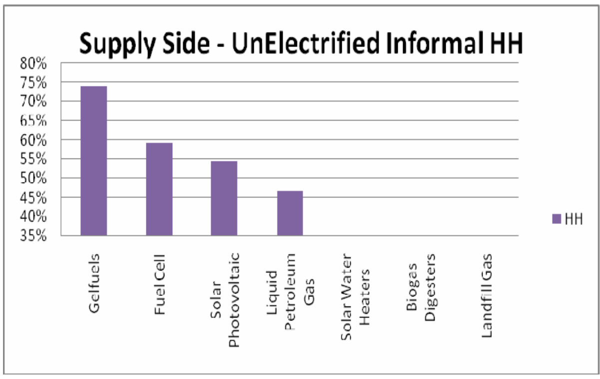


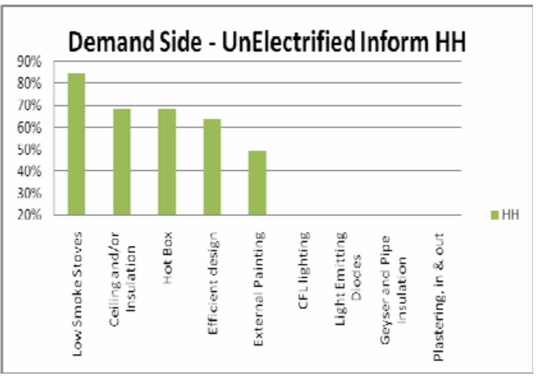


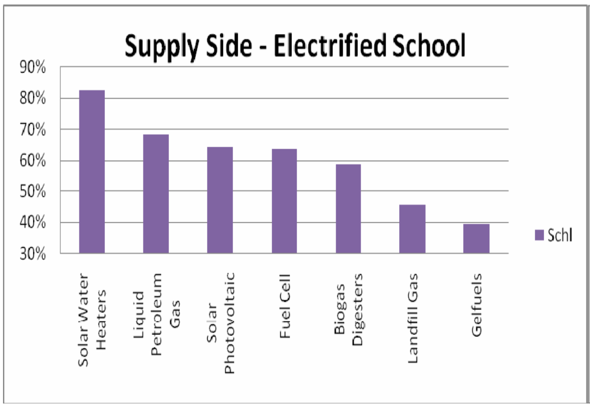


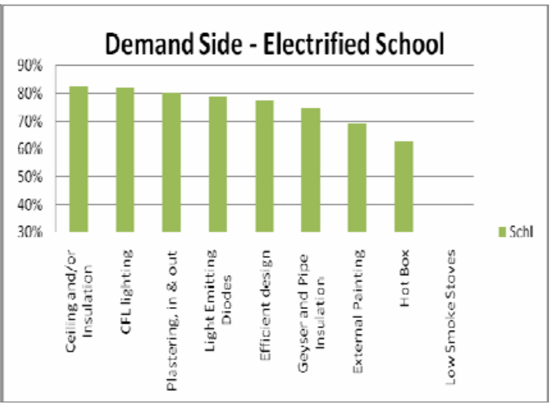


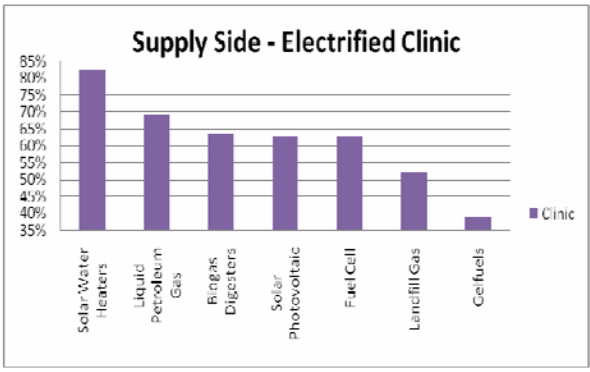


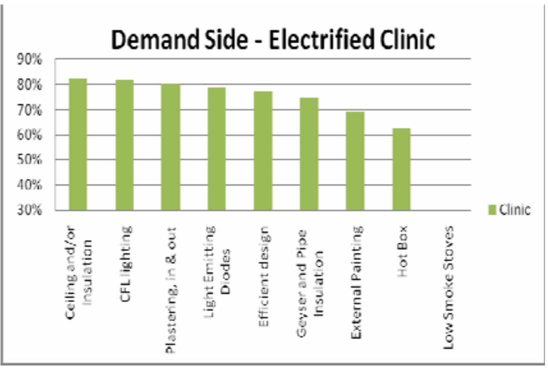












Technology Packages

Based on the rankings above and applying expert judgement the best potential packages of technologies for each user type are compiled. It is assumed that the households or institutions are already built and occupied and that the technologies would be retrofitted to the existing buildings. There is benefit in applying these packages of technologies, and more, at the design stage for new-build and comment is made on this for each household or institution type.

It is important to note that if a potential energy source does not appear in the technology packages below or is ranked low in the tables above it does not mean that this is not an energy source that should utilised. It simply means that that energy resource is not the most appropriate energy source for the residential and institutional users considered. For example, landfill gas is consistently ranked low as a supply option. This is due to a range of factors that make it unsuitable as an energy resource specifically directed at the users who are the focus of this study. These factors include the facts that landfill gas is a toxic gas which requires a lot of cleaning to enable it to be used at the household level, it is expensive and potentially hazardous to pipe and its supply is relatively unstable and located in only particular areas.. However, landfill gas is likely to be a viable option for the generation of electricity to insert into the general electricity grid where all these factors can be managed. This is a very different application from the set of applications considered in this study.

A summary of the technology packages for each user type is given in the table below. It also lists what the technologies provide to the user, what the technologies achieve and an estimate of both the capital cost and the reductions in operating cost to the user.

Proposed technology packages for user type

Type	***Technology Package***	***Providing***	***Achieving***	***Costing***
Private Electrified Household	SWH, LPG, CFL	Hot water, cooking, heating, thermal efficiency	Up to 44% drop in energy bill, better comfort	• CAPEX – R17,000/HH • OPEX saved – R1,600/a/HH
Formal Electrified Household	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 25% drop in energy bill, better comfort	• CAPEX – R19,500/HH • OPEX saved – R400/a/HH
Formal Electrified and Mixed Fuel Household	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 32% drop in energy bill, better comfort	• CAPEX – R13,500/HH • OPEX saved – R650/a/HH
Informal Un-Electrified Household	Gelfuel, PV, LPG, Ceiling & Insulation	Cooking, electricity, heating, thermal efficiency	Increase in energy bill if not subsidised, better safety, health and comfort	• CAPEX – R5,700/HH • OPEX incr – R288/a/HH
Standard Electrified School	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 25% drop in energy bill, better comfort	• CAPEX – R193,500/HH • OPEX saved – R2,200/a/HH
Standard Electrified Clinic	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 41% drop in energy bill, better comfort	• CAPEX – R94,500/HH • OPEX saved – R4,000/a/HH

To give an indication of the operating costs to the user, in addition to the savings identified above, a standard formal mixed fuel use household was selected and technologies for cooking and heating considered. Typically this type of household would use:

- electricity (about two thirds of the total energy use for lighting, TV/Radio and refrigeration),
- paraffin (about 40% of the total for cooking), and
- coal (about 26% of the total for heating).

The table below gives a comparative costing for cooking (three meals per day) or heating (matching the currently used energy) technologies.

Indication of Comparative Operating Costs for Mixed Fuel Household

Cooking Technology	**Cost per meal**	**Monthly Cost**
LPG - cylinder (@R18/kg)	R0.75	R68
Gelfuel (@R10/l)	R1.20	R108
Electricity (@45c/kWh)	R0.60	R54
Heating Technology	**Current Energy Used**	**Monthly Cost**
LPG - cylinder (@R18/kg)	540MJ	R170
Electricity (@45c/kWh)	540MJ	R68

Environmental Implications

The various proposed packages have different environmental, including air quality, impacts. All the proposed packages lead to net environmental improvements – implementation of some of the packages, however, would lead to greater local air quality improvements than others depending on what current energy use is being displaced. Those packages that displace more grid electricity will tend to have greater greenhouse gas reductions and will reduce pollution at the source of power generation but will have limited impact on local air quality. On the other hand, those packages that displace household fuels, such as coal and paraffin with cleaner fuels or lower energy use, will have important beneficial indoor air quality and ambient air quality impacts.

Coal is known to be a polluting energy source for households when compared with other options, both indoors and in the ambient air. While unhealthy emissions can be improved by improved combustion techniques, it generally remains a polluting option relative to other energy options. Paraffin also produces some indoor pollution, but significantly less than coal. LPG and piped gas are less polluting still. Ethanol gel is also significantly cleaner than paraffin in terms of indoor pollution.

Coal is generally the only significant contributor to ambient pollution, although where wood is extensively used (generally not the case in Gauteng townships) it can also contribute to poor ambient air quality. The impacts of coal on air quality and hence on human health are significant. These health impacts, aside from the human suffering, have been estimated to lead to social costs of between R202 million and R812 million per year in the Vaal Triangle alone [16].

Paraffin has additional health and safety problems – these include large numbers of poisonings due to children mistakenly drinking paraffin stored in bottles, as well as numerous household burns and accidents from paraffin stoves as well as fires that extend to multiple dwellings [15]. Paraffin, LPG, piped gas and ethanol do not result in noteworthy ambient air quality problems. Electricity has no local emissions at all.

From an emissions perspective therefore, fuels to be avoided where feasible are coal and paraffin, and fuels to be promoted are LPG and gel fuel. It should be noted, however, that where gelfuel is to be considered as a replacement for paraffin a standard needs to be established to ensure the quality of the fuel and the burners. It was found in a recent study [20] that most gel fuel burners did not meet an emission standard of a $CO:CO_2$ ratio of <0.02. Gel fuels themselves often have excessive water and condensation can dampen the flame.

The table below shows the differences in local air pollution between the household fuels.

Local air pollution coefficients

TYPE FUEL	Units	SO2	Particulates	NOx
Anthracite	kg/tonne	19	170	9
Coal	kg/tonne	8.5	1.2	1.5
Paraffin	Kg/1000l	8.5	0.2	1.5
LPG	kg/m3	0.006	0.22	1.45
Wood	kg/ton	0.2	15	5

Source: Coefficients used by Cape Town Air Pollution Control and A Dynamic Air Pollution Prediction System For Cape Town, South Africa.

Discussion of Rankings

The results of the ranking showed that solar water heaters are the best supply technology across the different user types. Liquid petroleum gas also features in all types with gel-fuels showing up in informal household types. Formal housing and institutions that do not have ceilings or plaster would all benefit greatly if these were to be installed – both from an energy saving and comfort perspective. Incandescent lighting that is swapped out with compact fluorescent lamps would reduce energy demand. Electricity supply by photo-voltaics or fuel cell technology only features in informal un-electrified households (mainly because its cost against grid electricity is still a barrier).

Of the four household types the one needing the greatest capital cost is the private electrified type where a solar water heater, liquid petroleum gas (LPG) system, ceilings/insulation, plastering and CFLs would cost about R19,500 per household and only 25% of its energy use would drop. This is partly due to the fact that a large portion of its energy goes to refrigeration and more efficient fridges are not readily available in South Africa yet. However, the formal electrified and mixed fuel type of household only requires R13,500 capital cost per household to achieve a saving of 32% and improved safety, health and comfort.

Informal un-electrified households need special mention because although the package of technologies' capital cost is only R5,700 per household there is a need to subsidise the operating costs as it otherwise increases from the current energy bill. This is because gel-fuel is more expensive than paraffin on an energy basis but is a safer and healthier option (assuming it is of good quality). Although LPG solutions are also possible for these households they were lower ranked for reasons related to capital costs, supply infrastructure, safety and user acceptability. If LPG solutions were implemented for un-electrified informal households they would also face similar recurrent cost challenges given the relatively high price of LPG.

To improve the thermal performance of institutions with no ceiling or plastered walls would have a relatively high capital cost but it would also help contribute (along with SWHs, LPG and CFLs) to reducing the electricity demand by 25% in schools and 41% in clinics. A typical school has an electricity demand of 1.6MWh per month and a typical clinic 1.9MWh per month so these saving are significant. The capital costs for the package of technologies for a school is about R193,500 and a clinic R94,500. It can be seen that the clinic requires a lower outlay to achieve a higher saving. This is due to its high use of hot water currently supplied by electrify and smaller area of ceiling and plaster compared to a school. Of course that is not to say that schools should be ignored, just that the demand reduction will need a greater outlay.

These conclusions give some insight into the benefits of installing alternative technologies into these typical user types. However, to capture all variations in household composition and energy use practices would be a vast and impractical exercise. Categorization had to be simplified which inevitably resulted in fewer, larger categories accommodating some variation within. An actual pilot project would need to take into account the local socio-economic and technical variations and therefore may arrive at a modified household energy package.

Conclusions and Recommendations

The key project conclusions are the identification of the most appropriate technology options and packages presented above. However a number of other conclusions and recommendations are presented which arise from the project research and analysis.

Pilot phase

It is recommended that a pilot phase is initiated so that the six user categories using the packaged technologies presented can be tested 'on the ground. This will give confidence in a larger scale roll out in the townships of these technologies which will reduce energy demand and costs, introduce more sustainable energy sources and improve the quality of life of households and residents.

A pilot project should be designed to provide useful information and insights into larger scale implementation programmes. In this regards the monitoring and evaluation of the pilot is important and should be structured to provide the province with the financial, social and technical information to assess the merits of any project option selected and to enable choices about project replication or extension. From a social impact perspective, GDACE should be aware that a baseline survey may be very valuable in order to measure these impacts post-project. The M&E system should also provide more general inputs into the envisaged Provincial Sustainable Energy Strategy.

Institutional and Regulatory Issues

Outside of a specific alternative energy pilot project a number of other recommendations can be made arising from the work conducted for this project. From an institutional perspective it is apparent that although the province does not have a formal energy supply mandate it can play an important role in ensuring the provision of more sustainable energy services which will have social, economic and environmental benefits.

Energy concerns impact on most sectors and activities and are therefore a prime example of an area requiring co-operation between the different spheres of government. The Provincial Government should actively seek to co-operate with other government bodies around energy concerns, with an aim to providing assistance, support, and leadership. Through a process of internal discussion as well as public participation, the Provincial Government should attempt to ensure that its efforts to develop the renewable energy sector and promote energy efficiency are co-ordinated with the efforts of other spheres of government relating to energy. This is particularly important in the context of Gauteng where the larger Metropolitan municipalities are developing their own internal sustainable energy strategies and plans.

The Province can play a leadership role in this area, by ensuring that its internal functioning promotes energy efficiency, and that it supports research and implementation of cleaner energy production, distribution and consumption. Other key areas where the Gauteng Province can promote sustainable energy in the short-term, probably via the Provincial Sustainable Energy Strategy, include:

- Facilitating coordination and synergies amongst the large metros who are already pursuing sustainable energy strategies.
- Supporting smaller municipalities who do not have the capacity to engage this area
- Ensuring that facilities over which they have influence are efficiently built and operated (clinics, schools, community facilities etc)
- Developing standard bylaws which municipalities can then adopt – e.g. around solar water heaters.
- Developing on overarching strategy in conjunction with municipalities.

The Province also has a role to play in identifying regulatory obstacles at the national, provincial or local level to alternative and renewable energy development and assisting in removing these obstacles. These include, for example, greater certainty over future regulation, and hence security of supply, of LPG prices and rapid certainty over the solar water heater subsidy programme and its applicability to all energy users.

Further issues relate to so-called net-metering – whereby renewable energy providers can feed electricity into the grid and be compensated for this, as well as the promotion of renewable feed-in-tariffs. These mechanisms can assist in making renewable energy generation projects financially viable.

Provincial Sustainable Energy Strategy and Energy Standards

The Province is in the process of developing a Sustainable Energy Strategy. This strategy is likely to have a broader ambit than the current project, as it will deal with all energy use in the province. This project has provided useful insights into a specific sub-sector of energy use and should form part of the Sustainable Energy Strategy background documentation.

This project can also support the development of targets or standards for sustainable energy provision in the province. It is useful to adopt a set of energy service standards which government should aim for in the residential sector. In this regard there are limited accepted standards to draw on either internationally or locally, although there is broad consensus on the types and quality of services which should be aimed for. These standards should follow from the above prioritisation analysis, but at a minimum should ensure pursuit of the Millenium Development Goals, which aim at poverty eradication, and therefore suggest that the informal un-electrified households be an important focus. The following are proposed as minimum standards for two different housing types:

Energy standards for informal, un-electrified households:

- Gel fuel or LPG (subsidised through the Free Basic Alternative Energy policy) provision (access to safe, healthy and affordable cooking fuels)
- Access to electricity (adequate illumination, opens up range of appliance use possibilities and supports education and learning goals)
- Ceiling installation (improved thermal comfort, reduced energy expenditure)

Energy standards for formal households:

- Access to electricity (adequate illumination, opens up range of appliance use possibilities and supports education and learning goals)
- Solar water heater installation (subsidy likely to be necessary in low income areas): improved and economically sensible hot water supply promoting health and welfare.
- Ceiling installation (improved thermal comfort, reduced energy expenditure)

In addition, access to well equipped facilities such as clinics and schools has been shown to be important in improving welfare in general, particularly of the poor. Addressing energy needs in these facilities therefore remains an important focus for government.

Carbon Finance and the Clean Development Mechanism

It appears that with careful design a provincial alternative energy project could qualify and be registered as a programmatic CDM project and hence gain carbon credits which could be used to offset project costs. The carbon finance component of any project should be identified and pursued if possible – particularly if it can be replicated on a larger scale within the province.

Large Scale Programme Implementation

Although not yet at this stage some important considerations to assist in preparing for a larger scale rollout involve the following additional investigations:

- identifying opportunities to align the rollout with other housing and energy projects and/or programmes
- investigating different project design, financing and implementation models - such as Energy Service Companies, the CDM, and so forth.
- financial modelling for a large scale rollout of infrastructure capital investment and household affordability.

In addition, many of the practical implementation aspects can be supported by lessons learnt during the pilot stage and hence it is important that the pilot implementation is designed with recovery of these lessons at front of mind.

Contents

Tables

Figures

1 Introduction

This investigation looks at alternative energy technologies for implementation into one or more of townships in Gauteng. The report considers alternative energy technologies, the socio-economic backdrop of the townships and a decision making process to shortlist the most appropriate technologies. The report also provides recommendations for consideration for the implementation of alternative energy technology projects in the province.

The Gauteng Department of Agriculture, Conservation and Environment (GDACE) has commissioned this project to contribute towards economic and social development, through sustainable energy provision which will contribute to enhancing the quality of life and sustainable utilisation of natural resources in the 20 prioritised township programme (20PTP) as well as other programmes of the province.

As a starting point for the analysis the socio-economic conditions and energy status in a range of different sectors are investigated. The report specifically looks at conditions within the following sectors;

- Population and households
- Infrastructure and Community Facilities

The details of the socio-economic assessment can be found in the background report attached at the end of this document (Appendix D: Socio-economic and energy profile). Based on this analysis the report provides an energy demand overview of selected application types of households and institutions which is required in order to define where the technologies need to be applied.

1.1 Energy Demand Overview

1.1.1 Defining Application Types

For the purpose of identifying alternative energy options and interventions, it is necessary to define a number of specific household and institutional types in terms of current energy use. This profile is then used as the basis of developing appropriate alternative energy options. While the Socio-Economic and Energy Report (Appendix D: Socio-economic and energy profile) identified a range of household types based on household stratifications identified in the Census 2001 as well as a number of socio-economic and energy analyses, these household types were presented as composite pictures. The information was gathered from a range of sources presenting a composite picture which captures the broad socio-economic contours of particular household types. To capture all variations in household composition and energy use practices would be a vast and impractical exercise. Categorization therefore had to be simplified which inevitably resulted in fewer, larger categories accommodating some variation within. A single *average* household was developed as representative of each type.

For the purpose of analysing actual interventions, what is required are more specific profiles of households and institutions; moving from the general to the specific, from the *average* household to 'actual' households which as closely as possible depict likely on-the-ground energy use patterns in the province. Such more specific energy use profiles were developed (see below). This was also one of the key issues raised by stakeholders at the workshop which has therefore now been addressed.

With regard to institutions there is no single size or standard model. While schools build in 2007 may all correspond to a single plan, the schools built in 1990 will differ, due to differences in budgets, governments and population densities, etc. What we have done is to identify reasonably standard institutional models which we have presented here as institutional application types.

Households

The housing types defined in the Socio-Economic and Energy Report (Appendix D: Socio-economic and energy profile) are composite profiles which include, within each profile type, a range of energy use patterns. For the evaluation of appropriate energy technology interventions it is necessary to use examples which are as representative of actual household energy use practices as possible. In deriving these household types, we drew on a number of previous township household energy studies (Annecke, 2005; Nicol, 2007; Cowan et al, 2004) and identified the most common sets of energy use practices and presented these as actual households. These application types represent the most common household energy use practices covering almost 75% of township households and will be highly representative of a range of areas within the province[2]. These include:

- Privately built formal electrified households; represent an exclusive yet expanding household type in Gauteng townships.
- Formal electrified households (mono-fuel); a government built formal house relying solely on electricity
- Formal electrified households (multiple fuels); a government built formal house relying on a mix of fuels including electricity, paraffin, candles, etc.
- Informal un-electrified household (multiple fuels); these households rely on a range of non-electrical energy sources including paraffin, candles, coal, etc.

Details on these types are shown in the tables and graphs below.

Table 1: Privately developed HH (electricity)

Demand	**kWh/month**	**R/month**	**% of total cost**
Geyser	300	R 135	45%
Cooking*	132	R 59	20%
Lights	45	R 20	7%
Water heating (kettle)	21.6	R 10	3%
Space heating	39	R 18	6%
TV/radio	15.6	R 7	2%
Refrigerator	107.25	R 48	16%
Total (kWh)	660.45	R 297	100%
R/kWh	R 0.45		
Total (R/month)	R 297		

* Cooking consumption is based on a microwave oven and an electric oven and hob

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[2] By including formal HH (elect) and formal HH (multiple fuels) as well as privately built HHs we cover the 59% formal household component. The inclusion of an unelectrified informal household represents 60% of informal HHs which collectively represent 23% of township households. 59% + (60% of 23%) 14% = 73%

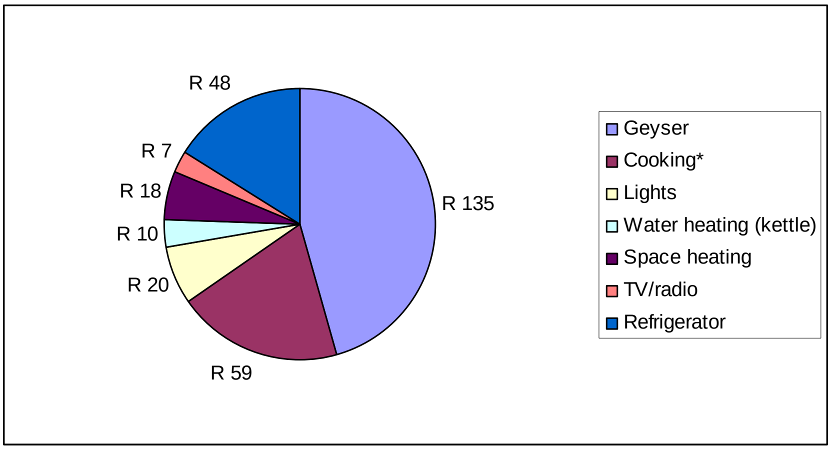

Figure 1: Privately developed HH energy cost breakdown

Table 2: Formal electrified HH (mono-fuel)

Demand	**kWh/month**	**R/month**	**% of total cost**
Geyser	0	R 0	0%
Cooking	90	R 41	30%
Lights	18	R 8	6%
Heating	78	R 35	26%
TV/radio	10.8	R 5	4%
Refrigerator	107.25	R 48	35%
Total (kWh)	304.05	R 137	100.00%
R/kWh	R 0.45		
Total (R/month)	R 137		

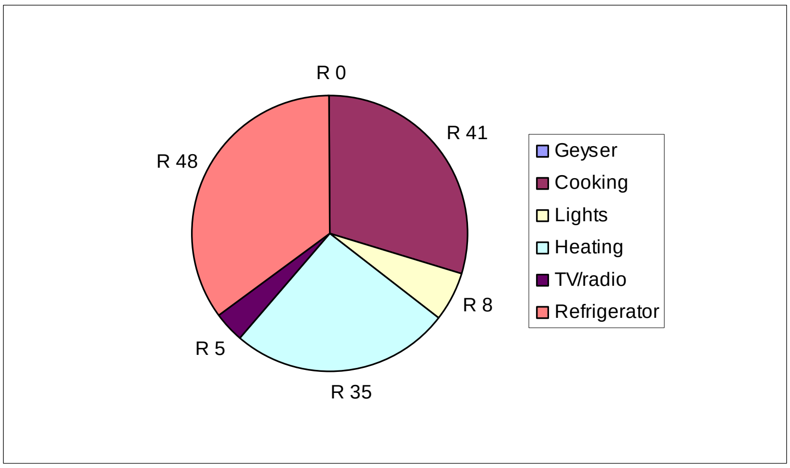

Figure 2: Formal electrified HH (mono-fuel) cost breakdown

Table 3: Formal electrified HH (multiple fuels)

Demand	kWh/month	Other	Units	cost	Total cost
Geyser	0				R 0
Cooking	30	Paraffin	9	R 54.00	R 68
Lights	15				R 7
Heating	30	Coal	15	R 30.00	R 44
TV/radio	11				R 5
Refrigerator	110				R 50
Total (kWh)	196				
R/kWh	R 0.45				
Total energy costs					**R 172**

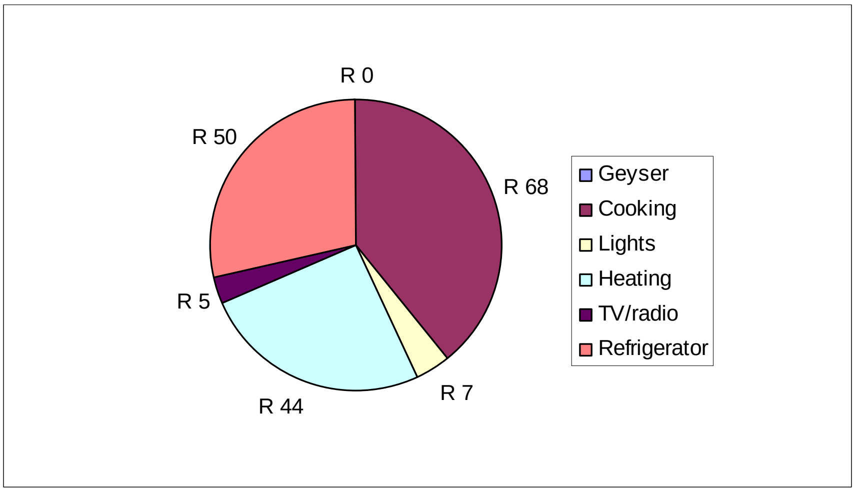

Figure 3: Formal electrified HH (multiple-fuel) cost breakdown

Table 4: Informal un-electrified HH (Multiple fuels)

Demand	Energy source	Units	cost
Geyser		0	R 0
Cooking	Paraffin	14	R 84
Lights	Candles	25	R 25
Heating	Paraffin	1	R 6
	Coal	16	R 32
Radio	Dry cell battery	1	R 20
Cell phone charge	Elect - external	4	R 20
Total			**R 187.00**

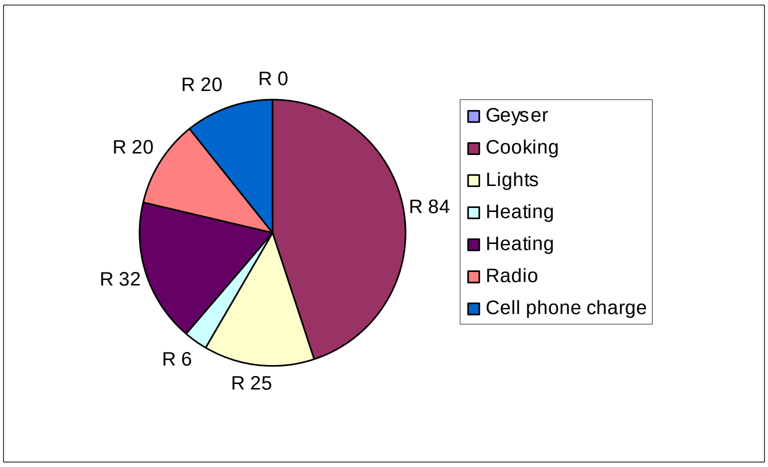

Figure 4: Informal un-electrified (multiple fuels) cost breakdown

Institutions

We have selected 2 types of institutions for the purpose of developing detailed energy use patterns as part of developing application types.

- Schools
- Clinics

Table 5: Energy profile of standard township school

Description	**#**	**Rating**	**Hrs/day**	**Whrs/day**	**kWh/month**	**% of energy**
Geyser	1	2000	5	10000	300	18%
Lights - Tubular FL	120	20	4	9600	288	18%
Lights - Incandescent	6	60	4	1440	43.2	3%
Lights - security	4	150	7	4200	126	8%
Computer	5	120	3	1800	54	3%
Electric bar heater	3	2000	2	12000	360	22%
Cooking (hotplate)	1	2000	3	6000	180	11%
Cooking (microwave)	1	1400	2	2800	84	5%
Radio	1	18	3	54	1.62	0%
Kettle	1	2400	1.5	3600	108	7%
Refrigerator	1	400	6.5	2600	78	5%
Total					**1622.82**	100%

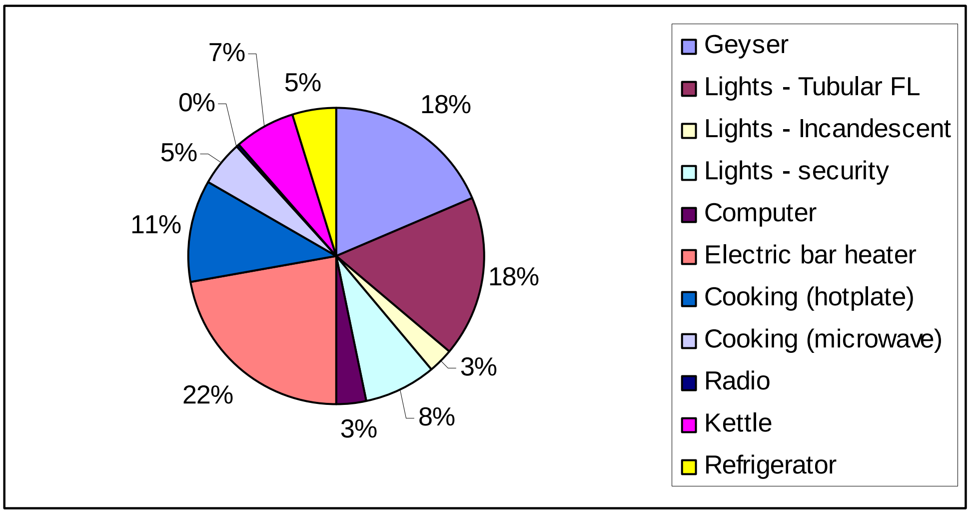

Figure 5: Standard school energy breakdown

Table 6: Energy profile of standard township clinic

Description	**#**	**Rating**	**Hrs/day**	**Whrs/day**	**kWh/month**	**% of energy**
Geyser	2	2000	5	20000	600	34%
Lights - Tubular fluorescent	48	20	4	3840	115.2	6%
Lights - Incandescent	20	60	4	4800	144	8%
Lights - security	4	150	7	4200	126	7%
Computer	1	120	3	360	10.8	1%
Heating	3	2000	2	12000	360	20%
Cooking	1	2000	3	6000	180	10%
TV/radio	1	20	5	100	3	0%
Kettle	1	2400	2	4800	144	8%
Refrigerator	1	550	6.5	3575	107.25	6%
Total					**1790.25**	100%

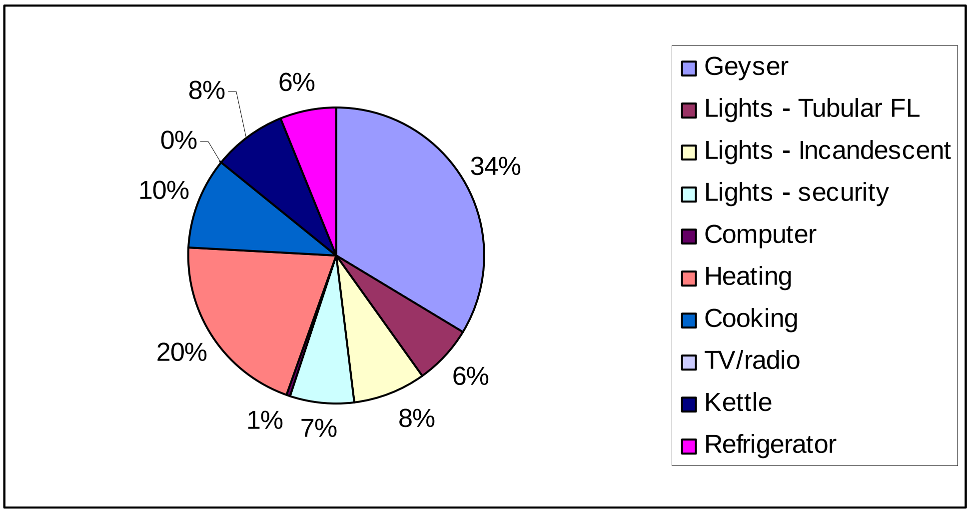

Figure 6: Standard clinic energy breakdown

2 Overview of Alternative Energy Options

This section gives a definition of alternative energy technologies and presents possible alternative energy options appropriate for various residential and institutional applications in Gauteng. The type of energy that each option supplies is given and the technology is described. The most relevant case studies from a literature survey are given along with the findings or lessons from each. The key issues such as pros, cons, risks and impacts of each technology are tabulated.

2.1 Definition of Alternate Energy Technologies

For the purposes of this study 'alternate energy technologies' shall be defined as those that are not currently mainstream in the residential areas of Gauteng, as well as those that present a cleaner or more sustainable option and that provide a social need.

The alternate technologies would improve the energy supply with less polluting and more decentralised options. These contribute to improved health conditions by reducing air pollution (especially within homes but in the townships in general), increased energy security (currently an important factor in light of load shedding by the national utility) and local job creation (by using on-site energy or energy efficiency measures supplied locally).

Decentralising energy supply means that electricity is generated where it is needed. The World Alliance for Decentralised Energy (WADE) states that:

"*Central generation ... generates electricity in large remote plants and power must then be transported over long distances at high voltage before it can be put to use. It does not matter what technology one employs, whether it is used in connection with an existing grid or in a remote village, or whether the power comes from a clean renewable source or from burning fossil fuel: if the generator is 'on-site' it is DE. This means that, strictly speaking, DE could imply technologies that are not necessarily cleaner for the environment such as diesel generators without heat recovery. More often than not, however, DE is synonymous with cleaner electricity- indeed that is one of DE's main benefits.*" [1]

2.2 Available Alternate Technology Options

An initial list of alternate energy options for consideration in the townships is provided. At this stage of the process of choosing technologies little consideration, besides being generally less polluting and decentralised, was given as to the appropriateness of the technologies.

The main technology groups are listed below in Table 7 (Supply Side) and Table 8 (Demand Side) along with the type energy they provide and a brief technical description. Supply side is defined as those technologies that provide energy in the form of electricity, heat or light whereas demand side is defined as those technologies that improve energy efficiency by providing the same service for less energy (through different technology, better thermal insulation or passive solar design).

Table 7: Description of Alternate Energy Technologies (Supply Side)

Technology	Provides	Technical Description
Solar Water Heating	Hot water for bathroom and kitchen use.	There are three main types: Solar Mat – flexible black pipes or extruded hollow sections absorb heat from the sun and transfer it to water flowing within. Flat-plate collector – the black interior of an enclosed flat case absorbs the sun's energy and heats water flowing in tubes. Vacuum tube collector – the sun heats an absorber rod within an evacuated glass tubes and transfers heat to the water flowing passed the absorber. [2] In direct systems the water is directly heated by the sun. In areas where the temperature drops below freezing anti-freeze is required to protect the collector. Indirect systems use a heat exchanger which is directly heated by the sun which then indirectly heats the water. No anti-freeze is required but the additional mass of the heat exchanger needs to be heated and will reduce the heat input into the water. The angle of panel affects the efficiency. Ideally it should face north at a tilt angle of between 10^o and 30^o.
Liquid Petroleum Gas (LPG)	Heat for cooking, warming water and space.	LPG is synthesised by refining petroleum or 'wet' natural gas. It has a calorific value of 94 MJ/m^3, equivalent to 26.1kWh/m^3. It is stored in pressurised containers and can be distributed in bottles or via a piped network. LPG mixes are primarily propane, primarily butane, and more commonly, mixes including both propane (60%) and butane (40%). [3]
Reticulated natural gas	Heat for cooking, warming water and space heating	This overlaps with Sasol gas below. In some limited areas of Gauteng, such as the older suburbs of Johannesburg, there are residential gas reticulation networks which used to use so-called town gas and have now been converted to using natural gas supplied by Sasol. These reticulation networks are limited in extent and are highly capital intensive to extend – especially in existing built-up residential areas.
Biogas	Heat for cooking, warming water and space. Can also provide electricity via biogas generator	Biogas is formed in digesters (airtight containers) in which a wet (or more recently 'dry') mixtures of organic wastes are acted upon by anaerobic (without oxygen) bacteria. The organic matter is biologically broken down by three primary sets of bacteria producing about $^2/_3$ methane (CH_4) and $^1/_3$ carbon dioxide (CO_2) and small amounts of nitrogen, hydrogen & hydrogen sulphide. Typically 1m^3 of unscrubbed biogas will provide 2 hours cooking time or 1.5kWh of electricity, and 2.5m^3 of unscrubbed biogas is equivalent to 1kg of LPG. Cow manure or faeces can produce about 40 l/kg while chicken litter produces about 80 l/kg. [4]
Landfill Gas	As above	The organic fraction of waste in landfills decomposes and releases gas that is essentially biogas with a similar chemical composition as above. The gas can be tapped by placing extraction pipes into the landfill which can then be distributed as a household gas or used to generate heat or power at the landfill.
Sasol gas	Heat for cooking, warming water and space heating	Sasol Gas markets and distributes hydrogen-rich gas produced at Sasolburg and methane-rich gas produced at Mpumalanga. Through its 1,500 km pipeline network in South Africa, it delivers pipeline gas to industrial and commercial sectors in Gauteng, Mpumalanga, the Free State and KwaZulu-Natal. [5]

SUPPLY SIDE continued		
Technology	**Provides**	**Technical Description**
Gelfuel	Heat for cooking and lighting	Bioethanol (made from sugar crops, starchy crops and cellulosic biomass) is mixed with a gelling agent to form a gel. Colouring may be added to enhance the visibility of the flame and give the gel a colour. [6] The calorific value varies depending on the quality of the fuel but is about 16kJ/kg. [7]
Other clean, smokeless fuels	Heat for cooking, warm water / space	Coal can be devolatised (to ~10% residual volatiles) to improve its pollutive emissions when burned. [8]
Solar cookers	Heat for cooking	The main forms of solar cookers are reflective parabolic dishes with a pot holder at the reflective focal point, or clear-top boxes with an inner reflective lining and central pot holder. Solar energy is reflected and absorbed by the pot to cook meals.
Wind electricity	Electricity	Wind energy turns a turbine which turns an electrical generator. The power is a cube function of the wind speed. The electricity produced can be stand alone or grid connected. The turbines can be vertical or horizontal axis machines and they can be building-mounted (usually on the roof) or free-standing. Wind farms can be single or groups of turbines and are normally MW machines. Smaller <1MW turbines may be more suitable for on-site and/or decentralised installations. [3] Control of power and protection in strong winds is achieved by pitch or stall (passive or active) control. The size of a turbine is usually its peak output at strong wind speeds.
Small hydro electricity	Provides electricity	Generally small hydro is 'run of the river' where water is diverted over a short distance and height drop through a penstock (or pipe) and flows through a turbine which spins a generator producing power. It can be grid connected or stand-alone.
Solar PV electricity	Provides electricity	Photovoltaic materials are usually solid-state semiconductors which generate electric direct current (DC) when exposed to sunlight (note it is light, rather than heat, which produces the electricity). Generally the panels are glass-based with aluminium-framed panels, but can also be plain cladding, solar roof tiles and custom built glazing with integral PV cells. [3] The angle of panel affects the efficiency. Ideally it should face north at an angle of between 20^o and 30^o tilt. The size of a panel is usually its peak output at optimum light. 1m^2 of PV is equivalent to about 140 Wp. Thin film technology developed by South African Vivian Alberts using CIGSSe-technology utilises copper, indium, gallium, sulphur and selenium. It has a high absorption capability in layers no thicker than a human hair. The photo-responsive alloy can be applied to most flexible surfaces and is suited to roof tiles or glass panes. New innovations such as reflectors that concentrate light onto a cell increase the efficiency of a solar PV panel. Systems that are able to track the sun also result in higher efficiencies.
Fuel Cell electricity	Provides electricity	A fuel cell is an electrochemical energy conversion device. It produces electricity from various external quantities of fuel (on the anode side) and oxidant (on the cathode side). These react in the presence of an electrolyte. Generally, the reactants flow in and reaction products flow out while the electrolyte remains in the cell. Fuel cells can operate virtually continuously as long as the necessary flows are maintained. Fuel cells consume reactant, which must be replenished. Many combinations of fuel and oxidant are possible. A hydrogen cell uses hydrogen as fuel and oxygen as oxidant. Other fuels include hydrocarbons and alcohols. Other oxidants include air, chlorine and chlorine dioxide [3].

Table 8: Description of Alternate Energy Technologies (Demand Side)

Technology	Provides	Technical Description
Plastering	Thermal insulation	Plastering a building improves the thermal insulation thereby reducing the need for heating or cooling.
External painting	Thermal cooling	White (or light colours) reflect solar radiation and help keep buildings cool.
Ceiling / insulation	Thermal insulation	A ceiling and/or insulation improves the thermal insulation of the roof thereby reducing the need for heating or cooling.
Efficient lighting and electrical appliances	Lighting	Efficient lighting and appliances provide the same service but at lower energy cost to the owner. The most basic lighting improvement is a compact fluorescent light (CFL) of which a 15W bulb gives similar light to a 60W incandescent bulb and lasts about 10 times longer. Light emitting diodes (LED) are even more efficient and have an even longer life (~80years). Refrigerators and other household appliances with an energy saving rating will use less energy for the same service.
Efficient design (for new build)	Thermal insulation and comfort	For new buildings orientation to the sun can allow passive heating or cooling especially if combined with overhangs that allow the low winter sun in (for heating) but shade the high summer sun (for cooling). Also double glazed windows improve thermal insulation. Interior comfort can be improved by selecting non-toxic materials (paints, carpets, etc), designing for through draft to improve air movement, etc.
Efficient cooking	Cooking	A hotbox is an insulated 'container' into which a hot pot can be placed. The heat is absorbed by the pot thus cooking continues without further energy input. Swapping paraffin stoves with more efficient less-polluting and safer stoves and use of improved coal stoves reduces energy costs and improves health and safety.
Geyser & pipe insulation	Hot water	Insulation of geysers and piping by geyser blankets and pipe sleeves with thermally insulating material reduces heat loss and therefore energy.

2.3 Lessons from Case Study Experiences

An extensive literature survey was conducted for case study experience of the list of alternative technologies in similar contexts. There were many good studies on solar water heater pilot projects and roll-outs as well as off-grid solar home systems. The details of this survey can be found in the background report attached at the end (Appendix C: Review of alternative technology options).

The three most relevant case studies, which gave a good overview of experience with solar water heaters, gas systems, wind, PV, thermal design, efficient lighting in South Africa were:

- **Moshoeshoe Eco-village** in Sol Plaatjie municipality in the Northern Cape comprises of 13 units as a demonstration phase for the Hull Street Project (>2 500 units). The municipality is grid connected and the eco-village includes a wide range of innovative housing solutions which advance the state of knowledge and experience in housing delivery in South Africa. The project was formally opened on 12 March 2002 [9].

  The main finding and lessons learned were:

    - A 15y LCC for SWH showed that they are nearly R4,000 less than 100 litre electric geyser
    - LPG bottles needed to be locked in cages to prevent theft
    - Hot boxes reduced energy use for cooking
    - First wind electricity on national grid and demonstration for distributed RE on grid
    - PV is not financially cost effective yet
    - Passive solar design, ceilings, appropriate window sizing / location improved thermal performance

- **The City Of Cape Town's Low-Cost Urban Housing Upgrade Project in Kuyasa, Khayelitsha** in the Western Cape has an initial pilot project of 10 installations which were completed in December 2003. The upgrade as a whole is the first registered CDM gold standard project in the world and the interventions include solar water heaters, energy efficient lighting and insulated ceilings in each unit. The pilot was a demonstration for a similar rollout to about 2 300 houses in Khayelitsha [10], [11].

  The main finding and lessons learned were:

    - Each house saved at least 900 kWh per annum of electricity (and 1.3 tonnes of CO_2) per annum for water heating by the use of a SWH
    - Houses more comfortable all year round
    - Ceiling and insulation use reduced demand in energy consumption by 1,494 kWh/a/house (1.3 tonnes CO_2/a/house) for heating or cooling
    - Two CFLs reduced electrical consumption by 257 kWh/a/house (0.2 tonnes CO_2/a/house) compared to two 60 W incandescent bulbs
    - Cost savings to the household and reduction in peak demand with associated electricity infrastructure savings

- **Folovhodwe Solar Village Project** in Limpopo Province is at least ten kilometres from the nearest existing power line. It is the first South African demonstration site for the solar electrification of a complete rural community. All 582 households in the village received Solar Home Systems (SHS). Through the Folovhodwe project it is hoped to demonstrate that solar photovoltaics provide a viable alternative for areas too far from the grid [12].

The main finding and lessons learned were:

- A R100 installation fee and R35/m service fee was required to make the project feasible but often the R100 was not paid and the community decided only to pay a R20/m service fee
- Installation should not have proceeded without a connection fee being collected from each household
- 15 to 20 solar modules were stolen from households (poles too short)
- Bavarian PV panels - do not have a protective aluminium frame making their installation difficult

2.4 Key Issues of Alternate Technology Options

The key alternate technology issues/questions – which are summarised as pros, cons, risks and impacts – arise from a need in the townships for reduced energy demand, more sustainable energy supply, improved quality of life by improved health and safety, and improved energy security. This section considers each of the alternative technologies and lists their main associated pros and cons, risks and impacts.

The key issues are presented in Table 9 (Supply Side) and Table 10 (Demand Side) below.

Table 9: Key Issues of Alternate Energy Technologies (Supply Side)

Technology	**Pros**	**Cons**	**Risks**	**Impacts**	**Remarks**
Solar Water Heating	• No/little electrical power required • On-site free energy supply • Grid independent • No energy distribution needed • Robust	• High capital cost • Clouds reduce effectiveness	• Needs funding or pay-for-service collection	• High impact on hot water provision • High impact on capital cost	• Upfront cost can be mitigated by including the cost in a home loan • Subsidies are becoming available
Liquid Petroleum Gas (LPG)	• Good calorific value • Good existing distribution	• Fuel needs to be purchased • Reliance on distributor and distribution network	• Explosion • Distributer cost recovery • Assurance of supply of LPG	• High impact on heating/cooking provision	
Biogas	• Energy from waste • On-site free energy supply • Sufficient calorific value • Fertiliser production	• Capital cost of digester • Large amounts of organic feedstock required • Scrubbing needed for generators • Skilled installation • Owner management required	• Variable supply according to seasonal ambient temperature changes • Customer buy-in	• High impact on heating/cooking provision assuming feedstock available • Medium impact on electricity supply depending on generation size	• Probably more suited to institutional or municipal level implementation and rural areas?
Landfill Gas	• Energy from waste • Sufficient calorific value	• Capital cost of plant • Scrubbing needed for generators • Not decentralised • Fuel needs to be purchased or is expensive to extract • Reliance on distributor and distribution network	• Explosion • Customer buy-in	• High impact on heating/cooking provision • High impact on electricity supply depending on generation size	
Sasol gas and Reticulated natural gas	• Natural gas • Sufficient calorific value	• Reliance on distributor and distribution network • Fuel needs to be purchased • Reliance on distributor and distribution network	• Explosion • Distributer cost recovery	• High impact on heating/cooking provision	
Gelfuel [7]	• Safer than paraffin • Cleaner if good quality	• Requires significant volumes of water to produce • Fuel needs to be purchased • Reliance on distributor and distribution network	• No quality control on fuel or stoves • Currently not economic (R/J) • Customer buy-in	• Medium impact on cooking provision, and low if quality low	

SUPPLY SIDE continued

Technology	Pros	Cons	Risks	Impacts	Remarks
Other clean, smokeless fuels - LSF [8]	• 10% smoke emission • Same look and ability as coal • Can use in existing coal cookers • White paper endorsed	• Still fossil fuel • Fuel needs to be purchased • Reliance on distributor and distribution network	• No buy-in from transport / distribution • LSF producer could just sell coal • Low price of coal	• High impact on heating/cooking provision	
Solar cookers	• No electrical power required • On-site free energy supply if good solar radiation • Grid independent • No energy distribution needed • Robust	• Heat control • Clouds reduce effectiveness	• Little success in rollout to villages	• Medium impact on cooking provision • High impact on demand side management	
Wind electricity	• On-site free clean energy supply if good wind regime • Can be grid independent or grid connected	• High capital cost • Skilled installation	• Capacity factor wind dependant • Spares availability	• High impact on electricity supply if good wind regime	
Small hydro electricity	• On-site free clean energy supply if water available • Can be grid independent or grid connected	• Long term investment • Skilled installation	• Water dependant	• High impact on electricity supply if good water resource available	
Solar PV electricity	• On-site free clean energy supply if good solar radiation • Can be grid independent or grid connected	• Very high capital cost • Skilled installation	• Theft • Limited use for cooking and heating at reasonable price	• High impact on electricity supply if good solar regime	
Fuel Cell electricity	• On-site clean energy supply if anode and gel easily serviceable • Can be grid independent or grid connected	• High capital cost • Skilled installation • Reliance on distributor and distribution network	• Theft • Limited use for cooking and heating at reasonable price	• High impact on electricity supply	• Good local job creation opportunity • Emerging technology

Table 10: Key Issues of Alternate Energy Technologies (Demand Side)

Technology	Pros	Cons	Risks	Impacts	Remarks
Plastering	• Easily applied • Well developed technology • Widely available	• Additional cost and upkeep		• Medium impact on thermal insulation	• Good local job creation opportunity
External painting	• Easily applied • Well developed technology • Widely available	• Additional cost and upkeep		• Low impact on thermal cooling	• Good local job creation opportunity
Ceiling / insulation	• Easily installed • Widely available	• Additional cost		• Medium impact on thermal insulation • Medium impact on energy efficiency	• Good local job creation opportunity
Efficient lighting and electrical appliances	• Easily installed • Lighting widely available • Lower operating costs • Better life (lighting)	• Higher capital cost • Appliances not as widely available.	• CFL disposal (mercury)	• High impact on lighting and appliance provision • High impact on energy efficiency	
Efficient design (for new build)	• Easily incorporated • No/small cost change in design • Lower thermal costs	• Retrofit impossible/difficult		• Medium impact on thermal insulation • High impact on energy efficiency	
Efficient cooking	• Lower operating costs • Low capital cost • Improved air quality			• Medium impact on cooking provision • High impact on energy efficiency	
Geyser & pipe insulation	• Low capital cost • Lower energy costs	• Easy installation		• Low impact on demand side management	

3 Development of a Decision-Making Framework

In order determine the most appropriate technologies for the townships in Gauteng a decision making framework is required. This process assesses each technology by initially screening them through qualifying criteria and then ranking them using weighted prioritising criteria.

3.1 Multi-Criteria Decision Analysis

Multi-criteria decision analysis (MCDA) has been used in this project as the basis for the required decision making framework. MCDA is both a process and a methodology together they provide a consistent approach to comparing alternatives that have impacts on, or relevance for, a number of different criteria [13, 14]. Options are evaluated on the basis of individual criteria, and these scores are aggregated to give overall scores for all options relative to each other. Thus, alternatives can be compared on the basis of individual criteria, on the basis of scores aggregated in logical groupings and on the basis of overall aggregated scores.

The MCDA process for this project was developed during initial discussions with the client and subsequent preparatory work, followed by an expert panel workshop amongst the team members. The specific criteria used were then tested and outlined for comment and discussion at the stakeholder workshop. The workshop endorsed the criteria with some comments. These comments were taken into account and a final run of the evaluation was done using the refined criteria, scores and arrangement of alternative options. The various spreadsheets flowing from this process have been made available as supporting documents for GDACE.

3.2 Criteria for Technology Evaluation

3.2.1 Disqualifying Criteria

The disqualifying criteria enable an increased focus on more relevant technology options by screening out the non-starters. The assessment of the technologies against this criteria will result in a 'yes' or 'no' answer which determines if it is 'in' or 'out'.

The disqualifying criteria are described below for supply side technologies (and listed in Table 11) followed by the criteria descriptions for demand side technologies (as listed in Table 12).

Supply side disqualifying criteria descriptions:

- **No energy resource** – if the energy resource required by a supply technology is poor or unavailable in the Gauteng area then this criterion will disqualify that technology. There is no control over or possibility of changing this criterion by creating the resource to qualify that technology.
- **Past failure** – if the technology has been tried in similar contexts in South Africa or similar contexts and failed then this criteria will disqualify that technology. There is very little, in the context of this study and timeline, control over or possibility of changing the past experience to qualify that technology.
- **Regulatory approval improbable** – if the technology has regulatory barriers that mean that its implementation is improbable then it will be disqualified.

There is very little, in the context of this study and timeline, possibility of changing the regulations or technology to qualify that technology.

- **EIA approval improbable** – if the technology has EIA barriers that mean that its implementation is improbable then it will be disqualified. There is very little, in the context of this study and timeline, possibility of changing the EIA process or technology to qualify that technology.

Table 11. Supply Side Disqualifying Criteria

No.	*Criteria*	*Control*	*Disqualifier*
1	No energy resource	None	Yes
2	Past failure	Very little	Yes
3	Regulatory approval improbable	Very little	Yes
4	EIA approval improbable	Very little	Yes

Demand side disqualifying criteria descriptions:

- **Past failure** – if the technology has been tried in similar contexts in South Africa or elswhere and failed then this criterion will disqualify that technology. There is very little, in the context of this study and timeline, control over or possibility of changing the past experience to qualify that technology.
- **No material or component supply** – if the material or component required by a demand technology is unavailable in Gauteng area then this criterion will disqualify that technology. There is very little control over or possibility of changing this criterion and creating the supply, in the context and timeline of this study, to qualify that technology.

Table 12. Demand Side Disqualifying Criteria

No.	*Criteria*	*Control*	*Disqualifier*
1	Past failure	None	Yes
2	No material/component supply	Very little	Yes

3.2.2 Prioritising Criteria

The prioritising criteria use a scoring system which gives a numerical value to each technology. This value then gets weighted according to the type of housing or institution to arrive at a final weighted score so that the technologies can be compared to each other and ranked.

Either five columns are chosen for each criterion with a score from 0 to 4 (with a typical range from 'poor' through to 'excellent') or three columns with a score of 0, 2 or 4 (with a typical range from 'negative' to 'neutral' to 'positive').

The prioritising criteria are described below for supply side technologies (and listed in Table 13) followed by criteria descriptions for demand side technologies (as listed in Table 14).

Supply side prioritising criteria:

- **Security of supply** – is the ability of the technology to deliver energy when required. It takes into account the consistency of the resource, fuel or feedstock required by the technology to generate energy. It also looks at the price stability of any required fuel.

- **Technical constraints** – are the installation or operation challenges that the technology presents.
- **Levelised costs** – of a technology is the energy supply costs as a present value average of the capital and operational costs over 15 years (or the life of the technology if less than 15 years) in R/kWh/a. This method removes inflation to give a present value cost. The scores are assessed on an approximate deviation from the current cost of energy to take into account current energy costs in the various circumstances considered.
- **Environmental Impacts** – has three criteria:
    - **Air** – is the impact the technology has on the local (at the point of use) air quality
    - **Water** - is the impact the technology has on the local (at the point of use) water quality (run off, river or groundwater)
    - **Waste** – is the amount of local (at the point of use) waste the technology produces
- **Employment potential** – is the potential that the technology has of providing jobs to the local community (manufacture, implementation or sales).
- **Regulatory barriers** – are the legal, policy or standards barriers that may limit the use of the technology in the area.
- **Social / user acceptability** – is the ease with which the technology is accepted by the user ('user normal') and community and includes the perception of the technology.
- **Safety to user** – is the potential danger of the technology to the health and safety of the user.
- **EIA barriers** – are the environmental, historic, heritage and visual barriers that may limit the use of the technology in the area.
- **Replicability potential** – is the potential that the technology is able to be replicated throughout the townships.
- **Opportunities for avoided cost** – is the opportunity that the technology provides for reducing the annual levelised energy costs of the user when compared to business as usual or the commonly used supplies.
- **Security risk (theft proof)** – is the risk of the technology being stolen and includes the potential second had market of the technology as well as its robustness to vandalism.
- **Tenure** – is the possibility of ownership of the technology by the home dweller which may impact whether the dweller buys in or not.
- **Public or private investment/subsidies** – is the potential to attract public or private investment or subsidies for the technology, either individually or on a mass roll-out basis, which will ultimately lower the cost to the user.
- **Carbon finance potential** – the potential for the technology to receive income by carbon avoidance finance mechanisms (certified or verified emission reduction certificates).

Table 13. Supply Side Prioritising Criteria

Criteria		***Rating / Score***				
		0	**1**	**2**	**3**	**4**
Security of supply		None	Poor	Neutral	Good	Excellent
Technical constraints		High		Neutral		Minimal
Levelised Costs (R/kWh/yr)		> +25%	> +10%	Neutral (+/- 10%)	< - 10%	< -25%
Environmental Impacts	Air	Negative		Neutral		Positive
	Water	Negative		Neutral		Positive
	Waste	Negative		Neutral		Positive
Employment potential		None	Poor	Neutral	Good	Excellent
Regulatory barriers		High	Moderate	Neutral	Limited	Supportive
Social / user acceptability		Poor	Cautious	Moderate	Good	Excellent
Safety to user		Poor	Moderate	Neutral	Good	Excellent
EIA barriers		High	Moderate	Neutral	Limited	N/A
Replicability potential		Poor	Moderate	Neutral	Good	Excellent
Opportunities for avoided cost		Poor	Moderate	Neutral	Good	Excellent
Security risk (theft proof)		Poor	Moderate	Neutral	Good	Excellent
Tenure		Negative		Neutral		Positive
Public or private investment/subsidies		None	Poor	Neutral	Good	Excellent
Carbon Finance Potential		None	Poor	Neutral	Good	Excellent

Demand side prioritising criteria:

- **Technical constraints** – are the challenges that the technology presents in installation or operation.
- **Levelised costs** – of a technology is the energy avoided costs as a present value average of the capital and operational costs over 15 years (or the life of the technology if less than 15 years) in R/kWh/a. This method removes inflation to give a present value cost. The scores are assessed on an approximate deviation from the current cost of energy to take into account current energy costs in the various circumstances considered.
- **Environmental Impacts** – has three criteria:
  - **Air** – is the impact the technology has on the local (at the point of use) air quality
  - **Water** - is the impact the technology has on the local (at the point of use) water quality (run off, river or groundwater)
  - **Waste** – is the amount of local (at the point of use) waste the technology produces
- **Employment potential** – is the potential that the technology has on providing jobs to the local community (manufacture, implementation or sales)
- **Regulatory barriers** – are the legal and policy barriers that may limit the use of the technology in the area.
- **Social / user acceptability** – is the ease with which the technology is accepted by the user ('user normal') and community, the perception of the technology.
- **Safety to user** – is the potential danger of the technology to the health and safety of the user.

- **EIA barriers** – are the environmental, historic, heritage and visual barriers that may limit the use of the technology in the area
- **Replicability potential** – is the potential that the technology is able to be replicated throughout the townships.
- **Opportunities for avoided cost** – is the opportunity that the technology provides for reducing household levelised energy costs of the user when compared to business as usual.
- **Security risk (theft proof)** – is the risk of the technology being stolen and includes the potential second had market of the technology as well as its robustness to vandalism.
- **Tenure** – is the possibility of ownership of the technology by the home dweller which may impact whether the dweller buys in or not.
- **Public or private investment/subsidies** – is the potential to attract public or private investment or subsidies for the technology, either individually or on a mass roll-out basis, which will ultimately lower the cost to the user.
- **Carbon finance potential** – the potential for the technology to receive income by carbon avoidance finance mechanisms (certified or verified emission reduction certificates).

Table 14. Demand Side Prioritising Criteria

Criteria		***Rating / Score***				
		0	**1**	**2**	**3**	**4**
Technical constraints		High		Neutral		Minimal
Levelised cost (R/kWh.annum)		> +25%	> +10%	Neutral (+/- 10%)	< -10%	< -25%
Environmental Impacts	Air	Negative		Neutral		Positive
	Water	Negative		Neutral		Positive
	Waste	Negative		Neutral		Positive
Employment potential		None	Poor	Neutral	Good	Excellent
Regulatory barriers		High	Moderate	Neutral	Limited	Supportive
Social / user acceptability		Poor	Cautious	Moderate	Good	Excellent
Safety to user		Poor	Moderate	Neutral	Good	Excellent
EIA barriers		High	Moderate	Neutral	Limited	N/A
Replicability potential		Poor	Moderate	Neutral	Good	Excellent
Opportunities for avoided cost		Poor	Moderate	Neutral	Good	Excellent
Security risk (theft proof)		Poor	Moderate	Neutral	Good	Excellent
Tenure		Negative		Neutral		Positive
Public/ private invest/subsidy/DSM		None	Poor	Neutral	Good	Excellent
Carbon Finance Potential		None	Poor	Neutral	Good	Excellent

3.3 Evaluation of Technologies Against User Types

Expert judgement and empirical data was applied to the above criteria to evaluate the various technologies against user types and hence specific applications.

3.3.1 Description of User Types & Energy Demand Profile

The detailed energy profile is given in Section 1.1.1 above but here the types are described.

Electrified Privately Developed (Formal) Household

This type is a privately built brick house of about 60m^2 which is grid connected. It typically has an electric geyser and incandescent electric lights (two inside and one outside) as well as electric stoves, kettles, electric heaters, TV/radio and a refrigerator. It has a ceiling with insulation and the walls are plastered. The inhabitants are middle income earners who pay an average of R297 per month on the electricity bill.

Electrified and Electricity Use Only Middle to Low Income (Formal) Household

This is a government built RDP style house of about 30m2 that is grid connected. It typically has incandescent electric lights (one inside and one outside) as well as an electric stove, an electric heater, a TV/radio and a refrigerator but no electric geyser. There is no ceiling or insulation and the walls are un-plastered. The inhabitants are middle to low income earners paying on average R137 per month on energy.

Electrified and Mixed Fuel Use Low Income (Formal) Household

This is a government built RDP style house of about 30m2 that is grid connected but uses, in addition to electricity, a mixture of fuels. Some of this type of house use electricity for cooking while others use paraffin and some use electricity for heating while others use coal. There are incandescent lights, (one inside and one outside) as well as an electric stove, an electric heater, a TV/radio and a refrigerator but no geyser. It is assumed for the ranking of technologies that all heating is by coal (only small group use electricity for space heating) and all water heating is by paraffin (meaning that 30kWh plus the free basic 50kWh per month is used for cooking). The inhabitants of this house are low income earners paying R172 per month on the energy mix.

Un-electrified Low Income (Informal) Household

This type is an informal house (or a 'shack') and it is assumed no bricks or mortar are used for construction. It is not grid connected and has no services. The house uses a mixture of fuels such as paraffin for cooking, candles for light, coal or paraffin for heat as well as a battery for a radio and external electricity use for cell phone charging (which is paid for). The inhabitants are low income earners but are paying R187 per month on the energy mix.

Standard Electrified School

This type of institution is an 830m2 brick building that is grid connected. The school has a range of electrical appliances, typically: a geyser, fluorescent tubes (120), 6 incandescent lights, 4 security lights, 5 computers, 3 electric bar heaters, a hot plate, a microwave, a radio, a kettle and a refrigerator. It is assumed that there is no ceiling and that the walls are un-plastered. The school has some forms of income and the electricity bill is about R730 per month on average.

Standard Electrified Clinic

This type of institution is an 290m2 brick building that is grid connected. The clinic has a range of electrical appliances, typically: 2 geysers, 48 fluorescent tubes, 20 incandescent lights, 4 security lights, 1 computer, 3 electric bar heaters, a hot plate, a TV/radio, a kettle and a refrigerator. It is assumed that there is no ceiling and that the walls are un-plastered. The clinic has some forms of income and the electricity bill is about R806 per month on average.

4 General Energy Technology Assessment

4.1 Disqualified Technologies

The technologies from the long list are now assessed using the disqualifying criteria of Table 11 and Table 12. Each criterion, starting from the top of the list, is applied and as soon the technology disqualifies then it is rejected and no further disqualifying assessment is required. If it passes then the technology qualifies and is retained. The assessment is shown in Table 15 (supply side) below.

Table 15. Supply Side Disqualifying Assessment

Tech	***Disqualifier***	***Technology applicability to criteria***	***Qualifies***
Solar Water Heaters (SWH)	No energy resource	Needs sunshine, solar radiation in SA is very good.	√
	Past failure	Well established worldwide, already widely utilised in SA	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√
Liquefied Petroleum Gas (LPG)	No energy resource	Gas suppliers are available	√
	Past failure	Well established worldwide, already widely utilised in SA	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√
Biogas	No energy resource	Faeces and organic waste available as feed stock	√
	No social need	Provides heat, needed by households and most institutions	√
	Past failure	Well established in India and China, emerging success in SA	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√
Landfill Gas	No energy resource	There are landfills in some areas (pass with qualification)	√
	Past failure	Limited international experience (pass with qualification)	√
	Regulatory approval	Possible but difficult – allowed for under Gas Act	√
	EIA approval improbable	Possible by complex due to hazard and risk potential	√
Sasol Gas and reticulated natural gas	No energy resource	Not generally available to townships and unlikely to be extended in foreseeable future on significant scale	**REJECT**
Gelfuel	No energy resource	Ethanol is available and gel suppliers exist in Gauteng	√
	Past failure	Quality issues but overcoming that, success Khayelitsha pilot	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√
LSF	No energy resource	Not avail yet in South Africa	**REJECT**
Solar cookers	No energy resource	Needs sunshine, solar radiation in SA is very good.	√
	No social need	Provides cooking, needed by households and most institutions	√
	Past failure	Roll out to villages has not been successful	√
Wind	No energy resource	Wind resource in Gauteng is generally low	**REJECT**
Hydro	No energy resource	Consistent volume / pressure head not available in townships	**REJECT**
Solar PV	No energy resource	Needs sunshine, solar radiation in SA is very good.	√
	Past failure	Established worldwide, wide off-grid and back-up use in SA	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√
Fuel Cell	No energy resource	Limited but available in area	√
	Past failure	Emerging but success in Namibia and SA	√
	Regulatory approval	No known issues	√
	EIA approval improbable	No known issues	√

Table 16. Demand Side Disqualifying Assessment

Tech	Disqualifier	Technology applicability to criteria	Qualifies
Plastering	Past failure	Thermal improvement documented	√
	No material/component supply	Widely available	√
External painting	Past failure	Thermal (cooling) improvement	√
	No material/component supply	Widely available	√
Ceiling / insulation	Past failure	Thermal improvement documented	√
	No material/component supply	Widely available	√
CFLs	Past failure	Successful use of technology worldwide	√
	No material/component supply	CFLs becoming widely available	√
LEDs	Past failure	Successful use of technology worldwide	√
	No material/component supply	LEDs less widely available but emerging	√
Electrical appliances	Past failure	Successful use of technology worldwide	√
	No material/component supply	Energy labelling not yet in SA, efficiency unknown	**REJECT**
Efficient design	Past failure	Successful use of efficient design worldwide	√
	No material/component supply	Can't be retrofitted, but appropriate for new build	√
Low Smoke Stoves	Past failure	Successful use of technology (eg.Basa Magogo)	√
	No material/component supply	Method only, new stoves available	√
Hot box	Past failure	Successfully used across all income groups	√
	No material/component supply	Widely available	√
GeyserPipe insulation	Past failure	Successfully used across all income groups	√
	No material/component supply	Widely available	√

4.1.1 Summary of disqualifying Process

Disqualified and rejected supply side technologies:

- Sasol Gas
- LSF
- Wind Power Electricity
- Small Hydro Electricity

The following alternative energy supply side technologies qualified for further assessment and were retained (qualified pool):

- SWH
- LPG
- Biogas
- Landfill Gas
- Gelfuel
- Solar PV Electricity
- Fuel Cell

Disqualified and rejected demand side technologies:

- Efficient Electrical Appliances

The following alternative energy supply side technologies qualified for further assessment and were retained (qualified pool):

- Plastering
- External Painting
- Ceiling and/or Insulation
- CFL and LED lighting
- Efficient design (new build)
- Low Smoke Stoves
- Hot Box
- Geyser and Pipe Insulation

4.2 Prioritised Technologies

The technologies from the qualified pool (Section 4.1.1) are now assessed using the disqualifying criteria of Table 12 and Table 13. This entails scoring and weighting each technology using expert judgement and case study lessons and findings. The weighting factors are shown below in bar graph format quickly indicating which are the most important. The summed weighted scores for each technology of each typical household and each typical institution are also given below with the detailed spread sheets given in the appendices.

4.2.1 Supply Side Prioritising Technology Assessment

The ranking assessment below is for a composite "typical" household and institution for supply side technologies.

The typical household and institution weighting factors for supply side technologies is shown in Figure 7. Security of supply, employment potential and opportunities for avoided costs to the user are the most important here.

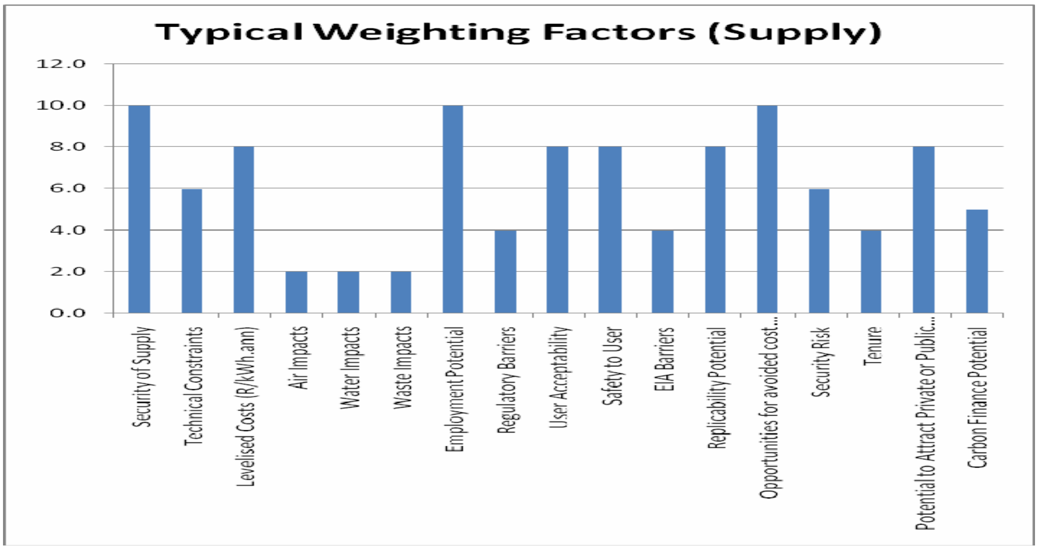

Figure 7: Typical criteria weighting factors for supply side technologies

The details of the weighted scoring for the supply side technologies are shown in (Appendix B – Technology Ranking Tables). The resultant weighted scores are summarised below in Table 17 in descending order for households (and each equivalent institution score):

Table 17. Supply side typical household and institution

	HH	INST
Solar Water Heaters	80%	80%
Gelfuels	76%	58%
Liquid Petroleum Gas	63%	62%
Fuel Cell	60%	60%
Solar Photovoltaic	57%	62%
Biogas Digesters	57%	57%
Landfill Gas	50%	57%

This is also represented graphically in Figure 8 below.

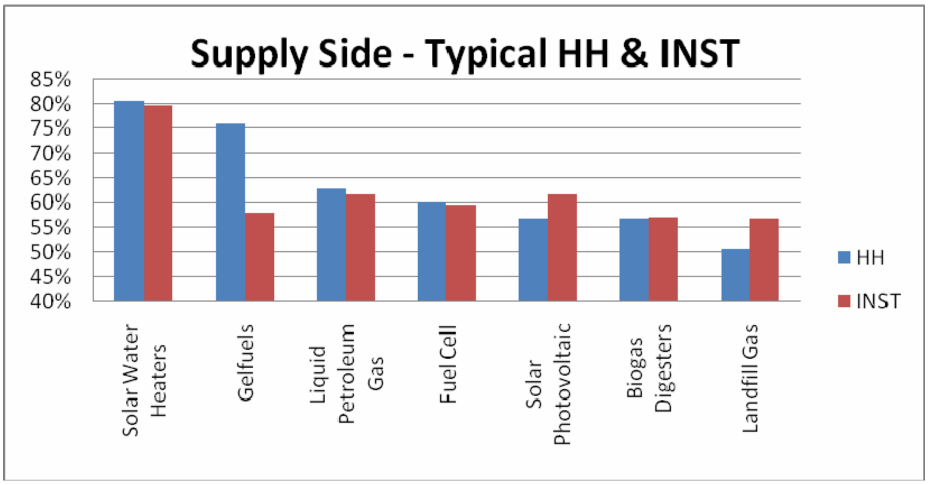

Figure 8: Supply side technologies for typical household and institution

It can be seen that for a typical household solar water heaters and gelfuels are prominent but liquid petroleum gas and fuel cells are also relevant. For a typical institution SWHs feature very strongly but solar PV and LPG are also worth considering.

The ranking shown above is a demonstration of the methodology, in Section 0 the process is applied to specific user types and is shown to have more applicable and more useful results for technology selection.

4.2.2 Demand Side Prioritising Technology Assessment

The ranking assessment below is for a typical household and institution for demand side technologies.

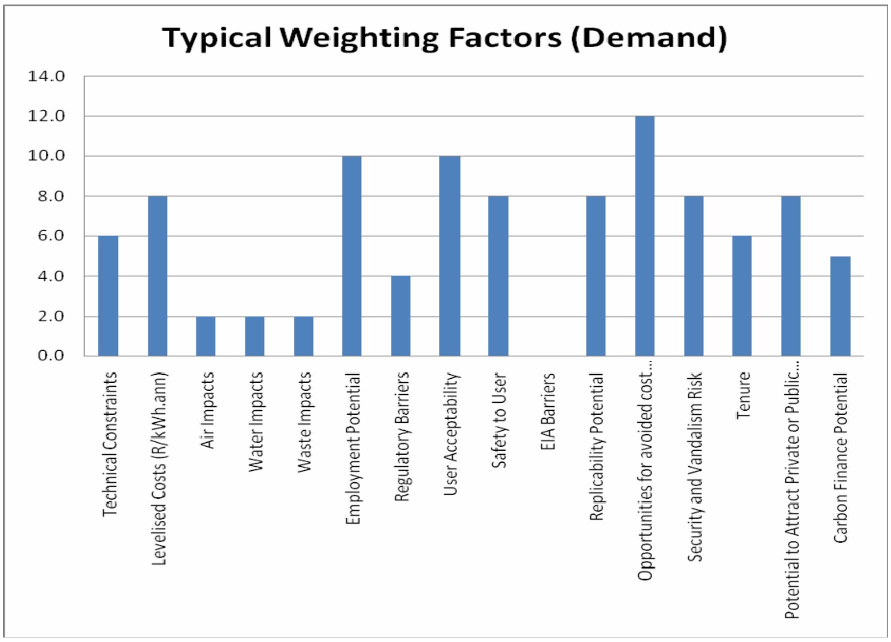

Figure 9: Typical criteria weighting factors for demand side technologies

The details of the weighted scoring for the demand side technologies are shown in Typical Ranking Demand Side. The resultant weighted scores are summarised below in Table 18 in descending order for households (and each equivalent institution score):

Table 18. Demand side typical household and institution

	HH	INST
Ceiling and/or Insulation	84%	86%
CFL lighting	83%	86%
Plastering, in & out	82%	85%
Light Emitting Diodes	78%	82%
Geyser and Pipe Insulation	77%	81%
Efficient design	77%	81%
Low Smoke Stoves	72%	72%
Hot Box	70%	70%
External Painting	71%	76%

This is also represented graphically in Figure 10 below.

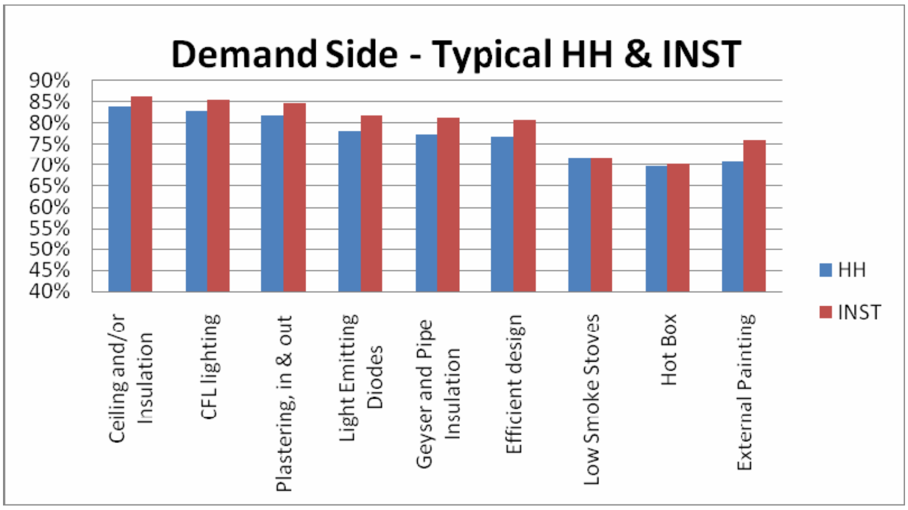

Figure 10: Demand side technologies for typical household and institution

It can be seen that for a typical household the technologies are fairly closely matched with ceilings/insulation ranked on top closely followed by CFLs and plastering. For a typical institution once again the technologies are fairly closely matched with ceilings/insulation, CFLs and plastering sharing the top rung.

As with the supply side, the ranking shown above is a demonstration of the methodology, in Section 0 the process is applied to specific user types and is shown to have more applicable and more useful results for technology selection.

5 Ranking Against User Type

This section presents the ranking of alternative energy technologies against user type. The categories are described in Section 1.1.1 and 3.3.1 and the methodology is described and demonstrated in Section 4.2 above.

Each type is assessed and the supply and demand side technologies ranked. Here the bar graphs are merely presented but this ranking is used in Section 6 to determine potential technology bundles or packages for each type.

5.1 Electrified Privately Developed (Formal) Household

5.1.1 Electrified Privately Developed Formal Household (Supply)

The ranking assessment below is for a privately developed formal electrified household for supply side technologies.

This household's weighting factors for supply side technologies is shown in Figure 11. The most important factor is security of supply as the private owner would want energy supply to be secure. Another significant factor is user acceptability as this type of owner would expect user normal technologies. The user's safety, ownership and opportunities for avoided energy costs are also deemed as important.

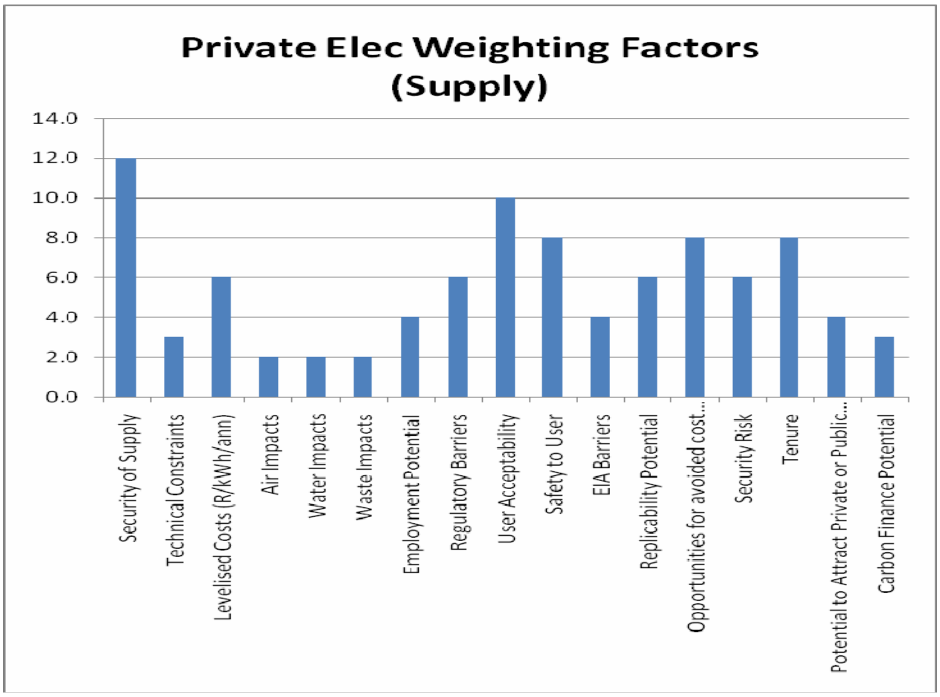

Figure 11: Criteria weighting factors for supply side technologies for privately owned electrified households

The details of the weighted scoring for the supply side technologies of privately developed electrified households are shown in appendix B - Private Electrified Household Supply Side. The resultant weighted scores are summarised below in Table 19 in descending order.

Table 19. Supply side ranking for privately owned electrified households

Solar Water Heaters	81%
Solar Photovoltaic	64%
Fuel Cell	63%
Liquid Petroleum Gas	62%
Biogas Digesters	50%
Landfill Gas	49%
Gelfuels	42%

This is also represented graphically in Figure 12 below.

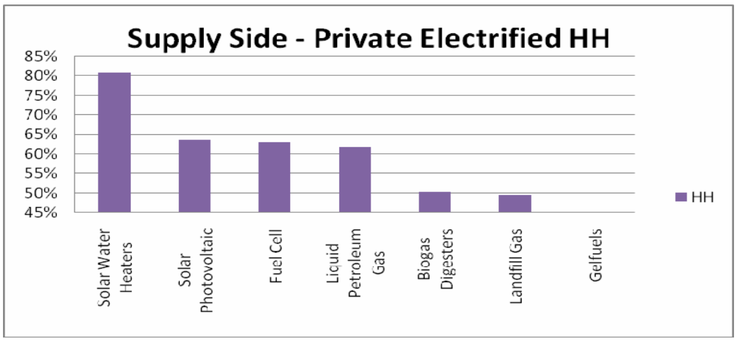

Figure 12: Supply side ranking for privately owned electrified households

5.1.2 Electrified Privately Developed Formal Household (Demand)

This household's weighting factors for demand side technologies is shown in Figure 13. The most important factor is opportunities for avoided energy costs that demand side technologies scan offer a household. User acceptability is also deemed as important.

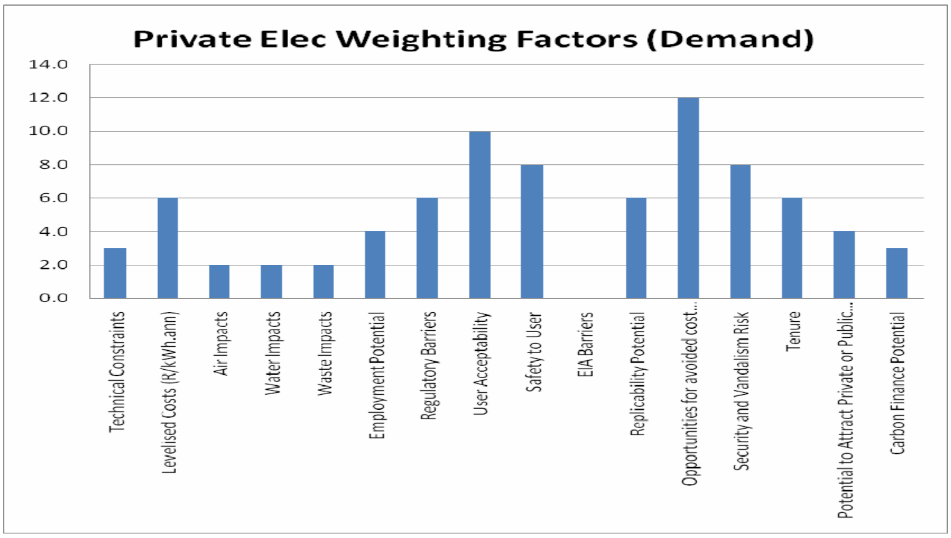

Figure 13: Criteria weighting factors for demand side technologies for privately owned electrified households

The details of the weighted scoring for the demand side technologies of privately developed electrified households are shown in appendix B - Private Electrified Household Demand Side. The resultant weighted scores are summarised below in Table 20 in descending order.

Table 20. Demand side ranking for privately owned electrified households

CFL lighting	83%
Light Emitting Diodes	80%
Efficient design	78%
Geyser and Pipe Insulation	76%
Hot Box	75%
External Painting	71%
Ceiling and/or Insulation	38%
Plastering, in & out	37%
Low Smoke Stoves	32%

This is also represented graphically in Figure 14 below.

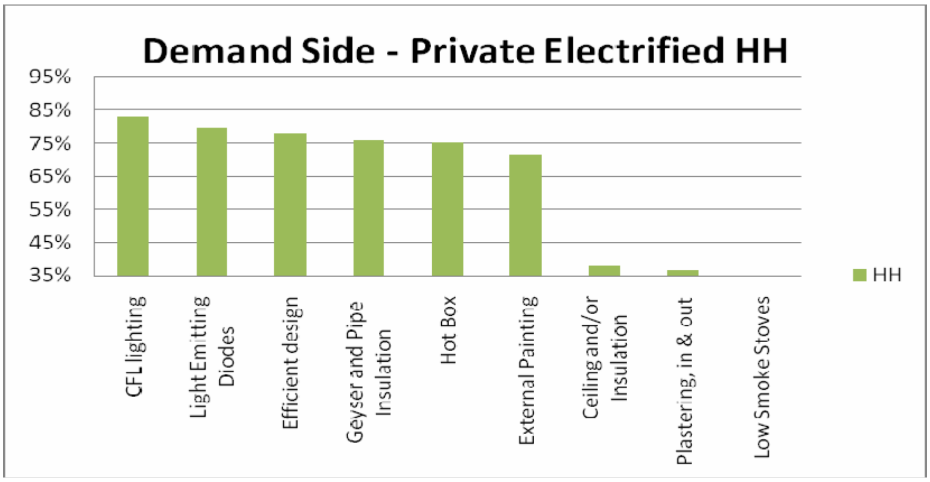

Figure 14: Demand side ranking for privately owned electrified households

5.2 Electrified Middle to Low Income (Formal) Household

5.2.1 Electrified Formal Household (Supply)

The ranking assessment below is for a formal electrified household for supply side technologies.

This household's weighting factors for supply side technologies is shown in Figure 15. The most important factor is security of supply as the owner would want energy supply to be secure. Other significant factors are user acceptability and opportunities for avoided energy costs.

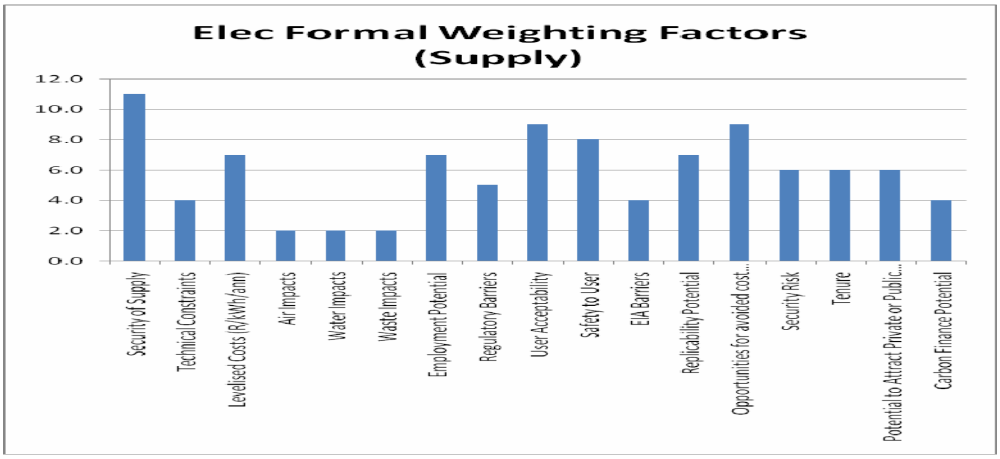

Figure 15: Criteria weighting factors for supply side technologies for formal middle income electrified households

The details of the weighted scoring for the supply side technologies of formal electrified households are shown in appendix B - Formal Electrified Household Supply Side. The resultant weighted scores are summarised below in Table 21 in descending order.

Table 21. Supply side ranking for formal electrified households

Solar Water Heaters	84%
Liquid Petroleum Gas	66%
Solar Photovoltaic	58%
Fuel Cell	58%
Biogas Digesters	52%
Landfill Gas	50%
Gelfuels	45%

This is also represented graphically in Figure 16 below.

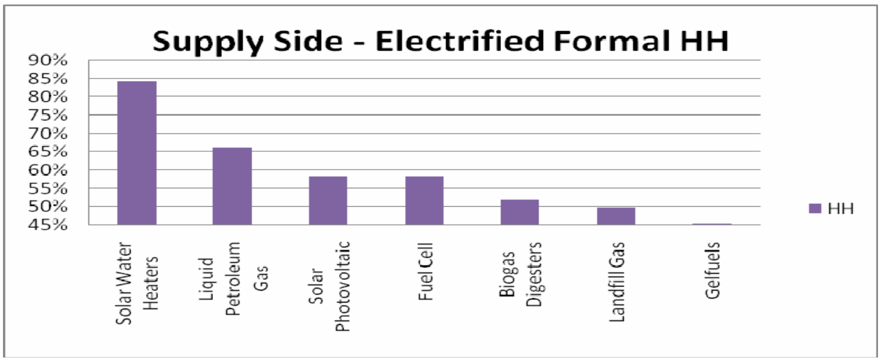

Figure 16: Supply side ranking for formal electrified households

5.2.2 Electrified Formal Household (Demand)

This household's weighting factors for demand side technologies is shown in Figure 17. The most important factor is opportunities for avoided energy costs that demand side technologies scan offer a household. User acceptability is also deemed as important.

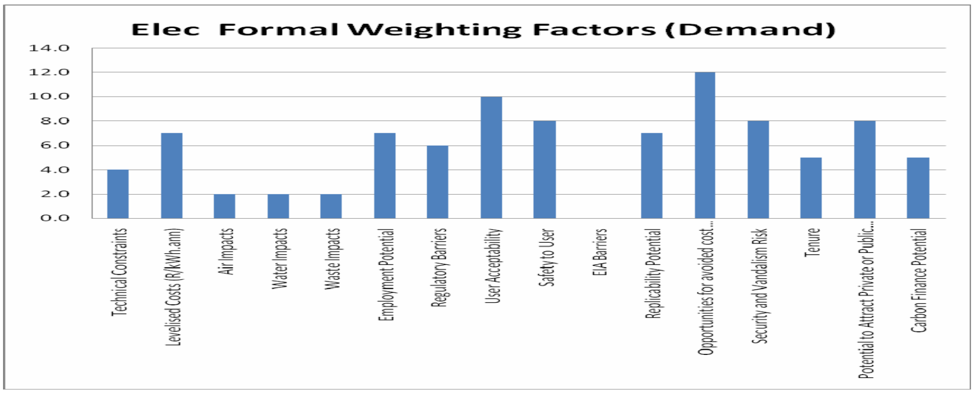

Figure 17: Criteria weighting factors for demand side technologies for formal electrified households

The details of the weighted scoring for the demand side technologies of formal middle to low income electrified households are shown in appendix B - Formal Electrified Household Demand Side. The resultant weighted scores are summarised below in Table 22 in descending order.

Table 22. Demand side ranking for formal electrified households

Ceiling and/or Insulation	87%
Plastering, in & out	85%
Efficient design	78%
CFL lighting	78%
Light Emitting Diodes	75%
External Painting	71%
Hot Box	62%
Geyser and Pipe Insulation	36%
Low Smoke Stoves	27%

This is also represented graphically in Figure 14 below.

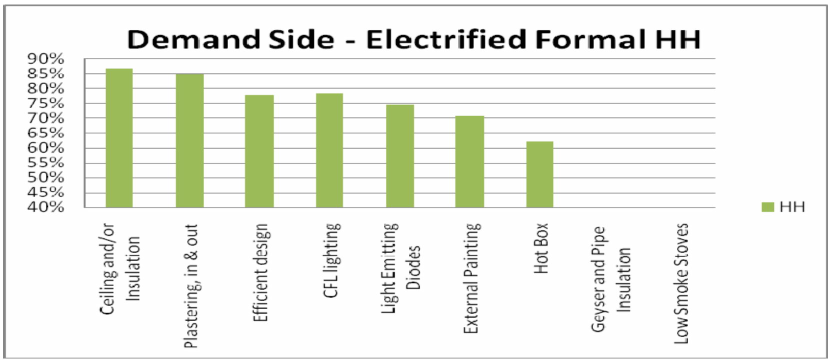

Figure 18: Demand side ranking for formal electrified households

5.3 Electrified and Mixed Fuel Use Low Income (Formal) Household

5.3.1 Electrified but Mixed Fuel Formal Household (Supply)

The ranking assessment below is for a formal electrified and mixed fuel household for supply side technologies. This household's weighting factors for supply side technologies is shown in Figure 19. The two most important factors are opportunities for avoided energy costs and security of supply.

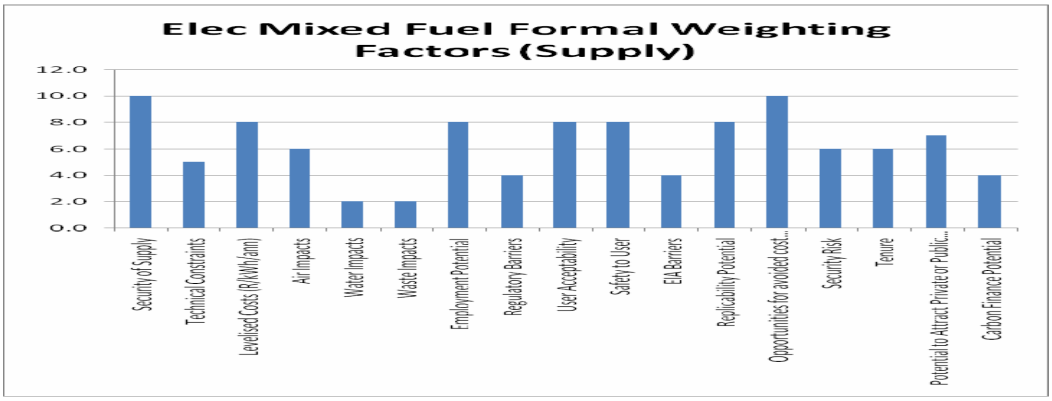

Figure 19: Criteria weighting factors for supply side technologies for informal electrified and mixed fuel households

The details of the weighted scoring for the supply side technologies of formal electrified and mixed fuel households are shown in appendix B - Formal Electrified and Mixed Fuel Household Supply Side. The resultant weighted scores are summarised below in Table 23 in descending order.

Table 23. Supply side ranking for formal electrified and mixed fuel households

Solar Water Heaters	83%
Liquid Petroleum Gas	77%
Biogas Digesters	61%
Gelfuels	61%
Landfill Gas	61%
Fuel Cell	57%
Solar Photovoltaic	56%

This is also represented graphically in Figure 20 below.

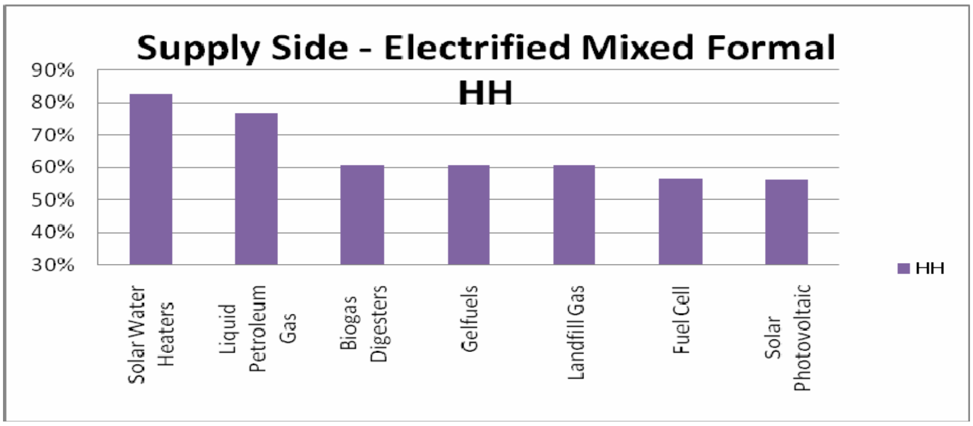

Figure 20: Supply side ranking for formal electrified and mixed fuel households

5.3.2 Electrified and Mixed Fuel Formal Household (Demand)

The ranking assessment below is for a formal electrified and mixed fuel household for demand side technologies. This household's weighting factors for supply side technologies is shown in Figure 21. The most important factor is opportunities for avoided energy costs. User acceptability is also important.

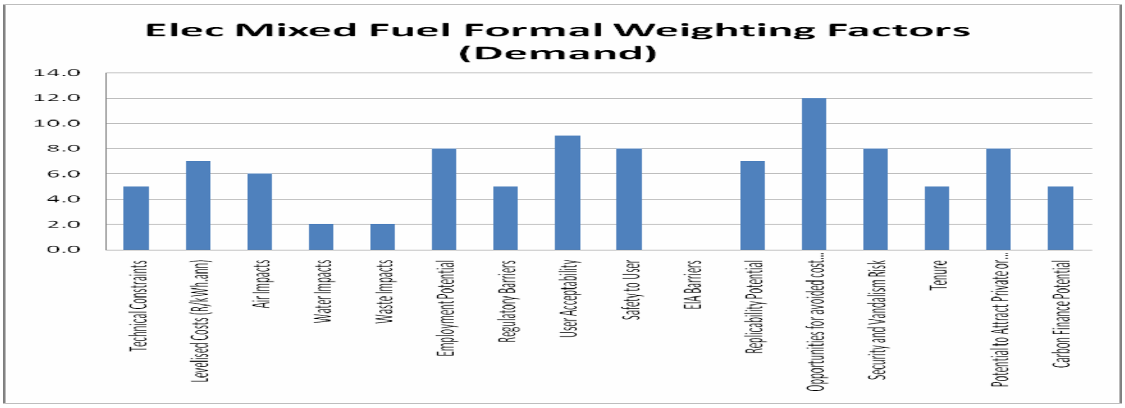

Figure 21: Criteria weighting factors for demand side technologies for formal electrified and mixed fuel households

The details of the weighted scoring for the demand side technologies of formal electrified but mixed households are shown in appendix B - Formal Electrified and Mixed Fuel Household Demand Side. The resultant weighted scores are summarised below in Table 24 in descending order.

Table 24. Demand side ranking for formal electrified and mixed fuel households

Ceiling and/or Insulation	87%
Plastering, in & out	85%
Efficient design	78%
Low Smoke Stoves	74%
CFL lighting	73%
Light Emitting Diodes	70%
Hot Box	70%
External Painting	70%
Geyser and Pipe Insulation	29%

This is also represented graphically in Figure 22 below.

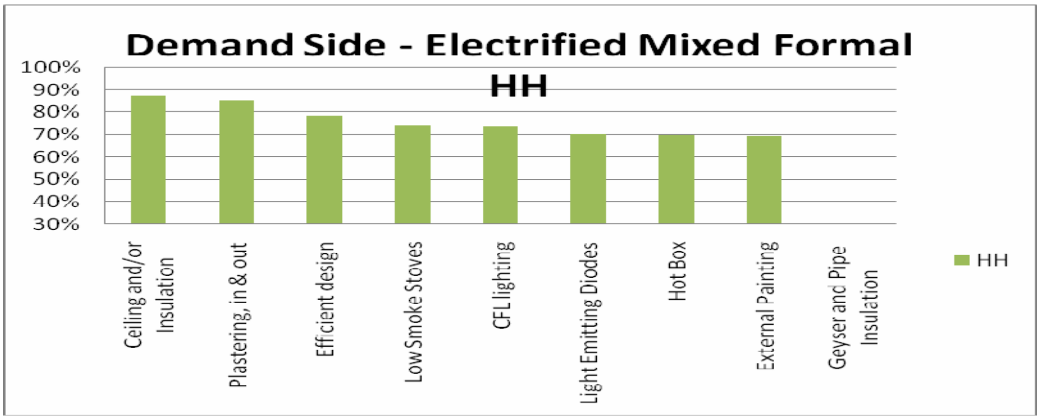

Figure 22: Demand side ranking for formal electrified and mixed fuel households

5.4 Un-electrified Low Income (Informal) Household

5.4.1 Un-electrified Low Income Informal Household (Supply)

The ranking assessment below is for an informal un-electrified household for supply side technologies.

This household's weighting factors for supply side technologies is shown in Figure 23. The most important factor is opportunities for avoided energy costs to the low income dwellers of the informal house. Also significant is security of supply and employment potential to help alleviate poverty in the area.

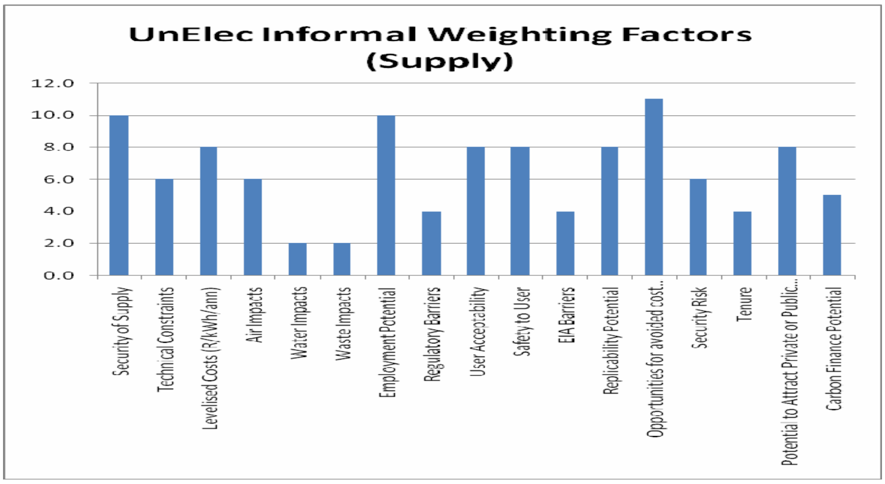

Figure 23: Criteria weighting factors for supply side technologies for informal un-electrified households

The details of the weighted scoring for the supply side technologies of informal un-electrified households are shown in appendix B - Informal Un-Electrified Household Supply Side. The resultant weighted scores are summarised below in Table 25 in descending order.

Table 25. Supply side ranking for informal un-electrified households

Gelfuels	74%
Fuel Cell	59%
Solar Photovoltaic	54%
Liquid Petroleum Gas	47%
Solar Water Heaters	35%
Biogas Digesters	29%
Landfill Gas	28%

This is also represented graphically in Figure 24 below.

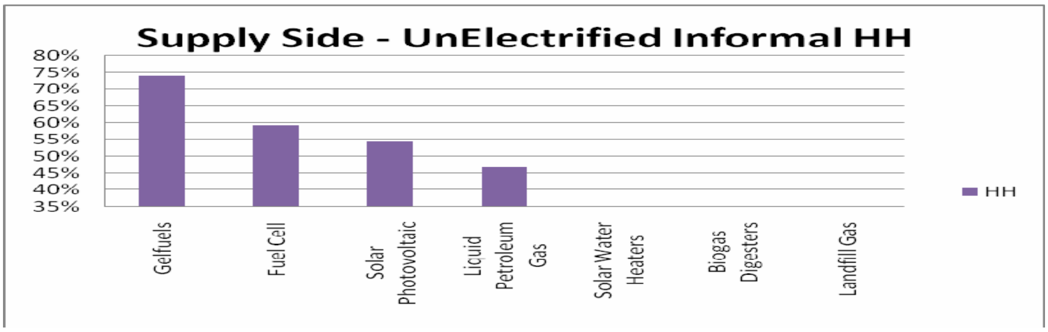

Figure 24: Supply side ranking for informal un-electrified households

5.4.2 Un-electrified Low Income Informal Household (Demand)

The ranking assessment below is for an informal un-electrified household for demand side technologies. This household's weighting factors for supply side technologies is shown in Figure 25. The most important factor is opportunities for avoided energy costs. User acceptability and employment potential are also important.

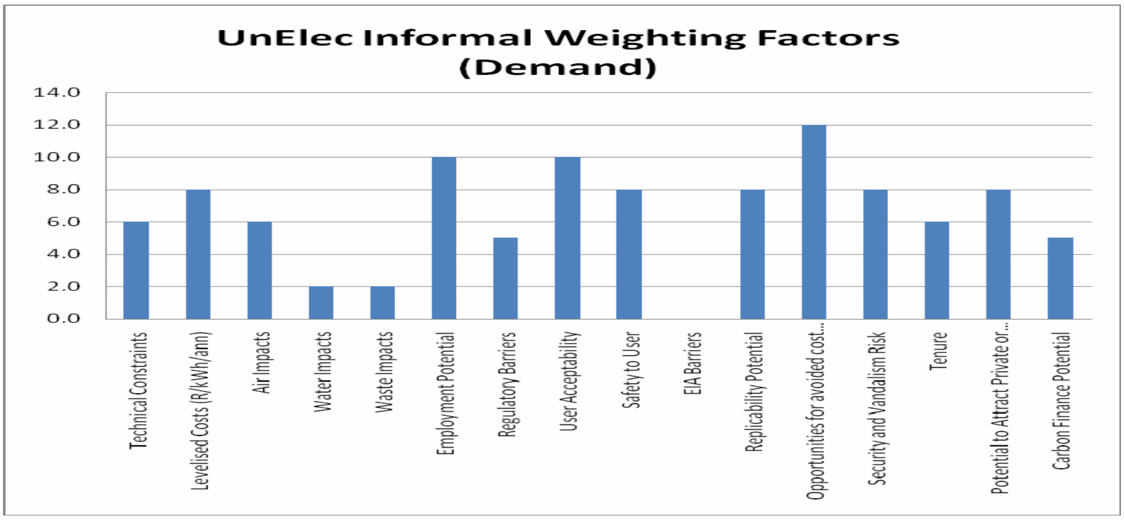

Figure 25: Criteria weighting factors for demand side technologies for informal un-electrified households

The details of the weighted scoring for the demand side technologies of informal un-electrified households are shown in appendix B - Informal Un-Electrified Household Demand Side. The resultant weighted scores are summarised below in Table 24 in descending order.

Table 26. Demand side ranking for informal un-electrified households

Low Smoke Stoves	85%
Ceiling and/or Insulation	69%
Hot Box	68%
Efficient design	63%
External Painting	49%
CFL lighting	20%
Light Emitting Diodes	20%
Geyser and Pipe Insulation	20%
Plastering, in & out	14%

This is also represented graphically in Figure 26 below.

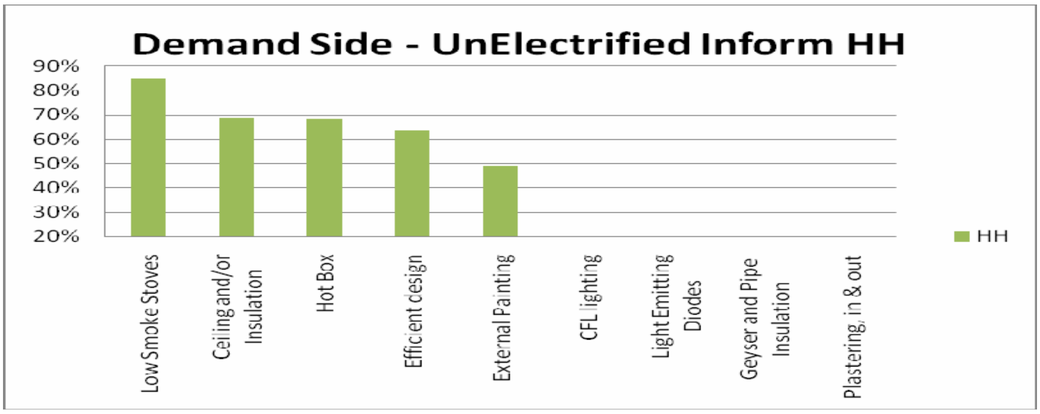

Figure 26: Demand side ranking for informal un-electrified households

5.5 Standard School (Institution)

5.5.1 Standard Electrified School (Supply)

The ranking assessment below is for a standard school (institution) for supply side technologies.

This school's weighting factors for supply side technologies are shown in Figure 27. The most important factor is security of supply to allow the school to operate effectively. Also significant is avoided cost, safety, tenure, ability to attract funding and user acceptability.

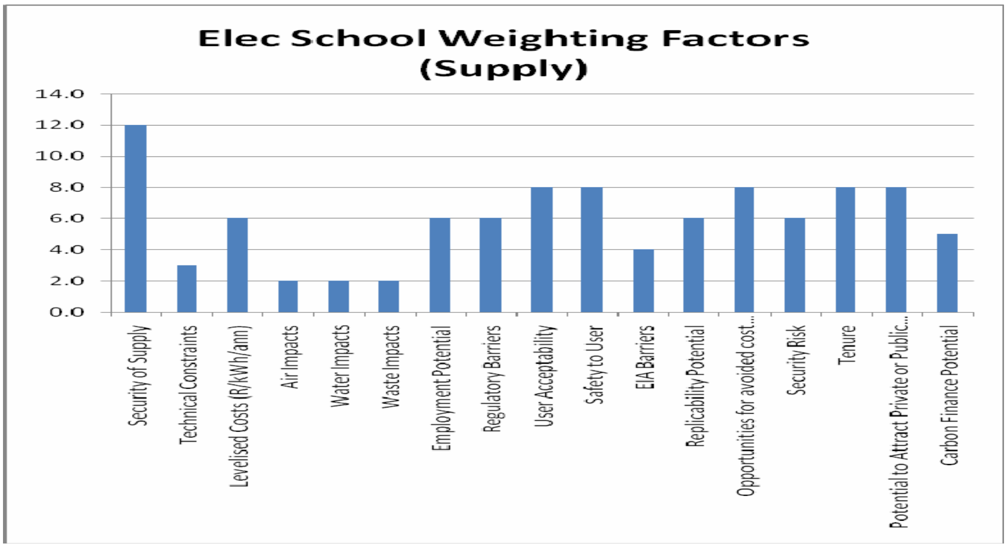

Figure 27: Criteria weighting factors for supply side technologies for a school

The details of the weighted scoring for the supply side technologies of a school are shown in appendix B - Electrified Standard School Supply Side. The resultant weighted scores are summarised below in Table 27 in descending order.

Table 27. Supply side ranking for schools

Solar Water Heaters	83%
Liquid Petroleum Gas	69%
Solar Photovoltaic	64%
Fuel Cell	64%
Biogas Digesters	59%
Landfill Gas	46%
Gelfuels	40%

This is also represented graphically in Figure 28 below.

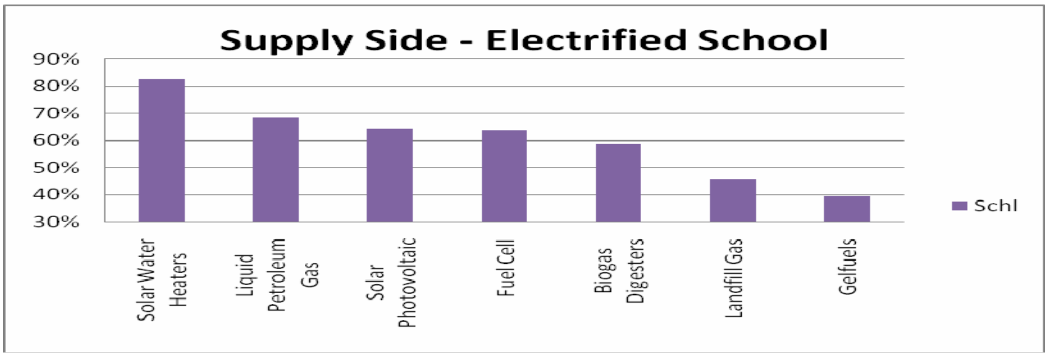

Figure 28: Supply side technology ranking for a school

5.5.2 Standard Electrified School (Demand)

The ranking assessment below is for a standard electrified school for demand side technologies. The school's weighting factors for supply side technologies are shown in Figure 29. The most important factor is opportunities for avoided energy costs.

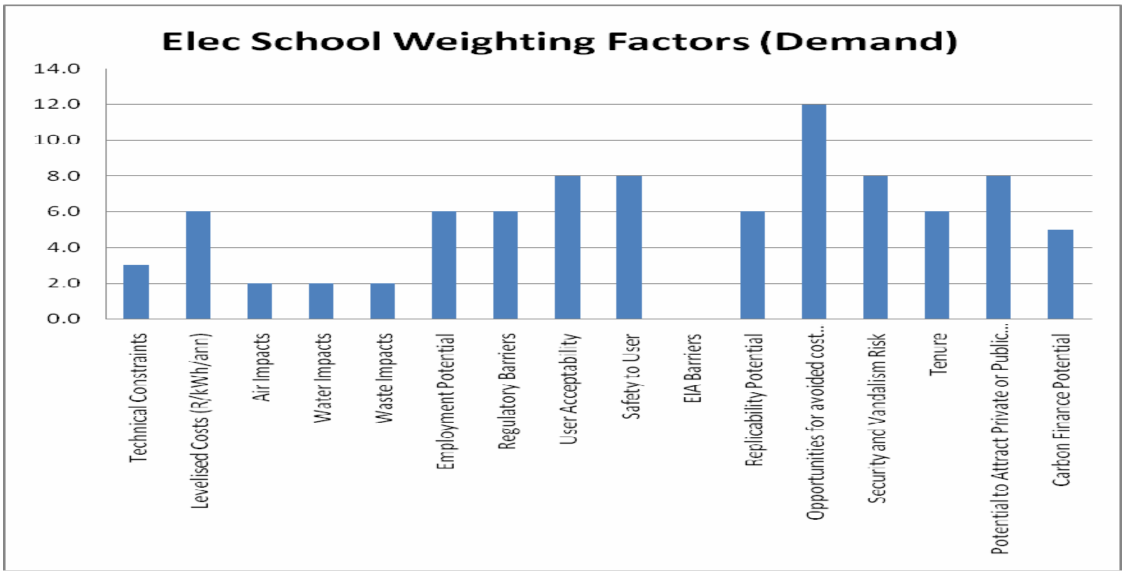

Figure 29: Criteria weighting factors for demand side technologies for electrified schools

The details of the weighted scoring for the demand side technologies of electrified schools are shown in appendix B - Electrified Standard School Demand Side. The resultant weighted scores are summarised below in Table 28 in descending order.

Table 28. Demand side ranking for electrified schools

Ceiling and/or Insulation	82%
CFL lighting	82%
Plastering, in & out	80%
Light Emitting Diodes	79%
Efficient design	77%
Geyser and Pipe Insulation	75%
External Painting	69%
Hot Box	63%
Low Smoke Stoves	30%

This is also represented graphically in Figure 30 below.

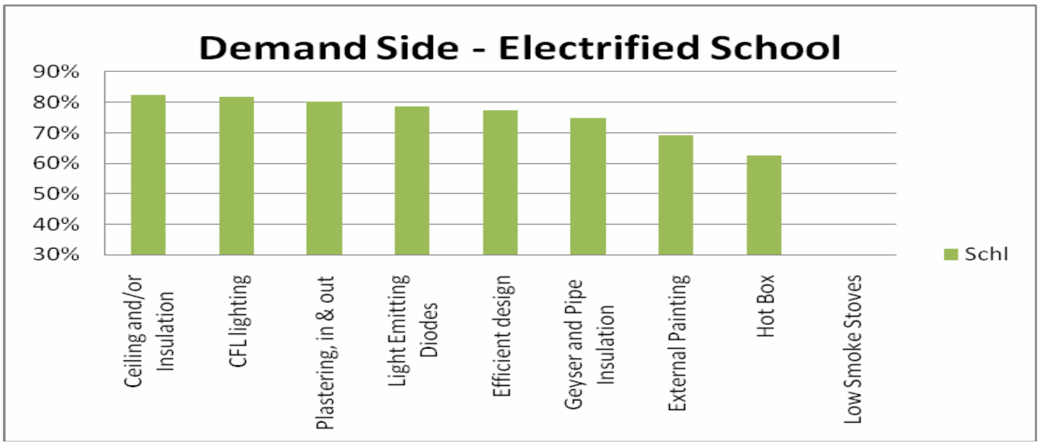

Figure 30: Demand side technology ranking for electrified schools

5.6 Standard Clinic (Institution)

5.6.1 Electrified Standard Clinic (Supply)

The ranking assessment below is for an electrified standard clinic for supply side technologies. This clinic's weighting factors for supply side technologies is shown in Figure 31. The most important factor is security of supply to ensure the continued operation of the clinic. Another significant weighting factor is opportunities for avoided energy costs.

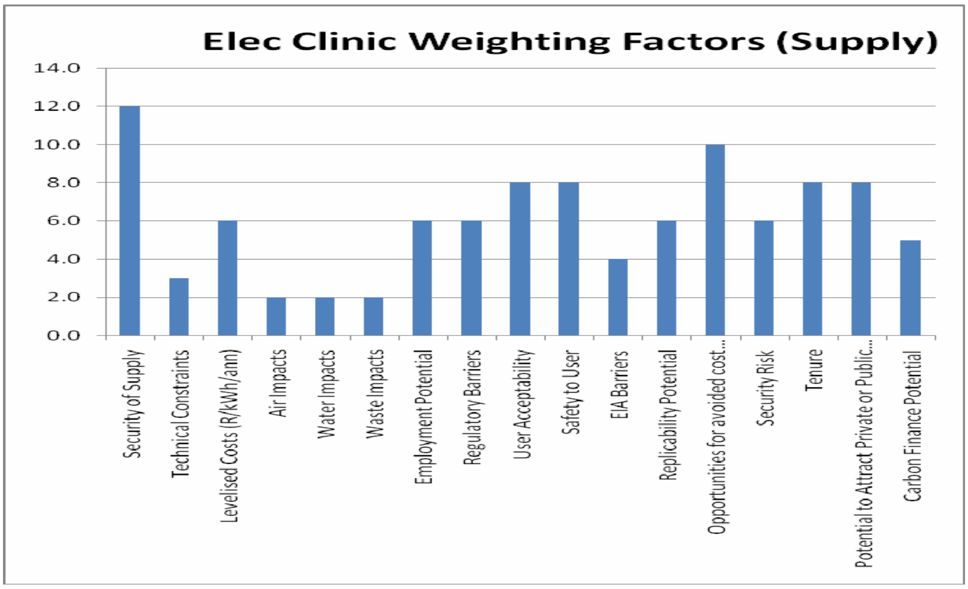

Figure 31: Criteria weighting factors for supply side technologies for electrified clinic

The details of the weighted scoring for the supply side technologies of electrified clinics are shown in appendix B - Electrified Standard Clinic Supply Side. The resultant weighted scores are summarised below in Table 29 in descending order.

Table 29. Supply side ranking for electrified clinic

Solar Water Heaters	83%
Liquid Petroleum Gas	69%
Solar Photovoltaic	60%
Biogas Digesters	59%
Fuel Cell	58%
Landfill Gas	46%
Gelfuels	32%

This is also represented graphically in Figure 32 below.

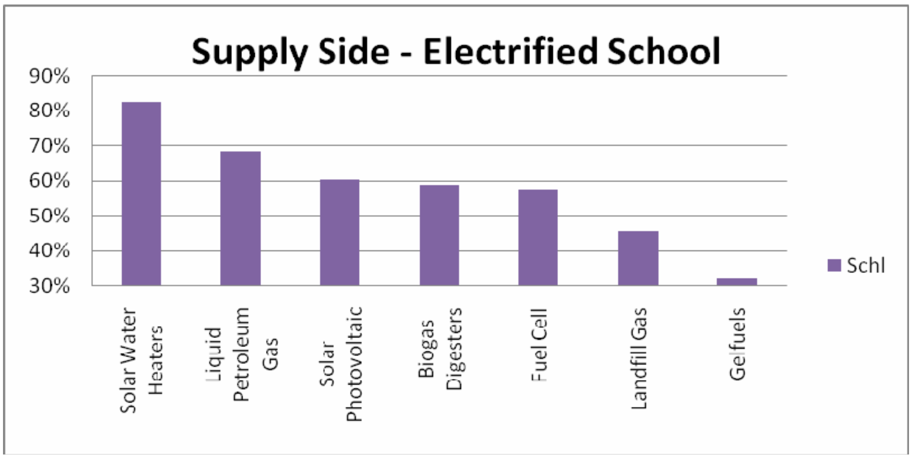

Figure 32: Supply side ranking for electrified clinics

5.6.2 Standard Electrified Clinic (Demand)

The ranking assessment below is for an electrified standard clinic for demand side technologies. This clinic's weighting factors for supply side technologies is shown in Figure 33. The most important factor is opportunities for avoided energy costs. User acceptability, safety and potential for funding are also important.

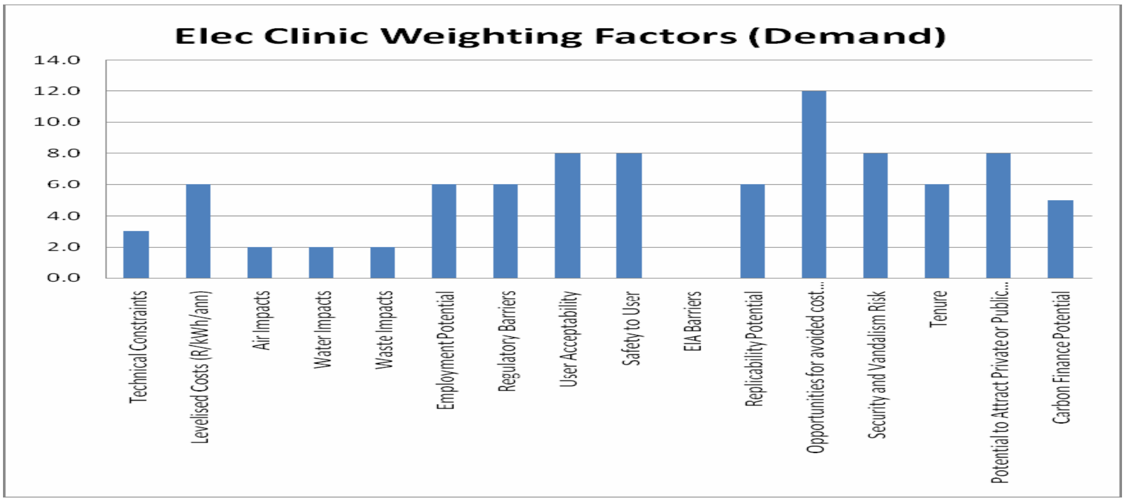

Figure 33: Criteria weighting factors for demand side technologies for electrified clinics

The details of the weighted scoring for the demand side technologies of electrified clinics are shown in appendix B - Electrified Standard Clinic Demand Side. The resultant weighted scores are summarised below in Table 30 in descending order.

Table 30. Demand side ranking for electrified clinics

Ceiling and/or Insulation	82%
CFL lighting	82%
Plastering, in & out	80%
Light Emitting Diodes	79%
Efficient design	77%
Geyser and Pipe Insulation	75%
External Painting	69%
Hot Box	63%
Low Smoke Stoves	30%

This is also represented graphically in Figure 34 below.

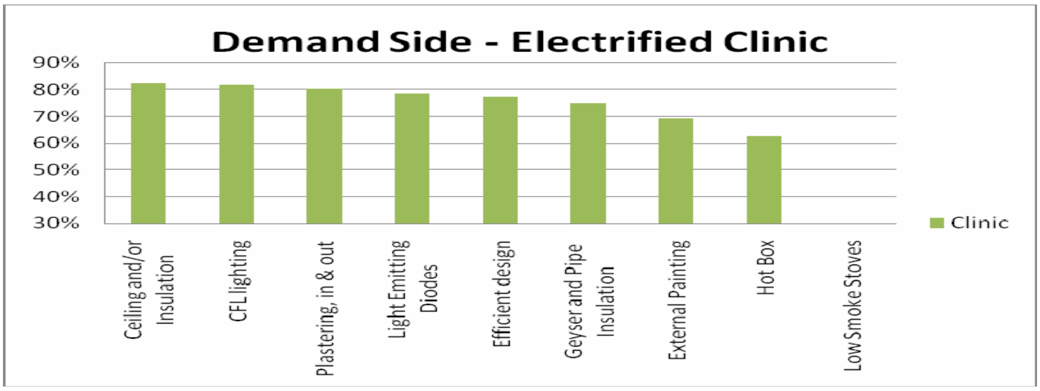

Figure 34: Demand side ranking for electrified clinics

6 Potential Technology Packages

Based on ranking results above in Section 5.1 and applying expert judgement the best potential packages of technologies for each user type are compiled below.

It is assumed that the households or institutions are already built and occupied using the energy as described in Section 1.1.1. In other words the energy package would be retrofitted to existing buildings. There is benefit in applying these packages of technologies and more at the design stage for new build and comment is made on this for each household or institution type.

6.1 Electrified Privately Developed (Formal) Household

6.1.1 Description of Package

SWHs are the highest ranked supply technology partly due to the fact that the privately developed electrified house spends 45% of their monthly energy cost on electric geysers for hot water – so there is a fair score of "opportunities for avoided costs".

This technology is easily replicable, has good tenure possibilities and is a good candidate for funding and carbon revenue. If this was packaged with LPG then cooking and hot water could be independent from the grid reducing 60%[3] of the demand to this type of household.

Solar PV or fuel cells[4] could contribute to electrical supply but will prove too expensive compared to grid electricity until, in the not too distant future, the price of grid electricity[5] surpasses the cost of PV or fuel cell technology (which are reducing in cost). For now PV or fuel cells are not be considered further for this household type. However, some reduction in electrical demand can be achieved by demand side technologies. More efficient CFL lighting (ranked higher than LED) will reduce the 7% (of the total energy) to about 2%.

Note that this type spends 16% on refrigeration. A way to bring this down would be through more efficient fridges but these are not readily available in South Africa yet.

6.1.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of house uses a baseline of grid electricity at 45c/kWh and the type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any 'pay for service' option, it is merely the savings from business as usual.

- SWH 200 litre high pressure close coupled system with electric back-up:
    - CAPEX – hardware R14,000 and installation R1,500 (R15,500)
    - OPEX reduction – R1,440 per year saved (electricity)
- LPG two plate burner and 4kg bottle:
    - CAPEX – hardware R400, zero on installation ('plug and play')
    - OPEX reduction - zero or slight increase compared to electricity
- LPG heater and 4kg bottle:
    - CAPEX R1,000, zero on installation ('plug and play')
    - OPEX reduction - zero or slight increase compared to electricity
- CFL lights, 2 inside and 1 outside:
    - CAPEX – hardware R45, zero on installation
    - OPEX reduction – R110 per year saved

Total cost per household:

- CAPEX – R17,000
- OPEX reduction — R1,600/a **saved** (R130/mo average, 44% of current bill)

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[3] Currently 45% is spent on an electric geyser. A SWH with electrical backup would reduce electrical demand by about 40%. Electric cooking uses 20% of the energy so the total reduction by SWH and LPG would be 60%

[4] Small sized on-site fuel cells which have anodes exchanged by a supply company do show some promise although the supply market is not well established and the technology still predominantly in pilot phases (see case study in background report, Appendix C: Review of alternative technology options)

[5] The 2008 electricity increase is 14% and 18% is expected in 2009

Note that for a new build of this household type the technologies described above could be easily integrated into the housing cost. At design stage it would cost very little extra to integrate passive solar design (such as orientation and overhangs) and good insulation specification which would further improve thermal performance.

6.2 Electrified Middle to Low Income (Formal) Household

6.2.1 Package Description

SWHs are by far the highest ranked supply technology for this household type. This is partly due to the fact that the formal electrified houses do not have electric geysers and therefore heat water on electric stoves or in kettles, assumed to contribute to about half of the share of cooking energy costs. Also SWHs have excellent security of supply, are easily replicable and are excellent technologies for funding and carbon finance. LPG would provide a better cooking option to the rest of the cooking needs (meals) compared to electrical stoves. Again PV or fuel cell electricity could contribute although these technologies are expensive compared to grid electricity and will not be considered here.

Besides geyser blankets and pipe insulation and low smoke stoves, which are not relevant to this type, the demand side technology ranking is very close. This implies that most of these technologies are well suited to a formal electrified house and will contribute to lower the energy demand. However, ceiling/insulation and plaster are certainly the best option from the demand technologies. These technologies will increase thermal efficiency and contribute in reducing the 26% spent on space heating. More efficient lighting (CFLs ranked higher than LEDs) will reduce the 6% (of the total) spent on lighting to about 2%.

Note that this type of household spends 35% on refrigeration. A way to bring this down would be through more efficient fridges but these are not readily available in South Africa yet.

6.2.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of house uses a baseline of grid electricity at 45c/kWh and the current type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any ‘pay for service’ option, it is merely the savings from business as usual.

- SWH 100 litre high pressure close coupled system with electric back-up:
    - CAPEX – hardware R10,000 and installation R1,500 (R11,500)
    - OPEX reduction – R240 per year saved (reduction stove top/kettle water heating)
- LPG two plate burner and 4kg bottle:
    - CAPEX – hardware R400, zero on installation (‘plug and play’)
    - OPEX reduction - zero or slight increase compared to electricity
- LPG heater and 4kg bottle:
    - CAPEX R1,000, zero on installation (‘plug and play’)
    - OPEX reduction - zero compared to electricity (with thermal improvement as below)

- CFL lights, 1 inside and 1 outside:
  - CAPEX – hardware R30, zero on installation
  - OPEX reduction – R70 per year saved
- Ceilings and Insulation:
  - CAPEX – materials R3,000[6], installation R1,500 (R4,500)
  - OPEX reduction – R84 per year saved
- Plaster (outside[7]):
  - CAPEX – materials R1,000[8], installation R1,000 (R2,000)
  - OPEX reduction – R17 per year saved

Total cost per household:

- CAPEX – R19,500
- OPEX reduction — R400/a **saved** (R34/mo average, 25% of current bill)

Note that for a new build of this household type the technologies described above could be easily integrated into the housing cost. At design stage it would cost very little extra to integrate passive solar design (such as orientation and overhangs) as well as specify ceiling/insulation and plaster.

6.3 Electrified and Mixed Fuel Use Low Income (Formal) Household

6.3.1 Package Description

Again SWH use is top ranked closely followed by LPG. These houses do not have geysers (see Section 3.3.1) so a SWH would therefore help reduce the 40% energy cost attributed to cooking (or the water heating part thereof), in fact it can be assumed that all paraffin use can be eliminated. SWHs have excellent security of supply, are easily replicable and are excellent technologies for funding and carbon finance. LPG could eliminate the electrical portion of the cooking bill as well as the heating bill (combined about 33% plus the 31% water heating by cost) for this household type.

The spread of the demand side technologies is close once again meaning that all would contribute to energy efficiency but here also air quality. Ceiling/insulation, plastering and low smoke stoves (those used for heating) will all contribute to reducing the hefty 26% of energy costs that space heating grabs. Although lighting is only 4% of the total cost CFLs still make sense and contribute to a 3% demand reduction.

Note that this type spends 29% on refrigeration. A way to bring this down would be through more efficient fridges but these are not readily available in South Africa yet.

6.3.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of house uses a baseline of grid electricity at 45c/kWh

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[6] Materials and installation based on 30m^2 house

[7] Outside only considered for ease of installation in already occupied house

[8] Materials and installation based on 30m^2 house

and coal and paraffin costs as well as the current type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any 'pay for service' option, it is merely the savings from business as usual.

- SWH 100 litre low pressure system with <u>no</u> electric back-up:
    - CAPEX – hardware R4,000 and installation R1,500 (R5,500)
    - OPEX reduction – R480 per year saved (paraffin reduction minus back-up by stove top/kettle water heating)
- LPG two plate burner and 4kg bottle:
    - CAPEX – hardware R400, zero on installation ('plug and play')
    - OPEX reduction – zero or slight decrease compared to paraffin
- LPG heater and 4kg bottle:
    - CAPEX R1,000, zero on installation ('plug and play')
    - OPEX reduction - zero compared to coal (with thermal improvement as below)
- CFL lights, 1 inside and 1 outside:
    - CAPEX – hardware R30, zero on installation
    - OPEX reduction – R70 per year saved
- Ceilings and Insulation:
    - CAPEX – materials R3,000[9], installation R1,500 (R4,500)
    - OPEX reduction – R72 per year saved
- Plaster (outside[10]):
    - CAPEX – materials R1,000[11], installation R1,000 (R2,000)
    - OPEX reduction – R14 per year saved

Total cost per household:

- CAPEX – R13,500
- OPEX reduction –– R650/a **saved** (R55/mo average, 32% of current bill)

Note that for a new build of this household type the technologies described above could be easily integrated into the housing cost. At design stage it would cost very little extra to integrate passive solar design (such as orientation and overhangs) as well as specify ceiling/insulation and plaster.

Another significant point here is that the package achieves an important target and that is to eliminate coal use in this household type.

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[9] Materials and installation based on 30m^2 house

[10] Outside only considered for ease of installation in already occupied house

[11] Materials and installation based on 30m^2 house

6.4 Un-electrified Low Income (Informal) Household

6.4.1 Package Description

The ranking changes quite dramatically when we consider un-electrified and informal houses. Gelfuels[12] now rise up as a prominent player to replace dirty and dangerous paraffin used by these houses for cooking. This scores better in this household type than LPG. Both fuel cells and solar PV also play a more significant role in replacing paraffin and candles for lighting but and also for radio use and cell phone charging (which is currently 21% of energy costs). The costing of small anode replacement fuel cells is not well documented and thus PV could preferentially be used as demonstrated renewable energy technology here[13]. The PV system will be a small home system of about 50W (12V AC) that can power lighting, a small radio and charge a cell phone. SWHs are assumed to be difficult to install in an informal house, and usually there is no piped water, so do not feature here. Coal and paraffin for heating could be replaced by LPG heaters and with improved insulation could result in a slight drop in operating cost compared to coal – but more importantly improved air quality. There are some alternative ways of envisaging an alternative energy package for these households, dependent on local circumstances. For example, if LPG were used as a heating fuel its use could be extended to cooking as well instead of gelfuels – depending on local cost, availability and acceptability.

The highest ranked demand side technology is a low smoke stove which here would contribute to air improvement for space heating where 17% of the monthly energy bill is spent. Some sort of ceilings and insulation under the roof of an informal house would increase thermal efficiency and reduce the heating bill but it is assumed that these would be 'homemade' or recycled ceilings from materials such as cardboard[14]. A hot box would assist with cooking in that it allows a meal to continue cooking without further energy input (cooking gobbles up a massive 45% of the monthly energy bill) and frees up the one or two plate stove. Efficient design may seem out of place for informal housing but a few small adjustments to a typical shack (such as overhangs to shade summer sun and novel joinery or sheeting to insulate walls) could make a big difference to the heating requirements and certainly comfort.

6.4.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of house uses a baseline of coal and paraffin costs as well as the current type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any 'pay for service' option, it is merely the savings from business as usual. In this household type the operation cost to the user is often more than is currently spent so the saving is sometimes negative.

- Gelfuel two plate burner:
    - CAPEX – hardware R160,

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[12] Note that a risk specified in Section 2.4 for gelfuels is their quality. Tests have shown that some brands on the market have a very low calorific value and high pollution factor. Good quality gelfuel is assumed in this study.

[13] It would be prudent to also investigate fuel cell technology for this household type.

[14] Some work has been done by the University of Cape Town and Stellenbosch University on assessing a DIY-Home Insulation Kit, although no funding was secured for a pilot phase.

  - OPEX reduction – -R288[15] per year (will cost R24/m more than paraffin)
- Small PV (50W, 12V AC):
  - CAPEX – R4,000, installation R500 (R4,500)
  - OPEX reduction – zero over 5 years (assumed battery life)
- LPG heater and 4kg bottle:
  - CAPEX – R1,000, zero on installation ('plug and play')
  - OPEX reduction - zero compared to coal/paraffin (with thermal improvement as below)
- Ceilings and Insulation:
  - CAPEX – materials zero[16], installation self
  - OPEX reduction – improvement small and already accounted for in LPG cost

Total cost per household:

- CAPEX – R5,700
- OPEX reduction — -R288/a **saved** (-R24/mo average more than BAU)

From an operating cost point of view an important note here is that in order for this type of household to 'buy-in' to this technology package the price of gelfuel would need to be subsidised at about R288 per year per household. Otherwise it is likely that paraffin will continue to be used.

Another point is that the better overall energy solution in terms of environmental health and safety and household costs is to move these households to formal, energy and thermally efficient housing.

6.5 Standard Electrified School

6.5.1 Package Description

SWHs (with electrical backup) are well suited to supply hot water to this type of institution and alleviate most of the 18% of the electricity bill that is spent on an electrical geyser. Electric bar heaters chew up 22% of the electricity bill and LPG (which is second ranked for supply technologies for this institution type) with improved thermal performance would help if gas heaters were installed instead. LPG could also replace the electric hotplate which consumes 11% of the energy although there is no cost benefit to the user. PV power comes in third and may be good to install as an educational demonstration but at this stage cannot complete cost-wise with grid electricity and is not considered further.

The spread of demand rankings is fairly even. However, ceiling/insulation and plastering are worth mentioning as this would improve thermal efficiency and reduce the high heating bill. CFL lighting could replace incandescent lights dropping the lighting bill to about 1% of the energy bill.

Note that this type spends 6% on refrigeration. A way to bring this down would be through more efficient fridges but these are not readily available in South Africa yet.

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[15] Gelfuel costs about R1.20 per meal so for 3 meals per day it will cost R108/mo, whereas paraffin is R84/m for this household type (R24/m more).

[16] Homemade

6.5.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of institution uses a baseline of grid electricity at 45c/kWh and the current type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any 'pay for service' option, it is merely the savings from business as usual.

- SWH 200 litre high pressure close coupled system with electric back-up:
  - CAPEX – hardware R14,000 and installation R1,500 (R15,500)
  - OPEX reduction – R1,400 per year saved (electricity)
- LPG two plate burner and 4kg bottle:
  - CAPEX – hardware R400, zero on installation ('plug and play')
  - OPEX reduction - zero or slight increase compared to electricity
- LPG heater and 4kg bottle (three heaters):
  - CAPEX R3,000, zero on installation ('plug and play')
  - OPEX reduction - zero compared to electricity (with thermal improvement as below)
- CFL lights, 6 lamps:
  - CAPEX – hardware R90, zero on installation
  - OPEX reduction – R190 per year saved
- Ceilings and Insulation:
  - CAPEX – materials R83,000[17], installation R41,500 (R124,500)
  - OPEX reduction – R444 per year saved
- Plaster:
  - CAPEX – materials R25,000[18], installation R25,000 (R50,000)
  - OPEX reduction – R108 per year saved

Total cost per institution:

- CAPEX – R193,500
- OPEX reduction –– R2,200/a **saved** (R180/mo average, 25% of current bill)

Note that for a new build of this institution type the technologies described above could be easily integrated into the building cost. At design stage it would cost very little extra to integrate passive solar design (such as orientation and overhangs) as well as specify ceiling/insulation and plaster.

6.6 Standard Electrified Clinic

6.6.1 Package Description

The heating demand (at 20%) could be lowered by ceiling / insulation, plastering and efficient design (for new build). CFL lighting would provide a lower demand for the

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[17] Materials and installation based on 830m^2 institution

[18] Materials and installation based on 830m^2 institution

clinics lighting bill (6% reduction on total due to incandescent replacement). SWHs are the clear winners for an institution that spends 34% of it's electricity on electric geysers. Heating is also a significant chunk of the bill at 20% with cooking coming in at 10%. Both cooking and heating can be more sustainably achieved using LPG.

Note that this type spends 35% on refrigeration. A way to bring this down would be through more efficient fridges but these are not readily available in South Africa yet.

6.6.2 Package Costing

The CAPEX costing of this package takes into account the hardware/material costs and the installation but does NOT include project or engineering costs. The saved OPEX costs to the user in this type of institution uses a baseline of grid electricity at 45c/kWh and the current type descriptions in sections 1.1.1 and 3.3.1. OPEX does NOT include any 'pay for service' option, it is merely the savings from business as usual.

- SWH 200 litre high pressure close coupled system, electric back-up (2 SWHs):
  - CAPEX – hardware R28,000 and installation R3,000 (R31,000)
  - OPEX reduction – R2,900 per year saved (electricity)
- LPG two plate burner and 4kg bottle:
  - CAPEX – hardware R400, zero on installation ('plug and play')
  - OPEX reduction - zero or slight increase compared to electricity
- LPG heater and 4kg bottle:
  - CAPEX R3,000, zero on installation ('plug and play')
  - OPEX reduction - zero compared to electricity (with thermal improvement as below)
- CFL lights, 6 lamps:
  - CAPEX – hardware R90, zero on installation
  - OPEX reduction – R640 per year saved
- Ceilings and Insulation:
  - CAPEX – materials R29,000[19], installation R14,500 (R43,500)
  - OPEX reduction – R384 per year saved
- Plaster:
  - CAPEX – materials R8,150[20], installation R8,150 (R16,300)
  - OPEX reduction – R96 per year saved

Total cost per household:

- CAPEX – R94,500
- OPEX reduction — R4,000/a **saved** (R335/mo average, 41% of current bill)

Note that for a new build of this institution type the technologies described above could be easily integrated into the building cost. At design stage it would cost very little extra to integrate passive solar design (such as orientation and overhangs) as well as specify ceiling/insulation and plaster.

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[19] Materials and installation based on 290m^2 institution

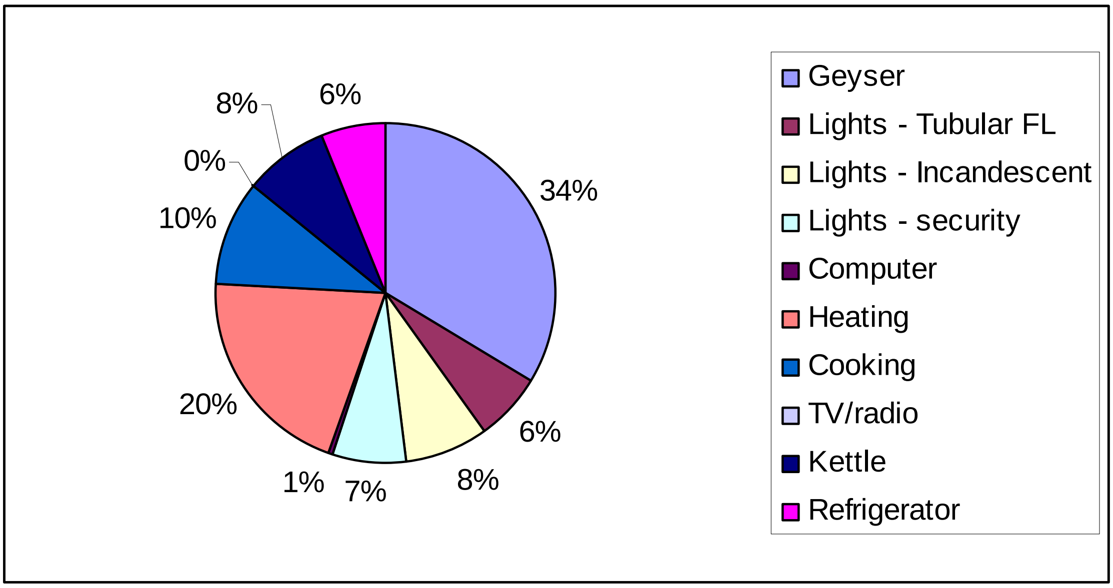
[20] Materials and installation based on 290m^2 institution

In addition to this technology package for a typical clinic, stakeholder and client comments suggested the option of a fully off-grid clinic as a potential technology solution. The appropriate technology and costs of this option are discussed below.

The below table and graph shows the standard clinic used as a basis for the investigation.

Table 31: Energy profile of standard township clinic

Description	**#**	**Rating**	**Hrs/day**	**Whrs/day**	**kWh/month**	**% of energy**
Geyser	2	2000	5	20000	600	34%
Lights - Tubular fluorescent	48	20	4	3840	115.2	6%
Lights - Incandescent	20	60	4	4800	144	8%
Lights - security	4	150	7	4200	126	7%
Computer	1	120	3	360	10.8	1%
Heating	3	2000	2	12000	360	20%
Cooking	1	2000	3	6000	180	10%
TV/radio	1	20	5	100	3	0%
Kettle	1	2400	2	4800	144	8%
Refrigerator	1	550	6.5	3575	107.25	6%
Total					**1790.25**	100%



The above is the standard clinic used as a basis for the study. In order for this to be made off-grid some changes need to be made to the supply and demand technologies as previously recommended. This would reduce the electricity demand and consumption so that a more affordable solar PV system could provide the electricity. The new and better energy option for a clinic would be as follows, where only the electricity components are added:

Description	**#**	**Rating**	**Hrs/d**	**Wh/d**	**kWh/m**	**Comment**
Geyser	2	-	-	-	-	SWH with no backup
Lights – Tub Fl	48	20	4	3840	115.2	
Lights - CFL	20	11	4	880	26.4	Incand replaced by CFL
Lights - security	4	150	7	4200	126	
Computer	1	120	3	360	10.8	

Heating	3	-	-	-	-	LPG
Cooking	1	-	-	-	-	LPG
TV/Radio	1	20	5	100	3	
Kettle		-	-	-	-	LPG
Refrigerator	1	550	6.5	3575	107.25	Could be LPG
Total Concurrent Demand		**1870 W**	**Total Consumption**		**388.7 kWh/m**	

The solar PV system required to supply the concurrent demand and total consumption would consist of a battery bank (to store power), a solar PV array (the supply power and charge the batteries) and an inverter (to convert DC to AC). Taking into account the system efficiency, the minimum depth of discharge of the batteries, the solar radiation available and the back-up for cloudy days the following system would be required:

- A battery bank - 1000Ah 48V
- A solar PV array – nine 125Wp panels
- An inverter/charger – 4kW bidirectional 48V

The approximate costing of the solar PV system is as follows:

Item	**Approx cost (ex VAT)**	**Comment**
Battery Bank	R69,600	24 x 2V deep cycle
Solar PV Panels	R54,000	9 x 125Wp
Inverter	R18,700	Pure sine, bidirectional
Installation	R30,000	Including sundries
TOTAL	**R172,300**	

Note that this system is a good quality robust system with pure sine wave inversion. There are many products on the market that are cheaper but not nearly as robust and often producing square wave alternating current which can damage equipment. Also if the battery bank is not made up of good quality deep cycle batteries the life of the bank will be limited.

6.7 Technology Package Summary

In summary the most suited package of alternative energy technologies for the six categories is listed in Table 32 below.

Table 32. Summary of Technology Packages

Type	***Technology Package***	***Providing***	***Achieving***	***Costing***
Private Electrified Household	SWH, LPG, CFL	Hot water, cooking, heating, thermal efficiency	Up to 44% drop in energy bill, better comfort	• CAPEX – R17,000/HH • OPEX saved – R1,600/a/HH
Formal Electrified Household	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 25% drop in energy bill, better comfort	• CAPEX – R19,500/HH • OPEX saved – R400/a/HH
Formal Electrified and Mixed Fuel Household	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 32% drop in energy bill, better comfort	• CAPEX – R13,500/HH • OPEX saved – R650/a/HH
Informal Un-Electrified Household	Gelfuel, PV, LPG, Ceiling & Insulation	Cooking, electricity, heating, thermal efficiency	Increase in energy bill, better safety, health and comfort	• CAPEX – R5,700/HH • OPEX incr – R288/a/HH
Standard Electrified School	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 25% drop in energy bill, better comfort	• CAPEX – R193,500/HH • OPEX saved – R2,200/a/HH
Standard Electrified Clinic	SWH, LPG, Ceiling & Insulation, Plaster, CFL	Hot water, cooking, heating, thermal efficiency	Up to 41% drop in energy bill, better comfort	• CAPEX – R94,500/HH • OPEX saved – R4,000/a/HH

7 Additional Factors in Technology and Project Selection

There are a range of additional factors which are beyond specific project evaluation criteria that may influence project selection. These are factors that are dependent on external decisions and/or information that cannot be incorporated into the multi-criteria decision making process.

For example, a key issue affecting the selection of the technology package is whether the project will be undertaken on existing housing and facilities or implemented in new-build areas. The brief to the consultants was to focus on existing stock. In the event that a change of circumstances or extension of the project allows for the inclusion of new-build in the process then a different set of technology options may become more preferable.

Other factors will also affect project choice. These include:

- *Once-off or ongoing subsidies*: some of the project options imply once-off capital costs while others would require ongoing household subsidies to provide the full social benefits and to allow low income households to be financially no worse off with the new options. In some, but not all, instances the free basic alternative energy subsidy may be available for the projects. A key project decision would therefore be whether an ongoing subsidy commitment would be entered into and by whom.
- *Regulatory framework*: the regulatory framework affects some of the technology options more than others. For example, the introduction of a SWH subsidy clearly favours SWH's. However, this subsidy programme may not include the lower-end of the SWH market (such as gravity fed systems) which may therefore remove this additional incentive for interventions in low income areas. The details of this regulatory/subsidy framework (currently not fully concluded) therefore may affect project choice. Similarly, it is apparent that security of supply of LPG is potential dependent on regulatory decisions, such a price regulation, affecting investment in the wholesale LPG industry. The provincial project option may therefore be affected by broader national regulatory decisions.
- *Institutional and implementation capacity*: whether the province intends to manage and implement the project itself or will enter into partnerships with other service providers. Most of the technology options will require some form of ongoing management and maintenance. It is unlikely that the province will want to take on this responsibility. The availability of suitable service providers is therefore critical to the sustainability of these options. Further, to ensure participation of private sector providers it will be necessary to provide some assurances that a sustainable revenue stream will be forthcoming from the project. If this proves not to be the case projects may become unsustainable without ongoing government support.

- *Cost Assessment*: The consultants were instructed to consider the projects on the basis that the full capital costs of the intervention was to be fully subsidised by government with ongoing project costs being borne by the project beneficiary/new technology owner. The costs have been considered in this way but it is worth noting that if another financial structure is followed the financial evaluations of the technology options may well change. For example – if the project were to be developed as a public-private partnership (PPP) the private provider would evaluate the project simply on a return on investment basis. This would almost definitely change the relative ranking of technology choices.

7.1 Institutional and Inter-Governmental Issues

Provinces have no specific energy mandate. However, energy is a cross-cutting theme, and clearly has some role in many of the core provincial competencies, particularly Environment, Air Pollution, Health, Education, Regional Planning and Development and Urban and rural development. It is generally not appropriate for the Provincial Government to act as an energy delivery agency – this typically falls to local government – and they are also not mandated to enter into the field of power generation. In addition, they do not determine energy policy – this is generally the realm of national government. Rather provinces typically have a facilitative role in this area – sitting between policy and delivery. Economic development, combating climate change, improving public transport, promoting sustainable practices and supporting local government all have energy dimensions. In this context, promoting renewable energy and energy efficiency is well within the Provincial Government mandate.

Energy concerns impact on a full range of sectors and activities and is therefore a prime example of an area requiring co-operation between the different spheres of government. The Provincial Government should actively seek to co-operate with other government bodies around energy concerns, with an aim to providing assistance, support, and leadership. Through a process of internal discussion as well as public participation, the Provincial Government should attempt to ensure that its efforts to develop the renewable energy sector and promote energy efficiency are co-ordinated with the efforts of other spheres of government relating to energy. This is particularly important in the context of Gauteng where the larger Metropolitan municipalities are developing their own internal sustainable energy strategies and plans.

The Province can play a leadership role in this area, by ensuring that its internal functioning promotes energy efficiency, and that it supports research and implementation of cleaner energy production, distribution and consumption. Other key areas where the Gauteng Province can promote sustainable energy in the short-term, probably via the Provincial Sustainable Energy Strategy, include:

- Facilitating coordination and synergies amongst the large metros who are already pursuing sustainable energy strategies.
- Supporting smaller municipalities who do not have the capacity to engage this area
- Ensuring that facilities over which they have influence are efficiently built and operated (clinics, schools, community facilities etc)
- Developing standard bylaws which municipalities can then adopt – e.g. around solar water heaters.
- Developing on overarching strategy in conjunction with municipalities.

7.2 CDM and Carbon Finance

The Clean Development Mechanism can potentially be used to provide additional financial support to some alternative energy projects as long as they lead to a net reduction in greenhouse gas reductions that can be measured and verified. The process to establish a CDM project is complex – particularly in the case of dispersed projects as envisaged by GDACE. Nevertheless, it is certainly worth considering the CDM options available. The key issues related to CDM project registration relevant to the possible options are outlined below.

CDM approval and methodologies

All methodologies used in CDM projects must be approved by the Executive Board (EB) of the CDM before the EB will accept a CDM project for registration. Unless it is registered, a CDM project has no ability to generate carbon revenue from the sale of certified emission reductions (CERs) even if it is in fact reducing emissions. Therefore, any project would need to use an existing approved methodology and achieve registration or develop a new methodology and submit that new methodology to the EB for its approval as part of its application for registration.

There are currently two basic tracks of methodologies that are relevant to the projects under consideration. The first is methodologies for "full scale projects" and the second is methodologies for "small scale projects". Some of the project options could use a small scale methodology for the type of project considered. This approach would require the project to meet all of the requirements of small scale projects as set forth in the international rules of the Kyoto Protocol. For example, a SWH project would most likely fall under "renewable energy project activities with a maximum output capacity equivalent to up to 15 MW(e)".

The EB adopted the "small scale" project track, in recognition of the fact that CDM projects can have long lead times, high development costs, and not be feasible for many communities with limited budgets. It was intended to encourage projects which offer sustainable development benefits at the community level. In general, small scale methodologies have simplified procedures including the pre-approved and standardized methodologies for determining a baseline and creating a monitoring plan and the ability to bundle project activities to reduce administrative costs.

The existing methodology that has been approved by the Executive Board of the CDM for SWH CDM projects has actually been used in South Africa before. It is a small scale methodology and is identified as AMS-I.C "Thermal energy for the user with or without electricity". The methodology can be seen in full on the website of the United Nations Framework Convention on Climate Change ("UNFCCC"). The URL for this methodology is: http://cdm.unfccc.int/EB/033/eb33_repan22.pdf. The project in South Africa that has used this small scale methodology is the Kuyasa CDM project developed in Khayelitsha by the City of Cape Town already discussed in the background reports. This therefore provides a good basis for CDM registration.

Programmatic CDM

In a series of recent decisions, which began in 2005 at the Conference of the Parties (COP) in Montreal, and have been evolving in a series of EB decisions since, a new approach to certain types of CDM projects has been approved and guidelines for it have been evolving. This new approach, which could be of significant interest to the Province in the development of a rollout of alternative energy technologies through a CDM project, is called a "Programme of Activities", commonly referred to as "programmatic CDM." This new approach can use existing approved small scale methodologies, with minor modifications.

Programmatic CDM Projects may be a more effective, inexpensive means of structuring a CDM project for a large scale rollout because the CDM decisions related to Programmatic CDM should result in significantly reduced transaction costs. The reduced cost results largely from the fact that there is no definition or limit on size and scope of a CDM project registered under a Programme of Activities. The CDM project that seeks registration as part of a programme of activities can be a very small project (for example, 50 houses that will install SWHs) and thus pay a very small registration fee which is based on the projected number of CERs a project will generate. Following this initial registration a large number of similar units (500,000 more houses, for example) can be added one or more at a time to the same project with no additional registration fee required and no need for additional validation. However, all units of the project must use the same approved methodology.

Registration of a Programme of Activities can allow for greater flexibility in the expansion of a project boundary and reduce the need for a rigid definition of the geographical area in which the activities will take place. While it is still necessary for the coordinating entity of a Programme of Activities to specify the geographical area, it appears that this geographic area can be very broadly stated – e.g. a municipality, a country or a number of countries.

A Programme of Activities is defined as "a voluntary coordinated action by a private or public entity which coordinates and implements any policy/measure or stated goal (i.e. incentive schemes and voluntary programmes), which leads to anthropogenic GHG emission reductions or net anthropogenic greenhouse gas removals by sinks that are additional to any that would occur in the absence of the PoA, via an unlimited number of CDM Programme Activities (CPAs)" and is set forth in CDM-EB-32, Annex 38, paragraph 1 (2007). Multiple CPAs under a Programme of Activities may be registered as a single CDM Project. This is subject to the proviso "that approved baseline and monitoring methodologies are used that, *inter alia*, define the appropriate boundary, avoid double-counting and account for leakage, ensuring that the emission reductions are real, measurable and verifiable..." .

It thus appears that with careful design a provincial alternative energy project could qualify and be registered as a programmatic CDM project and hence gain carbon credits which could be used to offset project costs. A simple assessment is provided in the table below of the likely eligibility and potential for the key options identified in the technology packages developed above.

Table 33. CDM Eligibility and Potential

Technology Option	CDM Eligibility and Potential
SWH	CDM eligible and has significant potential to offset capital costs of technology. Eskom is considering developing a broad SWH CDM project.
LPG	CDM eligible as a fuel switching measure but likely to have limited greenhouse gas reduction benefits and difficult to measure and verify
CFL	CDM eligible and has potential to offset capital costs. Eskom is considering developing a broad CFL CDM project.
Ceiling & Insulation and Plaster	Probably not CDM eligible due to measurement and monitoring constraints and carbon credit potential limited in any event
Gelfuels	CDM eligible but greenhouse gas reduction benefits are uncertain. The full life cycle impacts of the fuels would need to be taken into account which will be complex.
Solar PV	CDM eligible but the likely greenhouse gas reductions are small and will make a relatively minor contribution to offsetting capital costs

7.3 Net Metering and Possibilities of Grid Feed-In

At present there are a number of constraints to the feed-in of power generated by small scale power producers into the electricity grid. These constraints are technical, financial and regulatory. At present the grid codes for connection to the national grid are complex and are not designed to accommodate small scale energy producers – for example facilities with solar PV installations generating excess power. This provides a major technical barrier.

The regulatory framework also requires the registration with the National Energy Regulator of South Africa (NERSA) of any independent power producer feeding electricity into the grid. This is a relatively complex process and one which would be difficult for any small scale power producer. There are also currently no regulations or policy governing the financial arrangements of feeding in renewable power into the grid. This means that there are no simple mechanisms of producers receiving financial benefit from so-called net-metering, in which the net amount of electricity (i.e. the electricity flowing both too and from the user/provider) is accounted for.

At present NERSA is undertaking a project to develop a renewable energy feed-in-tariff system. The intention of this new approach is to allow and to encourage renewable energy generators to feed power into the grid at pre-approved and guaranteed tariffs. If implemented this system, currently in use in many developed countries, will provide a significant boost to renewable energy generation. However, a feed-in-tariff will not remove all the barriers to small producers supplying power to the grid. The first stage of the NERSA project is likely to focus on larger producers who can offer a relatively stable amount of power to the grid. There is considerable complexity in establishing a system that allows many small and intermittent energy providers to get a guaranteed tariff – including the fact that most of these will be feeding into the distribution network and will require some arrangement – both in metering and payment – that will involve local authorities.

The regulatory environment is therefore moving towards allowing net-metering approaches. Those systems, such as solar PV, which have the potential to generate electricity should be designed in such a way to accommodate future energy sales. That being said, of the prioritised technology options, it is only solar PV that has this potential as the other options are essentially options which reduce electricity demand but do not generate electrical power. Further, the scale of PV systems envisaged are likely to that small that the vast majority of the power is used on-site with little excess power being generated.

7.4 Stakeholder Comments

The stakeholder workshop comments, as well as other comments received from stakeholders through interview and written comments have been incorporated into this written report. The most significant change arising has been the use of the more detailed energy user types – rather than just one single comparison of technologies against each other. The feedback that led to this change is therefore acknowledged and has improved the detail and usefulness of this project.

Other minor changes, such as details of specific technology options, are embedded in the relevant points of the report. The full stakeholder workshop minutes are attached to this report as an appendix (see Appendix F: Stakeholder workshop).

7.5 Monitoring and Evaluation

For any selected pilot project it will be crucial to establish a workable and rigorous monitoring and evaluation (M&E) approach. This is built into Phase 2 of the project and is not dealt with in any depth here. It should be noted that if a CDM project is established this will require its own specific M&E requirements which will need to be carefully considered.

The design of the M&E system should be structured to provide the province with the financial, social and technical information to assess the merits of any project option selected and to enable choices about project replication or extension. The M&E system should also provide more general inputs into the envisaged Provincial Sustainable Energy Strategy.

8 Conclusions and Recommendations

A number of conclusions and recommendations are outlined arising out of the project research and analysis. The first and most specific of these relate to the selection of appropriate energy technologies, but other more general recommendations are also made.

Technology selection

The results of the ranking showed that solar water heaters, where technically feasible, are the best supply technology across the different user types. Liquid petroleum gas also features in all types with gelfuels showing up in informal household types. Formal housing and institutions that do not have ceilings or plaster would all benefit greatly if these were to be installed – both from an energy saving and comfort perspective. Incandescent lighting that is swapped out with compact fluorescent lamps would reduce energy demand. Electricity supply by photovoltaic or fuel cell technology only features in informal un-electrified households (mainly because its cost compared to grid electricity is still a barrier).

Of the four household types the one needing the greatest capital cost is the formal electrified type where a package made up of a SWH, LPG system, ceilings/insulation, plastering and CFLs would cost about R19,500 per household and only 25% of its energy use would drop. This is partly due to the fact that a large portion of its energy goes to refrigeration and more efficient fridges are not readily available in South Africa yet. However, the formal electrified and mixed fuel type of household only requires R13,500 capital cost per household to achieve a saving of 32% and improved safety, health and comfort. Informal un-electrified households need special mention because although the package of technologies' capital cost is only R5,700 per household there is a need to subsidise the operating costs as it increases from the current energy bill. This is because gelfuel is more expensive than paraffin but a safer and healthier option (assuming it is of good quality).

To improve the thermal performance of institutions with no ceiling or plastered walls would have a relatively high capital cost but it would also help contribute (along with SWHs, LPG and CFLs) to reducing the electricity demand by 25% in schools and 41% in clinics. A typical school has an electricity demand of 1.6MWh per month and a typical clinic 1.9MWh per month so these saving are significant. The capital costs for the package of technologies for a school is about R193,500 and a clinic R94,500. It can be seen that the clinic requires a lower outlay to achieve a higher saving. This is due to its high use of hot water currently supplied by electrify and smaller area of ceiling and plaster compared to a school. Of course that is not to say that schools should be ignored, just that the demand reduction will need a greater outlay.

These conclusions give some insight into the benefits of installing alternative technologies into these typical user types. However, to capture all variations in household composition and energy use practices would be a vast and impractical exercise. Categorization has had to be simplified which inevitably resulted in fewer, larger categories accommodating some variation within. A single *average* household was developed as representative of each type. For the purpose of analysing actual interventions, what is required are more specific profiles of households and institutions; moving from the general to the specific, from the *average* household to actual households.

Pilot phase

As outlined, there are also a range of other factors affecting the selection of pilot projects and technology packages. These include the financing arrangements and budget available, institutional mechanism, site selection and project time-frame. A full project feasibility assessment can therefore only be done rigorously for an actual pilot project.

It is thus recommended that a pilot phase is initiated so that the six user categories using the packaged technologies presented can be tested 'on the ground. This will give confidence in a larger scale roll out in the townships of these technologies which will reduce energy demand and costs, introduce more sustainable energy sources and improve the quality of life of households and residents.

A pilot project should be designed to provide useful information and insights into larger scale implementation programmes. In this regards the monitoring and evaluation of the pilot is important and should be structured to provide the province with the financial, social and technical information to assess the merits of any project option selected and to enable choices about project replication or extension. From a social impact perspective, GDACE should be aware that a baseline survey may be very valuable in order to measure these impacts post-project. The M&E system should also provide more general inputs into the envisaged Provincial Sustainable Energy Strategy.

Institutional and Regulatory Issues

Outside of a specific alternative energy pilot project a number of other recommendations can be made arising from the work conducted for this project. From an institutional perspective it is apparent that although the province does not have a formal energy supply mandate it can play an important role in ensuring the provision of more sustainable energy services which will have social, economic and environmental benefits.

Energy concerns impact on most sectors and activities and are therefore a prime example of an area requiring co-operation between the different spheres of government. The Provincial Government should actively seek to co-operate with other government bodies around energy concerns, with an aim to providing assistance, support, and leadership. Through a process of internal discussion as well as public participation, the Provincial Government should attempt to ensure that its efforts to develop the renewable energy sector and promote energy efficiency are co-ordinated with the efforts of other spheres of government relating to energy. This is particularly important in the context of Gauteng where the larger Metropolitan municipalities are developing their own internal sustainable energy strategies and plans.

The Province can play a leadership role in this area, by ensuring that its internal functioning promotes energy efficiency, and that it supports research and implementation of cleaner energy production, distribution and consumption. Other key areas where the Gauteng Province can promote sustainable energy in the short-term, probably via the Provincial Sustainable Energy Strategy, include:

- Facilitating coordination and synergies amongst the large metros who are already pursuing sustainable energy strategies.
- Supporting smaller municipalities who do not have the capacity to engage this area
- Ensuring that facilities over which they have influence are efficiently built and operated (clinics, schools, community facilities etc)
- Developing standard bylaws which municipalities can then adopt – e.g. around solar water heaters.
- Developing on overarching strategy in conjunction with municipalities.

The Province also has a role to play in identifying regulatory obstacles at the national, provincial or local level to alternative and renewable energy development and assisting in removing these obstacles. These include, for example, greater certainty over future regulation, and hence security of supply, of LPG prices and rapid certainty over the solar water heater subsidy programme and its applicability to all energy users.

Provincial Sustainable Energy Strategy and Energy Standards

The Province is in the process of developing a Sustainable Energy Strategy. This strategy is likely to have a broader ambit than the current project, as it will deal with all energy use in the province. This project has provided useful insights into a specific sub-sector of energy use and should form part of the Sustainable Energy Strategy background documentation.

This project can also support the development of targets or standards for sustainable energy provision in the province. It is useful to adopt a set of energy service standards which government should aim for in the residential sector. In this regard there are limited accepted standards to draw on either internationally or locally, although there is broad consensus on the types and quality of services which should be aimed for. These standards should follow from the above prioritisation analysis, but at a minimum should ensure pursuit of the Millenium Development Goals, which aim at poverty eradication, and therefore suggest that the informal un-electrified households be an important focus. The following are proposed as minimum standards for two different housing types:

Energy standards for informal, un-electrified households:

- Gel fuel or LPG (subsidised through the Free Basic Alternative Energy policy) provision (access to safe, healthy and affordable cooking fuels)
- Access to electricity (adequate illumination, opens up range of appliance use possibilities and supports education and learning goals)
- Ceiling installation (improved thermal comfort, reduced energy expenditure)

Energy standards for formal households:

- Access to electricity (adequate illumination, opens up range of appliance use possibilities and supports education and learning goals)

- Solar water heater installation (subsidy likely to be necessary in low income areas): improved and economically sensible hot water supply promoting health and welfare.
- Ceiling installation (improved thermal comfort, reduced energy expenditure)

In addition, access to well equipped facilities such as clinics and schools has been shown to be important in improving welfare in general, particularly of the poor. Addressing energy needs in these facilities therefore remains an important focus for government.

Carbon Finance and the Clean Development Mechanism

It appears that with careful design a provincial alternative energy project could qualify and be registered as a programmatic CDM project and hence gain carbon credits which could be used to offset project costs. The carbon finance component of any project should be identified and pursued if possible – particularly if it can be replicated on a larger scale within the province.

Large Scale Programme Implementation

Although not yet at this stage some important considerations to assist in preparing for a larger scale rollout involve the following additional investigations:

- identifying opportunities to align the rollout with other housing and energy projects and/or programmes
- investigating different project design, financing and implementation models - such as Energy Service Companies, the CDM, and so forth.
- financial modelling for a large scale rollout of infrastructure capital investment and household affordability.

In addition, many of the practical implementation aspects can be supported by lessons learnt during the pilot stage and hence it is important that the pilot implementation is designed with recovery of these lessons at front of mind.

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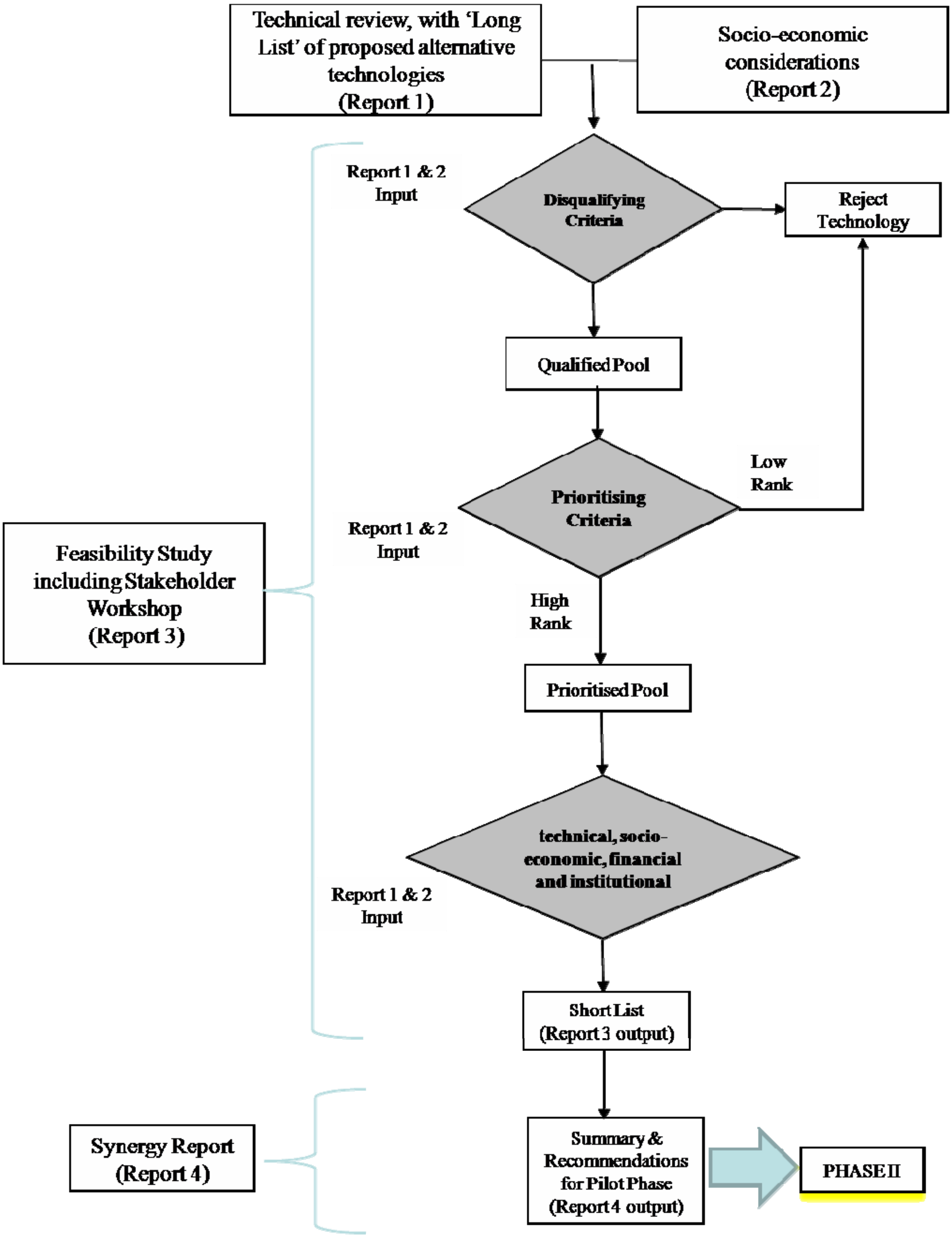
Appendix A - Phase 1 Project Flow



9 Appendix B – Technology Ranking Tables

9.1 Typical Ranking Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**	Institutions	INSTITUTIONAL RANKING
Weight	10.0	6.0	8.0	2.0	2.0	2.0	10.0	4.0	8.0	8.0	4.0	8.0	10.0	6.0	4.0	8.0	5.0	**105.0**	25.0	130.0
Normalised Weight	10%	6%	8%	2%	2%	2%	10%	4%	8%	8%	4%	8%	10%	6%	4%	8%	5%	**100%**	19%	100%
Solar Water Heaters	3	2	3	4	2	2	4	4	3	4	4	4	3	1	2	4	4	80%	4	80%
Liquid Petroleum Gas	3	2	2	4	2	2	3	4	2	2	4	4	1	2	2	3	2	63%	3	62%
Biogas Digesters	3	0	1	4	2	2	3	1	2	2	1	3	2	4	2	3	3	57%	3	57%
Landfill Gas	3	0	1	4	2	2	2	0	2	2	1	2	1	4	2	3	4	50%	4	57%
Gelfuels	2	4	4	4	2	2	3	4	2	4	4	3	2	3	4	3	3	76%	0	58%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	2	3	3	57%	4	62%
Fuel Cell	2	0	1	4	2	0	3	4	3	4	4	3	1	1	4	3	3	60%	3	60%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*420*	*4*	*550*

9.2 Typical Ranking Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	SCORE	Institutions	INSTITUTIONAL RANKING
Weight	6.0	8.0	2.0	2.0	2.0	10.0	4.0	10.0	8.0	0.0	8.0	12.0	8.0	6.0	8.0	5.0	99.0	25.0	124.0
	6%	8%	2%	2%	2%	10%	4%	10%	8%	0%	8%	12%	8%	6%	8%	5%	**100%**	20%	100%
Plastering, in & out	4	3	4	2	2	4	4	4	4	4	4	3	2	2	2	4	82%	4	85%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	71%	4	76%
Ceiling and/or Insulation	4	3	4	2	2	4	4	4	4	4	4	3	2	2	3	4	84%	4	86%
CFL lighting	4	2	4	2	2	2	4	4	4	4	4	4	2	4	3	4	83%	4	86%
Light Emitting Diodes	0	2	4	2	2	3	4	4	4	4	4	4	2	4	3	3	78%	4	82%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	77%	4	81%
Low Smoke Stoves	0	2	4	2	2	3	4	3	4	4	3	3	2	4	3	4	72%	3	72%
Hot Box	2	3	4	2	2	3	4	2	4	4	3	3	2	4	2	2	70%	3	70%
Geyser and Pipe Insulation	4	3	2	2	2	4	4	4	4	4	4	2	2	2	3	2	77%	4	81%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*396*	*4*	*500*

9.3 Private Electrified Household Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	12.0	3.0	6.0	2.0	2.0	2.0	4.0	6.0	10.0	8.0	4.0	6.0	8.0	6.0	8.0	4.0	3.0	**94.0**
Normalised Weight	13%	3%	6%	2%	2%	2%	4%	6%	11%	9%	4%	6%	9%	6%	9%	4%	3%	**100%**
Solar Water Heaters	3	2	3	2	2	2	4	4	3	4	4	4	3	1	4	4	4	81%
Liquid Petroleum Gas	3	2	2	2	2	2	3	4	2	2	4	4	1	2	2	3	2	62%
Biogas Digesters	2	0	1	2	2	4	3	1	1	2	1	3	2	4	2	3	3	50%
Landfill Gas	3	0	1	2	2	2	2	0	2	2	1	2	1	4	2	3	4	49%
Gelfuels	2	2	0	2	2	2	0	4	0	4	4	0	0	2	4	0	0	42%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	4	3	3	64%
Fuel Cell	2	0	1	2	2	0	3	4	3	4	4	3	1	1	4	3	3	63%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*376*

9.4 Private Electrified Household Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh.ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	3.0	6.0	2.0	2.0	2.0	4.0	6.0	10.0	8.0	0.0	6.0	12.0	8.0	6.0	4.0	3.0	**82.0**
	4%	7%	2%	2%	2%	5%	7%	12%	10%	0%	7%	15%	10%	7%	5%	4%	**100%**
Plastering, in & out	0	0	0	0	0	0	4	4	4	4	4	0	0	0	0	0	37%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	71%
Ceiling and/or Insulation	0	0	0	0	2	0	4	4	4	4	4	0	0	0	0	0	38%
CFL lighting	4	2	0	2	2	2	4	4	4	4	4	4	2	4	3	4	83%
Light Emitting Diodes	0	2	0	2	2	3	4	4	4	4	4	4	2	4	3	3	80%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	78%
Low Smoke Stoves	0	0	0	2	2	0	4	0	4	4	0	0	2	4	0	0	32%
Hot Box	2	4	2	2	2	3	4	3	4	4	3	4	2	4	0	0	75%
Geyser and Pipe Insulation	4	3	2	2	2	4	4	4	4	4	4	2	2	2	3	2	76%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*328*

9.5 Formal Electrified Household Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	12.0	3.0	6.0	2.0	2.0	2.0	6.0	6.0	8.0	8.0	4.0	6.0	8.0	6.0	8.0	8.0	5.0	**100.0**
Normalised Weight	12%	3%	6%	2%	2%	2%	6%	6%	8%	8%	4%	6%	8%	6%	8%	8%	5%	**100%**
Solar Water Heaters	3	2	3	2	2	2	4	4	3	4	4	4	3	1	4	4	4	83%
Liquid Petroleum Gas	3	2	2	2	2	2	3	4	2	2	4	4	4	2	2	3	2	69%
Biogas Digesters	3	0	2	2	2	4	3	1	1	2	1	4	2	4	2	3	3	59%
Landfill Gas	2	0	1	2	2	2	0	0	2	2	1	2	1	4	2	3	4	46%
Gelfuels	0	0	0	2	2	2	0	4	0	4	4	0	0	2	4	0	0	32%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	2	3	3	60%
Fuel Cell	2	0	1	2	2	0	3	4	3	4	4	3	0	1	2	3	3	58%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*400*

9.6 Formal Electrified Household Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh.ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	4.0	7.0	2.0	2.0	2.0	7.0	6.0	10.0	8.0	0.0	7.0	12.0	8.0	5.0	8.0	5.0	**93.0**
	4%	8%	2%	2%	2%	8%	6%	11%	9%	0%	8%	13%	9%	5%	9%	5%	**100%**
Plastering, in & out	4	3	4	2	2	4	4	4	4	4	4	4	2	2	2	4	85%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	71%
Ceiling and/or Insulation	4	3	4	2	2	4	4	4	4	4	4	4	2	2	3	4	87%
CFL lighting	4	2	0	2	2	2	4	4	4	4	4	3	2	4	3	4	78%
Light Emitting Diodes	0	2	0	2	2	3	4	4	4	4	4	3	2	4	3	3	75%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	78%
Low Smoke Stoves	0	0	0	2	2	0	4	0	4	4	0	0	2	4	0	0	27%
Hot Box	2	3	2	2	2	3	4	2	4	4	3	3	2	4	0	0	62%
Geyser and Pipe Insulation	0	0	2	2	2	0	4	4	4	4	0	0	2	2	0	0	36%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*372*

9.7 Formal Electrified and Mixed Fuel Household Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	10.0	5.0	8.0	6.0	2.0	2.0	8.0	4.0	8.0	8.0	4.0	8.0	10.0	6.0	6.0	7.0	4.0	**106.0**
Normalised Weight	9%	5%	8%	6%	2%	2%	8%	4%	8%	8%	4%	8%	9%	6%	6%	7%	4%	**100%**
Solar Water Heaters	4	2	3	2	2	2	4	4	3	4	4	4	3	1	4	4	4	83%
Liquid Petroleum Gas	4	2	3	4	2	2	3	4	2	4	4	4	3	2	2	3	2	77%
Biogas Digesters	1	0	2	4	2	4	3	1	1	4	1	3	3	4	2	3	3	61%
Landfill Gas	2	0	2	4	2	2	2	0	2	4	1	2	3	4	2	3	4	60%
Gelfuels	3	2	2	4	2	2	3	4	1	4	4	2	1	2	4	1	1	61%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	2	3	3	56%
Fuel Cell	2	0	1	2	2	0	3	4	3	4	4	3	1	1	2	3	3	57%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*424*

9.8 Formal Electrified and Mixed Fuel Household Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh.ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	5.0	7.0	6.0	2.0	2.0	8.0	5.0	9.0	8.0	0.0	7.0	12.0	8.0	5.0	8.0	5.0	**97.0**
	5%	7%	6%	2%	2%	8%	5%	9%	8%	0%	7%	12%	8%	5%	8%	5%	**100%**
Plastering, in & out	4	3	4	2	2	4	4	4	4	4	4	4	2	2	2	4	85%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	70%
Ceiling and/or Insulation	4	3	4	2	2	4	4	4	4	4	4	4	2	2	3	4	87%
CFL lighting	4	2	0	2	2	2	4	4	4	4	4	3	2	4	3	3	73%
Light Emitting Diodes	0	2	0	2	2	3	4	4	4	4	4	3	2	4	3	3	70%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	78%
Low Smoke Stoves	4	3	4	2	2	2	4	3	4	4	3	3	2	4	2	2	74%
Hot Box	2	3	4	2	2	3	4	3	4	4	3	4	2	4	0	0	70%
Geyser and Pipe Insulation	0	0	2	2	2	4	2	2	2	4	0	0	2	0	0	0	29%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*388*

9.9 Informal Un-Electrified Household Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	10.0	6.0	8.0	6.0	2.0	2.0	10.0	4.0	8.0	8.0	4.0	8.0	11.0	6.0	4.0	8.0	5.0	**110.0**
Normalised Weight	9%	5%	7%	5%	2%	2%	9%	4%	7%	7%	4%	7%	10%	5%	4%	7%	5%	**100%**
Solar Water Heaters	0	0	3	4	2	2	0	2	2	4	2	0	2	2	0	0	0	35%
Liquid Petroleum Gas	3	0	3	4	2	2	0	2	2	4	2	0	4	2	0	0	0	47%
Biogas Digesters	0	0	2	4	2	4	0	2	2	4	2	0	0	2	0	0	0	29%
Landfill Gas	0	0	2	4	2	2	0	2	2	4	2	0	0	2	0	0	0	28%
Gelfuels	3	4	2	4	2	2	3	4	3	4	4	2	2	2	4	3	3	74%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	0	3	3	54%
Fuel Cell	3	0	2	2	2	0	3	4	3	4	4	3	1	1	0	3	3	59%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*440*

9.10 Informal Un-Electrified Household Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	6.0	8.0	6.0	2.0	2.0	10.0	5.0	10.0	8.0	0.0	8.0	12.0	8.0	6.0	8.0	5.0	**104.0**
	6%	8%	6%	2%	2%	10%	5%	10%	8%	0%	8%	12%	8%	6%	8%	5%	**100%**
Plastering, in & out	0	0	2	2	2	0	2	0	0	4	0	0	2	2	0	0	14%
External Painting	0	1	2	2	2	2	4	4	4	4	3	1	2	2	0	0	49%
Ceiling and/or Insulation	2	0	4	2	2	3	4	4	4	4	3	3	2	2	2	3	69%
CFL lighting	0	0	2	2	2	0	2	2	2	4	0	0	2	0	0	0	20%
Light Emitting Diodes	0	0	2	2	2	0	2	2	2	4	0	0	2	0	0	0	20%
Efficient design	2	3	4	2	2	2	2	2	4	4	3	3	2	2	2	2	63%
Low Smoke Stoves	2	3	4	2	2	4	4	4	4	4	4	4	2	3	3	3	85%
Hot Box	2	3	4	2	2	3	4	3	4	4	3	3	2	2	2	0	68%
Geyser and Pipe Insulation	0	0	2	2	2	0	2	2	2	4	0	0	2	0	0	0	20%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*416*

9.11 Electrified Standard School Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	12.0	3.0	6.0	2.0	2.0	2.0	6.0	6.0	8.0	8.0	4.0	6.0	8.0	6.0	8.0	8.0	5.0	**100.0**
Normalised Weight	12%	3%	6%	2%	2%	2%	6%	6%	8%	8%	4%	6%	8%	6%	8%	8%	5%	**100%**
Solar Water Heaters	3	2	3	2	2	2	4	4	3	4	4	4	3	1	4	4	4	83%
Liquid Petroleum Gas	3	2	2	2	2	2	3	4	2	2	4	4	4	2	2	3	2	69%
Biogas Digesters	3	0	2	2	2	4	3	1	1	2	1	4	2	4	2	3	3	59%
Landfill Gas	2	0	1	2	2	2	0	0	2	2	1	2	1	4	2	3	4	46%
Gelfuels	0	0	0	2	2	2	0	4	0	4	4	0	0	2	4	0	0	32%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	2	3	3	60%
Fuel Cell	2	0	1	2	2	0	3	4	3	4	4	3	0	1	2	3	3	58%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*400*

9.12 Electrified Standard School Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	3.0	6.0	2.0	2.0	2.0	6.0	6.0	8.0	8.0	0.0	6.0	12.0	8.0	6.0	8.0	5.0	**88.0**
	3%	7%	2%	2%	2%	7%	7%	9%	9%	0%	7%	14%	9%	7%	9%	6%	**100%**
Plastering, in & out	4	3	4	2	2	4	4	4	4	4	4	3	2	2	2	4	80%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	69%
Ceiling and/or Insulation	4	3	4	2	2	4	4	4	4	4	4	3	2	2	3	4	82%
CFL lighting	4	2	0	2	2	2	4	4	4	4	4	4	2	4	3	4	82%
Light Emitting Diodes	0	2	0	2	2	3	4	4	4	4	4	4	2	4	3	3	79%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	77%
Low Smoke Stoves	0	0	0	2	2	0	4	0	4	4	0	0	2	4	0	0	30%
Hot Box	2	3	2	2	2	3	4	2	4	4	3	3	2	4	0	0	63%
Geyser and Pipe Insulation	4	3	2	2	2	4	4	4	4	4	4	2	2	2	3	2	75%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*352*

9.13 Electrified Standard Clinic Supply Side

Qualified Technology	Security of Supply	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	12.0	3.0	6.0	2.0	2.0	2.0	6.0	6.0	8.0	8.0	4.0	6.0	10.0	6.0	8.0	8.0	5.0	**102.0**
Normalised Weight	12%	3%	6%	2%	2%	2%	6%	6%	8%	8%	4%	6%	10%	6%	8%	8%	5%	**100%**
Solar Water Heaters	3	2	3	2	2	2	4	4	3	4	4	4	3	1	4	4	4	82%
Liquid Petroleum Gas	3	2	2	2	2	2	3	4	2	2	4	4	4	2	2	3	2	69%
Biogas Digesters	3	0	2	2	2	4	3	1	1	2	1	4	4	4	2	3	3	63%
Landfill Gas	2	0	1	2	2	2	0	0	2	2	1	2	4	4	2	3	4	52%
Gelfuels	2	2	0	2	2	2	0	4	0	4	4	0	0	2	4	0	0	39%
Solar Photovoltaic	3	0	0	2	2	2	3	4	3	4	4	4	0	0	4	3	3	63%
Fuel Cell	2	0	1	2	2	0	3	4	3	4	4	3	1	1	4	3	3	63%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*408*

9.14 Electrified Standard Clinic Demand Side

Qualified Technology	Technical Constraints	Levelised Costs (R/kWh/ann)	Air Impacts	Water Impacts	Waste Impacts	Employment Potential	Regulatory Barriers	User Acceptability	Safety to User	EIA Barriers	Replicability Potential	Opportunities for avoided cost (levelised R/ann for HH)	Security and Vandalism Risk	Tenure	Potential to Attract Private or Public Investment	Carbon Finance Potential	**SCORE**
Weight	3.0	6.0	2.0	2.0	2.0	6.0	6.0	8.0	8.0	0.0	6.0	12.0	8.0	6.0	8.0	5.0	**88.0**
	3%	7%	2%	2%	2%	7%	7%	9%	9%	0%	7%	14%	9%	7%	9%	6%	**100%**
Plastering, in & out	4	3	4	2	2	4	4	4	4	4	4	3	2	2	2	4	80%
External Painting	4	2	2	2	2	3	4	4	4	4	4	2	2	2	2	2	69%
Ceiling and/or Insulation	4	3	4	2	2	4	4	4	4	4	4	3	2	2	3	4	82%
CFL lighting	4	2	0	2	2	2	4	4	4	4	4	4	2	4	3	4	82%
Light Emitting Diodes	0	2	0	2	2	3	4	4	4	4	4	4	2	4	3	3	79%
Efficient design	4	3	4	2	2	2	4	4	4	4	3	3	2	2	3	4	77%
Low Smoke Stoves	0	0	0	2	2	0	4	0	4	4	0	0	2	4	0	0	30%
Hot Box	2	3	2	2	2	3	4	2	4	4	3	3	2	4	0	0	63%
Geyser and Pipe Insulation	4	3	2	2	2	4	4	4	4	4	4	2	2	2	3	2	75%
Max	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*4*	*352*

Appendix C: Review of alternative technology options

Appendix D: Socio-economic and energy profile

Appendix E: Evaluation of applicable energy options

Appendix F: Stakeholder workshop minutes