University of Pretoria

RESEARCH REPORT:

Contributions to the Theory and Practice of Technology Selection: The Case of Projects to Ensure a Sustainable Energy Base for Africa

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Abstract

Energy is essential for economic development in Africa. The current electrification figures show that countries in sub-Saharan Africa are facing major challenges in reaching positive economic growth and supplying basic energy services to rural communities. Sustainable energy technologies are available and can be used to great effect in Africa to alleviate this problem. Sustainable energy technologies can contribute to job creation and economic development. The implementation of renewable energy technologies in sub-Saharan Africa to date however has not always been successful due to both technical and non-technical factors. Prior to this study a comprehensive framework of factors to select renewable energy technologies did not exist. The purpose of this research was to develop such a framework and to validate it by means of empirical research.

Triangulation of methodologies was used to determine the framework of factors. The analysis of the literature investigated renewable energy technologies and their application, the challenges in renewable energy technologies for implementation in Africa and the selection methods in the fields of project, portfolio, programme and technology management. This was followed by a focus group with three experts in which thirty eight factors that need to be taken into account during the selection of renewable energy technologies in Africa were identified. The factors identified by the focus group were confirmed and the eleven most applicable factors were selected during a two-round Delphi study. Finally case studies on the implementation of renewable energy technologies were undertaken in three countries. These case studies confirmed the eleven factors identified during the Delphi study and identified a further two factors which needed to be added to the framework.

The final framework proposed in this study consists of thirteen factors that need to be considered before deciding on the technology appropriate for a specific implementation. For the implementation of the technology to succeed, it must be ensured that the technology can be maintained and supported on site over the life cycle of the technology, and that sufficient skills and resources exist to implement and maintain the technology. Sites for implementation of the technology must be selected in places where local champions exist to continue supporting the technology after the implementing agency has left, the community has the will to adopt the technology in the long term, sites are available for implementing pilot sites and sufficient sites with the correct characteristics are available for long term implementation. The technology must also contribute to economic development by creating jobs or improving the economic situation of households, and financing must be made available to ensure large scale adoption. Local businesses which aid with implementation need to have business management and technical skills as well as the financial capacity to implement the technology. Government support of the implementation of the technology is essential and the environmental benefits of the technology must be clear from the outset.

This report presents a framework that includes both the criteria and measures to be used for the selection of renewable energy technologies in Africa. Further work is required to implement these criteria and measures in a selection methodology.

Keywords: Renewable energy technology selection, developing countries, sustainable energy, selection criteria, framework of factors

Acknowledgements

'The fear of the LORD is the beginning of wisdom;
all who follow his precepts have good understanding.
To him belongs eternal praise.' - Psalm 111 vs 10

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Note: The appendixes of this study are not in the bound copy but can be accessed at: http://phd-thesis.wikispaces.com/. Please create an account and request membership.

List of Acronyms/Definitions/Abbreviations

AHP	Analytical Hierarchy Process
ANP	Analytical Network Process
CO_2	Carbon dioxide
ESMAP	Energy Sector Management Assistance Program
kgoe	Kilogram oil equivalent
IEA	International Energy Agency
MININFRA	Ministry of Infrastructure Rwanda
Mtoe	Millions of tonnes of oil equivalent
NAPA	National Adaption Program of Action
NDBP	National Domestic Biogas Program
NEPAD	New Partnership for Africa's Development
SNV	Netherlands Development Organisation
TWh	Tera Watt hour
UN	United Nations
UNEA	United Nations Energy Agency
UNECA	United Nations Economic Commission for Africa
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNIDO	United Nations Industrial Development Organisation

Definitions

Climate change	All forms of climatic variations, especially significant changes from one prevailing climatic condition to another.
Carbon intensity	The amount of carbon by weight emitted per unit of energy consumed.
Co-generation	A form of energy recycling where a power station or heat engine are used to produce both electricity and useful heat.
Developing countries	Countries which fall within a given range of GNP per capita, as defined by the World Bank.
Emissions	Flows of gas, liquid droplets or solid particles released into the atmosphere.
Energy demand	The amount of modern energy required by various sectors of (millions toe) a country.
Energy imports	The total cost of energy brought from foreign countries into (US$ million) the domestic territory of a given country.
Energy production	The amount of modern energy produced within the country. (million toe)
Energy reserves	Estimated quantities of energy sources that have been demonstrated to exist with reasonable certainty on the basis of geologic and engineering data (proven reserves) or that can reasonably be expected to exist on the basis of geologic evidence that supports projections from proven reserves (probable or indicated reserves).
Energy services	The end use ultimately provided by energy.
Energy sources	Any substance or natural phenomenon that can be consumed or transformed to supply heat or power.
Energy supply	Amount of energy available for use by the various sectors in a country.
Energy use per capita	The average amount of energy consumed (Kgoe) per inhabitant in a given country.

Fossil fuel	An energy source formed in the earth's crust from decayed organic material, e.g. petroleum, coal, and natural gas.
Geothermal energy	Natural heat from within the earth, captured for production of electric power, space heating or industrial steam.
Geothermal Plant	A plant in which the prime mover is a steam turbine that is driven either by steam produced from hot water or by natural steam that derives its energy from heat found in rocks or fluids at various depths beneath the surface of the earth. The fluids are extracted by drilling and/or pumping.
Global warming	An increase in the near surface temperature of the earth due to increased anthropogenic emissions of greenhouse gases.
Greenhouse effect	The effect produced due to certain atmospheric gases that allow incoming solar radiation to pass through to the earth's surface, but prevent the radiations which are reradiated from the earth, from escaping into outer space.
Greenhouse gas	Any gas that absorbs infrared radiation in the atmosphere.
Gross domestic product	The total output of goods and services (US$ million) produced within the territory of a given country.
Gross domestic product	The annual rate of increase/decrease in the gross domestic growth rate (per cent) product.
Gross national product	The total output of goods and services (US$ million) produced within the territory of a given country (GDP), plus the net receipts of primary income from investments outside the country.
Gross national product	The average income per inhabitant of a country, derived by per capita (US$) dividing the GNP by the population.
Household energy	The total amount of funds spent on energy consumed in, or expenditures delivered to, a housing unit during a given period of time.

Household stoves	Household heating and cooking devices.
Household	A group of people who share a common means of livelihood, such as meals, regardless of source of income and family ties. Members who are temporarily absent are included and temporary visitors are excluded.
Hydro turbine	A device used to generate electricity using kinetic energy from moving water.
Improved household	Household heating and cooking devices that have been stoves altered in design to improve their efficiency.
Institutional stoves	A heating and cooking device commonly used in medium and large institutions.
Kenya ceramic jiko	An improved household stove that uses charcoal and has a ceramic lining to improve efficiency. Widely disseminated in Kenya, and adopted in many African countries.
Less developed countries	Countries that are below a given level or threshold of per capita GNP as defined by the World Bank.
Micro hydro	Small-scale power generating systems that harness the power of falling water (above 100kW but below 1MW).
Modern energy	Refers to high quality energy sources e.g. electricity and petroleum products, as opposed to traditional energy sources such as unprocessed biofuels.
National budget	Estimated government expenditure on goods and services, (US$ million) including expenditure on national defence and security.
National debt	The direct liabilities of the government owed to debtors. (US$ million)
Petroleum consumption	The sum of all refined petroleum products supplied.
Photovoltaic cells	Devices used to transform solar energy into electrical energy.
Pico hydro	Small-scale power generating systems that harness the power of falling water (less than 100 kW).

Population (millions)	The total number of people living within the borders of a country, whether citizens or not.
Primary energy	Energy sources in their crude or raw state before processing into a form suitable for use by consumers.
Small and micro	An enterprise that generates income up to a certain preenterprises defined limit.
Small hydro	Small-scale power generating systems that harness the power of falling water (1-15 MW).
Solar collector	A device which is capable of absorbing solar radiation and converting it into some other form of energy.
Solar thermal	Devices that use the sun as the primary source of energy for technologies heat appliances, e.g. solar water heaters, solar dryers.
Solar water heaters	Devices that use solar energy to heat water for domestic, institutional, commercial and industrial use.
Sub-Saharan Africa	The term used to describe the area of the African continent which lies south of the Sahara. All African countries south of the North African countries Algeria Egypt, Libya, Morocco, Tunisia.
Sustainable energy	Sustainable energy supplies energy in a way that meets the needs of the present generation without compromising the ability of future generations to meet their energy needs. Sustainable energy usually includes technologies that improve energy efficiency.
Traditional energy	Low quality and inefficient sources of energy, predominantly biomass in nature and not often traded (e.g. wood fuel, crop residues and dung cakes).
Traditional stoves	Inefficient heating and cooking devices that use firewood, charcoal and other biomass based fuels.
Wind pumps/mills	Devices that use wind energy to lift water from underground sources.
Wind turbines	Devices used to generate electricity using kinetic energy from wind.
Wood stoves	Heating and cooking devices that use firewood as the main fuel.

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Chapter 1: Background

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1.1. Electrification and renewable energy in Africa

Energy is essential for economic development (International Energy Agency 2004). Consequently there are two major challenges which sub-Saharan Africa currently faces. The first is reaching a maintainable rate of positive economic growth to cope with urban growth. The second is to become sufficiently industrialised to provide basic energy services to off-grid rural communities (United Nations Energy Commission for Africa 2008). The difference between the energy supply and demand in Africa has widened in the last three decades. Experts predict that this disparity will continue with the unfortunate result, so-called, “energy poverty” which is a great hindrance to socio-economic growth (United Nations Energy Agency 2007).

The world’s population which is without electricity (2002 and projected to 2030) is shown in Figure 1-1. The startling prediction which is manifest in the map is that it is projected that electrification levels in sub-Saharan Africa will decrease rather than increase until 2030.

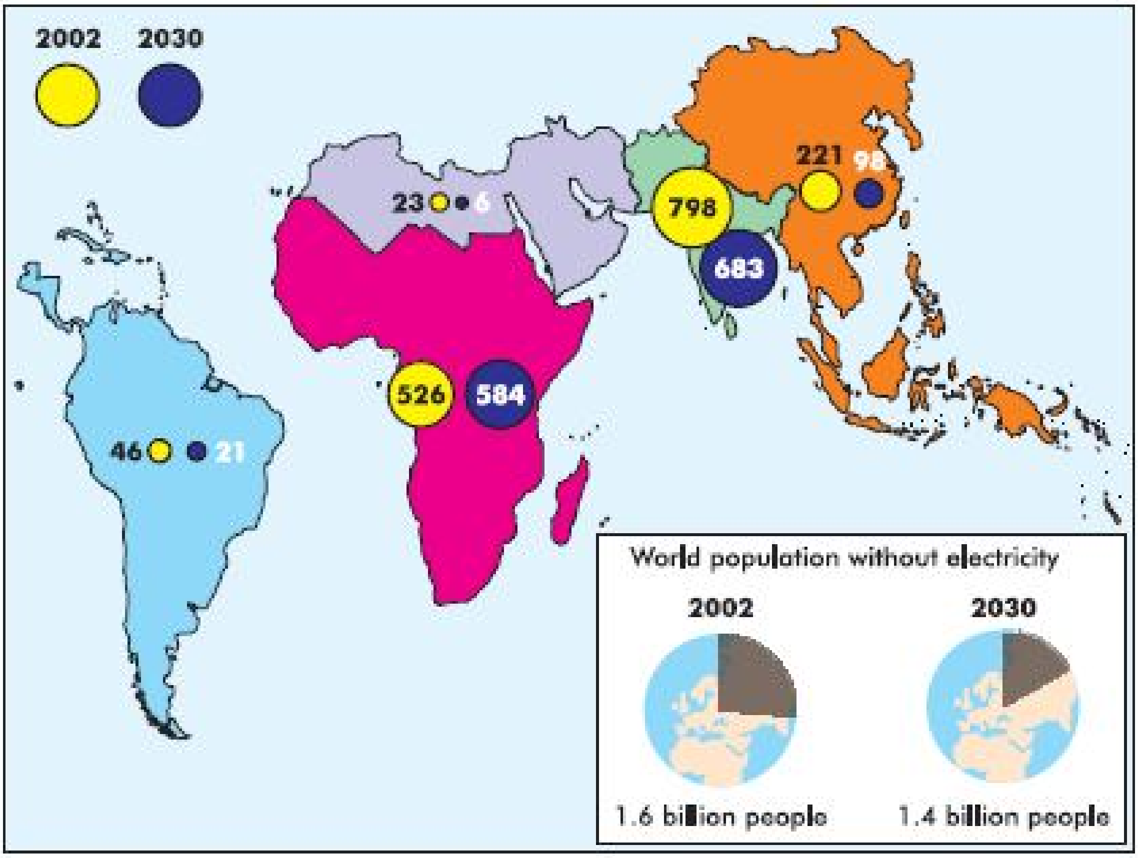


Figure 1-1: Electricity Deprivation (million) (International Energy Agency 2004)

According to the world energy outlook report for 2004 (International Energy Agency 2004), “two-thirds of the increase in global energy demand will come from developing countries”. The socio-economic development of any country is dependent on energy and increasing utilisation of energy is related to the economic growth and improvement of people's living standards (Nguyen 2007). This is critical in the case of developing countries. Africa has the lowest per capita use of energy of all continents primarily because there is an insufficient supply of energy. The cost of energy is too high for the majority of the population, inefficient distribution models are used, and there is a low security of supply (United Nations Energy Agency 2007).

The use of renewable energies is advocated to improve this situation for the reasons listed - renewable energy technologies are modular (low initial investment which can be incrementally expanded); the use of renewable energy technologies would imply less dependence on fossil-based fuels (these need to be imported in most cases and are subject to external price fluctuations); diversification of energy generation contributes to energy security provided that efficient, affordable and cost effective technologies are selected (United Nations Energy Agency 2007). Renewable energies are those obtained from a natural, recurring and continuous outflow of energy in the existing environment. They have the obvious advantage of inherent sustainability and no carbon emissions (Twidell et al. 2006 as cited in United Nations Energy Agency 2007)).

The use of renewable energy is seen as essential to ensure the security of the world's energy supply and to lessen the reliance of the world energy supply on fossil-fuels. When fossil fuels are not used, the generation of green house gases can be lessened (International Energy Agency 2007).

1.2. State of sustainable energy

> *"Although the environmental rationale for promoting renewables and energy efficiency in Africa is weak, there are strong energy security and socioeconomic reasons for promoting sustainable energy in Africa."* – (United Nations Industrial Development Organisation 2007a)

To determine whether renewable energy can provide a solution for the electrification challenges in Africa, it is necessary to investigate the state of sustainable energy. The state of sustainable energy and the consequent development goals of countries differ vastly. The electrification rate by region in terms of the percentage of the population which has access to electricity is shown in Table 1-1. The table shows that in 2002 only 24% of sub-Saharan Africa was electrified and the projections show that by 2030 only 51% of sub-Saharan Africa will be electrified.

Table 1-1: Electrification rates by region in terms of percentage of the population in developing countries (International Energy Agency 2004)

Region	2002	2015	2030
Africa	36 %	44 %	58 %
North Africa	*94 %*	*98 %*	*99 %*

Region	**2002**	**2015**	**2030**
Sub-Saharan Africa	*24* %	*34* %	*51* %
South Asia	43 %	55 %	66 %
East Asia and China	88 %	94 %	96 %
Latin America	89 %	95 %	96 %
Middle East	92 %	96 %	99 %
Total for developing countries	**66 %**	**72 %**	**78 %**

A more detailed breakdown of the 2002 data per region is shown in Table 1-2. Note that sub-Saharan Africa has the lowest rates for both rural and urban electrification. Africa has the lowest rate of electrification for developing countries and sub-Saharan Africa has the all time low electrification rate of only 23.6%.

Table 1-2: Urban, rural and total electrification rates by region in 2002 (International Energy Agency 2004)

	Population (million)	**Urban Population (million)**	**Population without electricity (million)**	**Population with electricity (million)**	**Rate (%)**	**Urban rate (%)**	**Rural rate (%)**
North Africa	143	74	9	134	93.6	98.8	87.9
Sub-Saharan Africa	688	242	526	162	23.6	51.5	8.4
Total Africa	831	316	535	295	35.5	62.4	19
China and East Asia	1,860	725	221	1,639	88.1	96	83.1
South Asia	1,396	390	798	598	42.8	69.4	32.5
Total developing Asia	3,255	1,115	1,019	2,236	68.7	86.7	59.3
Latin America	428	327	46	382	89.2	97.7	61.4
Middle East	173	114	14	158	91.8	99.1	77.6
TOTAL DEVELOPING COUNTRIES	4,687	1,872	1,615	3,072	65.5	85.3	52.4
TRANSITION ECONOMIES AND OECD	1,492	1,085	7	1,484	99.5	100	98.2
TOTAL WORLD	**6,179**	**2,956**	**1,623**	**4,556**	**73.7**	**90.7**	**58.2**

Detailed 2002 electrification rates for the countries in sub-Saharan Africa are shown in Table 1-3. The two countries with the highest electrification rate are Mauritius and

South Africa respectively after which electrification rates fall below 51% with Ethiopia at the lowest electrification rate of 2.6%.

Table 1-3: Electrification rates for sub-Saharan African countries in 2002 (International Energy Agency 2004)

Country	Electrification rate (%)	Population without electricity (million)	Population with electricity (million)
Mauritius	100.0%	0	1.2
South Africa	67.1%	14.7	30
Côte d'Ivoire	50.7%	8.1	8.3
Ghana	48.5%	10.5	9.9
Gabon	47.9%	0.7	0.6
Nigeria	44.9%	66.6	54.3
Zimbabwe	40.9%	7.6	5.3
Cameroon	40.7%	9.3	6.4
Namibia	34.7%	1.3	0.7
Senegal	31.4%	6.8	3.1
Sudan	31.0%	22.7	10.2
Botswana	26.4%	1.3	0.5
Benin	24.8%	4.9	1.6
Congo	19.6%	2.9	0.7
Eritrea	18.4%	3.3	0.7
Zambia	18.4%	8.7	2
Togo	17.0%	4	0.8
Burkina Faso	10.0%	11.4	1.3
Tanzania	9.2%	33	3.3
Kenya	9.1%	28.7	2.9
Mozambique	8.7%	16.9	1.6
DR Congo	8.3%	46.9	4.3
Madagascar	8.3%	15.5	1.4
Other Africa	7.0%	83.9	6.3
Malawi	5.8%	11.2	0.7
Angola	5.0%	12.5	0.7
Lesotho	5.0%	1.7	0.1
Uganda	4.0%	24	1
Ethiopia	2.6%	67.2	1.8
Sub-Saharan Africa	**23.5%**	**526.3**	**161.7**

The electrification rates of the majority of Africans are clearly very low - 526.3 million Africans do not have access to electricity. To improve these figures and meet the millennium development goals of the UN shown in Figure 1-3 (International Energy Agency 2004), approximately 500 million people worldwide will need to gain access to electricity by 2015 and approximately 600 million people worldwide will have to switch from traditional biomass energy (combustible renewables such as fuel wood, charcoal and agro-residues) for cooking and heating as shown in Figure 1-2.

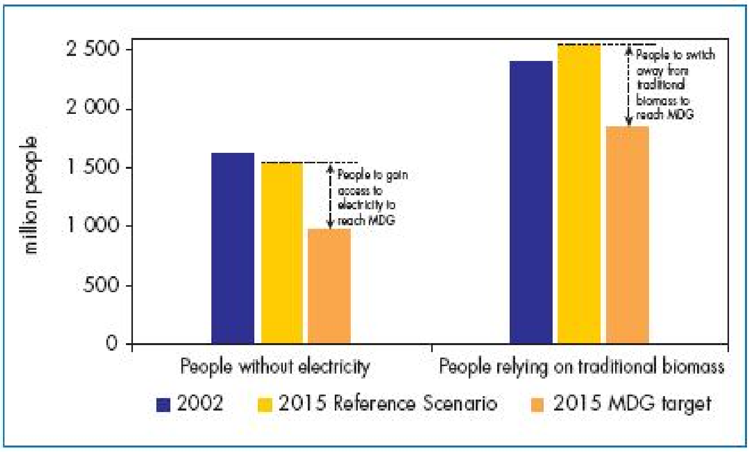
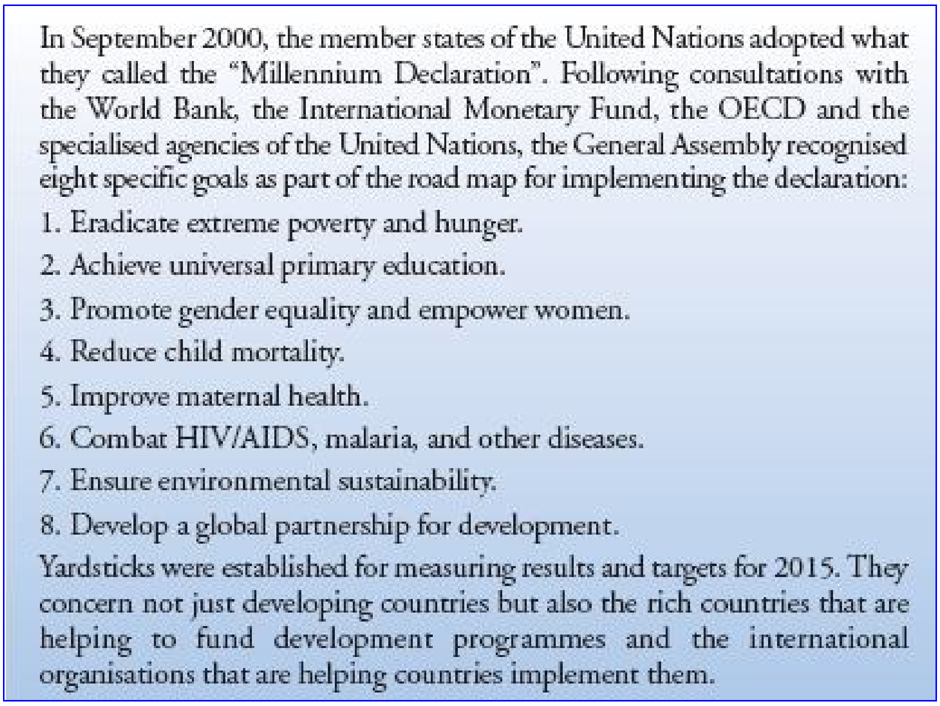


Figure 1-2: **Energy implications of meeting the Millennium Development Goals of the UN (International Energy Agency 2004)**


In September 2000, the member states of the United Nations adopted what they called the "Millennium Declaration". Following consultations with the World Bank, the International Monetary Fund, the OECD and the specialised agencies of the United Nations, the General Assembly recognised eight specific goals as part of the road map for implementing the declaration:

1. Eradicate extreme poverty and hunger.
2. Achieve universal primary education.
3. Promote gender equality and empower women.
4. Reduce child mortality.
5. Improve maternal health.
6. Combat HIV/AIDS, malaria, and other diseases.
7. Ensure environmental sustainability.
8. Develop a global partnership for development.

Yardsticks were established for measuring results and targets for 2015. They concern not just developing countries but also the rich countries that are helping to fund development programmes and the international organisations that are helping countries implement them.

Figure 1-3: **The millennium development goals of the UN (International Energy Agency 2004)**

The current production in terms of primary energy supply for Africa is less than ten percent of the world's energy (United Nations Industrial Development Organisation 2007a). As indicated in Table 1-4 less than twenty-six percent of this supply is from renewable sources (United Nations Industrial Development Organisation 2007a). The portion from non-renewable sources is shown in blue and the portion from renewable sources is shown in yellow in Table 1-4. The portion from renewable sources, namely biomass, is being utilised in an inefficient and unsustainable way (United Nations Industrial Development Organisation 2007a).

Table 1-4: Production of energy by source in Africa (United Nations Industrial Development Organisation 2007a)

Type	Amount (Mtoe)	Percentage
Crude oil	418.78	38.08
Coal	139.01	12.64
Gas	129.89	11.82
Petroleum products	128.56	11.69
Nuclear	3.30	0.3
Biomass	272.10	24.74
Hydro	7.30	0.66
Geothermal	0.68	0.06
Solar/wind	0.0058	0.01
Total	1,099.60	100.00

Despite the lack of use of renewable energies in sub-Saharan Africa, this region is ideally suited for the implementation of these technologies. A large number of countries in the region have a daily solar radiation ranging between 4 and 6 kW/m^2. Some parts of the region, especially at the coast, have good potential for wind generation and even in the landlocked regions, wind energy can be used for water pumping. In the east African rift, geothermal energy is available with a potential of producing 9,000 MW of electricity from water/steam based generation. There is further great potential in hydropower exploitation of permanent rivers and streams especially using small hydropower developments (United Nations Industrial Development Organisation 2007a).

Nevertheless, implementation of renewable energy projects in sub-Saharan Africa is not a government priority. Whether this reflects a reaction to the international concern that renewable energy implementation be impelled by the need to protect the environment and avoid climate change, or not, is not clear. The fact remains that carbon emissions in Africa are not currently perceived to be at detrimental levels and poverty alleviation is at the top of the African agenda (United Nations Industrial Development Organisation 2007a). In this context, the benefits of electrification using renewable energy in Africa should be promoted taking several factors into account, such as job creation, economic development, rural electrification, energy security, decreased dependence on fluctuating oil prices, poverty alleviation, improved quality of life, physical security, increased safety and availability of funding.

- *Job creation*. Renewable energy technology must be installed and maintained (Prasad and Visagie 2005). The job creation possibility for various types of energy technologies is shown in Table 1-5. As can be seen from the table, the potential for job creation in renewable energies is much higher than that of conventional energies (United Nations Industrial Development Organisation 2007a). Electrification also enables the creation of new opportunities for work, for example, welding, battery charging and electronic repair (United Nations Energy Commission for Africa 2008).

- *Economic development*. People become economically active as they gain access to electricity and poverty may consequently be alleviated (Prasad and Visagie 2005; United Nations Energy Agency 2007). Enhanced income from agricultural products becomes a possibility because agro-processing can be used (United Nations Energy Commission for Africa 2008) and this boosts the competitiveness of agricultural products (United Nations Industrial Development Organisation 2007a). Agricultural produce can also be preserved which leads to a reduction in harvest losses and support laboratories can be placed closer to the poor to facilitate artificial insemination (United Nations Energy Commission for Africa 2008).

Table 1-5: Estimated job creation possibilities for various energy technologies (United Nations Industrial Development Organisation 2007a)

Energy option	Construction, manufacturing and installation (employees/MW)	Operation and maintenance (employees/MW)	Total employment (employees/MW)
Geothermal	4.00	1.70	5.70
Wind	2.51	0.27	2.78
Natural gas	1.00	0.10	1.10
Coal	0.27	0.74	1.01

- *Rural electrification*. Rural areas can be electrified as renewable energy technologies are modular and can be implemented on a small scale. Prasad and Visagie (2005) state that renewable energy technologies can also be implemented at a lower cost than connection to the national grid. This means that the poor in scattered communities who do not currently have access to electricity can have access to power (United Nations Industrial Development Organisation 2007a). Decentralised renewable energy technologies can be located closer to the demand so that distribution and transmission costs are reduced; additionally, their operation is independent of fuel, and these energies are clean (Nguyen 2007). However, according to Brent and Rogers (2010) the cost of rural electrification was found to be high in a study in South Africa given the subsidies available, consequently this item will need to be further investigated.

- *Energy security*. The current conventional energy supply in Africa is unreliable (United Nations Industrial Development Organisation 2007a). Renewable energy technologies, if implemented correctly, can contribute to national energy security through diversification of supply (Prasad and Visagie 2005) and can influence production and competitiveness in this way (United Nations Energy Agency 2007).
- *Decreased dependence on fluctuating oil prices*. Most sub-Saharan countries import oil and with the current instability of the oil price, the balance of payments of these countries is adversely affected. The implementation of renewable energies can reduce this dependence (United Nations Industrial Development Organisation 2007a).
- *Poverty alleviation.* Renewable energy technologies can give affordable access to electricity to the poor which improves quality of life and enables economic participation (United Nations Industrial Development Organisation 2007a). Cogeneration schemes can also be used to ensure that revenue flows to poor communities (United Nations Industrial Development Organisation 2007a).
- *Improved quality of life.* Improved health care and education is possible with electrification. Another benefit, especially for women and children, is that they no longer have to spend hours gathering firewood (Prasad and Visagie 2005). This also translates into an increase in household income as income generating activities can be taken up after daylight hours (United Nations Energy Commission for Africa 2008). Medical and educational personnel are more likely to stay in rural areas where electricity and modern services are available.
- *Physical security*. Improved physical security is the result of lighting in public places which can reduce crime (United Nations Energy Commission for Africa 2008).

- *Increased safety.* Kerosene lamps and candles are replaced with electric light resulting in fewer accidents related to fire and house fires (United Nations Energy Commission for Africa 2008).
- *Availability of funding*. Although Africa makes a minimal contribution to greenhouse gases, there is funding available for renewable energy technologies which Africa can access as local environmental improvements also benefit the global scenario (United Nations Energy Commission for Africa 2008).

Given the current lack of access to energy by the population in sub-Saharan Africa, it is obvious that the implementation of renewable energy technologies must be addressed.

1.2.1. Current state of renewable energy implementation in Africa

There is evidence of renewable energy implementations in Africa which points to a less than successful outcome. Renewable energy projects are not always successful and for that both technical and non-technical factors are to blame (Mabuza*, et al.* 2007). Technical challenges include: incorrect design and lack of installation skills; quality control and warranties; maintenance and after sales service; training of locals for installation, maintenance and repair; local technical infrastructure availability (United Nations Industrial Development Organisation 2007b). The non-technical challenges include: lack of public awareness of reliability and cost of renewable energy; lack of government support with consequent non-supportive policies and regulations; lack of capital in rural areas to pay for implementation of renewable energies, and lack of ownership by the community (United Nations Industrial Development Organisation 2007b).

Because of the lack of financial as well as skilled human resources in sub-Saharan Africa, it is important that the correct technology for a given situation is chosen to ensure cost effectiveness. Forsyth (2010) states that not enough competent Africans are currently trained to fill technical positions. Currently, the most important factors to consider when selecting renewable energy projects in Africa have not been researched and prioritised.

The literature on the status of renewable energy projects in Africa does not contain a framework of the factors which can be used when selecting renewable energy technologies for Africa. *The aim of this study is to generate a structured framework and obtain empirical support for the framework*.

1.3. Project and technology selection

Project and technology selection fall into the fields of project management and technology management respectively. The literature on project and technology selection is analysed in detail in Chapter 3 of this study. A generic selection process which is applicable to most of the selection methodologies is shown in Figure 1-4.

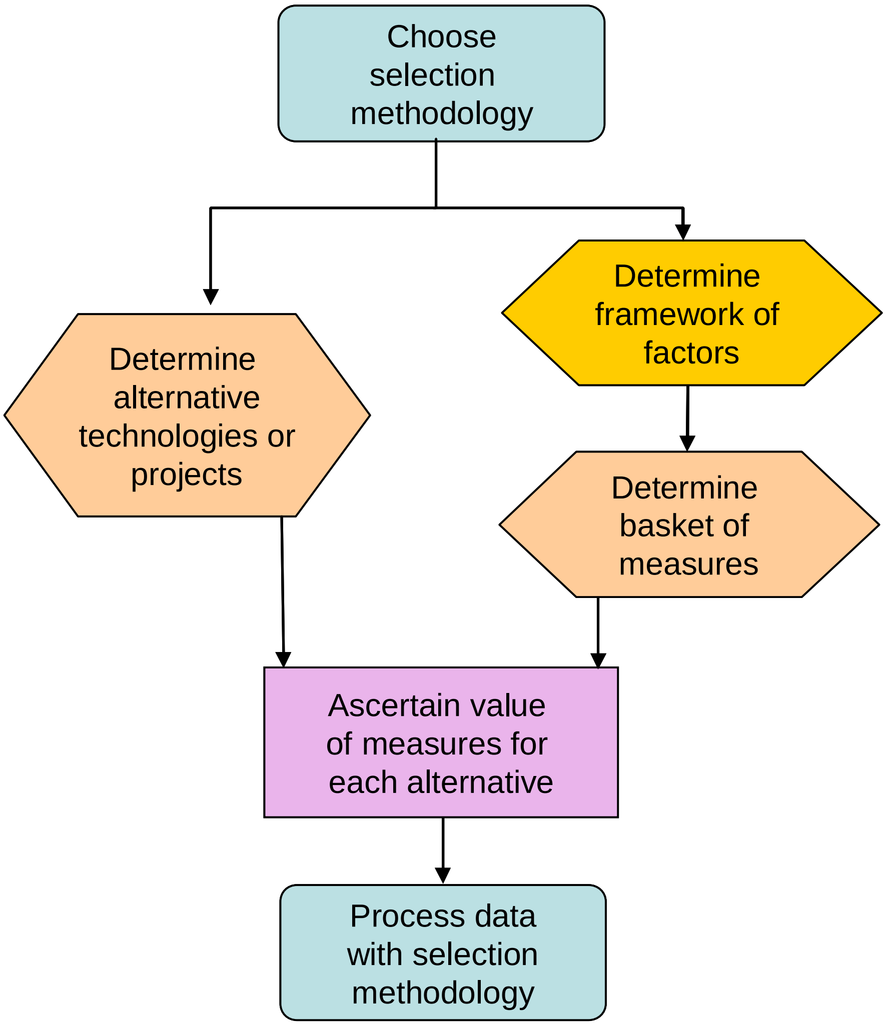


Figure 1-4: Generic selection process

For any selection methodology chosen, the various alternative technologies from which the selection is to be made must be determined. In terms of renewable energy technologies for use in Africa, the alternatives are summarised in Chapter 3. The list of alternatives will however grow as more research is done into renewable energy technologies.

A framework of factors which is applicable for the specific environment in which the technology will be applied has to be generated. A basket of measures for each factor also needs to be determined. The value for each measure can then be determined for each alternative technology and the data processed with the selection methodology chosen.

Many methodologies exist for project, technology, portfolio and programme selection. These methods can be summarised into the following categories:

- *Economic methods.* These methodologies compute the cost benefit of a technology or project. The factors taken into account by these methods are limited to economic data. The problem with these methodologies is that the data required are not easily available during the selection phase and take a lot of time and resources to compile (Cetron*, et al.* 1971; Lowe*, et al.* 2000; Martino 1995).
- *Combination of economic and other approaches.* These methodologies still focus on the cost benefit or economic factors but also take non-economic factors into account (Sefair and Medaglia 2005; Silverman 1981).
- *Comparative models.* These methods compare different projects or technologies to each other by considering the important factors for selection and then using theoretical models or simulations to select the best alternative (Archer and Ghasemzadeh 1999; Cook and Seiford 1982; Hall and Nauda 1990; Helin and Souder 1974; Martino 1995; Mohanty 1992; Souder 1978; Souder 1978).
- *Optimisation models.* These types of methods seek to optimise some objective function or functions subject to specified resource constraints. Different authors use a number of different objective functions, which are normally economically based, and different constraints to formulate the project selection problem (Carazo*, et al.* 2009; Chapman*, et al.* 2006; Cook and Seiford 1982; Saen 2006; Sener and Karsak 2007; Wang and Hwang 2007).
- *Strategic models.* These models allow allocations of resources to multiple organisational elements, organisational constraints and resources and multiple time periods are considered (Archer and Ghasemzadeh 1999; Bergman and Buehler 2004; Costello 1983; Haung*, et al.* 2009; Kim*, et al.* 1997; Lee and Song 2007; Lowe*, et al.* 2000; Martino 1995; Pecas*, et al.* 2009; Phaal*, et al.* 2006; Singh 2004).
- *Two phase methodologies.* These methodologies normally apply two filters to the selection process. The first filter is designed to filter out the non-promising alternatives and the second filter to select the optimal alternatives(Bard and Feinberg 1989; Khouja and Booth 1995; Shehabuddeen*, et al.* 2006; Yap and Souder 1993).
- *Combination methodologies.* These methodologies combine some of the models already mentioned (Hsu*, et al.* 2010; Kengpol and O'Brien 2001; Kengpol and Tuominen 2006; Lee and Hwang 2010; Malladi and Mind 2005; Prasad and Somasekhara 1990; Shen*, et al.* 2009; Tolga*, et al.* 2005; Yurdakul 2004).

- *Ad hoc methods.* These methods cannot be categorised into the abovementioned categories (Archer and Ghasemzadeh 1999; Hall and Nauda 1990; Martino 1995).

For renewable energy technologies, many alternatives exist, all of which have the ultimate goal of supplying energy in a given situation. The models discussed above can mostly be used to select between the alternatives. The selection of the alternative which will present the best long term impact and sustainable solution depends on the type of data that are used to populate the selected method.

For the purposes of this study, the type of data to be used is referred to as a *framework of factors*. A factor is defined as “a circumstance, fact, or influence that contributes to a result ” (Oxford Dictionary 2010). In any selection problem an infinite number of factors can contribute to whether an alternative will provide the best long term solution or not. But it is impossible to consider all these factors in one model and for that reason a framework of factors which addresses the most essential factors is used. The framework of factors has to be selected in such a way that the factors which are crucial for long term impact are included. The framework of factors selected is then imported into one of the selection models and the alternative selected depends on how well the framework of factors has been defined and selected.

To date research has been done on the failure and or success of some renewable technology implementations in Africa. The results of these studies have not been synthesised to produce a framework of factors which can be used to ensure long term impact and sustainability of the renewable energy technology alternative selected. This study therefore focuses on the identification, selection, prioritisation and verification of a framework of factors which can be used to populate one of the selection methodologies discussed, so as to select sustainable renewable energy alternatives in Africa.

1.4. Research motivation and objective

Renewable energy technologies are required in Africa to contribute to sustainable development. Currently many selection methodologies exist for the selection of technology and projects. However, to select the most appropriate alternative, most of these methodologies are dependant on a framework of factors. Currently the framework of factors which needs to be taken into account for the selection of renewable energy technologies in Africa is not clearly defined.

The objective of this research was to develop a structured framework of factors which is empirically validated and can be used for the selection of renewable energy technology alternatives in Africa to ensure long term sustainability of these technologies,

1.5. Research strategy

The new theoretical proposition in the form of a framework of factors was achieved by using a focus group and a Delphi study while testing of the new framework of factors was done with case studies. The new framework of factors generated is a first generation theory as it will still need to be tested in future studies.

The research strategy is shown in Figure 1-5.

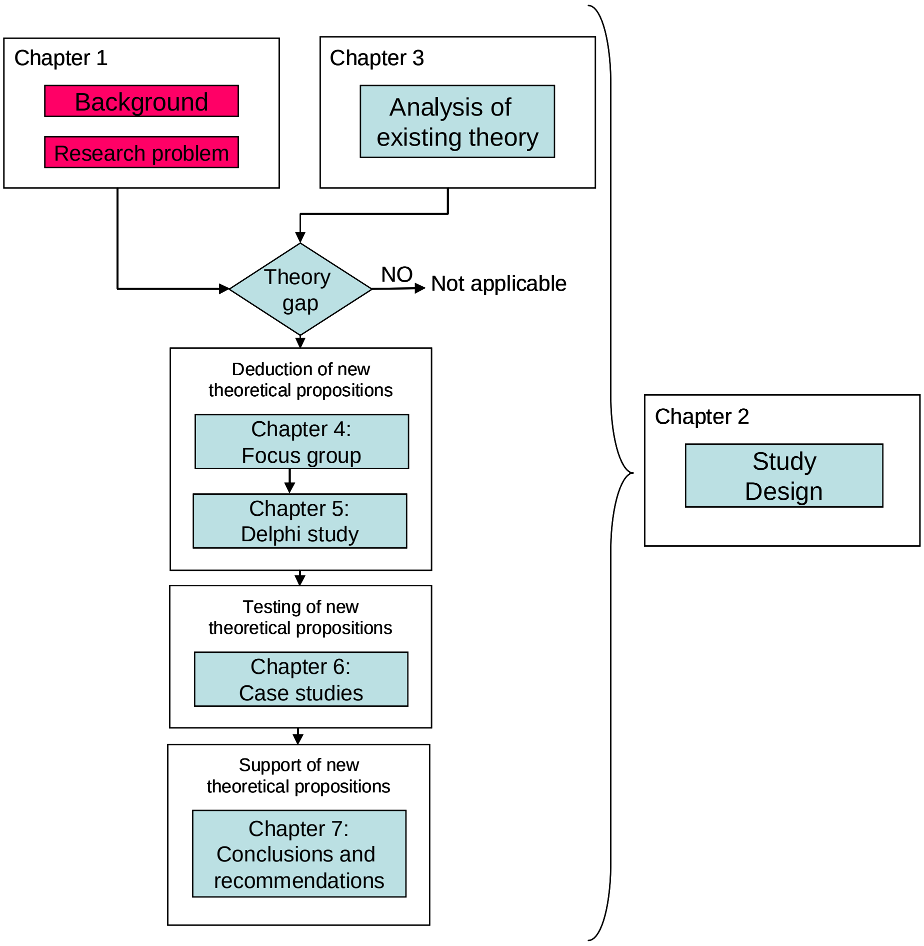


Figure 1-5: Study block diagram

Each of the chapters indicated in Figure 1-6 are discussed in more detail in paragraph 1.6.

1.6. Outline of chapters

Chapter 1 sketches the background to the problem, the research questions and the summarised rationale or methodology of the study.

Chapter 2 addresses the study design and discusses why the various research instruments were selected.

Chapter 3 is an analysis of the current literature on the state of renewable energy technologies and their implementation in sub-Saharan Africa, and also discusses selection methodologies.

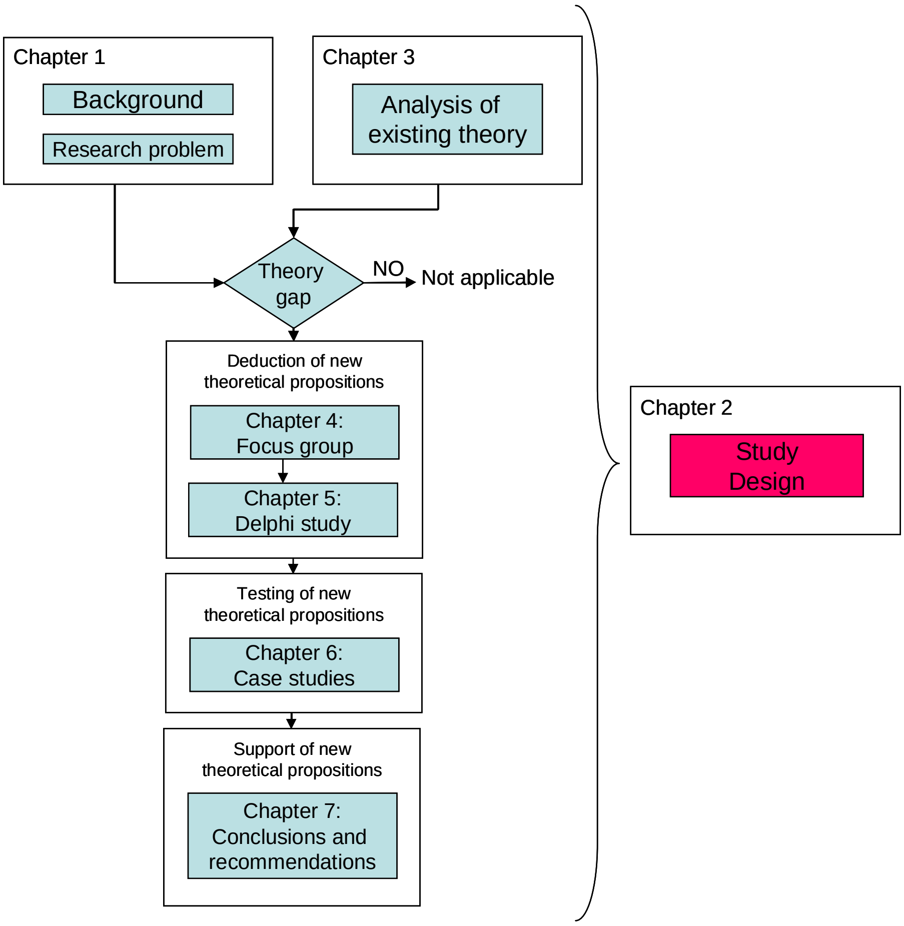
Chapter 4 describes the design, planning, execution and results of the focus group to elicit the first order factors from a group of three experts. This resulted in 38 factors being identified.

Chapter 5 describes the design, planning, execution and results of the Delphi study that used the factors identified in the focus group as a basis and used the expert opinion of seven people over two rounds to identify the eleven most important factors for project selection.

Chapter 6 describes the design, planning, execution and results of the case studies which was conducted in three countries with the goal of validating the factors identified by the Delphi study. The case study confirmed the eleven factors identified during the Delphi study and identified a further two factors that need to be added to the framework.

Chapter 7 discusses the proposed framework, including proposed measures, for the selection of renewable energy technologies in Africa and contains the conclusions and recommendations of the study.

Chapter 2: Study design



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2.1. Research strategy

In the literature on research philosophy, two major research paradigms are discussed namely logical positivism and idealism (Deshpande 1983). The former is a hypothetico-deductive quantitative paradigm whilst the latter is an inductive qualitative paradigm (Deshpande 1983). According to Locke (2007) inductive methods can be successfully used to build theory as an inductive approach proceeds from observed effects to the causes of these effects, whilst the deductive method starts with a theory from which deductions are then made. The theory is built on a accumulation of a great deal of positive data which supports the conclusions drawn with no contradictory evidence. This study is of a theory building nature. Literature exists on the implementation of renewable energy technologies in Africa but a framework for the selection of such technologies has not yet been developed.

True inductive theorising may take many years or even decades (Locke 2007). The approach of this study is to use an inductive approach to develop a first order framework for the selection of renewable energy technologies in Africa that can then be further tested in practice. Inductive research methods such as the focus group, Delphi study and Case studies have been selected.

Any chosen research method will have inherent flaws and the choice of method will always limit the conclusions which can be drawn (Scandura and Williams 2000). For this reason it is essential to obtain corroborating evidence by using a variety of methods. This is also known as triangulation. The use of a variety of methods in examining a topic might result in findings with a higher external validity (Scandura and Williams 2000). In a study on the patterns of research methods in management research across the middle 1980s and 1990s it was found that researchers were increasingly employing research strategies and methods that use triangulation to improve research integrity (Scandura and Williams 2000).

The important factors which need to be taken into account in research design are: generalisability to the population that supports external validity, precision in measurement, control of behavioural variables which affect the internal and construct validity, and realism of context (McGrath, 1982 as cited in Scandura and Williams 2000).

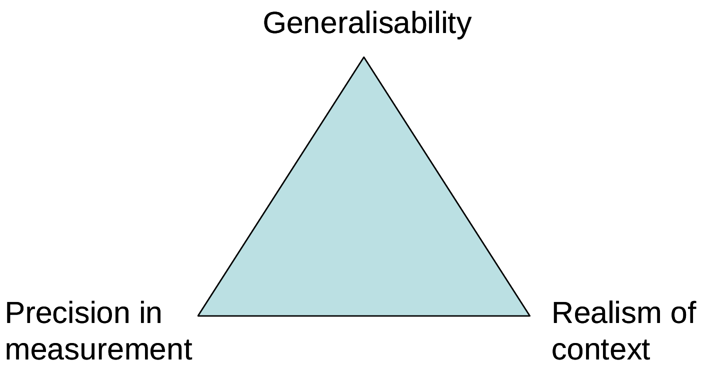


Figure 2-1: Important factors to consider in research design

The methods most commonly used in management research, as evidenced in the Academy of Management Journal, Administrative Science Quarterly and the Journal of Management, are shown in Table 2-1 together with mapping which is also done in terms of generalisability, realism of context and precision of measurement for each research method.

Generalisability to the external population supports the issue of external validity; precision of measurement relates to the control of the behavioural variables affecting internal and construct validity; realism of context relates to how closely the findings are based on available evidence (Scandura and Williams 2000).

Table 2-1: Methods used in management research (adapted from Scandura and Williams 2000)

Description	Explanation	Generalisability	Realism of context	Precision of measurement
Formal theory/ literature surveys	Literature is analysed and summarised in order to conceive models for empirical testing which can involve inductive reasoning and may also present new theories.	↑↑*	↓**	↓
Sample survey	A questionnaire sent to a portion of a population, the results of which are then generalised to the population.	↑↑	↓	↓
Laboratory experiments	Participants are brought into a laboratory and experiments are performed through which the researcher tries to minimise the effect of the laboratory on the results.	↓	↓	↑↑
Experimental simulation	The researcher uses simulated situations or scenarios to obtain data which are then analysed.	↓	↑	↑***

Description	**Explanation**	**Generalisability**	**Realism of context**	**Precision of measurement**
Field study: Primary data	Investigation of behaviour in its natural setting where the data is collected by the researchers.	↓	↑↑	↓
Field study: Secondary data	Investigation of behaviour in its natural setting where the data is collected by persons or agencies other than the researchers.	↓	↑↑	↓
Field experiment	This involves collecting data in the field but manipulating behavioural variables.	↓	↑	↑
Judgement task	Participants in the study judge or rate behaviour in a contrived setting.	↑	↓	↑
Computer simulation	Data are created artificially or by the simulation of a process.	↑	↑	↓

* ↑↑ - Very high
** ↓ - Low
*** ↑ - High

For this study the following four methods were used for triangulation: literature survey, focus group, Delphi survey, case study. The rating of this study in terms of the most important factors to be taken account for research is shown in Table 2-2.

Table 2-2: Rating of study in terms of most important factors

Description	**Generalisability**	**Realism of context**	**Precision of measurement**
Literature surveys	↑↑	↓	↓
Judgement task – Focus group	↑	↓	↑
Judgement task – Delphi study	↑	↓	↑
Field study: Primary data – Case study	↓	↑↑	↓

Generalisability or external validity of this study is improved by the literature survey and the two judgement tasks. The information gained in the case study is generalised to the theory and not to the larger population. Precision of measurement relates or the control of the behavioural variables affecting internal and construct validity, are high for the two judgement tasks and realism of context is ensured by the use of the case study method.

2.2. Research method

The research method followed in this study is shown in Figure 2-2. The methodologies used are a literature survey to determine the existing literature in the field, a focus group for first order data gathering, a two round Delphi study to confirm factors and to select the most appropriate factors followed by eight case studies in three different countries to confirm the factors in practice. The literature survey is described in detail in Chapter 3. This chapter will describe the methods followed for the focus group, Delphi study and case study respectively.

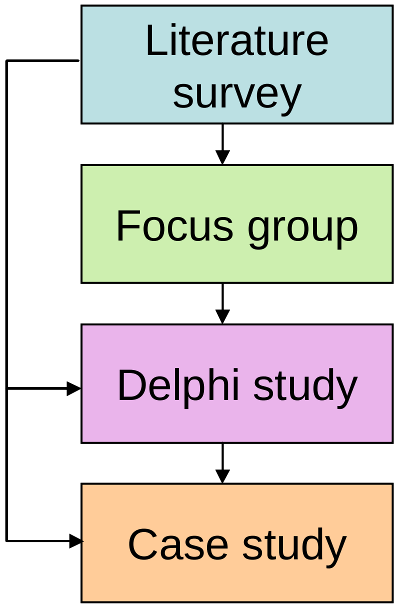


Figure 2-2: Research method

2.2.1. Focus group

The focus group technique is also called the 'group depth interview' or the 'focused interview' in the literature. Different authors ascribe the origin of the focus group method to different sources. Several opinions exist on the growth of the technique: it grew out of group therapy techniques applied by psychiatrists (Hutt 1979), the method originated with market researchers in the 1920s (Robinson 1999) or the technique was developed by Merton and his colleagues for data collection on the effectiveness of World War II training and propaganda films (Blackburn 2000).

Regardless of the origin of focus groups, they have been used successfully in many areas of research. By definition, focus groups are organised discussions or interviews, with a selected small group of individuals (Blackburn 2000; Gibbs 1997), discussing a specific, predefined and limited topic under the guidance of a facilitator or moderator (Blackburn 2000; Robinson 1999). A focus group is also a collective activity, in which several perspectives on the given topic can be obtained, and the data are produced by interaction (Gibbs 1997). A focus group is made up of individuals with specific experience in the topic of interest, which is explored during the focus group session (Gibbs 1997).

The focus group has the following purposes: basic research where it contributes to fundamental theory and knowledge, applied research to determine programme effectiveness, formative evaluation for programme improvement, and action research for problem solving (Robinson 1999). In this study, the focus group technique was used for basic research with the goal of contributing to the fundamental theory and knowledge of important factors for the selection of energy technologies in Africa.

One of the common uses of focus groups is during the exploratory phase, to inform the development of later stages of a study (Bloor*, et al.* 2001; Robinson 1999). One of the four basic uses of a focus group is problem identification (Morgan 1998). For this reason, it was decided to use the focus group technique in this study to explore the factors which would later be confirmed and rated in the Delphi study.

Focus group research has also been used in many applications. These include: determination of respondent attitudes and needs (Robinson 1999), exploration and generation of hypotheses (Blackburn 2000; Gibbs 1997) development of questions or concepts for questionnaire design (Gibbs 1997), interpreting survey results (Blackburn 2000), pretesting surveys (Ouimet*, et al.* 2004), counselling (Hutt 1979), testing research methods and action learning (Blackburn 2000), identification of strengths and weaknesses and information gathering at the end of programmes to determine outputs and impacts (Robinson 1999).

Focus group research has been applied in many fields including the social sciences, medical applications, market research, media, political opinion polls, government improvements, business, consulting, ethics, entrepreneurship research (Gibbs 1997), education (Ouimet*, et al.* 2004) and health care (Robinson 1999).

The benefits for the focus group participants include the opportunity to be involved in decision making, the fact that they feel valued as experts, and the chance to work in collaboration with their peers and the researcher (Gibbs 1997). Interaction in focus groups is crucial as it allows participants to ask questions as required, and to reconsider their responses (Gibbs 1997).

The advantages of the focus group method are many and include:

(i) An effective method of collecting qualitative data as common ground can be covered rapidly and inputs can be obtained from several people at the same time (Hutt 1979; Ouimet*, et al.* 2004).

(ii) During discussions, the synergistic group effort produces a snowballing of ideas which provokes new ideas (Blackburn 2000; Gibbs 1997).

(iii) Data of great range, depth, specificity and personal context are generated (Blackburn 2000).

(iv) In the process, the researcher is in the minority and the participants interact with their peers (Blackburn 2000).

The disadvantages include:

(i) Not all respondents are comfortable with working in a group environment and may find giving opinions in the bigger group intimidating (Gibbs 1997; Ouimet, *et al.* 2004).

(ii) The outcome can be influenced by the group effect in that the opinion of one person dominates, or some are reluctant to speak and an opportunity is not given for all participants to air their views (Blackburn 2000).

(iii) The researcher has less control over the data than in, for example, a survey because of the open-ended nature of the questions (Gibbs 1997).

The disadvantages can be mitigated by ensuring that the moderator has sufficient skills, that the data collection is reliable and that rigorous analytical methods are used (Blackburn 2000).

The purpose of the focus group in this study was to obtain the opinions of the group at the Council for Scientific and Industrial Research (CSIR), tasked with assisting the New Partnership for Africa's Development (NEPAD) to select sustainable energy research projects for Africa, in terms of the most important factors for the selection of these projects.

The main objectives of the focus group were as follows:

- Inform the focus group participants of the purpose and future plans of the study.
- Identify as many factors as possible which should be considered when selecting sustainable energy projects in Africa to be used as an input to the Delphi study.
- Identify knowledgeable participants for the Delphi study.

2.2.2. Delphi technique

2.2.2.1. Introduction

The Delphi technique, as first pioneered at Rand by Dalkey, Helmer and Rescher is an example of Lockean inquiry (Mitroff and Turoff 1974). The Lockean philosophy is based on the premise that truth is experiential and consequently the content of a system is entirely associated with its empirical content. Every complex proposition can be broken down into simple empirical observations. The validity of simple observations is obtained by agreement between human observers. The truth of the model does not rest on any theoretical considerations.

A Delphi study is Lockean as it uses raw data in the form of expert opinion and the validity of the resulting judgment is measured in terms of the consensus between experts (Mitroff and Turoff 1974).

Lockean inquiry systems should be used when the problem is well-structured and a strong consensual position exists on the nature of the problem situation. This makes a consensus-oriented Delphi appropriate for technological forecasting but inappropriate for technology assessment, objective or policy formulation, strategic planning and resource allocations analyses (Mitroff and Turoff 1974).

The Leibnizian philosophy on the other hand is based on the premise that truth is analytic and therefore based on theory. The truth of a model is based on its potential to offer a theoretical explanation for a range of general phenomena. The truth of the model further does not rest on any raw data from the external world. The theoretical model is not only considered to be separate from the raw data but is also considered to be prior to it (Mitroff and Turoff 1974).

In terms of Delphi, Leibnizian philosophy is often used to attack the scientific nature of Delphi studies. This happens when “being scientific” is equated with what is Leibnizian. Delphi studies have been improved by these criticisms but in the final analysis our understanding of human thought and decision processes is still too rudimentary to expect a generally valid formal model of the Delphi process (Mitroff and Turoff 1974).

Kantian philosophers believe that the truth is synthetic and both theoretical and empirical components are required (Mitroff and Turoff 1974). A Kantian model is measured in terms of its potential to associate every theoretical term with an empirical referent and how the underlying collection of every empirical observation can be associated with the theoretical referent. In this case neither the data input nor the theory has priority. The Kantian philosophy further advocates the examination of as many alternatives as possible.

Kantian Delphis have the explicit purpose of eliciting as many alternatives as possible so that a comprehensive overview of the issue can be taken. The design structure allows for many informed individuals in different disciplines or specialties to contribute information or judgments to a problem area to cover a much broader scope of knowledge than any one individual possesses.

Singerian-Churchmanian philosophy is based on the premise that truth is pragmatic (Mitroff and Turoff 1974). This means that the truth content of a system is relative to the overall goals and objective of the inquiry. In this philosophy, a model of a system is explicitly goal oriented. It is based on holistic thinking as no single aspect of the system has fundamental priority over any other aspect.

The Delphi used in this study was made up of a combination of the above philosophies. The focus group was Kantian in nature as panel members were asked to identify as many possible factors as that they could think of. The first round of the Delphi was also of a Kantian nature. The Delphi as a whole was Kantian as many experts from diverse fields of expertise on sustainable energy projects were asked to participate. This included technical experts, non governmental experts, academics, social scientists and researchers.

The later rounds of the Delphi were Lockean as an attempt was made to reach consensus on the most important factors for the selection of sustainable energy projects.

The entire study had a Singerian-Churchmanian approach in that an attempt was made to use holistic thinking through a triangulation of methods.

2.2.2.2. Contrasting Delphi with other methods

Various factors need to be considered before selecting a research method. This is a problem which does not have previous research or models to support it. A group decision making process is required as experts are available who have experience in the field. It is a complex open ended problem. When insufficient or contradictory information is available on a subject, a consensus method such as the interacting group method, brainstorming, nominal group technique or Delphi survey, can be used (Delbecq*, et al.* 1975; Hasson*, et al.* 2000).

The interacting group method is an unstructured meeting which is held to arrive at a decision (Delbecq*, et al.* 1975). The nominal group technique is based on a structured meeting in which members of the group write down their ideas before there is any discussion. The ideas are then recorded and presented to the group by round robin sharing. The ideas are discussed and then a vote is taken. Priority or consensus is mathematically derived through rank ordering or rating (Delbecq, *et al.* 1975).

The Delphi technique involves a structured series of questionnaires or surveys which is sent to participants for individual comment and rating. The results are then collated and fed back to the participants for reconsideration given the comments of the other participants (Crichter and Gladstone 1998). The Delphi study may involve several rounds. Priority or consensus is also mathematically derived. A comparison in terms of group interaction between the interacting group method, nominal group technique and the Delphi technique is shown in Table 2-3.

Table 2-3: Comparison of group interaction issues for group decision techniques (adapted from Delbecq*, et al.* 1975)

Group interaction issue	Interacting group method	Nominal group technique	Delphi technique
Role orientation of groups	Social-emotional focus	Balanced socio-emotional and task instrumental focus	Task-instrumental focus
Normative behaviour	Inherent conformity pressures	Tolerance for non-conformity	Freedom not to conform

Group interaction issue	Interacting group method	Nominal group technique	Delphi technique
Equality of participation	Member dominance	Member equality	Respondent equality in pooling of independent judgements
Methods of conflict resolution	Person-centred: Smoothing over and withdrawing	Problem-centred: Confrontation and problem solving	Problem-centred: Majority rule of pooled independent judgements
Closure to decision process	Lack of closure: Low perception of accomplishment	High closure: High perception of accomplishment	High closure: Medium perception of accomplishment

From Table 2-3 it can be seen that in terms of group interaction, the nominal group technique and Delphi technique seem to deliver the best results.

Table 2-4 shows a comparison between the different group techniques in terms of task related issues. From this table it is clear that the nominal group technique and Delphi technique deliver the best results. The nominal group technique is slightly superior because participants have better task motivation as a result of the social interaction.

Table 2-4: Comparison of task related issues for group decision techniques (adapted from Delbecq, *et al.* 1975)

	Interacting Group method	Nominal group technique	Delphi technique
Relative quantity of ideas	Low; focused “rut effect”	High; independent thinking	High; isolated thinking
Relative quality and specificity of ideas	Low quality; generalisation	High quality; high specificity	High quality; high specificity
Search behaviour	Reactive; short problem focus; task avoidance tendency; new social knowledge	Proactive; extended problem focus; high task centeredness; new social and task knowledge	Proactive; controlled problem focus; high task-centeredness; new task knowledge
Task motivation	Medium	High	Medium

Table 2-5 shows a comparison of the practical considerations for the different group decision making techniques. The table clearly shows that participant costs are lowest for the Delphi technique if participants are not geographically co-located and that the participant working hours is the lowest for the Delphi technique. The problems of course are that the calendar time taken is longer and that the administrative effort is higher. For this specific study however, participants were geographically dispersed and it was not possible to get them together for face to face meetings. Calendar time was also not of high importance. As long as this part of the study could be completed in about two months, which is possible using the Delphi technique, it was deemed acceptable.

Table 2-5: Comparison of practical considerations for group decision techniques (adapted from Delbecq, *et al.* 1975)

	Interacting Group method	Nominal group technique	Delphi technique
Participant working hours	High amount of hours required	High amount of hours required	Few hours required compared to other methods
Participant costs	High if not geographically co-located	High if not geographically co-located	Low
Calendar time	Relatively short	Relatively short	Relatively long
Administrative cost	Low	Low	High

Face to face meetings, especially when using the interacting group method, often lead to direct confrontation which can force participants to hastily formulate preconceived ideas and to close their minds to new ideas. There is also a tendency to defend a specific standpoint or be predisposed to change a standpoint because of the persuasiveness of other ideas. Delphi on the other hand is more conducive to independent thinking because it allows participants to gradually formulate and consider opinions (Dalkey and Helmer 1963).

Several different definitions are given for the Delphi technique. Delphi is a process for structuring group communication so that it is effective in allowing a group of individuals to deal with a complex problem (Linstone 1974). It is further a method of aggregating the judgments of a number of experts to improve the quality of decision-making (Delbecq, *et al.* 1975).

Another element of the technique is that participants can reconsider judgements and that is especially useful when the problem does not lend itself to precise analytical techniques (Crichter and Gladstone 1998). The technique is useful when objective data are scarce or the development of a mathematical computer model is too difficult or expensive (Gibson and Miller 1990).

In the Delphi process there are a number of rounds and feedback is given to the participants after which they are given an opportunity to modify their responses. Another element of the technique is anonymity of the responses. Delphi studies vary in application in panel size, composition and selection of panel, questionnaire design, number of rounds, form of the feedback and modes of reaching consensus. In

Delphi studies good research practice both in terms of qualitative and quantitative research should be followed (Mullen 2003).

In the literature numerous advantages of Delphi are given, including:

- Participants are forced to think through the complexity of the problem and submit specific, high quality responses because of pressure of a written response (Delbecq, *et al.* 1975)
- The anonymity of the method implies that participants will be free from conformity (Crichter and Gladstone 1998; Delbecq, *et al.* 1975; Gibson and Miller 1990). Anonymity also enables individuals to respond as individuals and not as members of the organisations they belong to (Crichter and Gladstone 1998). Participants can give an honest expression of views without intimidation, peer pressure or inhibition (Mullen 2003).
- Isolated idea generation produces high quality ideas (Delbecq, *et al.* 1975).
- The fact that responses are written allows experts to fit Delphi into their busy schedules (Gibson and Miller 1990).
- Participants have proactive search behaviour as they do not react on the ideas of others (Delbecq, *et al.* 1975)
- There is equality of participation because ideas and judgements are pooled (Delbecq, *et al.* 1975)
- Participants have a moderate sense of closure .and accomplishment on completion of the study (Delbecq, *et al.* 1975)
- The technique is suitable for studies in which the experts are geographically isolated and when it is not practical or too expensive to bring them together (Crichter and Gladstone 1998).
- Participants benefit from learning from the responses of the other participants as they are fed back to them during the study (Gibson and Miller 1990).
- Participants can revise their initial opinions in the light of other expert responses (Gibson and Miller 1990). This means that participants can change their viewpoints without public exposure.(Crichter and Gladstone 1998; Mullen 2003)(Hasson, *et al.* 2000).
- The technique is effective in developing consensus when solving complex problems (Delbecq, *et al.* 1975).

The Delphi technique has disadvantages which include the lack of opportunity for socio-emotional rewards in problem group solving, the lack of opportunity for verbal clarification which can create communication and interpretation difficulties. The pooling of ideas and adding of votes promotes majority rule which means that conflicts are not necessarily resolved (Delbecq, *et al.* 1975).

There are drawbacks in applying the Delphi technique. Delphi technique was severely criticised as it was averred by Sackman (1974) that the Delphi technique was scientifically suspect on the following grounds:

- A crude questionnaire design
- A lack of minimum professional standards for opinion item analysis and pilot testing
- A highly vulnerable concept of expert
- A poor possibility for reliable measurement and scientific validation of findings
- A confusing aggregation of raw opinion with systematic prediction
- Virtually no serious literature to test basic assumptions and alternative hypotheses
- No disclosure of names and consequently no individual accountability

According to Delphi commentators, Sackman (1974) did make a valid point in terms of the way in which the technique is often applied. Sackman's criticisms were however successfully refuted by Goldschmidt (1975). Delphi deals with areas which do not lend themselves to traditional scientific approaches and a Delphi survey is not an opinion poll as in survey research and therefore the same criteria cannot be applied (Mullen 2003). Woudenberg (1991) concludes that the main claim of Delphi that it removes negative effects of unstructured, direct interaction cannot be substantiated. He further notes that Delphi is good at obtaining consensus but that this is as a result of strong group pressure to conform. His study focused on quantitative Delphis which he evaluated negatively. Crichter and Gladstone (1998) wrote that a lot of the criticism against Delphi results from the fact that Delphi straddles the divide between quantitative and qualitative research and has hybrid epistemological status.

Gibson and Miller (1990) added to the debate by agreeing that although Delphi cannot be considered to be a quantitatively rigorous procedure, it is the best alternative solution when data are scarce and resources for a large-scale model are not available. They maintained that usefulness may prove to be the most important criterion for determining the success of this type of study in that it can help identify and specify the issues on which the greatest difference of opinion exists. Delphi can further identify areas of general agreement and enable the discovery of new ideas and solutions to problems which were not recognized before.

Crichter and Gladstone (1998) noted that Delphi presents technical difficulties in that the method has to be readapted every time it is applied. They further pointed out the difficulties of balancing closed and open-ended responses. They showed that the estimation of time for completion to give participants an indication of how much of their time is required for the questionnaire can be problematic and that one has to be careful not to construct artificial consensus when using the method. In summary, they stated that as with any social science tool, Delphi can be applied inappropriately by accident or through intent. To offset this potential difficulty Reid (1998, as cited in

Hasson*, et al.* 2000) suggests that the decision to employ the Delphi technique should be based on appropriateness of possible alternatives.

It was decided to use the Delphi technique in this part of the study with due caution. Firstly, a group decision technique needed to be selected as individual judgements needed to be investigated and combined to determine the most important factors for sustainable energy project selection. Much has been written in the literature about selection methods. However, only expert knowledge is available on the factors important for the selection of sustainable energy technologies in Africa. Secondly the persons with the necessary expertise on the subject were geographically dispersed. A further advantage of the Delphi technique was the fact that the time required from participants was minimised to ensure participation.

Other research methods, including a literature survey, the focus group technique and case study were used in conjunction with the Delphi method in this study.

The comparison between the Delphi method and the traditional survey method is shown in Table 2-6.

Table 2-6: Comparison of traditional survey with Delphi method (adapted from Okoli and Pawlowski 2004)

Evaluation criteria	Traditional survey	Delphi study
Summary of procedure	A questionnaire addressing the relevant issues is designed. Various issues concerning the validity of questions must be considered to develop a good survey. The survey can solicit qualitative and or quantitative data. A population that the hypotheses applies to is selected and the survey is then administered to a random sample of this population. The respondents choose to fill out the survey and return it. The usable responses are then analysed to investigate the research questions.	The issues about survey validity are also applicable to a Delphi study. An appropriate group of experts is selected on the basis of their qualification to answer the questions. The survey is administered and a next survey developed based on the analysis of the first survey. The second survey gives feedback to the participants and asks them to revise their original responses based on the feedback. The process is repeated until a satisfactory degree of consensus is reached. The respondents are anonymous to each other throughout the process.
Representative sample	Statistical sampling techniques are used to select a representative sample of the population of interest.	Questions normally investigated using the Delphi method are those with high uncertainty. A general population or subset of one might not have sufficient knowledge to answer the Delphi question properly. Delphi is a group decision technique used to overcome this by consulting expert opinion.

Evaluation criteria	Traditional survey	Delphi study
Sample size for statistical power and significant findings	A statistically significant sample size is required to detect statistically significant effects in the population. Power analysis is required to determine appropriate sample size.	The size of the Delphi panel is not dependant on statistical power but rather on group dynamics for arriving at consensus among experts. The literature recommends between 7 and 20 experts on a Delphi panel.
Individual vs group response	Researchers use the average of the individual's responses to determine the average response for the sample which is then generalised to the general population.	Studies have consistently shown that when questions require expert judgement, the average group response produces a better result than the average individual response. Research has shown that the Delphi method bears this out.
Reliability and response revision	An important criterion for the evaluation of surveys is the reliability of the measures. This is usually assured by pretesting and retesting to ensure test-retest reliability	Pretesting is also an important reliability assurance for the Delphi method. However, test-retest reliability is not relevant, since the method is based on the idea that participants will revise their responses.
Construct validity	Construct validity is assured by careful survey design and pretesting	Construct validation can be employed by asking participants to validate the researcher's interpretation and categorisation of the variables.
Anonymity	Respondents are always anonymous to each other and often to the researcher.	Respondents are always anonymous to each other but not necessarily to the researcher. This presents the researcher with the opportunity to follow up with the respondent for clarification and further qualitative data.
Non-response issues	Researchers need to investigate the possibility of non-response bias to ensure that the sample remains representative of the population.	Non response is typically very low in Delphi surveys if respondents are personally contacted and encouraged to participate. The research also shows that those who agree to participate are not necessarily biased.
Attrition effects	This is not applicable to single surveys but in multi-step surveys; attrition should be investigated to ensure that it is random and non-systematic.	As with non-response, attrition tends to be low in Delphi studies and the cause can easily be ascertained by contacting the drop outs.
Richness of data	The richness of data obtained by surveys is dependant on the form and depth of the questions asked. Follow-up is often limited as researchers might be unable to track respondents.	Delphi studies inherently provide richer data because of the iterations and the fact that open questions are asked. Delphi respondents tend to be open to follow-up interviews.

The survey technique which is statistically more valid could not be used in this study. In the first place the population of possible respondents was not large enough and in the second place the problem was not well defined enough to lend itself to the survey method.

2.2.3. Case study

2.2.3.1. Introduction

There are certain generic factors which have necessarily to be taken into account when selecting sustainable energy projects in Africa. These factors have been defined and prioritised during the Delphi study. The purpose of the case study research is to determine whether the factors identified during the Delphi study influence the success of implementation of renewable energy technologies in sub-Saharan Africa in the real-world context.

There are several steps to follow for a successful case study implementation. A combination of what is advocated by George and Bennett (2005) and Yin (2003) in terms of the phases of a case study is shown in Figure 2-3.

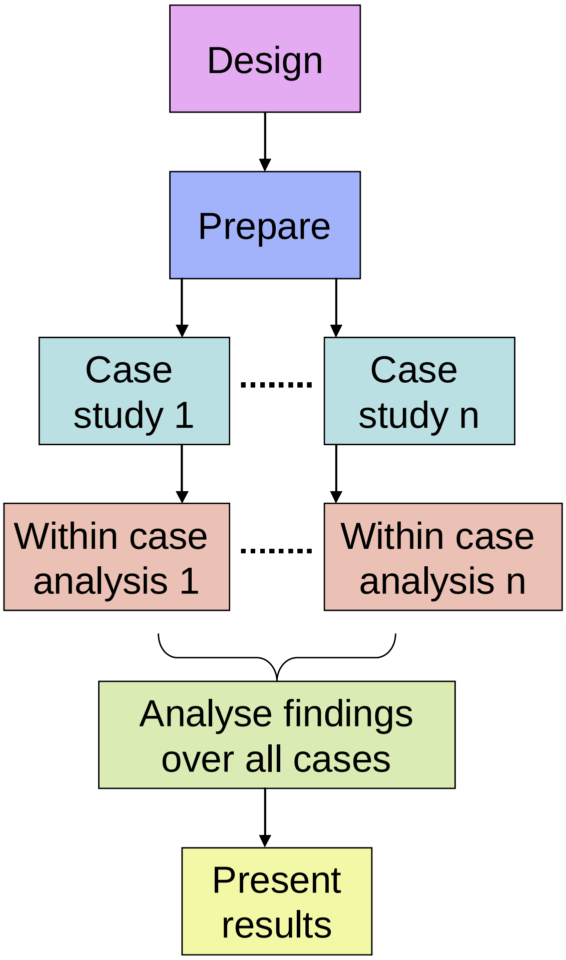


Figure 2-3: Phases of a case study

These were the phases that were applicable to this case study. The phases consisted of the design of the case studies; preparation for the case studies by drawing up questionnaires with the outputs from the Delphi study; performing the case study interviews and collecting the secondary data; analysing each case study on its own; analysing the findings over all the cases; and presenting the results of the case studies.

2.2.3.2. Definition of the case study method

A case study is a research strategy which is used to test a contemporary phenomenon in a real-life scenario and is especially helpful where the boundaries between the phenomenon and the scenario are not clearly defined (Yin 2003). The following areas make use of the case study method according to the literature - psychology, sociology, political science, social work, business, community planning, economics, teaching devices.

The case study undertaken in this study was to test whether the factors which had been identified from the literature survey and the two judgement tasks (i.e., the Focus group and Delphi study) were implemented in practice, would be useful in practice and could be implemented in practice.

George and Bennett (2005) propose the following six theory building research objectives for case studies namely:

- *Theoretical/ configurative idiographic case studies.* These studies do not directly contribute to theory but provide good descriptions for use in subsequent theory building research. Many of the current case studies in renewable energy technologies in Africa are of this nature.
- *Disciplined configurative case studies.* These studies use existing theory to explain a case by testing theory.
- *Heuristic case studies.* These studies are used to identify new variables, hypotheses, causal mechanisms and causal paths.
- *Theory testing case studies.* These studies are used to test the validity and scope conditions of single or competing theories.
- *Plausibility probes.* These studies are used to test untested theories and hypotheses to determine whether more in depth testing is warranted.
- *Building block studies.* These are single case studies or multiple case studies with no variance which can be used as parts of larger contingent generalisations and typological studies.

Eisenhardt (1989) proposes the use of case studies for building theories and proposes the following steps: definition of the research question and possible a priori constructs; case selection based on theoretical sampling; crafting multiple data collection instruments and protocols; collecting data whilst overlapping with within case analysis; shaping of hypotheses by tabulation of evidence for each construct; comparison with conflicting and similar literature; and reaching closure.

In his seminal paper on case study research, Flyvbjerg (2006) notes that there are five main misunderstandings around case study research. These misunderstandings and the way that he proposes to clarify them are summarised in Table 2-7.

Table 2-7: Summary of misunderstandings and clarifications (Flyvbjerg 2006)

Misunderstanding	Clarification
General theoretical (context-independent) knowledge is more valuable than concrete, practical (context-dependent) knowledge	Predictive theories and universals cannot be found in the study of human affairs. Concrete, context-dependent knowledge is, therefore, more valuable than the vain search for predictive theories and universals.
One cannot generalise on the basis of an individual case; therefore the case study cannot contribute to scientific development	One can often generalise on the basis of a single case, and the case study may be central to scientific development via generalisation as supplement or alternative to other methods. But formal generalisation is overvalued as a source of scientific development, whereas "the force" of example is underestimated.
The case study is most useful for generating hypotheses; that is, in the fist stage of a total research process, whereas other methods are more suitable for hypothesis testing and theory building	The case study is useful for both generating and testing of hypotheses but is not limited to these research activities alone.
The case study contains a bias towards verification, that is, a tendency to confirm the researcher's preconceived ideas.	The case study contains no greater bias toward verification of the researcher's preconceived notions than other methods of inquiry. On the contrary, experience indicates that the case study contains a greater bias toward falsification of preconceived notions than toward verification.
It is often difficult to summarise and develop general propositions and theories on the basis of specific case studies	It is correct that summarising case studies is often difficult especially as concerns case process. It is less correct in respect of outcomes. The problems in summarising case studies however, are more often the result of the properties of the reality studied than the case study as a research method. Often it is not desirable to summarise and generalise case studies. Good studies should be read as narratives in their entirety.

2.2.3.3. Quality in case studies

Yin (2003) lists the following tests that are applicable to case study research to ensure that they are of the highest quality: construct validity; internal validity; external validity and reliability. These tests, together with the case study tactics to improve quality and the phases in which these tactics are applicable.

2.2.3.4. Case study design

> *Certainly the case study as normally practiced should not be demeaned by identification with the one-group post-test-only design – Cook & Campbell (1979, as cited in Yin 2003)).*

The first phase in any case study application is research design. Research design is the plan for getting from "here" i.e., the current knowledge to "there", i.e., the conclusions of the study. This is graphically shown for this study in Figure 2-4. In this study "here" is defined as the factors that were confirmed during the Delphi study. In order to get to "there" which is the practical validity of the factors, the case study research questions were formulated, it was decided which data is relevant and should be collected and it was decided how to analyse the results.

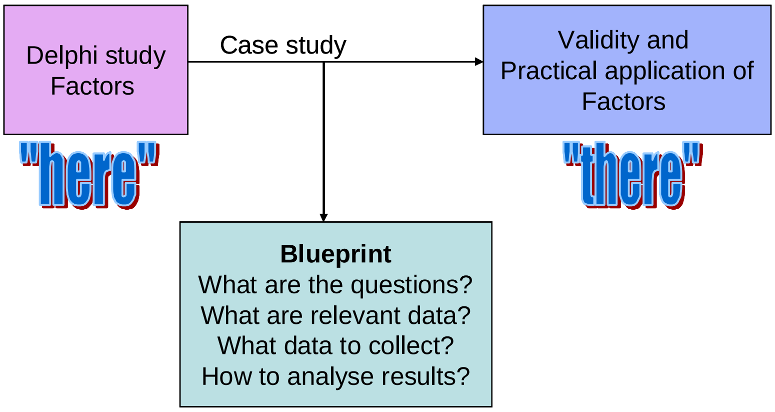


Figure 2-4: Graphical presentation of the research design (adapted from Yin 2003)

Yin (2003) lists the following five components to consider for a research design namely, questions of the study, propositions of the study if any, unit(s) of analysis to use, the logic linking the data to the propositions and the criteria to be used to interpret the findings. The steps in the design of a case study as advocated by George and Bennett (2005) are shown in Figure 2-5. This design process is iterative and may require several iterations.

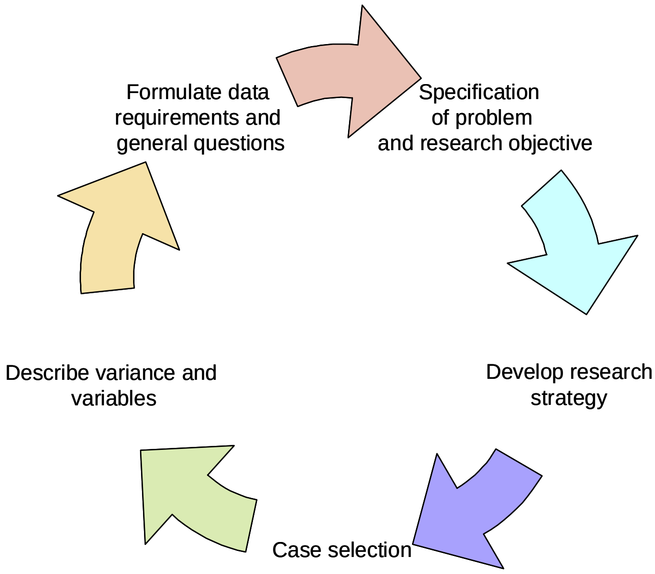


Figure 2-5: Steps in case study design (George and Bennett 2005)

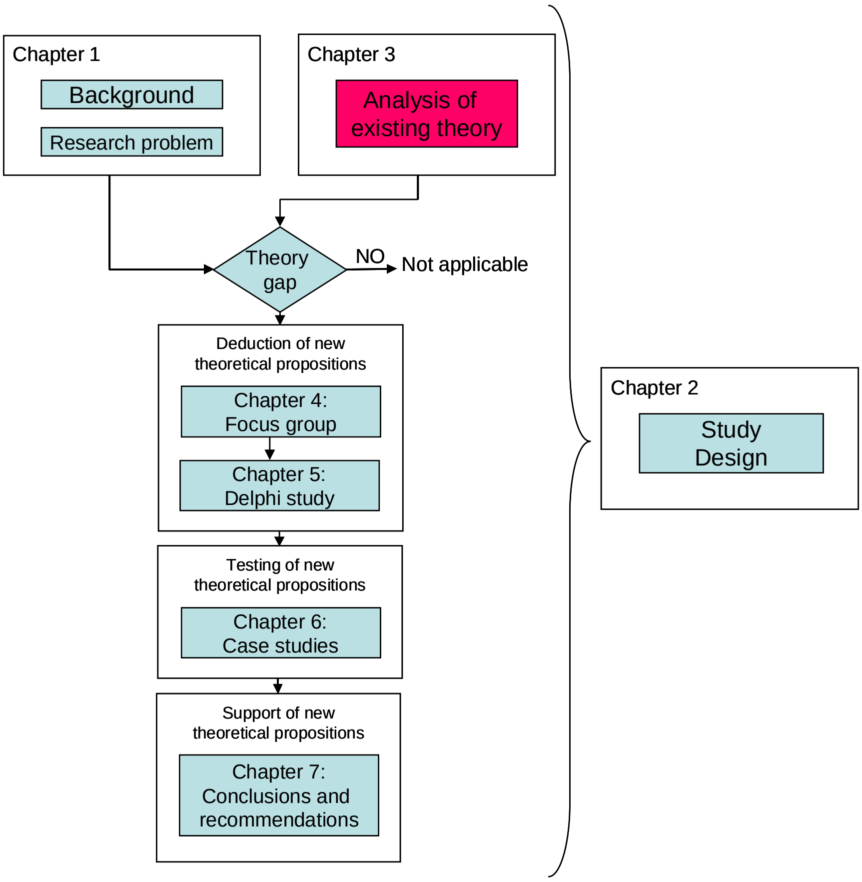
For purposes of this study the approaches advocated by George and Bennett (2005) and that of Yin (2003) were combined into the following steps:

1. *Specification of problem and research objective.* For this step the questions and propositions as advocated by Yin (2003) were defined.
2. *Development of research strategy*. In this step the unit of analysis was determined, the dependant and independent variables were defined, and the logic linking the data and propositions was defined.
3. *Case selection.* Cases with variance in the dependant variables were selected. A preliminary questionnaire was sent out to enable the researcher to select suitable cases.
4. *Description of variance in variables.* The variance in each variable selected in step 1 was described in terms of the type of evidence, either quantitative or qualitative outcomes.
5. *Formulation of data requirements and general questions*. This step indicated the logic linking the data to the propositions as well as the criteria used for interpreting the data. This step also specified the type of data collection method e.g. fieldwork, archival records, verbal reports, observations, ethnography etc.

2.3. Conclusion

This chapter was a discussion of the research method followed in this study. There was an evaluation of the triangulation process utilised with specific emphasis on the three methods used, namely, the focus group, the Delphi technique and the case study. In conclusion, it was decided to use a focus group to gather the initial factors, followed by a Delphi study to prioritise the factors. The Delphi study was then followed by case study research to confirm the factors identified and prioritised during the Delphi study. In the chapters which follow, the process and results for each of these methods is discussed in detail.

Chapter 3: Analysis of existing theory



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"A nation's ability to solve problems and initiate and sustain economic growth depends partly on its capabilities in science, technology, and innovation. Science and technology are linked to economic growth; scientific and technical capabilities determine the ability to provide clean water, good health care, adequate infrastructure, and safe food. Development trends around the world need to be reviewed to evaluate the role that science, technology, and innovation play in economic transformation in particular and sustainable development in general." – (Juma and Yee-Cheong 2005)

3.1. Introduction

The majority of the population in sub-Saharan Africa lives in rural areas and most of the people spend 5% to 20% of their monthly income on fuel (Energy sector management assistance program 2006). Currently only 23.6% of the total population has access to electricity. Only 8.4% of people in rural areas in sub-Saharan Africa have access to electricity. In those rural areas where electrification has taken place, the most common uses for electricity are lighting, access to media and limited use of appliances (the main appliances are irons, colour TVs, fridge/freezers, radios and electric fans) (Energy sector management assistance program 2006). Rural Africans do not use electricity for cooking as they prefer alternatives such as gas (Energy sector management assistance program 2006).

Countries in Africa import foreign technology to improve the quality of life of their citizens, for example by importing energy technology (Dunmade 2002). The majority of these imported technologies fail because the technologies are not sustainable (Dunmade 2002). The general success rate of World Bank financed electric power projects is 68%, whereas the success rate of such projects in sub-Saharan Africa is estimated to be only 36% (Dunmade 2002). In other developing countries such as Peru, for example, it has been found that despite energy reforms electricity supply is still designed to reach rural areas (Cherni and Preston 2007). Policy changes by government administration are required for renewable energy to provide the benefits required by the end users (Cherni and Hill 2009).

Through this research an attempt has been made to determine the factors which must be taken into account for the selection of renewable energy technologies in Africa so that the implementation of technologies will be sustainable. This chapter is an analysis of the current challenges which have to be faced in introducing renewable energy technologies in sub-Saharan Africa. Renewable energy technologies are first investigated. Then follows a section on the challenges of implementing such technology in sub-Saharan Africa. Finally an analysis of the selection methodologies, measures and ratings is presented. To understand selection decision-making there is a discussion about the different types of decision making methods which have been developed and applied in project selection, portfolio selection, programme selection and technology selection. Project selection methods are mainly used to select project portfolios and programmes.

3.2. Renewable Energy Technology

"Energy supply is essential for all aspects of life, industry and commerce. A successful economy depends on both supply and use being secure, safe and efficient." (United Nations Energy Agency 2007)

Energy can be viewed as the primary driver for achieving sustainable development (International Energy Agency 2007). Energy services are required to meet basic human needs, which include the need for shelter and the need for food; energy services further improve education and health services, and contribute to human development (Cherni and Hill 2009; International Energy Agency 2004) . Renewable energy technologies have a big role to play in ensuring that the rural poor in Africa are given access to energy (United Nations Energy Agency 2007). Renewable energy technologies are developed in stages and the stage in which the technology is at the time of implementation can affect the success of failure of the implementation.

Renewable energy technologies usually progress from research and development to fully commercial applications over a period of time. First generation technologies emerged from the industrial revolution at the end of the 19th century and these technologies are in the fully commercial phase; second generation technologies are now entering the renewables market because of research and development since the 1980s; these technologies are mostly supported commercial or fully commercial; third generation technologies are still under development. These technologies are in the research and development (R&D), demonstration and pre-commercial phases (International Energy Agency 2007).

There are many types of renewable energies which are currently being used or researched as shown in Table 3-1.

Table 3-1: Summary of types of renewable energy (adapted from International Energy Agency 2007)

Category	Description	Technology generation
Combustible renewables and waste		
• Solid biomass	Organic, non-fossil material of biological origin used for heat or electricity generation.	First
• Charcoal	Solid residue of destructive distillation and pyrolysis of wood and other vegetal matter	First

Category	Description	Technology generation
• Biogas	Gases composed principally of methane and carbon dioxide produced by anaerobic digestion of biomass and combusted to produce heat and/or power.	First
• Liquid biofuels	Bio-based liquid fuel from biomass transformation, mainly used in transportation applications.	First
• Municipal waste (renewables)	Municipal waste energy comprises wastes produced by the residential, commercial and public services sectors and incinerated in specific installations to produce heat and/or power. The renewable energy portion is defined by the energy value of combusted biodegradable material.	First
• Modern forms of Bioenergy	More modern forms of bioenergy include biomass-based power and heat generation, co-firing, biofuels for transport and short rotation crops for energy feedstocks. These are more advanced and each has its own unique benefits. Biomass is attractive for use either as a stand-alone fuel or in fuel blends, such as co-firing wood with coal, or mixing ethanol or biodiesel with conventional petroleum-based fuels.	Second
• Integrated bioenergy systems	The biomass integrated gasifier/gas turbine (BIG/GT) is not yet commercially employed, but substantial demonstration and commercialisation efforts are ongoing worldwide, and global interest is likely to lead to market deployment within a few years. Overall economics of biomass-based power generation should improve considerably with BIG/GT systems as opposed to steam turbine systems.	Third
Hydropower	Potential and kinetic energy of water converted into electricity in hydroelectric plants. It includes large as well as small hydro, regardless of the size of the plants. Hydropower is an extremely flexible technology from the perspective of power grid operation. Large hydropower provides one of the lowest cost options in today's energy market, primarily because most plants were built many years ago and their facility costs have been fully amortised.	First
Geothermal		
• Geothermal power and heat	Energy available as heat emitted from within the earth's crust, usually in the form of hot water or steam. It is exploited at suitable sites for electricity generation after transformation, or directly as heat for district heating, agriculture, etc.	First

Category	Description	Technology generation
	Geothermal power plants can operate 24 hours per day, providing base-load capacity. In fact, world potential capacity for geothermal power generation is estimated at 85 GW over the next 30 years.	
• Enhanced geothermal systems	Enhanced geothermal systems, known as hot dry rock, utilise new techniques to exploit resources which would have been uneconomical in the past. These systems are still in the research phase, and require additional research, design and development for new approaches and to improve conventional approaches, as well as to develop smaller modular units that will allow economies of scale on the manufacturing level.	Third
Solar energy		
• Solar heating and cooling	Solar radiation exploited for hot water production and electricity generation. Does not account for passive solar energy for direct heating, cooling and lighting of dwellings or other. Solar thermal collectors are already widely used in certain countries, primarily for hot water production. Various technologies are becoming more widely used, such as unglazed, glazed and evacuated tube water collectors, which have market shares of 30%, 50% and 20%, respectively.	Second
• Solar photovoltaics	The photovoltaic (PV) market has grown extensively since 1992. RD&D[what's this] efforts, together with market deployment policies, have effectively produced impressive cost reductions: every doubling of the volume produced prompted a cost decrease of about 20%.	Second
• Concentrated solar power	Three types of concentrating solar power (CSP) technologies support electricity production based on thermodynamic processes: parabolic troughs, parabolic dishes and solar central receivers. Solar thermal power plants concentrate solar radiation and convert this radiation into high temperature steam which is used to drive turbines (Greenpeace 2005).	Third
• Concentrated Photo Voltaics	Concentrated PV systems utilise high concentration mirrors or lenses to focus sunlight which is captured in miniature solar cells. This technology is potentially cheap as expensive silicon cells are replaced with inexpensive optical materials such as glass, aluminium and plastic (Sustainable energy technologies 2010).	Third
• Thin film technology	Traditional solar photovoltaics use crystalline silicon wafer which is expensive. Thin film technology in the form of amorphous silicon is used as a cheaper alternative for the	Third

Category	Description	Technology generation
	silicon wafer (Solarbuzz 2010).	
Wind energy	Kinetic energy of wind exploited for electricity generation in wind turbines. Wind technology has become very reliable, operating with availabilities of more than 98% and having a design life of 20 years or more. Also, as the costs of wind turbines have steadily declined, technical reliability has increased.	Second
Tide/Wave/Ocean energy	Mechanical energy derived from tidal movement, wave motion or ocean current, and exploited for electricity generation. Over the last 20 years, ocean energy technology received relatively little research, design and development funding. However, there is renewed interest in the technology, and several concepts now envisage full-scale demonstration prototypes around the British coast. But ocean energy technologies must still solve two major problems concurrently: proving the energy conversion potential and overcoming a very high technical risk from a harsh environment.	Third

First generation technologies have been implemented in rural Africa with low rates of success (Dunmade 2002). First generation technologies such as solid biomass and charcoal are used by the majority of rural Africans but in inefficient ways.

Renewable energy can be used in residential, commercial and industrial electrification scenarios. Each sector with its requirements and possible renewable energies that can be used is shown in Table 3-2.

Table 3-2: Sector energy requirements and possible Renewable energy solutions (adapted from Prasad and Visagie 2005)

Sector	Requirements	Technology
Residential	Fuel for lighting	PV solar, wind
	Fuel for cooking	Solar cookers, wind, small hydro, gel fuel, fuel wood and other biomass
	Fuel for space heating	Wind, small hydro, biomass, solar water heaters
	Fuel for water heating	Wind, small hydro, PV solar, biomass
	Fuel for refrigeration	Wind, small hydro, PV solar, biomass
	Fuel for cooling	Passive night cooling
Commercial	Fuel for lighting	Wind, small hydro, hybrid, PV solar

Sector	Requirements	Technology
	Fuel for commercial activities	Wind, small hydro, solar
	Fuel for water heating	Wind, small hydro, biomass, solar water heaters
Industrial	Fuels for lighting	Wind, small hydro
	Fuel for industrial activities	Wind, small hydro, co

Several renewable energy technologies remain expensive compared with conventional technologies because of the higher capital costs. This means considerable initial investment and financial support for long periods before these projects become financially viable (Prasad and Visagie 2005). Further development of second and third generation renewable energy technologies will require substantial investment in terms of capital and time (Prasad and Visagie 2005). These technologies will remain too expensive for large scale implementation in rural Africa until such time as they reach the fully commercial phase.

Cooking remains one of the greatest basic needs for rural communities. It was found that where electricity is available for use by the rural poor it is mainly used for lighting, radio and television, and that electricity is too expensive to use for cooking (Prasad 2008). This means that the rural poor continue using solid biomass and charcoal, often in an unsustainable way.

A brief discussion about the unique challenges presented by conditions in Africa when selecting renewable energy technologies follows.

3.3. Challenges in renewable energy technologies in Africa

Technology management in developing countries is very different from that of developed countries. In developed countries the emphasis is on the control and utilisation of technology as well as the offsetting of the undesirable consequences of technology. In developing countries on the other hand, because of the lack of skilled resources, the emphasis is on technology selection and transfer to achieve rapid economic and social development (Ruder*, et al.* 2008). Technology transfer for sustainable development has however failed to meet expectations. According to the International Environmental Technology Centre (2004) the following elements have to be taken into account for the successful transfer of technologies:

- *Context of implementation*. A different location or stage in the technology life cycle can mean that a given technology is no longer environmentally sound.
- *Challenges*. The challenges in technology transfer are dependant on the specific application but can include insufficient innovation; performance of the

technology being not-as-expected; the enabling environment not being optimal for the technology; and lack of information.

- *Informed choice*. The users and installers of the technology must have sufficient information to make choices of the most appropriate technology.
- *Certainty of success*. Renewable energy technologies are often perceived to have high levels of risk associated with their implementation as they are believed to be unproven. Proper risk management and support of financial institutions is required to alleviate the risks.
- *Effective and efficient communication*. Effective and efficient communication is essential to ensure that key stakeholders are actively removing barriers in implementation.
- *Stakeholder capacity*. It is essential to ensure that all stakeholders have the capacity to fulfil their roles in the technology transfer chain.
- *Commitment to overcome challenges*. All stakeholders must be committed to support the technology transfer efforts.

Most of the elements which are important for successful technology transfer are also important considerations for technology selection. Various researchers have discussed the factors for the selection of sustainable energy technologies, in general, in developing countries and some have focussed on the special characteristics for the selection of technologies in Africa.

According to the findings of Teitel (1978) in his study on the selection of appropriate technologies for less industrialised countries some industrial technologies are inappropriate because of “inadequate response to market requirement; failure to use and or adapt to the local supply of materials; failure to adapt to a smaller scale of production; insufficient use of labour because of price distortions and other restrictions; import of unsuitable machinery; selection of unsuitable technology because of restriction on the acquisition of technology”. Teitel (1978) further states that the top three reasons for badly implemented technology in developing countries are maintenance and repair complexities; obsolescence of components and the fact that the technology has not been adapted to the climate.

According to Dunmade (2002) the primary factor for sustainability of a technology is adaptability of the technology, whereas the secondary factors include technical sustainability, socio-political sustainability, environmental sustainability and economic sustainability.

In the SURE model, proposed by Cherni, *et al.* (2007) for the calculation of energy options for rural communities and tested in a Columbian rural community, use is made of a multi-criteria decision support system. The SURE model includes the following factors – physical resources including houses and roads; human resources such as skills and education; financial resources including wages and savings; social resources such as networks and social organisations and natural resources including land and water resources (Cherni*, et al.* 2007).

The factors mentioned in the literature for Africa specifically are discussed in the discussion which follows. The selection of emerging technologies is complex. This makes their selection and evaluation more complex because of the inherent uncertainty and ambiguity of emerging technologies (Haung*, et al.* 2009). Many renewable energy technologies are emerging technologies. Africa is also an emerging economy, so the introduction of new technologies is complicated.

The translation of research knowledge in and of Africa into economic and social benefits is very complex (Chataway*, et al.* 2006). The complexity of the technology selection problem grows as the number of factors and the number of alternatives to consider increases (Torkkeli and Tuominen 2001).

The lack of skilled resources creates great difficulties in Africa. These difficulties are experienced by the implementing organisations, government and users. Countries in Africa do not have the institutional capacity to implement effective environmental policies; this is mainly because building institutional capacity involves the development of material and human resources and Africa does not have skilled human resources (Ebohon*, et al.* 1997). Consumers in Africa do not easily accept renewable energy technologies because they lack knowledge about the advantages and opportunities for using these energies (Prasad and Visagie 2005). Other realities in Africa (for example poverty alleviation) can derail the implementation of renewable energies as conventional energy implementation is cheaper in the short term (Prasad and Visagie 2005). When renewables are first implemented, training and knowledge transfer needs to take place which means that resources, capital and time need to be expended (Jimenez*, et al.* 2007).

To overcome these difficulties in Africa it is important that training and education of the community, especially the poor, is undertaken before technologies are implemented (Energy sector management assistance program 2006; United Nations Energy Agency 2007). Training and skills development of communities will alleviate the lack of user acceptance and also ensure that the skills base of the community can be improved to help maintain the technology (Prasad and Visagie 2005). It is important that government create consumer awareness through information programmes to educate the potential users on the advantages of renewable energy technologies (Nguyen 2007). Training of personnel and setting of technical standards also helps overcome the difficulties of the lack of skills in Africa (United Nations Energy Agency 2007).

Government participation and support is important for the success of implementation of sustainable energy technologies in Africa. Institutional and political frameworks are essential to ensure the success of implementation of renewable energy technologies. The technology selected must impact on both the priorities of the local population as well as on the social and environmental targets of the government (Cherni and Hill 2009). The implementation of legal and regulatory frameworks, policies and strategies which support renewable energy technologies needs to be backed by government (Prasad and Visagie 2005). Further there has to be a willingness by government to subsidise technologies (Prasad and Visagie 2005). In China, also a developing economy, laws have been enacted for renewable energy development but a body for enforcement has not been clearly assigned. This will hamper implementation (Cherni and Kentish 2007). Government can also encourage the implementation of renewable energy technologies by removing taxes and duties to exempt components or renewable energy technologies which are imported and establish a specialised agency to plan and promote renewable energy technologies (Nguyen 2007).

Decentralised renewable energy systems in developing countries are unattractive for customers because of the initial high investment cost which low income rural households cannot afford. In addition those households expect that the grid will be extended to their households in future (Nguyen 2007). Governments can overcome these difficulties by setting targets for renewable energy dissemination and communicating the fact that grid extension is too costly to rural communities. (Nguyen 2007). By providing subsidies government can support the financial elements of renewable technology implementation (Nguyen 2007; Prasad and Visagie 2005). Another way of offsetting costs is by arranging consumer credit (Nguyen 2007) and finally, by setting up an energy body which installs systems, retains ownership and bills for services, government can show its commitment to renewable energy usage in a community (Nguyen 2007).

When implementing renewable energy technologies in informal rural communities commonly used economic measures of development and wealth are not applicable as these measures do not make allowance for cash income, payment in kind or the provision of basic services by government (Cherni and Hill 2009). The initial and operational costs of renewable energy technologies should be subsidised by government or donor agencies to ensure that renewable energy technologies can compete with conventional technologies (Prasad and Visagie 2005). Up front communication with the community about the costs associated with the use of electricity also contributes to success of implementation (Energy sector management assistance program 2006).

Renewable energy projects should support the improvement of life of the poor and should ensure job creation for the poor (Prasad and Visagie 2005). Research in Cuba shows that the success in implementation of renewable energy technologies in rural areas is dependant on the ability of the technology to change local community livelihoods and also to protect the environment (Cherni and Hill 2009).

The involvement of the community has also been shown to be important for the success of renewable energy technology implementation. Innovative energy products first reach the early adopters who have a visionary attitude and will adopt the innovation. An innovation chasm then exists in which the innovation does not reach the rest of the population. It is suggested that mainstream members of housing associations should be persuaded to adopt energy conservation innovations to ensure that the innovations reach the rest of the population (Egmond*, et al.* 2006). Support from the community of renewable energy projects is also needed to avoid theft (Energy sector management assistance program 2006).

In brief the challenges in implementing renewable energy technologies in Africa in a sustainable way have been outlined. What follows is a summary of the main project, technology, portfolio and programme selection methods which can be used according to the literature on the topic.

3.4. The selection problem

The selection problem addressed in this research deals with fulfilling the energy requirements of Africa by selecting the appropriate energy alternative (which alternatives are shown in Table 3-1).

To make a selection decision, a list of alternatives and the factors which will be used to judge the alternatives is required. A practical example might be in order here. For example, when selecting a microwave oven to purchase one can have a list of manufacturers - *LG*, *Samsung*, *Defy* and *Panasonic*. The factors which are important in the selection of the microwave oven might be size, cost and aesthetics. Once the alternatives and factors have been decided upon, the next step is to decide how each factor will be measured. In the case of a factor such as size, the measurement is easy as the data are available. Cost however can be more complex as one can measure the cost of the microwave oven in terms of the life cycle cost - the likely cost of spares and maintenance or the cost of electricity by looking at efficiency of consumption. Aesthetics is an elusive concept to measure – it could be subjective – to fit the colour scheme of the kitchen, or it could be about the design. Then a selection methodology must be chosen to compare the different measures for each alternative in a way that will give the best answer. As can be seen from the above example, selection decision-making is not easy. Decision theory exists to give decision-makers tools to make important decisions more effectively.

Decision theory as applied in technology selection, portfolio selection, programme selection and project selection shows that the selection activity has many features in common. The methods of technology, portfolio, programme and project selection are discussed in detail next. All the methods found in the literature are discussed for completeness' sake although not all the methods discussed have direct bearing on the research.

In investigating the decision-making methodologies it becomes clear that the answer given by the methods is only as good as the framework of factors that are considered to be important for the decision. To this end, the different types of factors taken into account in different scenarios are investigated later in this chapter.

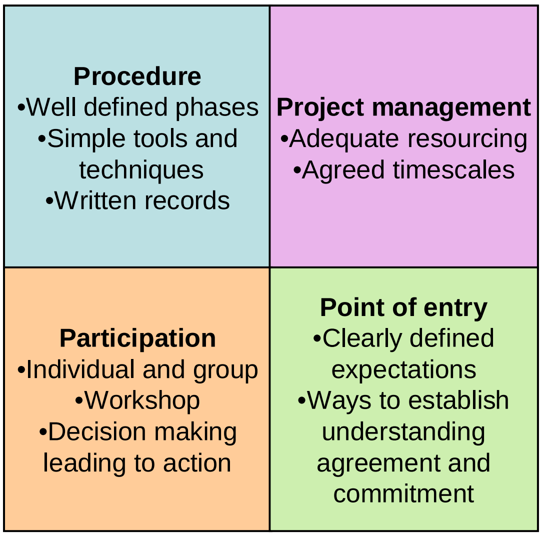
Lastly the measures used to determine ratings for factors are also investigated in this chapter. In some cases measures can be purely numerical, as for example, the power rating of the microwave oven in the exemplum above. In other cases the measure can be more subjective as is the case for the aesthetics of the microwave oven - then linguistic scales and other methodologies are used to determine the measurement.

3.4.1. Selection methodologies

A vast number of selection methods exist. The methods can be classified as economic methods; combination of economic and other methods; comparative methods; optimisation methods; strategic methods; and combination methods. Selection methods in general are discussed and then follows an elaboration on each of the methods.

A selection tool should be accessible to stakeholders, should be able to be used to evaluate investment, should include all applicable factors, should enable the use of established accounting principles and should produce results which can be verified by financial managers (Kengpol and O'Brien 2001).

Common characteristics of successful selection methodologies considered by (Torkkeli and Tuominen 2001) are shown in Figure 3-1.



Procedure •Well defined phases •Simple tools and techniques •Written records	**Project management** •Adequate resourcing •Agreed timescales
Participation •Individual and group •Workshop •Decision making leading to action	**Point of entry** •Clearly defined expectations •Ways to establish understanding agreement and commitment

Figure 3-1: Common characteristics of successful selection methodologies (Torkkeli and Tuominen 2001)

It is clear that choosing a selection methodology is not just about the method, factors, measures and ratings but also about the context in which the selection is taking place and the stakeholders involved.

An important point in developing a selection methodology is that the methodology can never completely address the complexities of the real world and will always make assumptions about the real world. The problem with the use of models is that real world issues are often ignored in an attempt to make the models less complex. A summary of the assumptions made when developing models versus the real world environment is shown in Table 3-3 (Souder 1978). The implications for this study are indicated in the last column of the table and will be taken into account when developing the framework of factors.

Table 3-3: Assumptions when Developing Models versus Real World Environment (adapted from Souder 1978)

Assumptions when developing models	Real world environment	Implications for this study
A single decision maker in a well-behaved environment	Many decision makers and many decision influencers in a dynamic organisational environment	A stakeholder analysis must be done to determine who the decision makers are and also who will influence the decisions
Perfect information about candidate projects and their characteristics; outputs, values and risks of candidates known and quantifiable	Imperfect information about candidate projects and their characteristics; outputs and values of projects are difficult to specify; uncertainty accompanies all estimates.	It must be accepted that imperfect information is available but the measures put in place must optimise the decision making process
Well-known, invariant goals	Ever-changing fuzzy goals	The long term strategy must be clear but the shorter term goals will remain fuzzy
Decision making information is concentrated in the hands of the decision maker, so that he has all the information needed to make a decision	Decision making information is highly splintered and scattered piecemeal throughout the organisation with no one part of the organisation having all the information needed for decision making.	The template for information gathering during the proposal phase must elicit the information necessary to make proper decisions
The decision maker is able to articulate all consequences	The decision maker is often unable or unwilling to state outcomes and consequences	Decision makers must be given tools that help them understand the outcomes and the consequences
Candidate projects are viewed as independent entities, to be individually evaluated on their own	Candidate projects are often technically and economically interdependent	The interdependencies between projects must be taken into account

Assumptions when developing models	Real world environment	Implications for this study
merits		
A single objective, usually expected value maximisation or profit maximisation is assumed and the constraints are primarily budgetary in nature	There are sometimes conflicting multiple objectives and multiple constraints and these are often non-economic in nature	The qualitative as well as quantitative measure of project must be taken into account
The best portfolio of projects is determined on economic grounds	Satisfactory portfolios may possess many non-economic characteristics	The qualitative as well as quantitative measure of project must be taken into account
The budget is optimised in a single decision	An iterative, re-cycling budget determination process is used	The methodology must cater for a cyclical process

Although an abundance of proposed selection techniques and lists of evaluation criteria have been reported, no consensus has emerged about an effective selection methodology (Hall and Nauda 1990). The selection of projects is a very complex problem with many factors which can and should be taken into account. It is however impossible for any model to take all factors into account (Meredith and Mantel 2003). In developing a project selection method for sustainable energy projects in Africa, the above assumptions will need to be tested against the real world environment.

Most project selection methods reported on in the literature have serious drawbacks with the central issues of concern being the uncertainty of the future business environment and the technical results of R&D (Costello 1983). Project selection methods must take into account the heuristic nature of project selection and the fact that decisions on project selection are taken at many different levels in the organisational hierarchy (Winkofsky, *et al.* 1980).

Any method proposed for the selection of sustainable energy projects should therefore take into account the following (Winkofsky, *et al.* 1980):

- *Project selection methods*. Careful consideration of the method to be used for project selection. All the existing methods have advantages and disadvantages. It may be that the best solution for this problem will be made up of a combination of some of the existing methods or that a new method needs to be developed.
- *Criteria for energy project selection*. The important criteria for energy project selection need to be determined. All methodologies are based on certain criteria which are important in specific instances with the result that even if an existing methodology is used, the criteria that are important for successful energy projects in Africa need to be considered.

- *Determination of stakeholders*. It is very important to specify the stakeholders for project selection as the attitudes and requirements of the stakeholders will have a large impact on the method and factors selected.
- *Understand the project selection cycle*. The project selection cycle over time needs to be understood to be able to decide whether the method must be applicable to periodic processes only or whether it is applicable to an ongoing process.
- *Criteria or factors*. Finally, all the methods described enable projects to be selected using specific criteria or factors.

What follows is a more detailed discussion of each of the methods.

3.4.1.1. Economic methods

Economic methods attempt to compute the cost benefit of performing a project or attempt to quantitatively assess the financial risk of performing a project (Hall and Nauda 1990). These methods are also used in technology selection (Chan*, et al.* 2000; Shehabuddeen*, et al.* 2006). The problem economic models have is that it is difficult to obtain the data, which include investment cost, gross income, expenses, depreciation, salvage value, interest rate which is required to do the calculation at the time that the technology is selected (Chan*, et al.* 2000) A summary of the economic methods with authors is shown in Table 3-4.

Table 3-4: Summary of economic methods

Methodology description	Author(s)
Payback period	Lowe*, et al.* 2000
Net present value	Cetron*, et al.* 1971; Lowe*, et al.* 2000; Martino 1995
Internal rate of return	Lowe*, et al.* 2000; Martino 1995

Payback period (PP) compares the amount of time that different projects or technologies will take to recover initial capital outlay (Lowe*, et al.* 2000).

Net present value (NPV) converts the cash flow of projects to a single value, stated in present monetary value, which makes comparisons between early and late values in the same cash flow stream possible as well as a comparison between cash flows which have different profiles of income and expenditure (Lowe*, et al.* 2000; Martino 1995). In a survey by Cetron (1971), nine of the methods that were examined utilised NPV. NPV allows for the comparison of projects in terms of their differing streams of expenses and revenues. The main difficulty in the utilisation of NPV is that cash flows for R&D projects are not very predictable. A further drawback of NPV is that an assumption is made that a constant discount rate is applicable over time (Martino 1995).

The internal rate of return (IRR) is the discount rate that would reduce the NPV of a cash flow profile of a project to zero. For the selection of projects, the greater the IRR, the better the project as it will achieve payback sooner (Martino 1995). The advantage of this method over NPV is that future interest rates need not be estimated, but just as with NPV, the future cash flows of R&D projects must be estimated (Lowe*, et al.* 2000).

The drawback of the use of economic methods alone for selection is that the identification of the economic data required at the start is often not possible and as a consequence inaccurate data are used to make the decision. Other important factors are also ignored if economic methods are used in isolation and this is treated in the discussion of the combination of economic and other methods.

3.4.1.2. Combination of economic and other methods

When combining economic and other methods, these methods still focus on the cost benefit but also take other factors into account. A summary of the combination of economic and other methods with authors is shown in Table 3-5.

Table 3-5: Summary of combination of economic and other methods

Methodology description	Author(s)
Cost benefit method	Silverman 1981
Risk analysis approach that maximises net present value	Sefair and Medaglia 2005

The cost benefit method proposed by (Silverman 1981) combines a scoring/economic approach for estimating the relative merits of R&D projects. The method requires the estimation of three vectors of economic and scoring values, i.e., energy benefits, consumer savings and societal factors. The advantage of this method is that it focuses on managerial issues but that is to the detriment of the technical project issues which are not addressed.

As an example of *a risk analysis approach*, (Sefair and Medaglia 2005) proposes a mixed integer programming method which maximises the sum of net present values of chosen projects, while minimising the risk of the projects. The method combines the project selection and sequencing decisions while considering risk and profitability as optimising criteria. The advantage of the approach is that it takes more factors into account than the NPV approach. On the other hand, the risks of R&D projects are not always easy to quantify, especially over the longer term.

The economic methods combined with other methods still have an emphasis on the economic viability of the technology or the project and are not preferred for this research study.

3.4.1.3. Comparative methods

Comparative methods compare different projects or technologies with each other by considering the important factors for selection and then using theoretical methods or simulations to select the best alternative. A summary of the comparative methodologies with author(s) is shown in Table 3-6.

Table 3-6: Summary of comparative methods

Methodology description	Author(s)
Ordinal ranking	Cook and Seiford 1982
Q-sort which is a structured psychometric communication method	Archer and Ghasemzadeh 1999; Helin and Souder 1974; Souder 1978
Pairwise comparison	Hall and Nauda 1990; Martino 1995; Mohanty 1992; Souder 1975
Electre method uses decisional scenarios for comparison	Beccali, *et al.* 2003
Scoring methods where each project proposal is scored in respect of available and determinable criteria	Archer and Ghasemzadeh 1999; Hall and Nauda 1990; Martino 1995
Analytic hierarchy process (AHP)	Bick and Oron 2005; Chan, *et al.* 2000; Firouzabadi, *et al.* 2008; Gokhale and Hastak 2000; Jimenez, *et al.* 2007; Lee and Hwang 2010a; Libertore 1987; Saaty 1990
Analytic network process (ANP)	Mulebeke and Zheng 2006
Fuzzy analytic hierarchy process	Chan, *et al.* 2000; Dagdeviren, *et al.* 2009
Rule-based expert system using interactive question and answer session with user	Masood and Soo 2002
Multi-objective evolutionary approach for linearly constrained project selection under uncertainty	Medaglia, *et al.* 2007
Weighting method using different scenarios	Chandler and Hertel 2009
Four level multi-criteria decision making method	Ruder, *et al.* 2008
Probabilistic rule-based decision support system	He, *et al.* 2006
Decision method for selecting slightly non-homogeneous technologies	Saen 2006a
Phased group decision support system	Torkkeli and Tuominen 2001

Methodology description	Author(s)
Deterministic parallel selection technique	Jeong and Abraham 2004
Profile method	Martino 1995

A brief discussion of the various methods follows. For *ordinal ranking*, each member of a committee is asked to rank a set of projects ordinally along a set of dimensions. It is then assumed that a cardinal weight is assigned to each dimension which is used to simplify the problem into a single dimension. An index indicating the degree of agreement of the committee members is given. A constrained linear assignment method is then used to allocate the relative project priorities (Bernado, 1977 as referenced in (Cook and Seiford 1982).

The ordinal ranking method is simple and easy to use. Despite the advantage of simplicity, the disadvantages include the fact that the method assumes that dimensions can all be collapsed through the use of a set of weights, which is equivalent to proposing the existence of a utility function. The method is also structured for small problems and will be cumbersome for more than 50 projects (Cook and Seiford 1982).

Q-sort is a structured group communication psychometric method for classifying a set of items according to the individual judgment of a group of persons selecting the projects. Each individual successively sorts items into preconceived categories. The anonymous scores are tallied and these tallies are then used as a starting point for open discussion (Souder 1978).

This method is a valuable procedure for facilitating scientist/scientist and scientist/manager communications within a project evaluation process as a clear indication of the opinions of the various group members is obtained (Souder 1978).

Helin (1974) reports that participants on a Q-sort experiment felt that the method was too imprecise to yield final decisions. They also felt that the process was highly subjective to personal preferences, ignorance and misunderstanding (Helin and Souder 1974). The process is cumbersome as the large number of comparisons involved has to be redone if another project is introduced (Archer and Ghasemzadeh 1999).

When using the *pairwise comparison method*, projects are compared (for example, preference for project *i* against project *i+1*, project i against project *i+2*, etc) until every pairwise comparison is explored (Hall and Nauda 1990). The most common methods for converting the comparisons into rankings are the dominance count method and the anchored scale method (Martino 1995). A more sophisticated approach which also uses pairwise comparison is discussed by (Mohanty 1992). In this approach a final acceptability index is given for each project which is used to rank the set of projects. The main advantage of pairwise comparison is that it elucidates conflicts and differential perceptions of R&D objectives. It also induces articulation of value structures and disclosures of hidden social-interpersonal conflicts (Souder 1975). The disadvantages are once again that the comparisons have to be redone if another project is introduced (Archer and Ghasemzadeh 1999) This method can result in many projects having the same ranking especially in the middle range (Martino 1995).

The *Electre method* is a multi-criteria decision making method which uses decisional scenarios (Beccali*, et al.* 2003) in the selection of renewable energy technologies in Sardinia. This method evaluates the alternatives according to certain criteria, followed by partial aggregation of preferences. Then the index of concordance under given criteria and the index of global concordance are calculated followed by the final ranking of criteria. Three decisional scenarios were used namely: environmental oriented scenario, economy-oriented scenario and energy saving and rationalisation scenario.

Scoring methods require individuals to specify the merit of each project proposal with respect to available and determinable criteria. The scores are then aggregated to determine an overall project rank. The highest ranking projects which can be performed within budget constraints are selected (Hall and Nauda 1990). Scoring methods have many advantages including simplicity of use and formulation. They can also take into account both objective and judgemental data (Martino 1995) and projects can be added and deleted without recalculating the merit of other projects (Archer and Ghasemzadeh 1999). The value of a scoring method is however based on how the decision criteria are selected, and whether these criteria are really known or based on estimates.

The *Analytic Hierarchy Process* (AHP) is conducted in two stages namely hierarchic design and evaluation (Saaty 1990). Design of the hierarchy involves structuring all the elements of the selection problem into a hierarchy. The method is based on determining weights of a set of criteria in one level of the problem hierarchy to the level just above. By repeating the process level by level, the priorities of the alternatives at the lowest levels can be determined according to their influence on the overall goal of the hierarchy (Libertore 1987). The main advantage of AHP is that it allows the R&D project selection problem to be linked to the business strategic planning process (Libertore 1987). The disadvantages are once again that the comparisons have to be redone if another project is introduced (Archer and Ghasemzadeh 1999). AHP is also extensively used in technology selection (Chan*, et al.* 2000; Jimenez*, et al.* 2007; Lee and Hwang 2010b) for example in the selection of reverse osmosis technology (Bick and Oron 2005). Firouzabadi (2008) and Gokhale (Gokhale and Hastak 2000)(2000) advocate the use of AHP together with zero-one goal programming.

Some authors criticise AHP by referring to “a lack of a theoretical framework to method decision problems into a hierarchy; use of subjective judgements in making pair wise comparisons; the use of the Eigen Vectors method for estimating relative weights and the lack of formal treatment of risk” (Choudhury*, et al.* 2006) . Another criticism of AHP is that it is only able to deal with hierarchical relationships and ignores inter-functional compatibility relationship issues (Mulebeke and Zheng 2006).

Because of these criticisms, the *Analytical network process* has been developed as an improvement on the AHP. The analytical network process takes into account intra functional relationship and deals with interdependencies amongst clusters (Mulebeke and Zheng 2006).

Because all measures of the factors to be taken into account for AHP are not always easily quantifiable, *fuzzy multi-criteria decision making* was developed to accomodate the uncertainty (Chan*, et al.* 2000; Dagdeviren*, et al.* 2009).

A *rule-base expert system* using interactive question and answer sessions with the user to input the data has also been proposed (Masood and Soo 2002) as well as a multi-objective evolutionary approach, which can be used when projects are partially funded, multiple uncertain objectives are to be met and the projects have a linear resource constraint (Medaglia*, et al.* 2007).

A *weighting method using different scenarios* addresses sub-factors or lowest level technical attributes and an overall score is determined by weighted summation and decision makers are asked to consider different scenarios of operation (Chandler and Hertel 2009).

The *four level multi-criteria decision making method* is very similar to the weighting method in which the four levels consist of identification of stakeholders, identification of current core competencies, identification of alternate technologies and selection criteria, identification of functions and weights for criteria as well as assessment of alternatives (Ruder*, et al.* 2008).

A *probabilistic rule-based decision support system* which is automated, takes into account domain knowledge and uses a Bayesian network to recommend the best technology as well as provide a measure on the reliability of the answer (He*, et al.* 2006).

The *decision method for selecting non-homogeneous technologies* can be used when not all the technologies under consideration consume common inputs to produce common outputs (Saen 2006a). The missing values for the technologies which have different inputs or outputs are calculated in this method.

The phased group decision support system has the following phases to select technologies - mapping and classification of factors; determination of the most important factors; assessment of alternatives, analysis of results of selection, analysis of impact of results of selection (Torkkeli and Tuominen 2001).

The *deterministic parallel selection technique* has the following key features: decisions are based on knowledge of the problem; input values to the method are crisp and tangible; parallelism exists among criteria and the tool enables its users to propose alternatives (Jeong and Abraham 2004).

In the *profile method* thresholds are set for different project characteristics for example cost, market share, market size and probability of success. Projects that fall below the preset thresholds are automatically rejected (Martino 1995).

Comparative methods are the most applicable to this study of all the methods discussed to date. These methods enable the consideration of multiple factors and as discussed in paragraph 3.3 multiple factors need to be considered in the African scenario.

3.4.1.4. Optimisation methods

Optimisation methods seek to optimise some objective function or functions subject to specified resource constraints. Various authors use a number of objective functions, which are normally economically based, and different constraints to formulate the project selection problem. These methods are conceptually attractive as they optimise specific quantitative measurements of R&D performance subject to budget and organisational constraints. Surveys have however shown that these methods are not very widely used (Archer and Ghasemzadeh 1999). A summary of optimisation methods with authors is shown in Table 3-7.

Table 3-7: Summary of optimisation methods

Methodology description	Author(s)
Integer programming	Cook and Seiford 1982
Multi-objective binary programming method which optimises project scheduling	Carazo, *et al.* 2009
Multiple test framework	Chapman, *et al.* 2006
Fuzzy R&D portfolio selection method	Wang and Hwang 2007
Fuzzy regression and fuzzy optimisation method	Sener and Karsak 2007
Mathematical programming where both ordinal and cardinal data is available	Saen 2006b

Various types of optimisation methods exist including integer programming, linear programming, non-linear goal programming, non-linear dynamic programming and a multiple test framework.

Integer programming consists of an optimization where the variables may only take integer values, i.e. 0,1,2,3,... .

A value v_l is assigned to each project l. The cost c_l of funding that project is determined. The binary knapsack problem must then be solved:

Maximise $\sum_{l=1}^{L} v_l \quad x_l$ Subject to $\sum_{l=1}^{L} c_l \quad x_l \leq B$ x_l = 0 or 1

where B is the available budget. x_l = 1 implies that the project l is funded (Cook and Seiford 1982).

The advantage of this method is that it is a very simple integer programming problem to solve. The drawback is that the values and costs are not always available in an objective way and the degree of preference for one project versus another needs to be expressed. In many cases it is unrealistic (Cook and Seiford 1982).

The other programming techniques all have similar formulas which can be solved using a computer programme.

A *multi-objective binary programming method* is proposed by (Carazo*, et al.* 2009) for the selection of project portfolios which takes into account organisational objectives. These objectives are often in conflict with each other as well as optimal project scheduling which makes for allowance of uneven availability and consumption of resources.

The *multiple test framework* proposed by (Chapman*, et al.* 2006) consists of a traffic light process where individual projects are submitted to six tests, each of which has a simple traffic light outcome. If a project gets a green light for all six measures it is accepted. A red light on any of the measures means immediate disqualification. A project with one or more orange lights is reconsidered at the next planning phase.

This method allows for more criteria than purely NPV to be taken into account. For marginal and complex choices however the review process becomes a lot more difficult (Chapman*, et al.* 2006).

The *Fuzzy R&D portfolio selection method* uses fuzzy set theory to convert fuzzy project information into a crisp integer programming mathematical method which selects projects from a risk averse perspective (Wang and Hwang 2007).

The *fuzzy regression and fuzzy optimisation method* use fuzzy regression to assess relationships between factors and non-symmetric triangular fuzzy coefficients to deal with the vagueness that cannot be modelled with symmetric fuzzy coefficients (Sener and Karsak 2007).

The *mathematical programming method using both ordinal and cardinal data* measures qualitative data on an ordinal scale for inclusion in the mathematical process (Saen 2006b).

The optimisation methods are on the whole complicated to apply and for that reason were not considered for this study.

3.4.1.5. Strategic methods

Various strategic planning methods are discussed in the literature. These methods allow allocations of resources to multiple organisational elements, organisational constraints and resources as well as multiple time periods are considered. The methods are limited to use in periodic processes. A summary of strategic methods with authors is shown in Table 3-8.

Table 3-8: Summary of strategic methods

Methodology description	Author(s)
Cluster analysis	Lee and Song 2007; Martino 1995
Decision tree diagramming	Martino 1995
Decision process methods	Martino 1995
Matrix analysis	Singh 2004
Fuzzy consistent matrix	Haung, *et al.* 2009
Quality function deployment matrix	Kim, *et al.* 1997; Lowe, *et al.* 2000
Systems approach: R&D risk and scientific merit	Costello 1983
Authority activity method	Bergman and Buehler 2004
Iteration between requirements and project selection	Bergman and Mark 2002
Interactive project selection method	Archer and Ghasemzadeh 1999; Martino 1995
Life cycle engineering method	Pecas, *et al.* 2009
Portfolio method for strategy and selection	Phaal, *et al.* 2006
Technology roadmap	Shenbin, *et al.* 2008
Systems approach	Bergman and Mark 2002; Costello 1983
Benefit, resource and technical interdependency method	Santhanam and Kyparisis 1996
Options theory and mean variance theory method	Wu and Ong 2008
Digraph and matrix method	Rao and Padmanabhan 2006

These methods are discussed in more detail in the sections that follow. *Cluster analysis* focuses on selecting projects which support the strategic positioning of an organisation. In essence the list of projects is taken and clustered together in a hierarchy according to their degree of similarity. A cluster or clusters of projects are then funded which support the organisational strategy (Martino 1995). The main advantage of this method is that clusters which support the most important objectives of the organisation are funded (Martino 1995). On the other hand funding all the projects in one cluster and not funding the other clusters may mean that the organisation can lose competitive advantage which could be obtained with a more balanced portfolio.

Decision tree diagramming can be used for project selection when the decision maker is faced with a series of projects to choose from and with chance outcomes following each choice. At the end of the sequence of choices and chances some payoff will be achieved (Martino 1995). The advantage of this method is that decision tree theory can be used to prune the branches of the tree, which guides the decision maker as to which choice will achieve the highest expected value. Further, decision trees are simple to use and can be easily incorporated in a spreadsheet. The disadvantage of this approach is that the probability of the possible outcomes has to be known with a reasonable degree of certainty (Martino 1995).

The *decision process methods* are the most sophisticated techniques which have been developed for project selection and resource allocation. These methods have been proposed by (Mandakovic and Souder 1985). They are based on a hierarchical organisation involving multiple divisions in the decision process.

The *fuzzy consistent matrix methodology* uses technology fore-sighting as an evaluation indexing system consisting of a fuzzy consistent matrix to select technology (Haung*, et al.* 2009).

The *quality function deployment matrix* is used to identify customer requirements, technical requirements and future services. A planning matrix, technology and interrelationship matrix is then prioritised to set technical targets (Kim*, et al.* 1997; Lowe*, et al.* 2000).

The *systems approach considering risk and scientific merit* is a multi-hierarchy approach as senior management determines and ranks the priorities, middle managers and research staff generate the proposals and middle management evaluate the proposals according to the priorities set by senior management (Costello 1983)

NASA use an *authority-activity method* for the selection of technologies for the new millennium programme (Bergman and Buehler 2004) which combines organisational authority and procedural activities required during technology selection.

Another systems approach consists of *iterations between requirements and project selection* to select a portfolio of projects (Bergman and Mark 2002).

The *interactive project selection method* on the other hand follows an iterative process between project managers and decision makers until the best projects are selected (Archer and Ghasemzadeh 1999; Martino 1995).

The *life cycle engineering method* compares the performance of technologies over the life cycle of these technologies in three independent dimensions namely, economic; technical and environmental (Pecas*, et al.* 2009).

The *portfolio method for strategy and selection* assesses and manages the risks, competence, business benefit, supporting strategy, benchmarking, assessment and auditing of technology portfolios (Phaal*, et al.* 2006).

Technology can also be selected by using a *technology roadmap* which gives a time-phased view of the relationship between products and markets (Shenbin*, et al.* 2008).

In the Costello (1983) *systems approach* attempts to gather the existing information from different parts of the organisation in a systematic way. Different parts of the organisation assess R&D risk and scientific merit is specifically evaluated (Costello 1983).

The Bergman (2002) *systems approach*, selects projects using an iterative process between requirements analysis and project selection. The advantages in following a systems approach are that there is normally a strong commitment to research projects selected, the important differences in the alternative research proposals are highlighted and the approach is relatively simple. The main disadvantage is the time that must be spent in meetings to reach consensus.

The *benefit, resource and technical interdependency method* identifies and models benefits, resources and technical interdependencies among candidate projects (Santhanam and Kyparisis 1996).

Project selection method using *options theory and mean variance theory* maps projects according to probability of success and uncertainty of risk of the investment. Different portfolios are then drawn up, given probability and risk which can then be used by decision makers to select the optimal portfolio of projects (Wu and Ong 2008).

The *digraph and matrix method* uses a digraph to determine the relative importance between factors and then a matrix to calculate the selection index (Rao and Padmanabhan 2006).

The strategic methods are relatively complex to apply. In the African context decision makers do not necessarily have the required skills to apply the more complex methods and for this reason were not considered for this study.

3.4.1.6. Two phase methods

Several two phase methods exist in which selection of projects and technologies are done in two phases. These methods normally apply two filters to the selection process and one or both of the filters can be one of the methods already discussed. A summary of the two phase methods with author(s) is shown in Table 3-9.

Table 3-9: Summary of two phase methodologies

Methodology description	Author(s)
Practical technology selector	Shehabuddeen, *et al.* 2006;;
Multi-attribute theory and probabilistic network method	Bard and Feinberg 1989
Data envelopment analysis and multi-attribute decision theory method	Khouja 1995
Filter system for technology selection	Yap and Souder 1993

The *practical technology selector* uses two filters, namely, technology selection requirements and technology adaption (Shehabuddeen*, et al.* 2006).

The *multi-attribute theory and probabilistic network method* first ranks and eliminates inferior technologies and then assigns resources using a probabilistic network which is solved using Monte Carlo simulations (Bard and Feinberg 1989).

The *data envelopment analysis and multi-attribute decision theory method* first identifies which technologies are the best solution for the problem from vendor specification and then uses a multi-attribute decision making method to select the most appropriate technology (Khouja 1995).

The *filter system for technology selection* first eliminates the technologies which do not support the missions, capabilities and environment of the organisation and then uses a utility method with linear programming to select the technologies to be funded based on the available resources (Yap and Souder 1993). A two filter approach was contemplated for this study as the first filter excludes the worst fit technologies and in that way simplified the decision making problem.

3.4.1.7. Combination methods

Combination methods combine the methods already discussed in this section. Several methods are discussed in the literature which combine the methods already discussed.

Table 3-10 illustrates through a matrix what the methods are which have been discussed and showing who the authors of the methods are. The matrix shows various methods (already discussed in paragraph 3.1.4.3) in the first column and in the first row. The authors that have used a combination of methods are then indicated in the row and column where the methods that they combine intersect.

Table 3-10: Combination of methodologies by author (s)

	AHP	Fuzzy AHP	ANP
Delphi	Prasad and Somasekhara 1990;		Kengpol and Tuominen 2006
Fuzzy Delphi	Shen, *et al.* 2009 plus patent co-citation	Hsu, *et al.* 2010	
Goal programming	Yurdakul 2004		Lee and Kim 2000
Cost benefit and statistical analysis	Kengpol and O'Brien 2001		
Mixed integer programmeming	Malladi and Mind 2005		
Fuzzy replacement analysis	Tolga, *et al.* 2005		

As most of these combination methods are based on comparative methods they can be considered for this research.

3.4.1.8. Ad hoc methods

Ad hoc methods are those methods that do not readily fall into one of the categories described above. There are several ad hoc methods that are referred to in the literature. Some of these methods include profiles, interactive selection and the genius award method. A summary of the ad hoc methods with author(s) is shown in Table 3-11.

Table 3-11: Summary of ad hoc methods

Methodology description	Author(s)
Profile method	Martino 1995
Interactive project selection method	Archer and Ghasemzadeh 1999
Genius award method	Hall and Nauda 1990

To use the *profile method*, each project is given a score on each of several characteristics, for example cost, market share, market size, and probability of success. For each characteristic a preset threshold is set. If the characteristics of a project fall below the preset cut-off the project is rejected (Martino 1995). The advantages of this method are that profiles are easy to display and are an effective starting point for negotiations on thresholds. Profiles are also an effective means for reporting to higher management since profiles directly show the effects of each threshold. Profiles however do not always deliver the optimal solution.

For the *interactive project selection method*, an interactive and iterative process is followed between project champions and responsible decision makers until a choice of the best projects is made (Archer and Ghasemzadeh 1999). According to (Martino 1995) this has the advantage that the selection criteria become better and better as the process proceeds. On the other hand (Martino 1995) states that if the objectives are too narrowly defined at the outset, many potential rewarding projects will never be proposed.

The *genius award method* simply provides funding to proven researchers to work on any project of their choice (Hall and Nauda 1990). The advantage of this method is that researchers are motivated to deliver because they are working on their favourite subject. The disadvantage is that strategic objectives and planning are not necessarily taken into account.

The ad hoc methods discussed above were not considered further in this study as these methods do not address multiple factors.

The paragraph that follows addresses the framework of factors that was developed in this study.

3.4.2. Framework of factors

The selection of technologies and projects is a complex problem as can be seen from the plethora of selection methods available. Each of these selection methods attempts to select the best alternative from a large number of alternatives to give the best long term solution for the problem. Each of the selection methods further uses a list, set or framework of factors as an input. This section explores how a framework of factors is designed.

Technology selection should focus on factors which can be collected and enforced objectively, and business-related criteria are important (Ahsan 2006). It is therefore important to have factors which can be easily collected and objectively measured.

Various descriptions are used to distinguish factors that can be numerically measured from those which cannot in literature. These include objective and subjective (Chan*, et al.* 2000); quantitative and qualitative (Bick and Oron 2005); and economic and non-economic (Bhavaraju 1993). The problem with objective, quantitative or economic factors is that absolute values for these factors are not always available during the selection phase and also these factors do not give the entire picture.

As with dropping a pebble in a pond, the selected technology does not only influence the project which it is selected for but also the business environment and the external environment as shown by the concentric circles in Figure 3-2. Technologies have certain factors which influence their success or failure, these are shown in the pink circle; technologies need to succeed in order to positively influence factors in the business environment, these are shown in orange; finally technologies have to operate successfully in an external environment in order to positively influence influence factors in this environment.

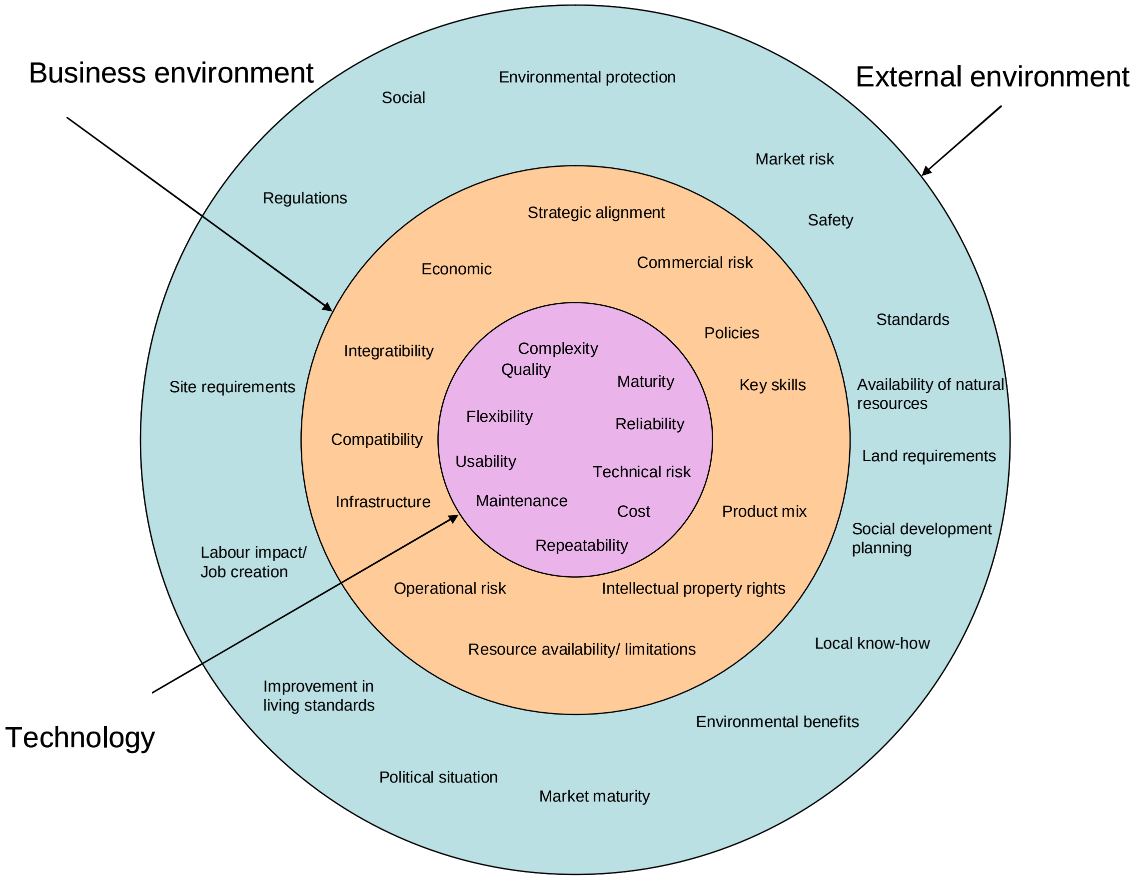


Figure 3-2: Summary of generic technology selection factors from the literature

The ultimate success or failure of technology is not only dependent on the factors related to the technology but is also influenced by factors in the business environment and the external environment. Furthermore the choice of technology is influenced by the environment and the environment is influenced by the technology.

Various authors (Beccali*, et al.* 2003; Bhavaraju 1993; Bick and Oron 2005; Chan*, et al.* 2000; He*, et al.* 2006; Lee and Hwang 2010b; Shehabuddeen*, et al.* 2006) discuss factors to take into account for the selection of technologies in specific applications. A summary of these factors at a generic level is shown in Figure 3-2. These factors are seen to be generic at this stage as they have been gathered from the above authors from different application areas. The purpose of this study is to determine which of these factors are cardinal to the selection renewable energy projects in Africa.

Ultimately all these generic factors will have an influence on renewable energy technology selection in Africa. The purpose of this study is to determine a framework of the most essential factors to ensure the long term impact of sustainable energy technologies in Africa and in that way provide decision makers with a tool for selecting factors.

3.4.3. Basket of measures

A basket of measures is required to measure each factor in the framework. There are various ways in which factors can be measured. Whether the measure of a factor is numeric or non-numeric is dependent on the type of factor. For non-numeric factors several methods of rating are used:

Linguistic scales. Qualitative linguistic scales can be used to to assign a rating to a factor (Beccali, *et al.* 2003; Jeong and Abraham 2004; Lowe, *et al.* 2000; Masood and Soo 2002; Pecas, *et al.* 2009; Prasad and Somasekhara 1990). An example of a linguistic scale is: “Very applicable”, “Applicable”, “Not applicable”, “Certainly not applicable”. Linguistic scales are sometimes converted into triangle fuzzy numbers (Chan, *et al.* 2000).

Weighting. A weight is assigned for each factor and a total weighted score calculated for each alternative (Haung, *et al.* 2009; Hsu, *et al.* 2010; Shehabuddeen, *et al.* 2006).

Pair-wise comparison. Saaty’s fundamental scale for pair-wise comparison can be used to determine the relative weight of each factor (Bick and Oron 2005; Lee and Hwang 2010a; Luong 1998; Malladi and Mind 2005).

3.5. Conclusion

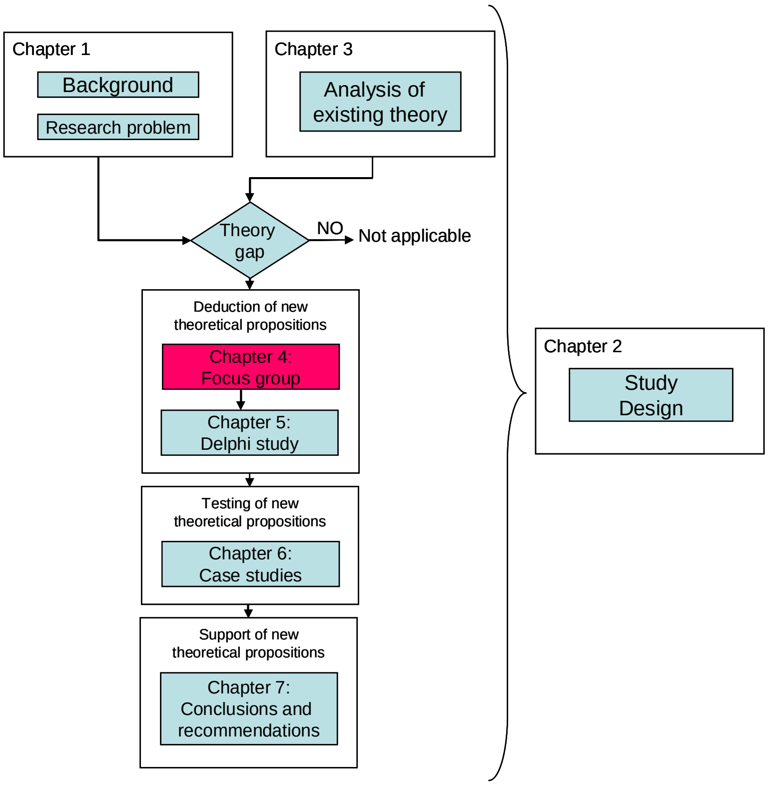
The implementation of renewable energy technology in Africa is required to improve the quality of life of the people in Africa. There are many benefits to the introduction of renewable energy technologies.

Several selection methodologies have been developed for both project and technology selection. The effectiveness of these methodologies is dependent on the framework of factors used to populate the selection methodology.

In the theory gap portrayed in Figure 1-6, the framework of factors for the implementation of renewable energy technologies in Africa, does not exist and the purpose of this study was to develop an appropriate framework and obtain empirical support for the framework.

Chapters 4 to 6 which follow cover the focus group, Delphi and case study research done to develop the required framework.

Chapter 4: Focus Group



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4.1. Introduction

The purpose of the focus group was to gather information on as many factors as were required for the selection of renewable energy technologies as possible from experts in the field. These factors were then used as an input to the Delphi study.

The main stages of the focus group process are: planning, recruiting, moderating, and analysis and reporting (Blackburn 2000) as shown in Figure 4-1. During the planning stage, the researcher familiarised herself with the focus group technique and did a literature survey on the factors which are important for the selection of sustainable energy technologies.

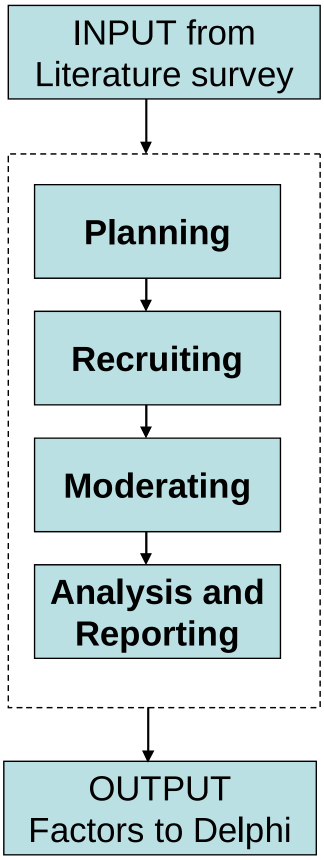


Figure 4-1: Main stages of the focus group process (Blackburn 2000)

4.2. Planning and recruiting

The role of the moderator or facilitator is critical to the success of the focus group (Blackburn 2000; Delbecq, *et al.* 1975). The moderator must clearly state the purpose and the consequential expectations of the group, facilitate interaction (Gibbs 1997) by outlining the topics to be discussed and control the direction of the conversation (Blackburn 2000). The moderator is the conversational controller (Hutt 1979) who promotes open debate by using open-ended questions and probes deeper into motivations for statements made (Gibbs 1997). The moderator further ensures that the conversation does not drift but that the group addresses the key topics of interest (Blackburn 2000; Delbecq, *et al.* 1975).

Focus groups are in-depth, open-ended group discussions. This implies that the focus group is not very structured (Robinson 1999). Focus groups should be semi-structured but not highly structured (Hutt 1979). The use of an interview guide or list of questions to be answered during the focus group is recommended (Blackburn 2000; Hutt 1979; Robinson 1999). It is important to limit the number of questions. Whether the interview is more or less structured will depend on the specific application (Blackburn 2000).

To this end, a presentation was prepared during the planning stage. This was used to inform the participants about the purpose of the focus group. The structure planned for the focus group is shown in Table 4-1.

Table 4-1: Focus group structure

Item	Description
1.	Purpose, rationale and methodology of the study
2.	Identification of the most important factors for project selection
3.	Classification of factors
4.	Preliminary ranking of factors
5.	Identification of Delphi study participants

The literature survey during the planning stages identified the eleven factors important for the selection of renewable energy technologies listed in Table 4-2.

Table 4-2: Factors identified during the literature review

Quantitative factors	Qualitative factors
Economic measures Future savings in capital Operational and maintenance costs Profits Improvement in productivity	Political and senior management support Client and public support Environmental impact Technical and educational relevance Interface to existing projects Impact on project portfolio

Focus groups can consist of pre-existing groups if those groups have the expertise required (Bloor, *et al.* 2001). For this study, the existing group in the CSIR were selected because these scientists all have interest in and experience of sustainable energy. In the literature there is little consensus on the size of a focus group with recommendations for the size of a focus group ranging from four to fifteen participants (Gibbs 1997), six to ten (Blackburn 2000), and up to fourteen (Ouimet*, et al.* 2004). Group sizes of more than eight become less manageable (Blackburn 2000). Focus groups can vary in size from three to fourteen participants and small groups can be an advantage if the topic is complex or when dealing with experts (Bloor*, et al.* 2001). It is important to choose a group of people that are not too heterogeneous so that participants will be comfortable in sharing their views (Gibbs 1997).

The existing Council for Scientific and Industrial Research (CSIR) group consisted of five individuals and knew each other from previous projects. Each of these individuals was contacted personally and asked to participate, and all five agreed. The arrangements were made at the beginning of December 2006 for the end of January 2007. This could explain the fact that only three individuals participated in the focus group in the end. December is a vacation period in South Africa and people often make new plans after the holidays without considering previous commitments.

The typical duration of a focus group can be one to two hours (Gibbs 1997 Robinson 1999) or 75 to 90 minutes (Ouimet*, et al.* 2004). The focus group in this study was scheduled for three hours. The focus group was semi-structured. An introduction was given by the moderator, participants were then allowed to discuss the parameters in the study, and a nominal group technique was then used to identify factors. The factors were classified and participants were asked to supply the names and contact details of possible participants for the Delphi study.

Some of the disadvantages, discussed above, can also be mitigated by using the nominal group technique in conjunction with the focus group technique (Ouimet*, et al.* 2004). The nominal group technique is a group meeting technique which is structured in such a way that participants silently generate ideas, after which these ideas are discussed by the group (Delbecq*, et al.* 1975). This ensures that all participants air their views and that the ideas of one participant do not dominate. This method was also used in this study.

The ethical standards of a focus group, in line with the requirements of the University of Pretoria (South Africa) were met. Full information on the purpose and objectives of the study were given to the participants beforehand (Gibbs 1997). It is important that focus group sessions are tape recorded to facilitate data analysis (Blackburn 2000; Gibbs 1997; Hutt 1979; Ouimet*, et al.* 2004; Robinson 1999) but permission must be obtained from the respondents before doing so (Hutt 1979). The confidentiality of the participants must also be ensured by not identifying individuals in any publications (Blackburn 2000). The permission of the participants was obtained and the focus group session was tape recorded.

It is important that a facility is selected which is neutral to the group or if a pre-existing group exists, their regular meeting room can be used (Gibbs 1997). The focus group was held in a conference room at the CSIR in Pretoria, South Africa, as this was a place familiar to all participants.

4.3. Data gathering and analysis

4.3.1. Panel selection

Focus groups can consist of pre-existing groups if those groups have the expertise required (Bloor, *et al.* 2001).

As a pre-existing group existed in the CSIR it was decided to use this group to provide the first inputs for the study. All the members of the panel are involved in renewable energy projects in the CSIR. They are also part of the group which is involved in the NEPAD energy platform. The members of the panel were as shown in Table 4-3.

Table 4-3: Focus group participants

Name	Surname	Affiliation	Energy interest
Christelle	Beyers	CSIR, Built Environment	Sustainable human settlements
Thomas	Roos	CSIR, Defence, Peace, Safety and Security.	Renewable energy technology
Brian	North	CSIR, Material Science and Manufacturing	Clean coal technologies
Monga	Mehlwana	CSIR, Natural Resources and the Environment	Energy policy
Alan	Brent	CSIR, Natural Resources and the Environment	Sustainability of energy technologies

Christelle Beyers and Monga Mehlwena were unable to attend the session. This meant that the focus group consisted of 3 members.

4.3.2. Focus group session

The focus group session was structured as shown in Table 4-4.

Table 4-4: Focus group agenda

Item	Description	Duration	Responsible
1.	Purpose, rational and methodology of study	30 minutes	Marie-Louise Barry
2.	Identification of factors for technology selection	1 hour	All
3.	Classification of factors	1 hour	All
4.	Preliminary ranking of factors	30 minutes	All
5.	Identification of Delphi study participants	30 minutes	All

4.3.3. Purpose, rationale and methodology of the study

A previously prepared presentation included in Appendix A was presented to the focus group. The purpose of the presentation was to sketch the background to the study.

The focus group was tape recorded with the permission of the attendees. A list of summarised discussing points is given in Appendix B.

4.3.4. Identification of the factors for technology selection

The nominal group technique was used to identify factors to be considered when selecting renewable energy technologies in Africa. This technique was used rather than the interacting group technique. The nominal group technique produces better ideas as it does not inhibit the creative process (Delbecq, *et al.* 1975).

The focus group was conducted using a nominal group technique as follows.

Each participant was given six pieces of paper which would result in the generation of 18 factors. The participants were then asked to independently write down the six factors which in their opinion were the most important for the selection of renewable energy projects. The participants were asked to work independently and not discuss their ideas.

Before the participants started this task, however, the question was raised as to how a sustainable energy project is defined. Did it mean that projects would continue after implementation or did it mean that projects would have a triple bottom line, i.e. make a profit, be environmentally friendly, etc?

After this, each participant identified six factors. The pieces of paper where then taken in by the moderator. Each factor was discussed by the group and clarified. If what the participant wrote on the piece of paper was not clear, it was clarified. Any new factors that came out during the discussion were written down on a new piece of paper and also classified. The factors were pasted on a white board and a preliminary classification of factors was done.

Once all 18 initial factors were discussed, participants were given the opportunity to write down independently any other factors which they felt had been overlooked. The same process of discussion, clarification and classification was then followed.

In conclusion, the researcher presented factors which she had identified from the literature. Those factors which had not yet been added and were deemed important by the participants were then added.

The final factors identified are as follows:

1. Maturity of technology – proven track record
2. End of life, exit strategy or decommissioning plan in place
3. Maintenance/support
4. Transfer of knowledge and skills
5. Create employment/ not eliminate jobs
6. Equity/ GIMI – income for more than one sector of the economy
7. Education – skills development
8. Empowerment for education
9. Local content (Labour component) Create industry
10. Regulatory financial incentive, tax regimes need to be supportive, institutional capacity
11. Does it fit under national priorities (Self evident? E.g. role of women)
12. Must contribute to and not detract from energy security
13. Environmental impact assessment
14. Available budget – the finances to support a project
15. Equity financing
16. Compliance for green funding
17. “Local Hero” – champion to continue after implementation
18. Passion/ ownership/ buy-in/ adoption by community, Responsibility
19. Ability to replicate (up-scaling)
20. Must match available resources (HR. natural, wind, solar, water, gas, geothermal etc) Infrastructure
21. Pilot study site selection issues
22. Resource beneficiation/ optimisation land, water etc.
23. Partnerships along the value chain
24. Efficient use of energy
25. Community engagement

26. Community acceptance (can traditional structures be accommodated?)
27. Society/Institution trust – see community acceptance
28. Specific local factors – resource availability, access to market, size and skills level of community
29. Must positively affect GDP at national level
30. Economic development (community eventually able to pay) economic sustainability
31. Ability to profitably sustain after funding ends
32. Synergies (salt production and desalinated water)
33. Add value to raw product
34. Community income generation
35. Proper project management
36. Training of personnel
37. Capacity
38. Financial capability

4.3.5. Classification of factors

During the identification a preliminary classification of factors was made by pasting the pieces of paper on the whiteboard in different clusters. To classify the factors, some of the clusters were combined. The following final classifications were decided on:

1. Technology factors
2. Social factors
3. Institutional regulatory factors (compliance)
4. Site selection factors
5. Economic/ Financial factors
6. Achievability by the specific organisations

4.3.6. Preliminary ranking of factors

For a first order indication of the importance of factors, the participants were then given five stickers numbered one to five and asked to stick them next to the factors which they felt were most important as shown in Table 4-5.

Table 4-5: Preliminary ranking of factors

Importance	Participant 1	Participant 2	Participant 3
1.	Regulatory financial incentive, tax regimes must be supportive, institutional capacity	Community engagement	
2.	Does it fit under national priorities (Self evident? e.g. role of women	Must match available resources (HR. natural, wind, solar, water, gas, geothermal etc) Infrastructure	Community income generation
3.	Ability to replicate (up-scaling)	Ability to profitably sustain after funding ends	
4.	Maintenance/Support	Local content (Labour component) Create industry	
5.	Create employment/ not eliminate jobs	Must contribute to and not detract from energy security	Synergies (salt production and desalinated water)

Because there were only three participants and a wide range of factors was identified by them as important, this was not the final answer but rather a preliminary indication of the importance of factors.

4.3.7. Identification of Delphi study participants

At the end of the session, each participant was given a sheet to complete in which they were asked to identify individuals whom they thought might be willing to participate in the Delphi study.

4.4. Conclusions and recommendations

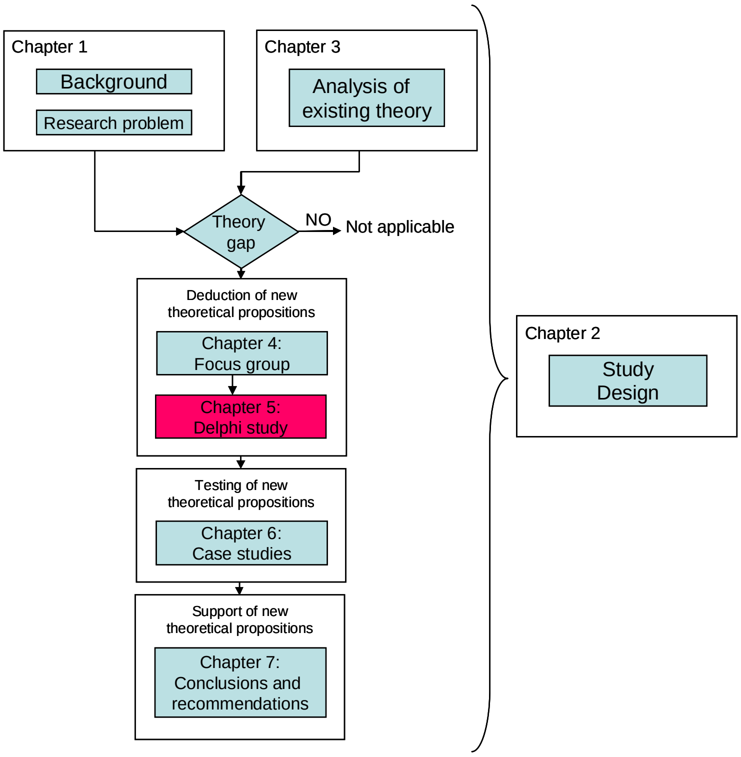
The thirty eight most important factors that need to be taken into account during the selection of energy technological systems in Africa were identified, categorised and rated. The eleven factors identified during the literature survey were expanded to thirty eight factors in the focus group. The categorised factors which were identified and which were used as an input to the Delphi study are shown in Figure 4-2.

Technology factors	***Social factors***	***Achievability by performing organisation***
Maturity of technology – proven track record End of life exit strategy or decommissioning plan in place Maintenance or support Transfer of knowledge and skills	Create not eliminate jobs Equity – income from more than one sector of the economy Education – skills development Empowerment for education Local content – labour component Create industry	Proper project management Training of personnel Capacity Financial capability
Site selection	***Institutional/ Regulatory factors (compliance)***	***Economic/ Financial factors (profit and return)***
Local hero – champion to continue after implementation Passion/ownership/buy-in/adoption by community/responsibility Replicability – can be up scaled Must match available resources (human, natural, infrastructure etc) Pilot study site selection Resource beneficiation/ optimisation land, water etc Partnerships along value chain Efficient energy use Community engagement Community acceptance – can traditional structures be accommodated Society/institutional trust Specific local factors-resource availability, market size, and skills level of community	Regulatory financial incentive, tax regimes must be supportive, institutional capacity Does it fit under national priorities (for example role of women) Must contribute to and not detract from energy security Environmental impact assessment Available budget-finances to support a project Equity financing Compliance for green funding	Must positively affect gross domestic product at national level Economic development (community eventually able to pay) economic sustainability Ability to profitably sustain after funding ends Synergies (for example salt production and desalinated water) Add value to raw product Community income generation

Figure 4-2: Categorised factors

The participants in the focus group also contributed names of 19 experts in the field of sustainable energy who would possibly take part in the subsequent Delphi study. The purpose of the Delphi study was to expand on the factors identified during the focus group in the first round and then to prioritise the most important factors during the second round.

Chapter 5: Delphi study



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5.1. Introduction

During the literature survey and focus group of this research study thirty eight factors were identified which should be taken into account when selecting renewable energy technologies in Africa.

In this Delphi study the objectives were to expand on the previously identified factors which need to be considered when selecting sustainable energy technologies for Africa, estimate the relative importance, feasibility and desirability of each factor to produce a prioritized list of factors, and to explore the underlying assumptions of judgements and reasons for disagreement between respondents.

The procedure followed in the Delphi portion of this study is shown in Figure 5-1.

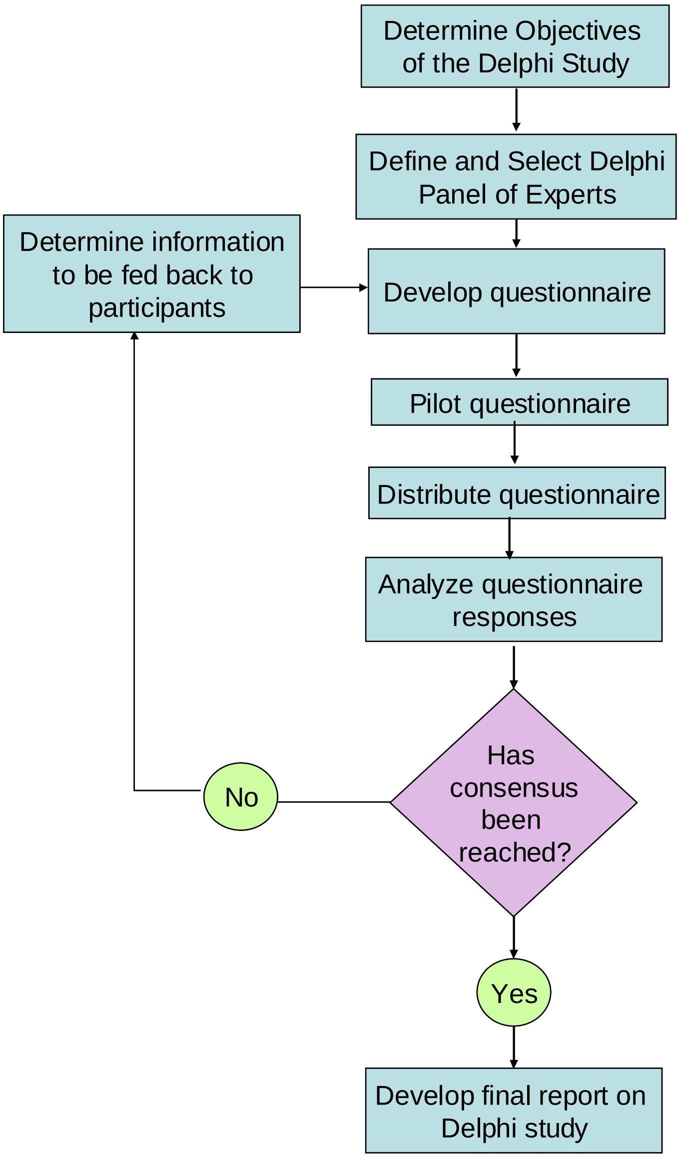


Figure 5-1: Suggested procedure for engineering and technology management research

The first step is to determine the detailed objectives of the Delphi study. This is followed by defining and selecting the Delphi panel of experts. The first round questionnaire is then developed and piloted. The questionnaire is distributed and the responses are analysed. If consensus has not been reached after the first round, information is extracted from the responses of the questionnaire that is then fed back to the respondents for consideration during the second round. The same process is repeated for the second and following rounds of the study. If consensus is reached after the end of a round, the final report on the Delphi study is developed.

The process that was followed is discussed in more detail.

5.1.1. Definition and selection of the panel of experts

A knowledge nomination worksheet approach was followed to select the respondents. The list of respondents is contained in Appendix C. A total of 62 respondents were identified during this phase. The last column in the Appendix C indicates who nominated the respondent. A reason why this person is suited to take part in this study is also given.

The main search categories are shown in Figure 5-2,

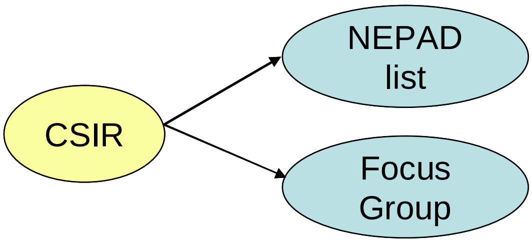


Figure 5-2: Search category CSIR

The focus group was conducted with CSIR personnel. Members of the focus group nominated respondents. The CSIR are in the process of corresponding with other researchers in the New Partnership for Africa's Development (NEPAD) on the topic of sustainable energy. The database of researchers was included in this study under the NEPAD list. The list was supplied by Alan Brent.

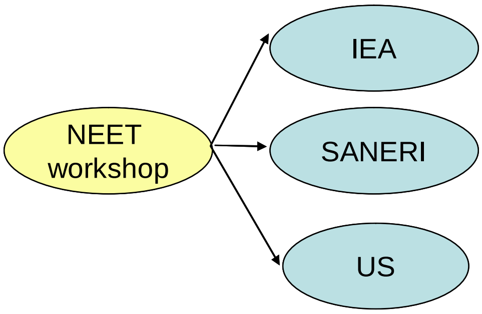


Figure 5-3: Search category NEET workshop

The researcher attended the South African Network of Expertise in Energy Technology (NEET) workshop on Energy Technology Collaboration on 20 February 2007 at the Sandton Convention Centre. Contacts were obtained there from the International Energy Agency (IEA), the South African National Energy Research Institute (SANERI) and Stellenbosch University.

Using the inputs from the information obtained from the CSIR and the NEET workshop, an internet search was done to identify further respondents. Other South African universities namely, the University of Cape Town (UCT), the University of the Witwatersrand (Wits) and the University of Johannesburg (UoJ) were found to have capabilities in sustainable energy.

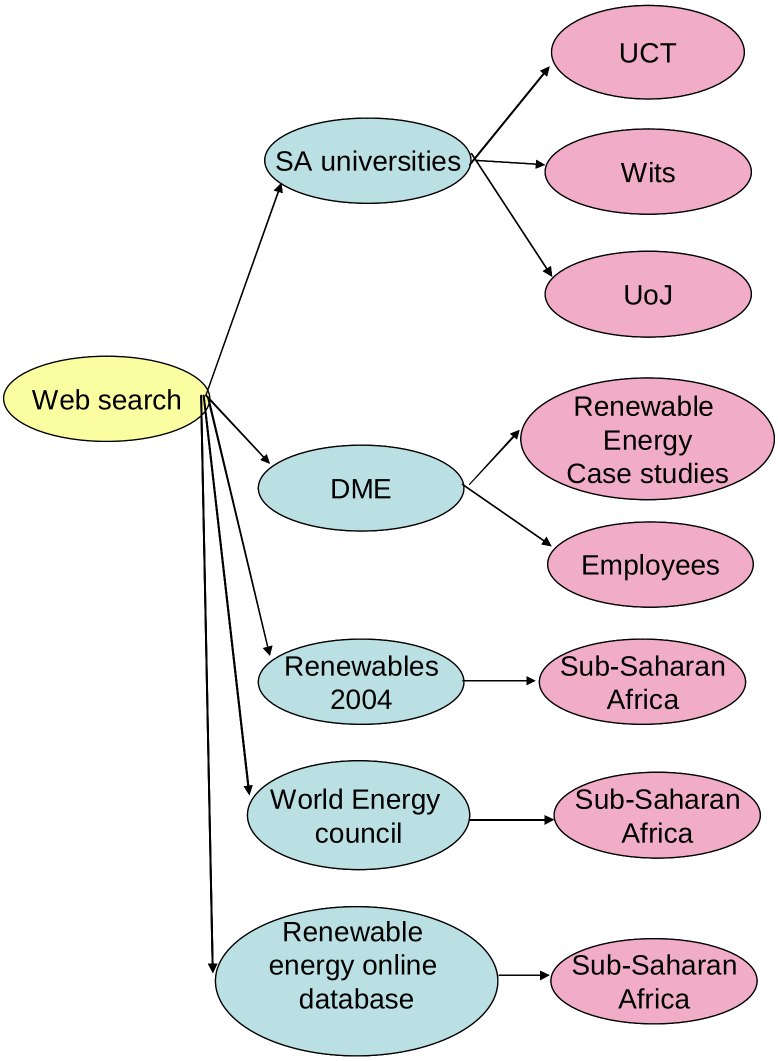


Figure 5-4: Search category Web search

The website of the Department of Mineral and Energy Affairs (DME) was investigated. Some of the employees of the DME were added and a list of sustainable energy case studies was found and the contact persons for these case studies were added to the list of respondents.

In searching for the details of some of the respondents identified by the focus group, three additional websites with relevant information were identified. The first was the website for Renewables 2004, International Conference for Renewable Energies which was held in Bonn from 1 to 4 June 2004. This website listed all delegates to the conference but without contact details. The country of origin of each delegate was given. A further web search was then undertaken to identify the contact details of delegates from Sub-Saharan Africa.

On the World Energy Council website, contact details of those who deal with projects in Sub-Saharan Africa were added to the list. The renewable online database is a database with the names of people worldwide who are involved in renewable energy projects. Once again the contact details of those working in sub-Saharan Africa were added to the list of respondents so as to compile a list of 62 suitable respondents who were then used for the first round of the Delphi study.

5.2. Data gathering process

The data gathering process used in this Delphi study is shown in Figure 5-5.

The factors identified from the focus group are used as an input for the generation of the first questionnaire, after which the questionnaire is piloted. In parallel to the questionnaire development, the characteristics of the participants are identified and possible participants are identified. The first round questionnaire is then administered and the data analysed. The second round questionnaire is then prepared using the analysed data from the first round questionnaire as an input. The second round questionnaire is piloted, administered and the data gathered is analysed. A decision is then made if another Delphi round is required. If another round is not required as was the case in this study, the final report is generated. In this study the final factors from the Delphi study were then used as an input to the case study.

5.2.1. Develop Questionnaire

The questionnaire was compiled using the factors identified during the focus group. The questionnaire was implemented in SurveyMonkey in such a way that the document in portable document format (PDF) could be sent to participants who do not have access to the Internet. The web-based survey meant that respondents entered their data directly into the SurveyMonkey database and as a consequence data capturing was not necessary, which cancelled out data capture errors.

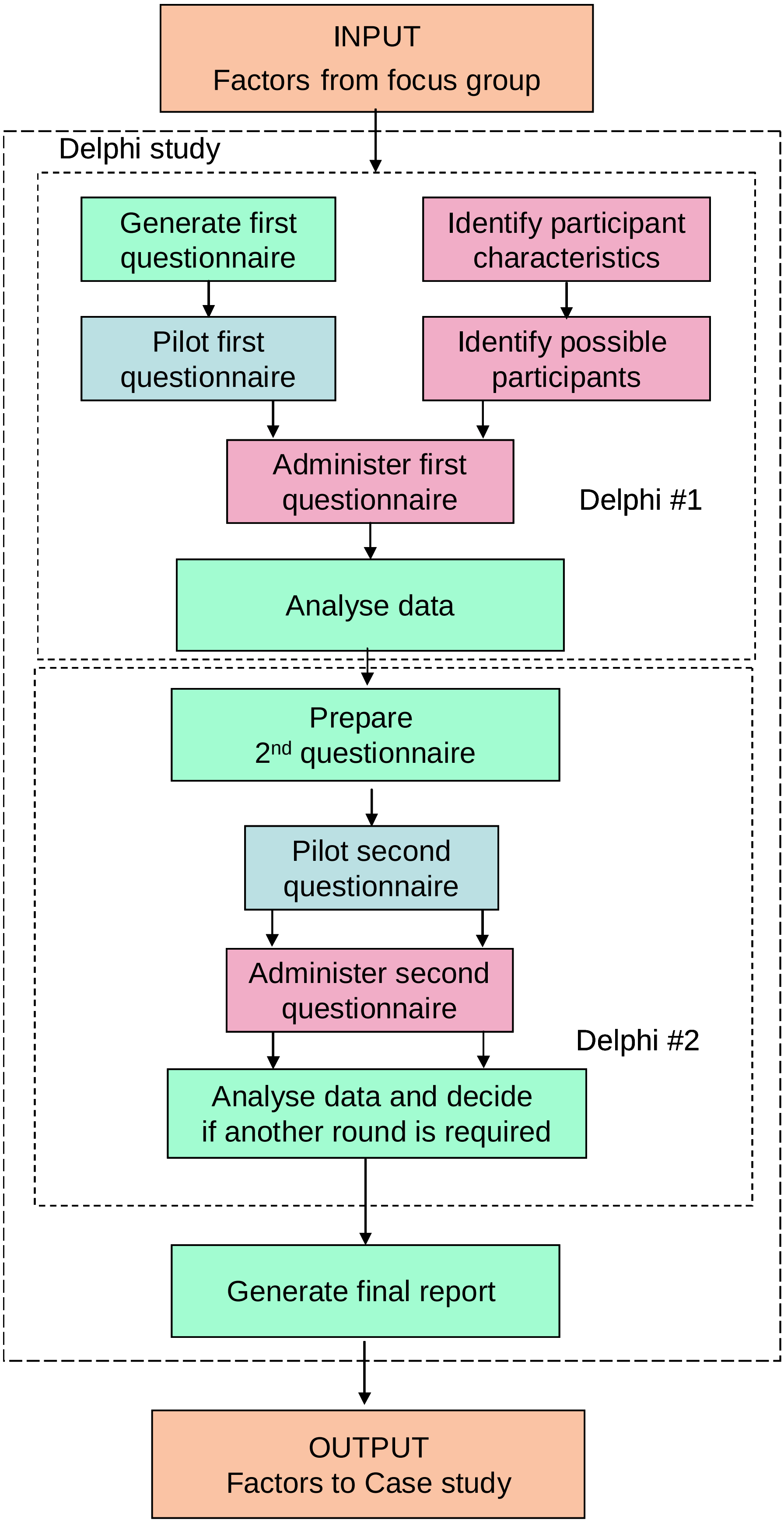


Figure 5-5: Delphi data gathering process

The questionnaire consisted of the following sections:

Rationale of the study. In this section the reason for the study, anonymity of respondents, study leaders, result distribution, number of rounds and time to complete the study were detailed.

Demographic information. This section captured the following demographic information on each respondent: e-mail address, geographical area, type of organisation, years of experience in the energy field, publications in the energy field, highest qualification, monetary value of projects, indemnity.

Introduction to Delphi cycle 1. The purpose of this section was to give the respondents a background on the questionnaire and how to complete it. The table to be used for evaluation of desirability, feasibility and importance was also presented here for the first time (see Table 5-3).

Section for each factor. Each factor was presented in its category namely, technology factors, social factors, institutional or regulatory factors, site selection factors, economic or financial factors, or factors in terms of achievability by specific organisation. The description of the factor categories, as obtained from the focus group, is given as shown in Table 5-1. The respondents were then given the opportunity to comment on the wording of the factors, place the factor in a different category if desired, evaluate the factors in terms of desirability, feasibility and importance which are defined in

Table 5-2 (a link is provided to Table 5-3) and motivate their reason for desirability, feasibility and importance of the factors.

Additional factors. For each category of factors, the respondents were given the opportunity to add four more factors if they wished. They were asked whether they wished to add more factors and if they responded positively, they were taken to a screen to enter an additional factor. If they answered negatively they were taken to the next factors. On the additional factor screen they were asked to enter the description of the additional factor, evaluate the factor in terms of desirability, feasibility and importance, and to motivate the desirability, feasibility and importance.

Participant motivation. On the penultimate screen of the survey, participants were asked how pertinent their answers were to the objective of the study, whether they were still motivated to continue, and whether the study would have value in their organisation.

End of survey. On the final screen of the survey, participants were asked to estimate the time taken to complete the survey, and to add any other comments they had on the study.

Table 5-1: Descriptions of categories

Category	Description
Technology factors	These factors are related to the maturity and complexity of the technological system.
Social factors	These factors relate to the community where the technological system will be implemented.
Institutional regulatory factors (compliance)	These factors relate to the applicable laws, regulations and government priorities.
Site selection	These factors related to the physical as well as people side of the site selection.
Economic/ financial factors (profit and return)	These factors relate to the economic and financial viability of implementing the technological system.
Achievability by the specific organisation	These are the factors which must be taken into account in terms of the specific organisation that will be implementing the technological system.

The rating method for factors as proposed by Jillson (1975) to rate objectives in a study on a national drug-abuse policy was used. Jillson (1975) proposes that three ratings namely feasibility, importance and desirability be used for rating. A detailed definition as shown in Table 5-3 was given to the participants to ensure that each participant used the same interpretation for each scale reference point. In essence feasibility relates to whether it is feasible and practicable to have the information required to investigate a factor available during the proposal phase; desirability relates to the benefit to the final outcome to consider the factor during the proposal phase; and importance relates to the priority which the factor should have for consideration during the proposal phase.

Table 5-2: Definition of Importance, Feasibility and Desirability

Evaluation measure	Definition
Feasibility	The feasibility of taking this factor into account during the selection of renewable energy technology, i.e., whether the information can be obtained and quantified.
Importance	The importance of the factor relates to the relevance of taking this factor into account during technology selection.
Desirability	The desirability of a factor relates to the benefit or advantage that the use of this factor will have for technology selection.

Table 5-3: Table for evaluating desirability, feasibility and importance of factors (Adapted from (Jillson, 1975))

Likert No	Desirability scale	Feasibility scale	Importance scale
1.	Highly desirable Factor has positive and little or no negative effect on success of implementation Factor justifiable on own merits	Highly feasible to gather information during proposal phase Minimum additional resource required No major political roadblocks in utilising this factor	Highly relevant. First order of priority Factor has direct bearing on major issues for technology selection Must be resolved dealt with or treated
2.	Desirable Factor has positive and minimum negative effect on success of implementation Factor justifiable in conjunction with other factors	Feasible to gather information during proposal phase Some additional resource required Some political roadblocks in utilising this factor	Relevant factor. Second order of priority Factor has significant impact on issues for technology selection Does not have to be fully resolved
3.	Neither desirable nor undesirable Factor has equal positive and negative effect on success of implementation Factor justifiable in conjunction with other desirable and highly desirable factors	Contradictory evidence that information can be gathered during proposal phase Increase in resource required Political roadblocks in utilising this factor	May be relevant factor. Third order of priority Factor may have impact on issues for technology selection May be a determining factor to a major factor
4.	Undesirable Factor has little or no positive effect on success of implementation Factor may be justifiable in conjunction with other highly desirable factors	Some indication that information cannot be gathered during proposal Large scale increase in resource required Major political roadblocks in utilising this factor	Factor insignificantly relevant. Low order of priority Factor has not impact on issues for technology selection Not a determining factor to a major factor
5.	Highly undesirable Factor has major negative effect on success of implementation Not justifiable	Information required cannot be gathered during proposal phase Unprecedented allocation of resources required Politically unacceptable	Factor not relevant. No priority Factor has no impact on issues for technology selection Factor should be dropped

5.2.2. Pilot study

The questionnaire for the pilot round of the survey (referred to as Delphi #1) is given in Appendix D.

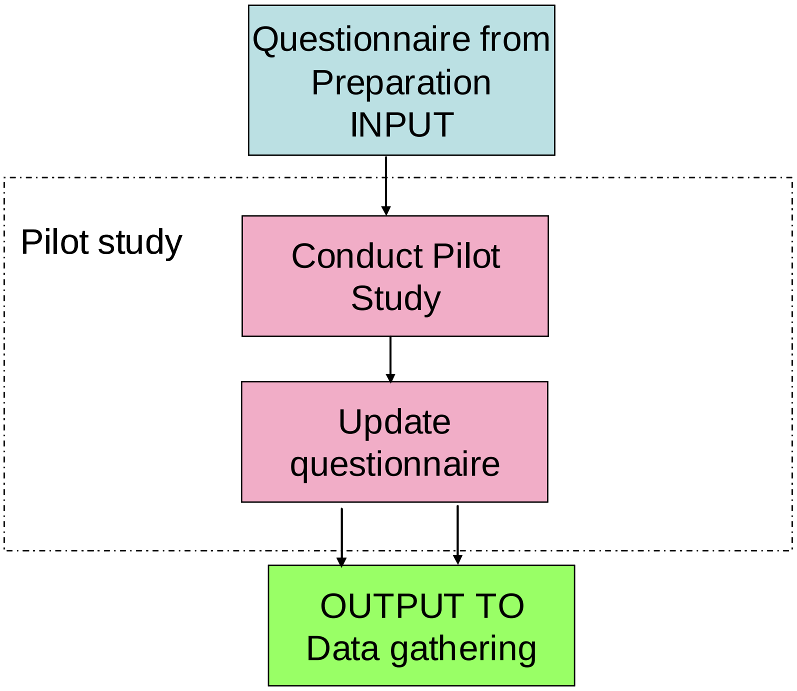


Figure 5-6: Steps in the pilot study

The pilot study was launched on 5 June 2007. The survey was sent to four respondents. The two study leaders had already given input to the study during the BETA 1 to 4 iterations of the survey questionnaire. The BETA 5 iteration of the questionnaire was sent to the pilot panel. Three of the respondents completed the survey online and one respondent completed the paper-based version.

For purposes of the pilot study the survey was changed to allow respondents the opportunity to comment on each page.

The results of the pilot study and the changes made to the questionnaire are contained in Appendix E.

5.2.3. First round Delphi

5.2.3.1. Data gathering

The steps followed during the data gathering process are shown in Figure 5-7.

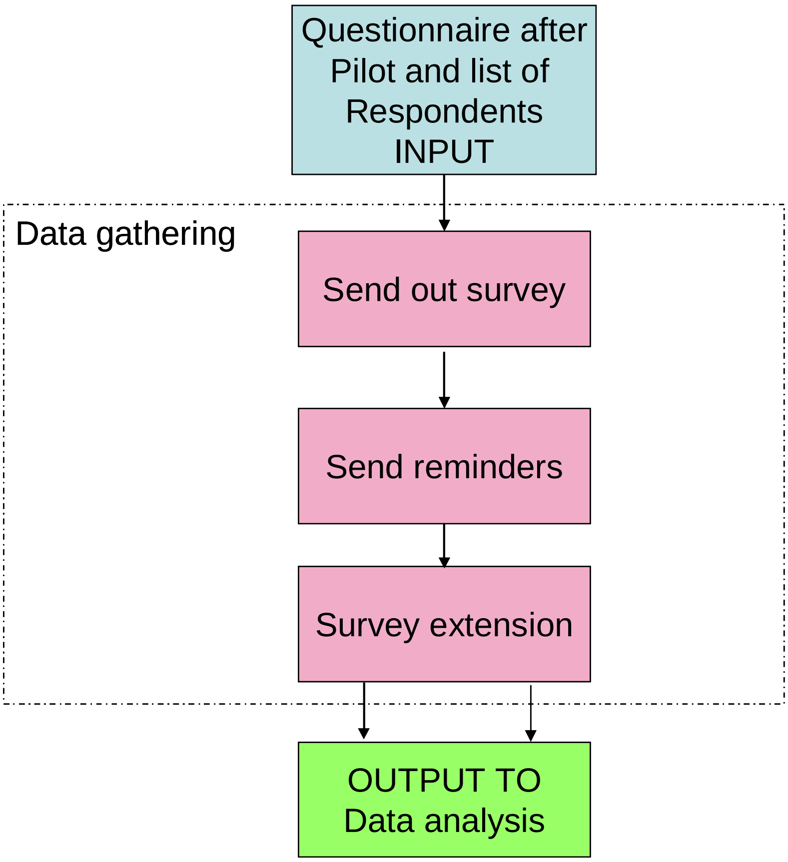


Figure 5-7: Steps in the data gathering process

The survey was sent out on 1 October 2007 using the SurveyMonkey collection tool. In this tool one enters the names of the respondents and then one composes an e-mail which is subsequently sent to all the respondents. The total list of 62 respondents was entered. The e-mails of 11 recipients bounced back. This meant that they were not able to complete the survey, which brought the list of respondents down to 51. The respondents who did not receive the survey are indicated with an asterisk (*) in Appendix C. All the correspondence is shown in Appendix F.

A copy of the survey is shown in Appendix G. Only one of the factors is shown as each of the factors has exactly the same information.

Regular reminders were sent every week during the study. The reminders were sent out on 8 October, 15 October and 18 October. By the closing date, only three respondents had participated. Personal reminders were then sent out to the NEPAD participants by one of the study leaders. Reminders were sent to those respondents who had started the survey and not completed it. Finally an extension to the survey was created and sent out to all the selected respondents. The PDF version of the survey was also sent this time with instructions as to how to fax back the results. By 30 October, more than 7 respondents had answered the questions; only the last question had 6 respondents.

5.2.3.2. Data analysis Delphi #1

The survey was started by 17 respondents. All these respondents supplied the demographic information required. The number of respondents in each section is shown in Table 5-4.

Table 5-4: Number of respondents per section

Respondent ID	Demo-graphics	Category evalua-tion	Factor Evalua-tion	Techno-logy factors	Social Factors	Institutional factors	Site Selection factors	Economic factors	Achievability factors	Participant motivation	End of survey
No of Respondents	17	6	11	8	7	7	7	7	6	5	4

Demographic information

As stated above, 17 respondents supplied demographic information. In the analysis of this information, only those respondents who continued with the study were analysed. The respondents who completed the first four sections were analysed. This entailed 11 respondents.

The geographical region of the respondents is shown in Figure 5-8.

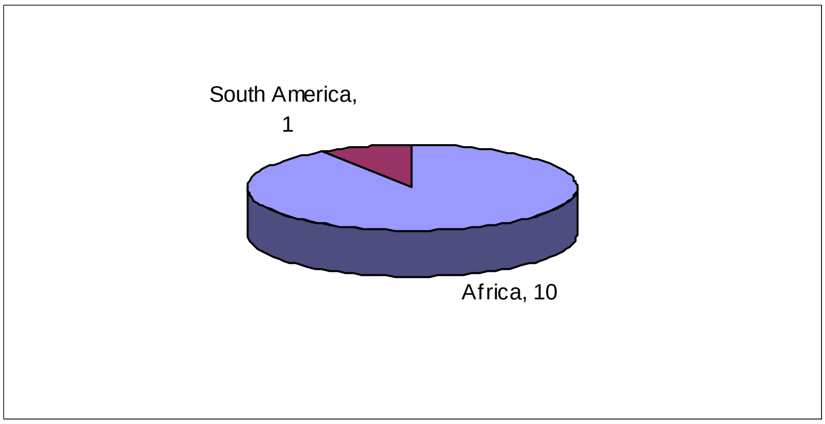


Figure 5-8: Number of respondents per region

As indicated in Figure 5-8, 10 of respondents are from Africa and only one from South America. Since the focus of the study is Africa, this is acceptable. Africa and South America are both seen as third world continents, so the respondent from South America can share lessons learned in this continent, which will also be applicable to Africa.

The respondents were asked to select one of the following types of organisation:

- Donor agency
- Research organisation/ university
- Government

- Project developers/implementer
- Energy (electricity)
- Technology company (fuel cells, PV supplier etc.)
- Multi-lateral institution (NEPAD, EU, SADC)
- Other (please specify)

Two of the participants who selected “other” indicated that they worked in an energy consultancy and one indicated a petrochemical company (Figure 5-9). As can be seen from the figures, the respondents are well distributed among the different types of organisations, with no type of organisation dominating.

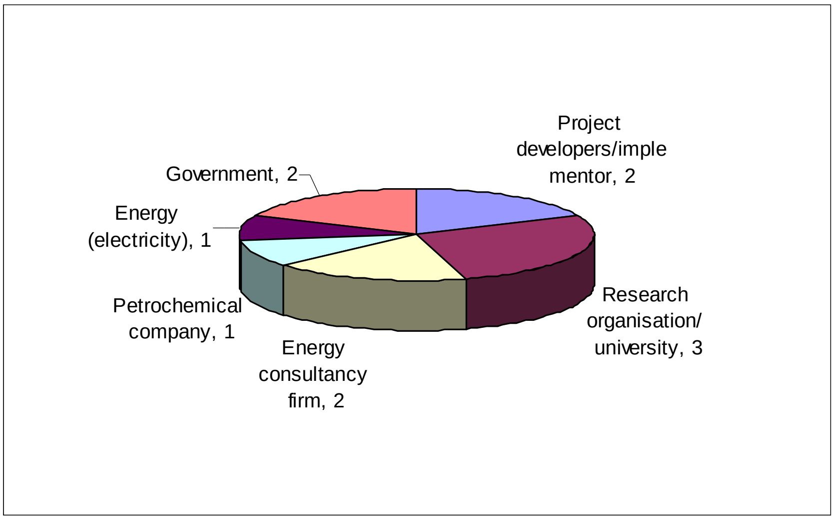


Figure 5-9: Number of respondents per type of organisation

The total years of experience came to 201, with an average of 20.5, a minimum of 10 and a maximum of two. This meant that the respondents had significant experience in the field of renewable energy.

Respondents were asked how many publications they had in the field of energy. Publications included journal papers, conference papers and books. Three respondents did not answer this question with one indicating that he/she had lost count. Of the nine respondents who did respond, the total number of publications is 373, the average 41.5, the minimum 3 and the maximum 135. This indicated that the panel is by and large respected by their peers in the field.

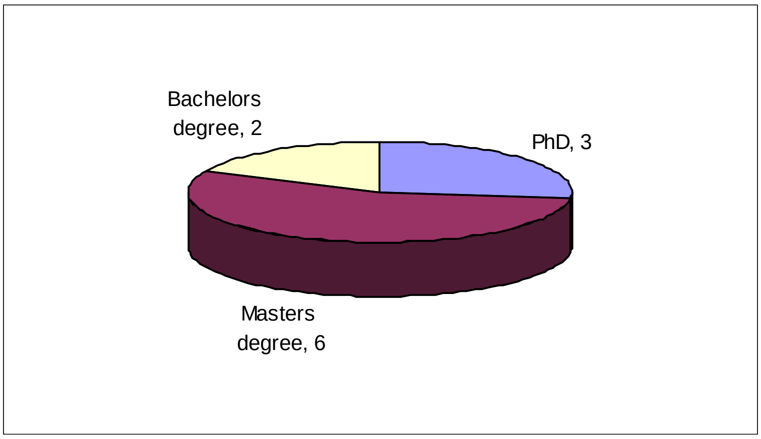


Figure 5-10: Number of respondents per qualification

The respondents were asked to indicate their highest qualification. The options given were as follows:

- PhD
- Masters degree
- Bachelors degree
- Graduate diploma
- Other (please specify)

One respondent selected "other", his/her qualification is Dipl.Ing. Mechanical (German). This has been equated to a bachelor's degree as the German methods of awarding qualifications differ from those in Africa.

Only ten of the respondents answered the question relating to the monetary size of the project in which they were involved. The projects of the respondents varied from four of the respondents being responsible for projects between $1 million to $ 10 million to one respondent having projects of more than $1 billion as shown in Figure **5-11**.

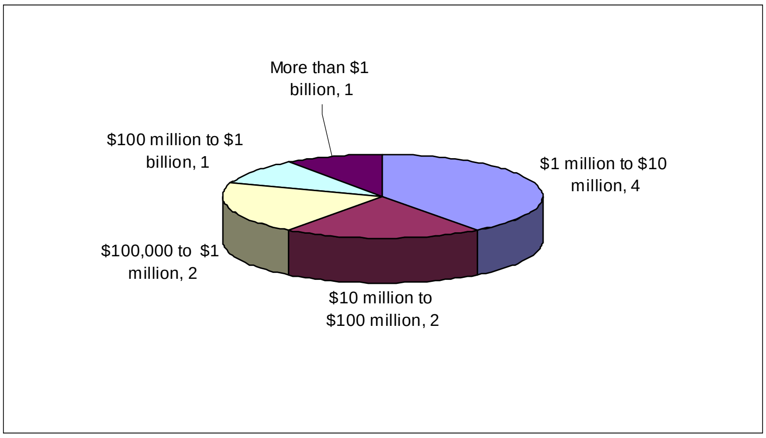


Figure 5-11: Number of respondents for size of project determined by cost

Categories and categorisation of factors

The analysis of the categorisation of factors is included in Appendix H. The descriptions of Table 5-1 were refined and the final descriptions are shown in Table 5-5. The final categories for factors are shown in Table 5-6.

Table 5-5: Category descriptions

Category	Description
Technology factors	These factors are related to the maturity, accessibility, adaptability and complexity of the technological system."
Social factors	These factors relate to the community where the technological system will be implemented
Institutional/ regulatory factors	These factors relate to the applicable laws, regulations and government priorities as well as regulation of donor agencies
Site selection factors	These factors are related to the physical (including infrastructure) as well as people side of the site selection
Economic/ financial factors	These factors relate to the economic and financial viability of implementing the technological system, this includes a good IRR as well as availability and access to financing and life cycle costs
Achievability by specific organisation factors	These are the factors that must be taken into account in terms of the specific organisation that will be implementing the technological system."

Table 5-6: Final categories for factors

Category	Description
Technology factors	Maturity or proven track record of technology in the world Ease of maintenance and support over the life cycle of the technology Ease of transfer of knowledge and skills to relevant people in Africa Synergy of technology with other available technologies Replicability (i.e. the possibility of up scaling) Must match available resources

Category	Description
Social factors	Create employment/ not eliminate jobs Share holding equity – income for more than one sector of the economy Local labour used and new industries created
Institutional/ regulatory factors	Degree of environmental impact of the technology Does it fit under national priorities? Must contribute to, not detract from national energy security Positive EIA Compliance for green funding
Site selection factors	Local champion to continue after implementation Adoption by community Suitable site readily available for pilot studies
Economic/ financial factors	Existence of tax and other financial incentives Availability of finance Possibility of equity financing by local partners Implementation of technology must be profitable Economic development Synergy with other types of projects Reliability of energy supply in the African context
Achievability by specific organisation factors	Project Management Human resource capacity Technological capacity Financial capacity Political capacity

Factor evaluation

The detailed evaluation of each factor is shown in Appendix H. The detailed calculations for the means for feasibility, desirability and importance can also be found in Appendix H.

The means of all the factors for feasibility, desirability and importance have been summarised in Table 5-7. The factors are also ranked. The factors are ranked first according to feasibility. If a factor is not feasible it does not matter whether it is desirable and important. The factors are then sorted according to desirability and then importance.

Table 5-7: Factors sorted according to feasibility, desirability and importance

1st round factor ID	1st round factors	Feasibility	Desirability	Importance
T2	Ease of maintenance and support over the life cycle of the technology	1.56	1.78	1.56
SS3	Suitable site readily available for pilot studies	1.71	1.71	1.43
I7	Compliance for green funding	1.71	1.86	2.29
T1	Maturity or proven track record of technology in the world	1.78	1.78	1.89
I4	Positive EIA	1.86	1.71	1.57
T5	Reliability of energy supply in the African context	1.89	1.78	1.56
T4	Degree of environmental impact of the technology	1.89	2.00	1.56
A1	Project Management	2.00	1.50	1.67
A2	Human resource capacity	2.00	1.67	1.67
I5	Availability of finance	2.00	1.71	1.71
T8	Must match available resources	2.11	1.67	1.67
I3	Must contribute to, not detract from national energy security	2.14	1.86	1.86
SS1	Local champion to continue after implementation	2.14	1.71	2.00
T3	Ease of transfer of knowledge and skills to relevant people in Africa	2.22	1.89	1.78
E1	Implementation of technology must be profitable	2.29	1.71	1.57
SS2	Adoption by community	2.29	1.71	1.71
I2	Does it fit under national priorities	2.29	1.86	2.14
S1	Create employment/ not eliminate jobs	2.43	2.14	2.43
A5	Political capacity	2.50	1.83	1.67
T7	Replicability (i.e. the possibility of up scaling)	2.56	2.11	2.00
S3	Local labour used and new industries created	2.57	1.71	1.57
I1	Existence of tax and other financial incentives	2.57	1.57	1.71
A4	Financial capacity	2.67	1.83	1.50
A3	Technological capacity	2.67	2.17	2.00
T6	Synergy of technology with other available technologies	2.67	1.89	2.11
E2	Economic development	2.71	2.14	2.29
I6	Possibility of equity financing by local partners	2.71	1.71	2.43
E3	Synergy with other types of projects	2.83	2.50	2.33
S2	Share holding equity – income for more than one sector of the	3.00	2.00	2.57

The factors were prioritised and are discussed in more detail below using the scoring system shown in Table 5-8 (Jillson, 1975).

Table 5-8: Scoring system for prioritisation (Jillson, 1975)

Mean value	Desirability scale	Feasibility scale	Importance scale
Less than 1.8	Highly feasible	Highly desirable	Highly important
Less than 2.6 and equal to or greater than 1.8	Feasible	Desirable	Important
Less than 3.4 and equal to or greater than 2.6	Neither feasible nor infeasible	Neither desirable nor undesirable	Neither important nor unimportant
Less than 4.2 and equal to or greater than 3.4	Infeasible	Undesirable	Unimportant
Less than 4.2	Highly infeasible	Highly undesirable	Highly unimportant

No factors were rated to be of indeterminate importance or indeterminate desirability, infeasible, highly infeasible, undesirable, highly undesirable, unimportant or highly unimportant.

A summary of the number of factors that were rated highly feasible is shown in terms of desirability and importance in Table 5-9. No factors were rated to be of indeterminate importance or indeterminate desirability.

Table 5-9: Summary of desirability and importance ratings for highly feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	3	1	0
Desirable	0	1	0
Indeterminate desirability	0	0	0

The highly feasible factors with high desirability, high importance or importance are shown in Table 5-10. Two technology factors and two site selection factors are included in this table. The information for SS4 however, is based on the evaluation of only one respondent as this is a newly added factor.

Table 5-10: Factors rated highly feasible, highly desirable, highly important or important

Factor No	Factor description
SS3	Suitable site readily available for pilot studies
SS4	Access to suitable sites can be secured
T1	Maturity or proven track record of technology in the world
T2	Ease of maintenance and support over the life cycle of the technology

A summary of the number of factors which were rated feasible is shown in terms of desirability and importance in Table 5-11. No factors were rated to be of indeterminate importance or indeterminate desirability.

Table 5-11: Summary of desirability and importance ratings for feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	1	1	0
Desirable	3	4	0
Indeterminate desirability	0	0	0

The feasible factors with high desirability, high importance, desirability or importance are shown in Table 5-12. These factors are evenly distributed amongst the factor categories.

Table 5-12: Factors rated feasible, highly desirable, highly important, desirable or important

Factor No	Factor Description
A1	Project Management
A2	Human resource capacity
E1	Implementation of technology must be profitable
E4	Reliability of energy supply in the African context
E5	Existence of tax and other financial incentives
E6	Availability of finance
I1	Does it fit under national priorities
I2	Must contribute to, not detract from national energy security
I3	Positive EIA
S1	Create employment/ not eliminate jobs
S3	Local labour used and new industries created
SS1	Local champion to continue after implementation
SS2	Adoption by community
T5	Replicability (i.e. the possibility of up scaling)
T6	Must match available resources

A summary of the number of factors that were rated neither feasible nor infeasible is shown in terms of desirability and importance in Table 5-13.

Table 5-13: Summary of desirability and importance ratings for factors with indeterminate feasibility

	Highly important	Important	Indeterminate importance
Highly desirable	0	1	0
Desirable	1	6	0
Indeterminate desirability	0	0	0

The feasibility of six factors was indeterminable. The reason for this was either that some respondents rated the factor feasible while others rated it infeasible and those that are truly indeterminate as the modal response are neither desirable nor undesirable. The distribution of these indeterminable factors are shown in Table 5-14.

Table 5-14: Distribution of indeterminable factors

Factors indeterminate in terms of feasibility		Very high	High	Indetermir	Low	Very low	Mode
A2	Human resource capacity	0.0%	50.0%	25.0%	25.0%	0.0%	2
I4	Compliance for green funding	0.0%	25.0%	62.5%	12.5%	0.0%	3
S2	Share holding equity – income for more than one sector of the economy	0.0%	0.0%	100.0%	0.0%	0.0%	3
E7	Possibility of equity financing by local partners	0.0%	12.5%	62.5%	25.0%	0.0%	3
A5	Political capacity	0.0%	62.5%	62.5%	25.0%	0.0%	3
Factors indeterminate in terms of importance							
S2	Share holding equity – income for more than one sector of the economy	12.5%	12.5%	62.5%	12.5%	0.0%	3

Pertinence of responses, motivation of respondents and value to organisations

The participants were asked to comment on the pertinence of their answers to the questions, their motivation to continue with the survey and whether the results of the survey would be valuable to their organisation. The detailed results are contained in Appendix H.

The aims of the study, namely, to develop a generic set of factors for technology selection, were not expressed clearly enough. This was rectified in the next round. Most of the respondents answering the question were prepared to continue with the study. The respondents felt that the information obtained would add value in their organisations

End of Survey

In this section, the respondents were asked the average time that they took to complete the survey and they were given the opportunity to add any other comments they wanted.

The average time to complete the survey was 61.6 minutes, which is 1.6 minutes longer than what was indicated.

Table 5-15: Other comments made by the respondents on the study

	Other comments
1.	THIS STUDY IS CAPABLE OF MOVING AFRICA OUT OF ABJECT POVERTY.
3.	Unfortunately I have little time to elaborate on open questions.

Conclusion

The information gathered in the first round Delphi was processed. The analysis was presented to the respondents in the second round as is discussed in paragraph 5.2.4.

5.2.4. Second round Delphi

5.2.4.1. Introduction

In the second round of the survey (Delphi #2) respondents were given all the factors in Table 5-7 in the current ranking order and were then asked to rank the factors using a 5 point Likert scale. Respondents were asked whether they wanted to comment on the wording or descriptions of the factors. All the respondents were finally asked to supply information on possible sites for case studies that would be conducted to verify the factors.

5.2.4.2. Preparation of Questionnaire

The questionnaire was compiled using the factors identified during Delphi #1 and shown in Appendix I. The questionnaire was implemented in SurveyMonkey in such a way that the document in portable document format (PDF) version could be sent to respondents who do not have access to the internet. The web-based survey meant that respondents entered their data directly into the SurveyMonkey database and consequently data capturing was not necessary, which cancelled out data capture errors. The questionnaire consisted of the following sections:

Introduction. In this section the purpose of the study was stated again, a link was made available for respondents to access the report on the Delphi #1 results, the estimated duration for completing the questionnaire was given and the date by which the questionnaire had to be completed was given. According to the ethical requirements of the University of Pretoria, respondents were then informed that the information they supplied would be treated confidentially and that the results would be published. Respondents were then given the opportunity to opt out of the study if they wished.

Demographic information. This section captured the following demographic information of each respondent: geographical area, type of organisation, years of experience in the energy field, publications in the energy field, highest qualification, monetary value of projects.

Factor evaluation. The factors were presented first in terms of feasibility, then in terms of desirability followed by importance. The same description for the rating of each category on a five point Likert scale, was used as in Delphi #1. Respondents could click on each factor to obtain the report on the results of Delphi #1. After the factor evaluation, respondents were asked if they wished to comment on the factor description wording. If they responded with “yes” they were taken to the section to comment. If they responded with “no”, they were taken to the final comments.

Comments on factors and descriptions. In this section, the wording of each factor as well as the wording of the description of each factor was presented to the respondents. Respondents were given the opportunity to comment on both.

Final comments. On the penultimate screen of the survey, participants were asked how long it had taken them to complete the survey and to enter any further comments on the study. The next phase of this study involved a case study to validate the factors identified during the focus group and Delphi study. For this reason, respondents were asked to recommend suitable sites for the case study.

End of survey. This section expressed thanks to the respondents for their participation.

5.2.4.3. Pilot study

A pilot study was done with four respondents. The respondents were the study leaders and two members of the Department of Statistics at the University of Pretoria. The pilot study was sent out on 20 November 2007. Positive feedback was obtained on the Delphi #2 questionnaire, especially because the time to complete had been reduced from 2 hours to 15 minutes. The pilot respondents were also of the opinion that respondents would be able to complete the survey in that time. No changes were recommended and the same questionnaire was used for the final Delphi #2 survey.

5.2.4.4. Data gathering

The survey was sent out using the e-mail facility on SurveyMonkey. The survey was sent to all the respondents (50) who had previously received the survey except for one respondent who had indicated in the Delphi #1 that he did not wish to receive further survey questionnaires. A different covering letter was used for each of the following categories of respondents: respondents who had completed the Delphi #1 survey (8), respondents who had started but not completed the Delphi #1 survey (8) and respondents who had not started with the Delphi #1 survey (34). The correspondence is attached in Appendix J.

The first e-mail was sent out on 21 November 2007. Respondents were requested to complete the survey before 1 December 2007. Reminders were sent to all respondents on 26 and 27 November 2007. Only 10 responses were received by 1 December 2007 of which only five were completed.

As the respondents of the survey are dispersed in Africa and South America and telephone numbers were not available for all the recipients, it was not possible to contact all the respondents telephonically. One of the study leaders knew some of the respondents outside South Africa and he sent all these respondents an e-mail requesting them once again to complete the survey. The researcher telephoned the respondents in South Africa for whom telephone numbers were available.

By 12 December 2007, 15 responses were received of which eight respondents completed the survey. The amount of respondents that answered each section is shown in Table 5-16.

Table 5-16: Number of respondents per section for Delphi #2

	Demographic information	**Factor evaluation**	**Comments on factors and descriptions**	**Final comments**	**Case study information**	**Completed Delphi #1**
No of respondents	13	8	0	9	6	6

This translates to a response rate of 16% (using a sample size of 50) for the factor evaluation part of the questionnaire. During the data analysis only the responses of the eight respondents who had completed the survey were utilised. Six of the respondents who participated in Delphi #1 also started with Delphi #2 but only four of these respondents completed the survey. It is not clear what the contact details of the respondents marked with a question mark are as these respondents used the link sent via e-mail to respond and not the SurveyMonkey link. The result was that SurveyMonkey could not track the identities of these respondents.

5.2.4.5. Data analysis

Demographic information

The geographic region of the respondents is shown in Figure 5-12. As in Delphi #1 the majority of respondents are from Africa with the one respondent from South America participating once again.

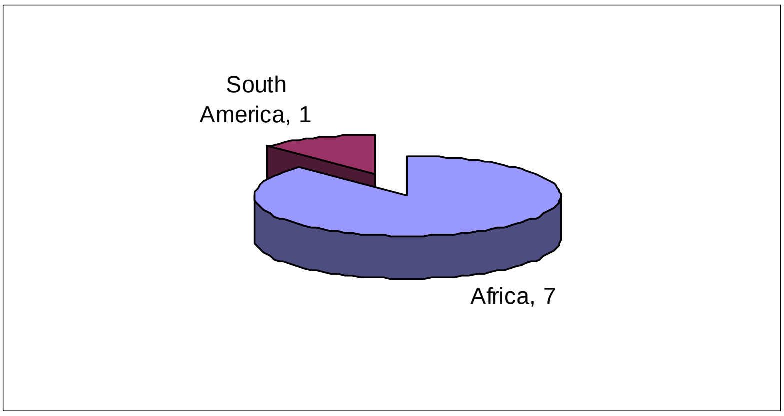


Figure 5-12: Number and percentage of respondents per geographical region

For Delphi #2 in terms of level of implementation, there was a 50/50 split in terms of macro and micro level implementation as shown in Figure 5-13.

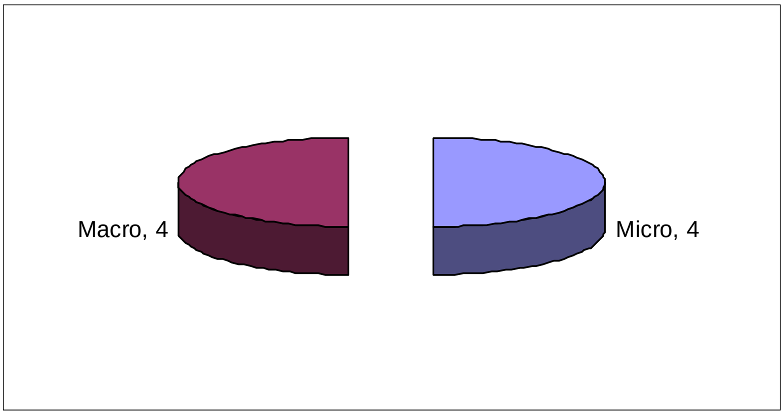


Figure 5-13: Number and percentage of respondent in terms of level of implementation

The distribution of the types of organisations in which the respondents operate, changed to the distribution shown in Figure 5-14. When compared to the results of Delphi #1, the number of respondents from research organisations or universities had increased by one as well as the number of respondents from energy suppliers. The one petrochemical company, two government organisations and two project developers/ implementers are no longer represented.

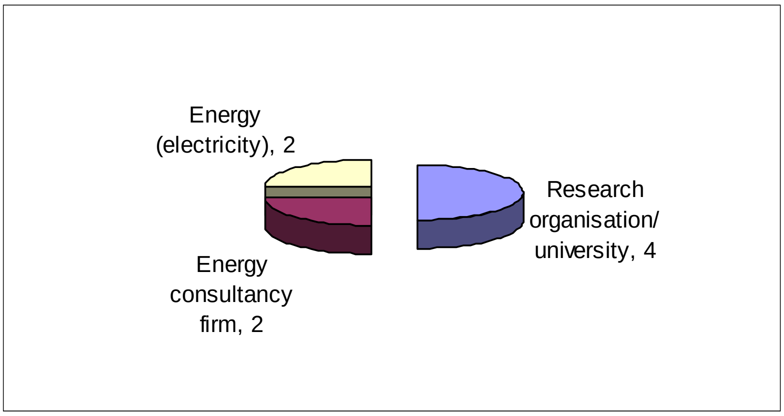


Figure 5-14: Number of respondents per type of organisations

The respondents were asked how many years experience they had in the energy field. The total years of experience came to 181, with an average of 22.6, a minimum of 10 and a maximum of 32. This meant that the Delphi #2 respondents had more experience than the Delphi #1 respondents.

Respondents were asked how many publications they had in the field of energy. Publications included journal papers, conference papers and books. Of the eight respondents who did respond, the total number of publications was 239, the average 28.8, the minimum 10 and the maximum 70. This indicated that the panel was by and large respected by their peers in the field.

The distribution of the qualifications of the respondents is shown in Figure 5-15 and this indicates an increase of one in PhDs and a decrease of two in Masters degrees when compared to Delphi #1.

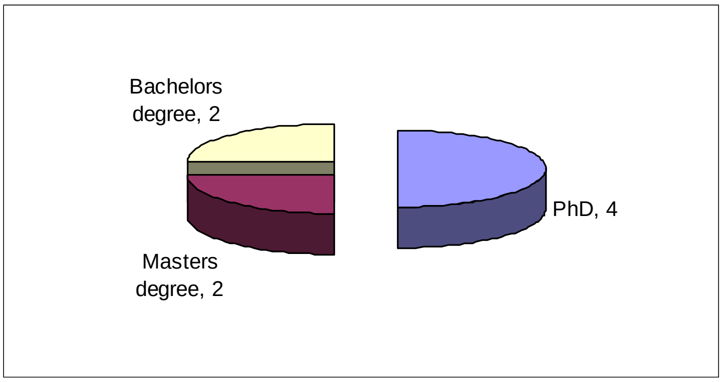


Figure 5-15: Number of respondents per qualification

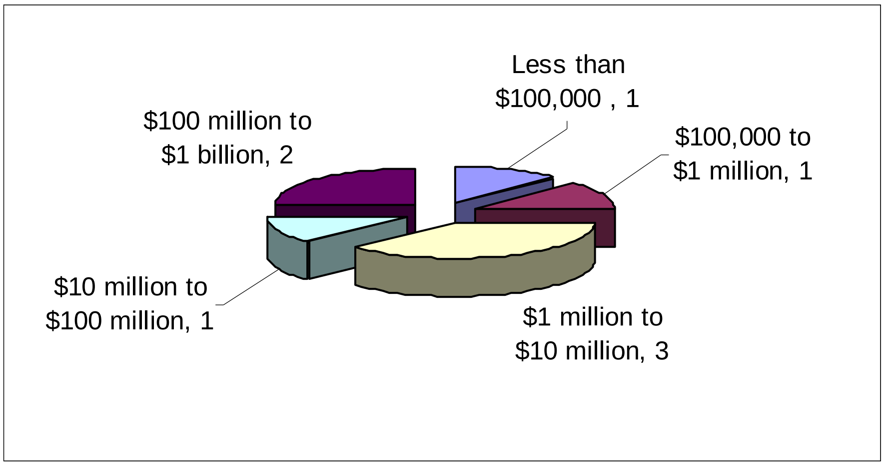


Figure 5-16: Number of respondents for size of project determined by cost

The monetary value of typical energy-related projects undertaken by the respondents changed in Delphi #2 when compared to Delphi #1. This change is shown in Table 5-17. The monetary value of the projects undertaken by the organisations in the Delphi #2 decreased from those in Delphi #1.

Table 5-17: Change in monetary value of projects respondents are involved in from Delphi #1 to Delphi #2

Monetary value	Delphi #1	Delphi #2
Less than $100,000	0	1
$100,000 to $1 million	2	1
$1 million to $10 million	4	3
$10 million to $100 million	2	1
$100 million to $1 billion	1	2
More than $ 1 billion	1	0

Factor evaluation

The factors in the questionnaire were listed in the order as prioritised at the end of Delphi #1. Respondents rated each factor on the same Likert scale as during Delphi #1. The prioritised list of factors as obtained from the Delphi #2 first in terms of feasibility, then desirability followed by importance is shown in Table 5-18. The smaller the value of the mean, the more feasible, desirable or important the factor is.

Table 5-18: Delphi #2 factors with mean values for feasibility, desirability and importance

Number	Factor Description	Feasibility	Desirability	Importance
T2	Ease of maintenance and support over the life cycle of th	2.00	1.00	1.25
T6	Must match available resources	2.25	1.88	2.13
SS1	Local champion to continue after implementation	2.25	1.38	1.38
I2	Must contribute to, not detract from national energy secu	1.88	1.88	1.75
T3	Ease of transfer of knowledge and skills to relevant peop	2.25	1.75	1.50
E1	Implementation of technology must be profitable	2.50	1.75	2.00
SS2	Adoption by community	2.38	1.63	1.75
I1	Does it fit under national priorities	2.13	2.00	1.88
S1	Create employment/ not eliminate jobs	2.25	1.50	2.13
A5	Political capacity	3.13	2.00	2.25
T5	Replicability (i.e. the possibility of up scaling)	2.13	1.75	2.00
SS3	Suitable site readily available for pilot studies	2.00	1.63	1.75
E5	Existence of tax and other financial incentives	2.38	2.38	2.13
S3	Local labour used and new industries created	2.25	1.50	2.00
A4	Financial capacity	2.50	1.75	1.50
T4	Synergy of technology with other available technologies	2.00	1.75	1.88
A3	Technological capacity	2.25	1.25	1.50
E7	Possibility of equity financing by local partners	3.13	1.88	2.50
I4	Compliance for green funding	2.88	2.25	2.38
E2	Economic development	2.13	1.50	1.63
E3	Synergy with other types of projects	2.38	1.88	2.00
S2	Share holding equity – income for more than one sector	3.00	2.13	2.75
T1	Maturity or proven track record of technology in the worl	2.13	1.63	2.13
SS4	Access to suitable sites can be secured	2.13	1.63	1.63
I3	Positive EIA	2.38	1.75	2.00
E4	Reliability of energy supply in the African context	2.25	1.50	1.88
I5	Degree of environmental impact of the technology	2.50	1.75	2.13
A1	Project Management	2.13	1.38	1.38
A2	Human resource capacity	2.75	1.50	1.25
E6	Availability of finance	2.50	1.63	1.75

The scoring system shown in Table 5-8 was used to prioritise the factors (Jillson, 1975).

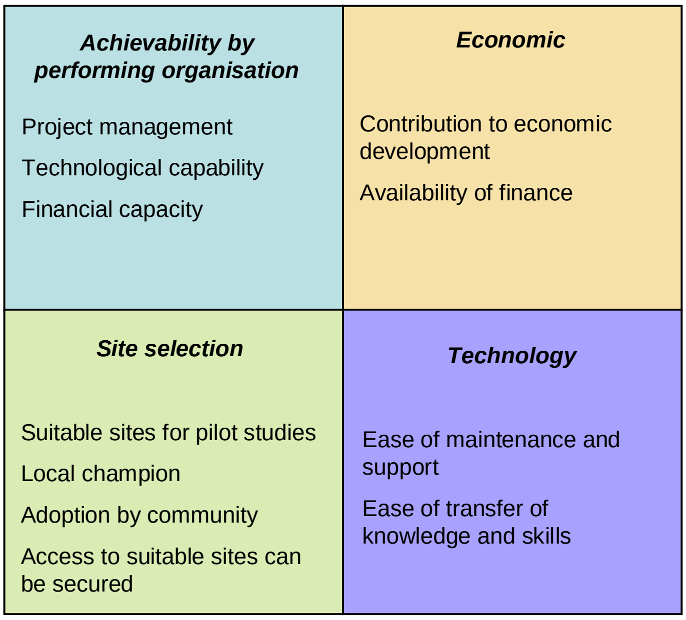
The rating scale of the feasibility, importance and desirability was the same as for the first round Delphi. None of the factors identified in this study was found to be highly feasible. This is of concern, as feasibility is related to how easily the information required to evaluate a factor can be obtained during technology selection. None of the factors was found to be infeasible or highly infeasible.

A summary of the desirability and importance ratings of the factors which scored feasible is shown in Table 5-19.

Table 5-19: Summary of desirability and importance ratings for feasible factors

	Highly important	Important	Indeterminate importance
Highly desirable	11	9	0
Desirable	1	4	
Indeterminate desirability	0	0	0

The eleven most important factors as identified during the Delphi study are shown in Figure 5-17.



Achievability by performing organisation

Project management

Technological capability

Financial capacity

Economic

Contribution to economic development

Availability of finance

Site selection

Suitable sites for pilot studies

Local champion

Adoption by community

Access to suitable sites can be secured

Technology

Ease of maintenance and support

Ease of transfer of knowledge and skills

Figure 5-17: Eleven most important factors identified in the Delphi study

The feasibility of five factors and the importance of one factor were indeterminable. The reason for this was either that some respondents rated the factor feasible while others rated it infeasible and those that are truly indeterminate as the modal response are neither desirable nor undesirable. The distributions of these indeterminable factors are shown in Table 5-20.

Table 5-20: Distributions of indeterminable factors

Factors indeterminate in terms of feasibility		Very high	High	Indetermin	Low	Very low	Mode
A2	Human resource capacity	0.0%	50.0%	25.0%	25.0%	0.0%	2
I4	Compliance for green funding	0.0%	25.0%	62.5%	12.5%	0.0%	3
S2	Share holding equity – income for more than one sector of the economy	0.0%	0.0%	100.0%	0.0%	0.0%	3
E7	Possibility of equity financing by local partners	0.0%	12.5%	62.5%	25.0%	0.0%	3
A5	Political capacity	0.0%	62.5%	62.5%	25.0%	0.0%	3
Factors indeterminate in terms of importance							
S2	Share holding equity – income for more than one sector of the economy	12.5%	12.5%	62.5%	12.5%	0.0%	3

Comments on factors and descriptions

Respondents were given the final opportunity to comment on the wording of the factors and their descriptions. None of the respondents opted to comment and it was assumed that the wording and descriptions of the factors were acceptable.

Final comments

The average time to complete the survey was 19 minutes with a minimum of 10 and a maximum of 30. This is 4 minutes more than the estimate that was made during the pilot study.

Final comments on the study were as shown in Table 5-21.

Table 5-21: Respondent comment on the study as a whole

Respondent ID	Comment
1.	I found the survey somewhat confusing to complete, as there was insufficient up front information to tell me more about the way in which factors would be used and the purpose of the ratings. Are why trying to select which factors will be applied in selecting projects, and to provide some information to help rank these factors? I think a better intro would help, or perhaps a discussion with the researcher prior to completing the survey. Also note that the order (feasibility, desirability, importance listed on the survey is different to that given in the table which describes the rankings. This may have led to confusions/inadvertent errors by those completing the survey. If the researcher does wish to discuss this with me, I would be happy to discard this version and repeat the exercise (but now better informed)
2.	At face value many of the factors seem similar or to overlap. Therefore it actually required some time to consider the actual definitions of the factors.
4.	None
5.	Took longer because clicking on a link to a factor to read about it led to loss of completed entries on section 3. These had to be re-entered
8.	None

The following sites for suitable case studies were identified during the second round Delphi by the respondents:

(i) NuRa concession rural energy utility in South Africa;
(ii) Kuis community project in South Africa;
(iii) Increasing Access to Sustainable Biomass Energy Products and Services in the Lake Victoria Basin, Wakiso District, Uganda;
(iv) Multi function platforms in West Africa (e.g. Mali), West Africa; and
(v) Multifunctional platforms, Tanzania.

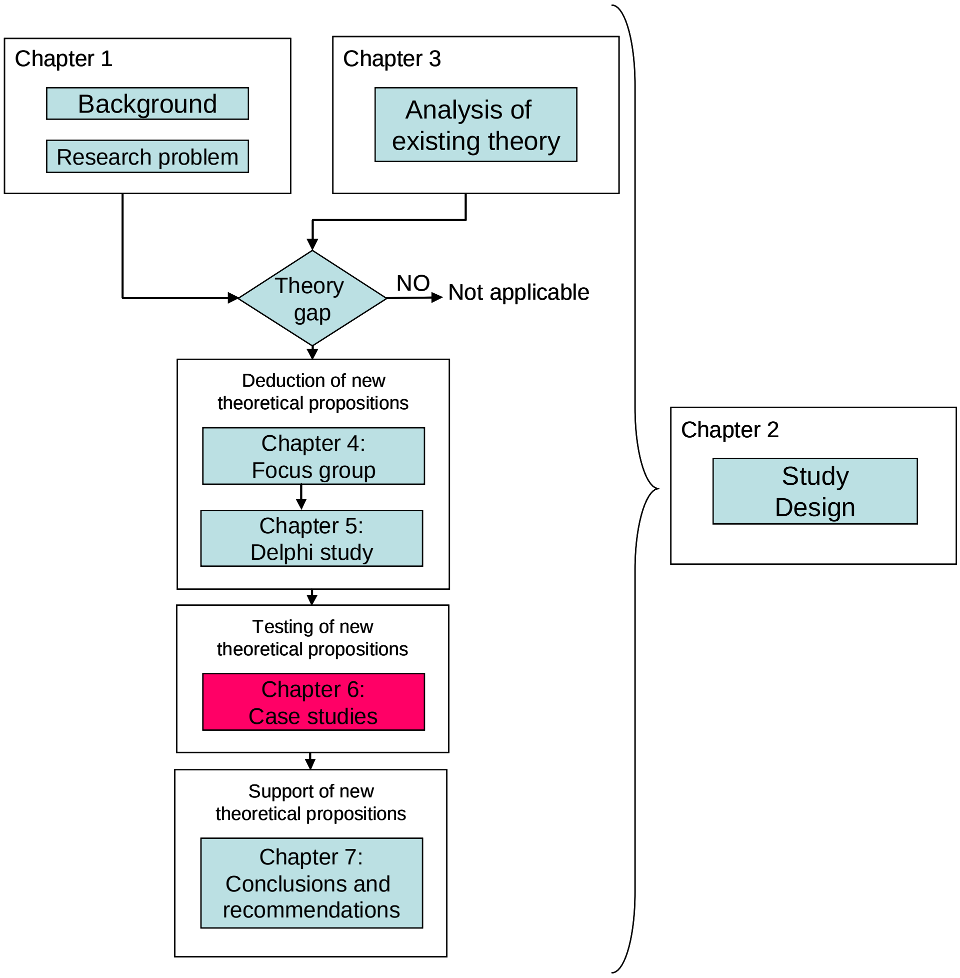
In the end, none of these suggested case studies was used as the contact e-mail addresses were incorrect or a suitable time for investigation could not be scheduled.

Conclusion

The Delphi method was successfully applied to identify the 11 most important factors from the 38 identified by the focus group.

The 11 factors identified were used in the case studies when determining which factors are used in practice.

CHAPTER 6: Case Study



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6.1 Introduction

The high level case study methodology (Yin 2003) was followed for this case study; the methodology is shown in Figure 6-1. The methodology consists of the design of the case study; the case study is then conducted by preparing for data collection and collecting the case study evidence; the data is then analysed; and finally the report is generated.

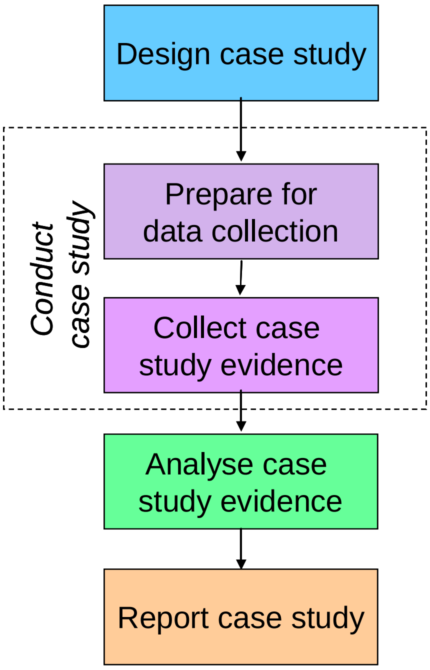

Figure 6-1: High level case study methodology (Yin 2003)

6.2 Case study design

For purposes of this study, it was decided to use a multiple embedded case study design. The use of multiple case study designs over single case study designs is advisable (Yin 2003). This is because the benefits of the analysis of multiple case studies. Among the benefits is the possibility of directly replicating case studies, and improving generalisability if a common conclusion can be reached in different contexts.

As the study is focussed on renewable energy projects in Africa, it was decided that the multiple cases would be three different countries in Africa. The units of analysis would be different renewable energy initiatives in each country.

The multiple case study method used in this study is shown in Figure 6-2 (Yin 2003). The define and design phase involves developing the theory that is to be tested, which in this case is the factors defined in the Delphi study. The cases are then selected using convenience sampling and the data collection protocol is designed. The prepare, collect and analyse phase involves collecting data for each case study and writing up the individual case study reports. The analyse and conclude phase involves drawing cross-case conclusions, modifying the developed theory, developing policy implications and writing the cross-case study report.

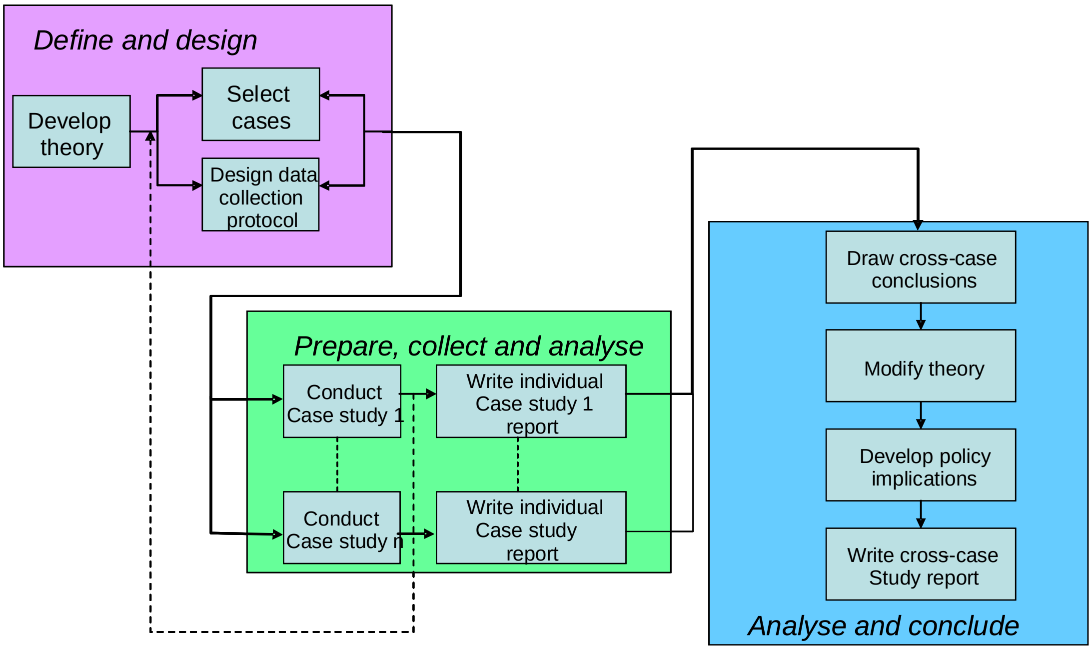

Figure 6-2: Multiple case study method (Yin 2003)

6.3 Execution of case study

6.3.1 Preparation for data collection

When preparing for data collection the elements shown in Figure 6-3 need to be taken into consideration (Yin 2003).

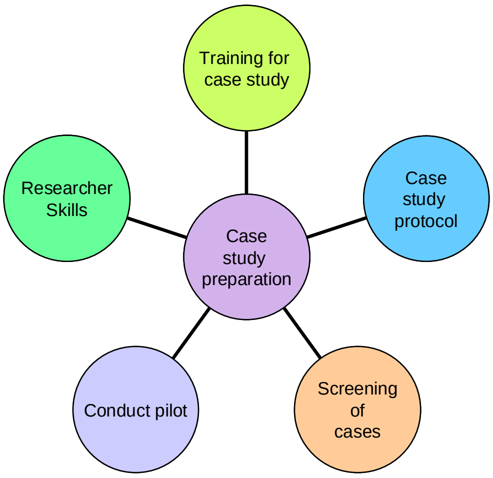

Figure 6-3: Elements to consider in preparation for data collection (Yin 2003)

The main elements that need to be considered are: training of the researcher; the researcher skills; conducting a pilot study; screening of case studies; and case study protocol development.

For this case study, two researchers worked together during the data gathering phase, each gathering data for two separate case studies.

The generation of a case study protocol to ensure validity of the case study is advised (Yin 2003). The protocol for a case study is attached in Appendix K.

As part of the case study protocol, two questionnaires for data collection were also generated. Two questionnaires were required as two different levels of participants were interviewed during data collection. Interviews were conducted with government institutions and implementers and the other level of interviews was with end users. The two questionnaires are attached in Appendix L and Appendix M respectively.

Processes for screening are proposed which included a unique case, specific cases and more than 30 cases (Yin 2003). In this case, the researcher had access to specific cases[1] which where then chosen as the case studies thus convience sampling was used. The specific cases where diverse enough to satisfy the requirements of the case study. For this reason it was decided to investigate the cases to which access was readily available in three African countries. The cases selected are shown in Table 6-1 . The cases are distributed over three countries namely Rwanda, Tanzania and Malawi.

Table 6-1: Summary of case studies

Country	Type of renewable energy service	Implementation model
Rwanda	Household biogas Institutional biogas	SNV with government support
Tanzania	Solar PV Biogas for cooking Efficient ovens Efficient stoves	Non government aid agency
Malawi	Efficient stoves Efficient barns	Government driven with support from ProBEC

A pilot case study was conducted with Mr Maxwell Mapako, of the South African Council for Scientific and Industrial Research. A biogas implementation programme in Zimbabwe was used for the pilot study. For the pilot study no secondary

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[1] Access to the case study information was obtained via the South African Council for Scientific and Industrial Research (CSIR) with the help of Mr Maxwell Mapako.

documentation was available and data gathering consisted of an interview only. The interview was helpful to test the questionnaire for government and implementers and after the pilot interview; the questionnaire was updated to clarify some of the questions.

6.3.2 Collection of evidence

The six sources of evidence which can be used during the collection of case study evidence are shown in Figure 6-4 (Yin 2003). The six sources of evidence are: documents; physical artifacts; participant observations; direct observations; interviews and archival records.

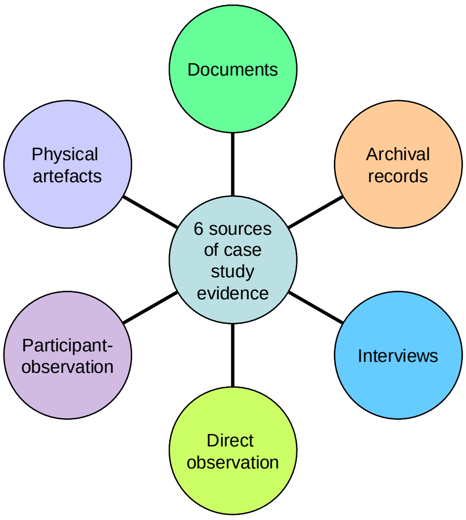


Figure 6-4: Six sources of case study evidence (Yin 2003)

Three principles of data collection were used namely: multiple data sources, the creation of a case study database, and maintenance of the chain of evidence (Yin 2003).

In this case study, the multiple sources of evidence which were used were: documents, interviews and direct observations. Direct observations were limited to observing the trained users use the equipment and the templates that were supplied and supported the finding that training had been successfully completed.

A detailed database of case study evidence is included in Appendices N to P.

6.4 Analyses of case study evidence

6.4.1 Introduction

The preferred strategy for analysing case study evidence is to rely on theoretical propositions (Yin 2003). The proposition of this study was that the factors identified during the Delphi study were the most important factors for the selection of renewable energy technologies in Africa. Pattern matching is the most preferred technique for analysing case study data as it compares an empirically based pattern with a theoretical pattern (Yin 2003). In this study, pattern analysis was used and the data gathered was analysed by comparing it to the findings of the Delphi study.

6.4.2 Background to case study countries and technologies employed

6.4.2.1 Biogas for cooking in Rwanda

Rwanda is a small poor rural third world country in Africa and is landlocked by Democratic Republic of Congo (DRC), Uganda, and Tanzania. With a population of 10 million people, Rwanda is the most densely populated country in Africa and 90% of the population is engaged in agricultural activities (CIA 2010a).

The energy need of 94% of Rwandese is met by biomass which is made up of combustible wood and vegetal residue (MINITERE 2006). The current production of electricity is dependant on hydro schemes, which are susceptible to droughts and there have been prolonged periods of drought in Rwanda in the last 20 years (MINITERE 2006).

Most of the Rwandan population needs energy for cooking and lighting. The main lighting fuel sources are: oil (64%), wood (17.5%) and kerosene (10%) (even in urban areas like Kigali only 37% of households use electricity) and the main rural cooking fuel sources are: firewood (90.4%), charcoal (7.4%) and agricultural residue (2.2%) (Dekelver*, et al.* 2006).

One of the goals of the government’s National Adaption Program of Action (NAPA) is the reduction of wood energy utilization form 94% to 60% by 2010 and to 50% in 2020 (MINITERE 2006). NAPA has identified the low capacity of human and financial resources, focusing on hydroelectricity to the exclusion of mixed solutions and resistance to change as the main risks for this programme.

Two case studies were selected in Rwanda namely the domestic biogas programme and the institutional biogas programme. One of the projects started by the Ministry of Infrastructure (MININFRA) to support NAPA is the National Domestic Biogas Program (NDBP). The goal of the NDBP is to implement 15,000 biogas plants for Rwandan households with two to three zero grazing cows (i.e. cows kept in a pen) by December 2011 (NDBP 2008).

The NDBP was selected as a case study for the research as it is an example of a renewable energy implementation in Africa where a development organization is working together with the government of an African country to implement the programme.The household biogas programme was initiated by the Rwandan government in 2003 when discussions started with SNV. SNV is a professional development cooperation organisation, based in the Netherlands, which currently operates in 32 countries in the world and has extensive experience in biogas implementation especially in Nepal (SNV, 2009). Biogas is environmentally friendly as a biogas plant replaces 4.6 tons of carbon dioxide annually (SNV, 2007). Advantages of biogas plants for individuals include (SNV, 2007): less smoke which improves health due to less respiratory diseases and eye infections; less dirt on pots from fires; less or no wood collection required; better fertilizer and better sanitation available.Primary data was gathered by conducting interviews with the implementing organizations as follows: informal introductory discussions with a senior advisor to MININFRA; formal interview using technical questionnaire with a senior biogas technician; formal interview using technical questionnaire with a biogas senior advisor from SNV. Secondary data in the form of reports were provided by the interviewees (see Table 6-2).

Interviews with two households that have biogas plants were conducted in the Rulindo district. Rulindo has a population of 261,018 inhabitants with a high average population density of 448 inhabitants per square kilometre (Huba and Paul 2007). The district has 25,126 cattle-raising households of which 99.6% practice zero grazing and 90% of the population work in agriculture on a surface of 226 km^2 (Huba, E.M. 2007).

The households interviewed were all part of the pilot biogas pilot programme initiated in 2007. The first user interview was with a mother who is the head of a household with five teenagers. She is very satisfied with her biogas digester and manages to cook all the family meals using biogas. Biogas in this household is used for both cooking and lighting. The cow at this household was very well-fed and the biogas pressure was 10 KPa which means that there is sufficient biogas for their daily needs.

The second user interview was with the father of a household of nine. The household consists of the parents and seven children, two of whom are over 18. In this household the father indicated that the major impact of the biogas digester in the household was that the children did not need to spend so much time collecting wood every day and that money was saved because they did not have to purchase firewood so often. In this household however, wood is still used twice a week to cook beans which is one of the staple foods in Rwanda. In this household the cow was less well-fed and the pressure on the biogas meter was below 6 kPa.

Twenty eight biogas systems have been installed in institutions in Rwanda since 2001 while another eight are under construction. Of the total of 36 units, thirteen were installed in secondary schools, eleven in prisons, seven in community households, two in military camps, two in training centres and one in a hospital (Munyehirwe and Kabanda, 2008).

In 14 (50%) of the 28 operating biogas digesters only human waste is being used (typically for the prisons and some schools) while others use a combination of human and animal waste, mainly cow dung. It has been found that 11 of 28 completed digesters operate very well, 5 operate with major defects while 6 were abandoned or even never operated due to wrong design. The survey found that schools were the worst performers with only 2 out of 10 installed systems in operation.

The major causes for malfunctioning of the systems were found to be lack of commitment of the management and/or a lack of a qualified biogas operator and this was found more the case in the bigger institutions than in small systems operated by missions and farms

There is also a serious shortage of technical support to assist institutions in carrying out simple modifications and reparations of leakages and damaged stoves. More capacity is required in this area to ensure that the existing systems function properly which will give confidence to other institutions to follow the example.

Primary data was gathered by conducting interviews with the implementing organizations as follows: informal introductory discussions with a senior advisor to MININFRA; formal interview using technical questionnaire with a senior biogas technicial. Secondary data in the form of reports were provided by the interviewees (see Table 6-2).

6.4.2.2 Energy sources other than wood in Tanzania

Tanzania is situated in east Africa. The borders of the country include the Indian Ocean, Kenya, Uganda, Rwanda, Burundi, the Democratic Republic of Congo, Zambia, Malawi and Mozambique (CIA 2010b). Tanzania has a population of more than 40 million people and 80% of the population is involved in agricultural activities (CIA 2010b).

The main source of electricity in Tanzania is hydro-electric plants with over 90% of the energy in Tanzania coming from hydro (CIA 2010b) with thermal plants providing for peak loads (Tanzania Ministry of Energy and Minerals 2009). In terms of household energy consumption, 97.7% of all household energy for cooking, heating and lighting derives from biomass (Mwakaje 2008).

Tanzanians have limited access to electricity with only 10% of the population connected to the grid, of which only 1% of the population is in rural areas (Tanzania Ministry of Energy and Minerals 2009).

The Tanzanian energy policy (Tanzania Ministry of Energy and Minerals 2009) emphasises the need for a more reliable, environmentally friendly energy supply to improve economic sustainability and eradicate poverty.

In terms of rural energy supply, the energy policy (Tanzania Ministry of Energy and Minerals 2009) has the following objectives: the support of research and development into rural energy alternatives; promotion of energy sources other than wood fuels to reduce deforestation, indoor smoke and time spent collecting firewood; promotion of entrepreneurship and involvement of the private sector in developing the rural energy market; continued electrification to make electricity affordable and accessible to the low income group; establishment of norms, standards guidelines and codes of practice for affordable rural energy supply.

Four case studies were selected in Tanzania namely domestic biogas technology, solar energy, efficient stoves and efficient ovens. A study was done by Mwakje (2008) regarding the opportunities and constraints of biogas use in the Rungwe district in south west Tanzania . The history of biogas in Tanzania started in 1975 when the small industries development organisation constructed 120 floating drum plants in Arusha. At the end of 1989, 200 biogas plants had been installed all over Tanzania and in 1992 this increased to 600 plants. No further figures are given from 1992 to the present.

The study found that there is opportunity for implementation of biogas use in Tanzania due to: availability of zero grazing cows (i.e. cows kept in pens); the general dependence on and shortage of firewood; the government energy policy supporting a diverse range of renewable energy; the benefits to the environment; impact on poverty alleviations including better environmental conditions, labour saving and energy cost saving; and the high cost of firewood.

Primary data was gathered by conducting interviews with a biogas implementer and a biogas user. Mr Elisa (2008) is an employee of the Kilimanjaro Industrial Development Trust (KIDT). KIDT was started in 1978 by the government of Japan to industrialise the Kilimanjaro region of Tanzania, to disseminate knowledge and to provide on the job training. KIDT have constructed eight tubular type biogas plants which have been running for a year. Mr Kidini (2008) lives in the foothills of Kilimanjaro. He has had a biogas installation for 15 years. His biogas installation is still operational. He also has electricity and an electric stove, but prefers not to use biogas for cooking due to the prohibitive cost of electricity. He is an influential man in the community.

The solar energy case study is being implemented by Tanzania Traditional Energy Development and Environmental Organisation (TaTEDO), a non-governmental organisation (NGO) based in Tanzania that specialises in the development of sustainable modern energy services for Tanzanian residents (TaTEDO, 2007). The main goals of TaTEDO are: to improve the quality of life of Tanzanians by facilitating access to modern energy services; to minimise harm to the environment and to contribute to the reduction of Tanzania's dependence on imported energy (TaTEDO, 2007).

Primary data was gathered by interviewing two TaTEDO employees Arnold Nzali and Thomas Mkunda. Secondary data was gathered from three websites, TaTEDO (2007), Mwanza project (Mwanza, 2009) and the Tanzania Solar Energy Association (TASEA, 2009). Secondary data was also obtained from Banks et. al. (2007).

The efficient stove case study is also being implemented by TaTEDO. The project involves the construction of stoves in Hai and Rombo districts in Tanzania. The aim is to install stoves for 6000 to 10000 household over 2 years. Primary data for this case study was gathered during an implementer interview with two TaTEDO employees Arnold Nzali and Thomas Mkunda as well an end user interview with Mr Kidini (2008).

The efficient oven case study is also being implemented by TaTEDO. There are more than 200 small scale bakers using the improved TaTEDO charcoal ovens. Primary data was gathered by interviewing one of the small scale bakers. A shorter interview than ideal had to be conducted due to lack of time. Beatrice Exaud is a small scale baker who uses TaTEDO's efficient charcoal ovens. She was interviewed while she was preparing her batch of bread for the day.

Secondary data in the form of reports were provided by the interviewees (see Table 6-2).

6.4.2.3 Efficient stoves in Malawi

The Republic of Malawi is a small country in southern Africa. It shares borders with Zambia, Tanzania and Mozambique. Malawi is one of the least developed countries in the world, ranking 168 out of a total of 174 countries (GTZ 2009) and more than 90% of the export revenue of the country comes from agricultural products.

The deforestation rate in Malawi is 2.8% per year and is the highest in Africa which is contributed to by the fact that 95% of Malawi's primary energy supply and 90% of total energy is from biomass, mainly in the form of firewood and charcoal (GTZ 2009). Other energy sources used in Malawi include electricity (mainly from hydro) petroleum products, coal and other renewable energy sources but these account for only 7% of the total supply with only 6% of the population of Malawi having access to electricity (GTZ 2009).

Generation of hydro electricity is susceptible to droughts which have become more prevalent and in the south with the progressive deforestation and this has caused deposition of silt and debris in rivers which affects the operation of the hydro plants (GTZ 2009).

In terms of use of biomass, more than half of urban households use charcoal while 38% of peri-urban households use firewood and 97% of rural households use wood (GTZ 2009).

At government level, energy issues are managed by the Ministry of Energy, Mines and Natural Resources which has a Department of Energy Affairs. This department us currently attempting to promote alternatives to charcoal (nine tonnes of wood is required to produce one tonne of charcoal) in the form of gel fuel stoves and ethanol stoves (GTZ 2009). The government energy policy is known as the National Energy

Policy (NEP) and this policy emphasises the reform of the energy sector to ensure a more flexible, private sector-driven energy supply industry (GTZ 2009).

The National Sustainable and Renewable Energy Programme (NSREP) has the goal of promoting renewable energy technologies in Malawi which include solar photovoltaic and photo-thermal, wind energy, biogas and biomass briquettes (GTZ 2009).

The energy policy of Malawi has the target of allowing access to electricity to 10% of the population by 2010, where currently only 7.5% of the population has access to electricity with access to 1% of the rural population and 30% of the urban population (Department of energy affairs 2006).

Two case studies were selected in Tanzania namely efficient stoves and efficient tobacco barns.

The Department of Energy Affairs in Malawi has started substantial energy programmes in Malawi. The goal of these programmes is to decrease the large scale use of charcoal in the country (Chitenje 2008).

The Department of Energy Affairs in Malawi is working with the Programme for Basic Energy and Conservation in Southern Africa (ProBEC) is a programme started by the Deutsche Gesellschaft fuer Technische Zusammenarbeit (GTZ) in the Southern African Development Community (SADC).

The goal of ProBEC is to ensure that low-income population groups in SADC are enabled to satisfy their energy needs in a social and environmentally sustainable manner and this is done by promoting improved energy solutions through market development and policy support (GTZ, 2009). ProBEC follows a commercial approach actively trains producers to manufacture energy saving cooking devices in order to ensure that a market is developed which will be sustainable once ProBEC funding is no longer available. ProBEC uses results based monitoring to measure the success of projects (GTZ, 2009).

ProBEC has several initiatives in Malawi including the promotion of clay stoves, metal efficient stoves and targeting of employers to install efficient stoves for their workers in their homes. Primary data was gathered for the efficient stoves by conducting implementer interviews with the deputy minister of Energy affairs, ProBEC employees and an employee from one of the tea estates where a fixed type stove is manufactured as well as end user interviews with a group of women involved in stove building and promotion as a business, a metal stove manufacturer, a domestic efficient stove user and a small scale metal stove producer. Secondary data in the form of reports were provided by the interviewees (see Table 6-2).

The efficient tobacco barns were developed for small scale farmers in conjunction with the tobacco industry and NGOs in order to address the damage caused to the environment due to the fact that conventional tobacco drying method uses a lot of wood to cure tobacco. Primary data was gathered by interviewing a GTZ employee. Secondary data in the form of reports were provided by the interviewees (see Table 6-2).

6.4.3 Units of Analysis

The Units of Analysis for the case studies are shown in Figure 6-5.

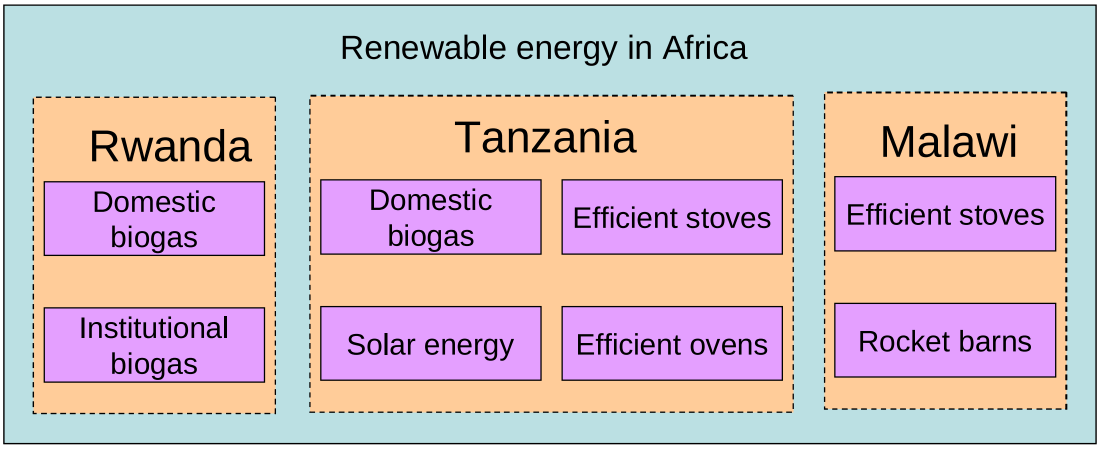


Figure 6-5: Case studies units of analysis

The case studies conducted with primary and secondary data are summarised in Table 6-2.

Table 6-2: Summary of case study primary and secondary data

Case description	Primary data	Secondary data
Domestic biogas in Rwanda	**Implementer interviews:** (Uwizeye 2008a) (Dekelver 2008) **User interviews:** (Speciose 2008) (Gervais 2008) Observation	(Dekelver, *et al.* 2005) (Dekelver, *et al.* 2006) (Huba and Paul 2007) (Bajgan and Shakya 2005)
Institutional biogas in Rwanda	**Implementer interview:** (Uwizeye 2008b)	(Munyehirwe and Kabanda 2008)
Domestic biogas in Tanzania	**Implementer interviews:** (Elisa 2008) **User interview:** (Kidini 2008a) Observation	(Mwakaje 2008)

Case description	Primary data	Secondary data
Solar energy in Tanzania	**Implementer interviews:** (Nzali and Mkunda 2008b)	(TaTEDO 2009) (Banks, *et al.* 2007)
Efficient stoves in Tanzania	**Implementer interviews:** (Nzali and Mkunda 2008a) **User interview:** (Kidini 2008b) Observation	(TaTEDO 2009)
Efficient ovens in Tanzania	**User interview:** (Exaud 2008) Observation	
Efficient stoves Malawi	**Implementer interviews:** (Chitenje 2008) (Gondwe, *et al.* 2008) (Vutuza 2008) (Sukasuka 2008a) **User interviews:** (Mwalimu, *et al.* 2008) (Chipyoza 2008) (Chilewe 2008) (Banda 2008) Observation	(Department of energy affairs 2006) (Gondwe 2007) (Nyengo 2006) (Brinkmann 2004) (Malinski 2008)
Improved tobacco barns	**Implementer interview:** (Sukasuka 2008b)	(Scott 2008)

6.4.4 Case study analysis

In order to facilitate the analyses, the sources of data presented in Table 6-2 are given in Table 6-3 with labels. In the paragraphs that follow, the case study sources are listed using these labels.

The factor numbering which is used in Table 6-5 is explained in Table 6-4.

Table 6-3: Alphabetical sources with labels

Label	Source description
a	(Bajgan and Shakya 2005)
b	(Banda 2008)
c	(Banks, *et al.* 2007)
d	(Brinkmann 2004)
e	(Chilewe 2008)
f	(Chipyoza 2008)
g	(Chitenje 2008)
h	(DeGabriele and Msukwa 2007)
i	(Dekelver, *et al.* 2005)
j	(Dekelver, *et al.* 2006)
k	(Dekelver 2008)
l	(Department of energy affairs 2006)
m	(Elisa 2008)
n	(Exaud 2008)
o	(Gervais 2008)
p	(Gondwe, *et al.* 2008)
q	(Gondwe 2007)
r	(Huba and Paul 2007)
s	(Kidini 2008a)
t	(Kidini 2008b)
u	(Malinski 2008)
v	(Munyehirwe and Kabanda 2008)
w	(Mwakaje 2008)
x	(Mwalimu, *et al.* 2008)
y	(Mwanza 2010)
z	(Ndiwo 2008)
aa	(Nyengo 2006)
ab	(Nzali and Mkunda 2008a)
ac	(Nzali and Mkunda 2008b)
ad	Observation domestic biogas Rwanda, 2008
ae	Observation domestic biogas Tanzania, 2008
af	Observation efficient ovens Tanzania, 2008
ag	Observation efficient stoves Malawi, 2008
ah	Observation efficient stoves Tanzania, 2008
ai	(PAESP 2006)
aj	(Scott 2008)
ak	(Speciose 2008)
al	(Sukasuka 2008a)
am	(TaTEDO 2009)
an	(Uwizeye 2008b)
ao	(Uwizeye 2008a)
ap	(Vutuza 2008)

Table 6-4: Factor descriptions for each factor number

Factor Number	Factor description
	Technology factors
T1	Ease of maintenance and support over the life cycle of the technology
T2	Ease of transfer of knowledge and skills to relevant people in Africa
	Site selection factors
SS1	Local champion to continue after implementation
SS2	Adoption by community
SS3	Suitable sites ready for pilot studies
SS4	Access to suitable sites can be secured
	Economic/ financial factors
E1	Economic development
E2	Availability of finance
	Achievability by performing organisation
A1	Project management
A2	Financial capacity
A3	Technological capacity
	Newly identified factors
N1	Government support
N2	Environmental impact

The analysis of the case studies per factor is based on the summary in Table 6-5. The detail of this analysis is discussed in Appendix N to P. The number of each factor from Table 6-4 is listed in the left-most column. For each factor an indication is then given by using a '√' to indicate which source of evidence supports the inclusion of this factor into the framework of factors.

Table 6-5: Summary of case study data

	Domestic biogas			Institutional biogas		Biogas			Solar		Efficient stoves			Efficient ovens		Efficient stoves			Improved tobacco barns	
Factors	**Interviews**	**Documents**	**Observation**	**Interviews**	**Documents**	**Interviews**	**Documents**	**Observation**	**Interviews**	**Documents**	**Interviews**	**Documents**	**Observation**	**Interviews**	**Observation**	**Interviews**	**Documents**	**Observation**	**Interviews**	**Documents**
	Technology factors																			
T1	√	√	√	√	√	√	√	√	√	√	√		√	√	√	√	√	√	√	√
T2	√	√	√		√	√	√	√	√	√	√		√	√	√	√	√	√	√	√
	Site selection factors																			
SS1	√	√	√		√	√		√	√	√	√		√	√		√	√	√	√	
SS2	√	√			√	√	√		√	√	√	√		√		√	√		√	√
SS3	√	√							√	√						√			√	
SS4	√	√					√		√	√						√	√		√	
	Economic / financial factors																			
E1	√	√		√	√	√	√		√	√	√	√		√		√	√		√	
E2	√	√		√	√	√	√		√	√	√	√		√		√	√		√	√
	Achievability by performing organisation																			
A1	√	√		√	√	√			√	√	√					√	√		√	
A2	√	√				√			√	√	√					√	√		√	
A3	√	√			√	√	√		√	√	√					√	√		√	
	Newly identified factors																			
N1	√	√				√	√		√	√	√					√	√			
N2	√	√					√				√	√				√	√		√	

The paragraphs that follow discuss the case study data captured from each data source for each factor in detail. In order to aid readability, the labels indicated in Table 6-3 are used to reference the sources rather than the Harvard system which is used in the rest of this study.

6.4.4.1 Technology factors

6.4.4.1.1 T1: Ease of maintenance and support over the life cycle of the technology

Ease of maintenance and support over the life cycle of the technology was found to be very important in all the cases examined. The main reason for this is that if the technology is not in working condition, the users will simply abandon it and return to their traditional methods (ai, h, aa, d).

Ease of maintenance and support is ensured in the various cases by implementing the following:

Quality installations. There is a strong focus on quality of installation in the Rwandan domestic biogas programme (i, j, ad). Quality is ensured by monitoring and supervision by the government (j) enforced design, quality and service criteria (a) as well as implementation of national standards (k). In the Tanzanian solar implementations standards to ensure quality were also identified as being important (c). The Malawian efficient stove programme is also monitored and evaluated by the government (g, q). Poor quality undermines end user confidence in technology (ai, h, aa, d, af, ag)

Maintenance plans. Maintenance plans are in place for the Rwandan domestic biogas programme (j). Installing companies are contractually bound to do maintenance for the Rwandan domestic biogas programme (ao and o). This includes follow up visits to ensure operation and optimal use of the biodigestors (k) and a record which is kept by the owner of each plant (ao). A maintenance plan was not drawn up during the implementation of institutional biogas digesters in Rwanda and there is now a serious shortage of technical support for these digesters (ao and v). The biogas digesters installed by KIDT in Tanzania are supported for six months after which the users have to pay for maintenance (m). Maintenance plans should also address the maintenance funding model to be used (c)

Training of technicians. It is important that local technicians be trained (ao, v, s, w, ab, an). Lack of technical support is one of the largest problems in the biogas installations in Tanzania (s and w) as well as for the institutional biogas installations in Rwanda (an). The lack of trained technicians to maintain the solar systems has resulted in a lack of confidence in the systems by the users (y) and the users are also not getting value for money with these systems (am). The solar systems need to be maintained by a technician every six years (ac). The lack of sufficient technicians for the efficient ovens in Tanzania means that users sometimes need to wait for maintenance which creates a problem as the stoves are used in businesses (n).

Maintenance training for users. A formal booklet in the local language is left with the plant owner that describes the maintenance activities required (ao, k). There is no user manual for the Rwandan institutional biogas plants (an) and this has been identified as necessary to help users solve and avoid minor technical problems (ao, ad and v). User training is also required for these plants (v). Users are trained in the use of the new technology in Malawi in order to ensure that they use the technology optimally (q, h, ag).

Keeping maintenance simple. User maintenance is done by the women and children for the biogas plants in Rwanda (ak and o). Maintenance is limited to cleaning of the chimney on a regular basis for the efficient stoves in Tanzania; this means that maintenance can be done by the owner (ac, ae, ah). Maintenance of efficient stoves in Malawi is very simple and close to what the people know (ap, al, ag)

Adapting the technology to the specific environment. Technology implemented in Africa must be robust and easy to handle (r), obtaining spares is a large problem in developing countries (w) and thus the technology selection must take into account the availability of local material (i, aj) and continued research is required to ensure optimal utilisation of the technology (j). Technology must be adapted to the specific environment and requirements of the users (ac, ab, ah, ag). In Malawi the government follows the principle of selecting technology which is as close as possible to what the people already know (g) and continued research is done to ensure durability (u, d). In Malawi for example, the technology was adapted so that the structures of traditional barns could be used to build the efficient barns which saves on material costs (aj). Peripheral issues such as availability and sizes of pots to use must also be taken into account when adapting the technology (h).

6.4.4.1.2 T2: Ease of transfer of knowledge and skills to relevant people in Africa

In general, the simpler the technology selected, the easier the transfer of knowledge and skills to the relevant people in Africa. This is because of the shortage of trained people in Africa in general. The shortage of trained people is more severe in rural areas.

To ensure proper transfer of skills, the following must be considered:

Stakeholders to train. It is important that the correct target group be selected for each training session (h). The following target group must be trained: users (ao, k, ak, o, a, al) including women (i, j), installers / producers (ao, k, a, al), financial institutions (j, a), field facilitators or extension officers (p, aa), trainers (ai), national government (a) and local government (a). In Tanzania, shop owners were selected as the local champions for the technology, and they had to nominate technicians to be trained (ac). This presented a problem during training as some technicians were not adequately skilled and were consequently not trainable - training took longer than anticipated (ac). Sometimes village chiefs also nominated trainees without skills or interest (ac). In Tanzania an awareness programme as also implemented for decision makers to inform them on the benefits of solar technology (c).

Methods of skills transfer. The following methods can be used: user manuals (ao, k, ac, h, d), formal workshops (ac, ai), informal training during and after installation (ak, o), demonstrations (z). Training must be practical (ak, h, ae, ah, af, af). Users are often not willing to pay for training (z). In some cases the performance testing of the technology as well as comparison with the old technology is a prerequisite (h, ag). In Rwanda the private sector federation arranged some of the training workshops (j). Training should be developed in cooperation with women's groups, breeder unions, agricultural and veterinary extension technicians, schools and local NGOs (r). In some of the cases, users are trained by the installers / producers as recommended by the implementing agency (al, h).

Skills to be transferred to users. Training should include technical aspects of operation and maintenance (r, ae, ad, ah) but should also include topics outside of the technology, as for example, cooking techniques (r, aa, u, ag), slurry application (r, ad, ae), hygiene (r), household management (u) and recipes (p, u). The first issue which must be addressed in user training is what the advantages are of adopting new technology rather than keeping the old technology and this can be hampered if influential people in the community, for example, traditional doctors, oppose the implementation (aa).

Skills to be transferred to installers/ producers. Installers/ producers must be trained in installation, (ao), manufacture (u), maintenance (ao, v), quality control (d, u), pricing (u) marketing (p, d, u) and management (ao, y). In the solar PV project in Tanzania, it was found that the majority of technicians did not have electrical installation certificates. It was decided that these technicians could receive limited training which excluded the sizing of installations which would enable them to install and maintain systems (y). In Malawi, a study was conducted to determine whether the people had skills in pottery before the efficient stove project was implemented (p). In cases where the technology is simple as for example the efficient stoves in Malawi, producers who are trained by ProBEC can then train other producers (al).

Quality of training. High quality training is needed (h). Quality of training is ensured by tracking the progress of trainees and supplying additional training if required (ac, ab). Skills transfer can be problematic as trainees often do not have the correct initial skills (ac, y, z). When the technology is basic as for example the efficient ovens implemented in Tanzania, user training is simple (n). In Malawi, the initial training of stove producers was followed up with more training to improve the quality of the stoves and because of the simple technology, the transfer of skills was easy (x, ap, e). Training is necessary when implementing renewable energy technologies to ensure that benefits accrue as expected (q). The quality of the tobacco barns is ensured by ProBEC as each barn is checked after construction (al).

Formalisation of skills transfer. The transfer of knowledge of renewable energy technologies can be formalised by updating school curricula (ac, d, ab) and academic curricula (ao). In Tanzania a course in solar PV is now presented at the Vocational Education Training Authority (y, c)

6.4.4.2 Site selection factors

6.4.4.2.1 SS1: Local champion to continue after implementation

Local champions of renewable energy technologies in Africa are required because much information in rural Africa is communicated by word of mouth as most households do not have access to modern communication technology. Projects in Africa are often successful in the short term when the donor agencies or NGOs are on site with the implementation, but fail when these agencies leave.

Identification of local champion. Local champions in the case studies varied from households (ak, m, s, c, n, t, ad, ae, ah), producers / installers (ac, y, p, e, ai, ab) donor agencies (h, i) specially selected promoters (d) and partner organisations (al). For the Rwanda domestic biogas programme, local champions were identified as the project progressed (ao) but the implementation plan emphasised the use of women as local champions (j, r).

Value of the local champion. Local champions are used for social marketing (Malinski 2008). Demonstration sites are often installed at the houses of the champions and prospective adopters are then brought to these households for demonstrations (ak). It is important that the owners of the demonstration technology are satisfied with the performance of the technology (k, j, r, t). As renewable energy technologies are often new to the areas where they are implemented, innovative individuals who are prepared to take the risk of implementation are required (i, r). In the institutional biogas implementations in Rwanda, the cases where there is a local champion for the plant are successful in the long run (v). Local champions assist in training (al, h), quality control (al), promotion (ai, a, c, x, t), installation (ai), service (ai), .monitoring and supervision (h). If the local champions are properly trained, they can also assist in conflict resolution (aa).

6.4.4.2.2 SS2: Adoption by community

It is important that before a renewable energy project is implemented the capacity in the community be determined. To facilitate adoption by the community the benefits of adoption must be determined and the information must be distributed to the community. Client satisfaction is very important - without this other members of the community will not be willing to adopt a new technology.

Capacity determination. It is important to determine how many households have the capacity to implement the technology (ao, j). Capacity does not necessarily lead to adoption if the cost of the technology is too high (m, s).

Benefits that facilitate adoption. The benefits identified for renewable energy implementations include: smoke reduction (k, d, f, ab), time saving for women and children (k, o, j, r, a, y, ac, am, ai, q, d, ab), improvement in health (k, i, j, r, a, v, w, y, ac, ai, h, z, aa, d, al, an), improved fertiliser (ak, o, a, w), improved effluent management (ak, j, r, a, v), having light at night (ak, w), environmental benefits (k, ak, j, v, ac, am), financial benefit because of the need to purchase less firewood, kerosene and fertiliser (o, r, v, m, s, w, am, ai, h, z, d, f, t), improvement in health services (y), improved time for cooking and curing (h, z, aj) and convenience (j).

Information distribution. It is important that people are made aware of the benefits of the technology to change their attitudes (a, b, z) as negative attitudes can hamper implementation (ap, al). The awareness of the population was raised about solar energy during the Tanzania solar implementation. Before the implementation very few households were aware of the benefits of solar technology (ac, c). This raised awareness resulted in increased enquiries about solar energy (c, y). If the value of the technology is perceived to be low by the community, adoption will be limited (al). Awareness campaigns are necessary to ensure that the consumer population can make rational choices about energy (ai). It was found that the higher the education level of the community the better the adoption rate (d). If people feel that they do not have access to the information about a new technology they will not adopt that technology (d).

Client satisfaction. Quality control is important (ao) to ensure adoption. Client satisfaction is very important to ensure success (a). The technology selected must be close to what the people know and involvement by the community is important (g). The needs of the community must be understood before implementation (p, al). During the implementation of efficient tobacco barns in Malawi, client satisfaction was the main driver in the success of the project (al, aj).

6.4.4.2.3 SS3: Suitable sites ready for pilot studies

In three of the cases, namely the implementation of institutional biogas in Rwanda, domestic biogas in Tanzania and efficient ovens in Tanzania, no evidence was found that pilot studies are important. However, in all the other cases pilot sites were found to be important. The two issues considered were the selection of pilot sites and the value of pilot sites.

Selection of pilot sites. Pilot sites can be selected using partner organisations that work in the local community (ao, al). Implementation at the selected pilot sites must have high quality of implementation and training (j, r, a). Public places such as school or health facilities can be used for pilot sites (ac, y, p).

Value of pilot sites. Pilot sites can be used for training (ao), as part of the promotion campaign (r), iterative development (a, al) and as demonstration plants (ac, al, ab).

Lessons learnt during the pilot phase can be used to improve future implementation (y).

6.4.4.2.4 SS4: Access to suitable sites can be secured

To secure access to suitable sites, the case study implementations used the following methods: determining the priorities of the population in to decide what type of technology is the most important; setting of implementation targets; identification of the criteria that a site must meet before the technology can be implemented there; and identification of suitable sites.

Determine priorities of the population. Energy plans and policies can be investigated (i). Household priorities were investigated and it was determined that replacement of lighting energy had a priority for the households because of the cost of kerosene and candles (r). It is important to understand the priorities of the population as the population might not understand the benefits of a specific technology (ac).

Set implementation targets. Implementation targets can be set in phases (ao, c, ac). Estimates can be made of the number of possible sites (k, y, l, ab).

Identify site criteria. For the biogas plant installations the following criteria were identified to determine suitable sites: climatic conditions must be favourable (i, j), zero grazing is in place (i, r, w), at least two head of cattle (r), water is available at the sites (i), at least 20 kg of dung can be collected per day (j, r), there is a scarcity of firewood (r) and there are community groups in the area which can train and network (r). Lack of connectivity to the grid is also a site criterion (ac, y, l). In the case of tobacco barns in Malawi, the following criteria were identified: farmers must have at least one hectare of land, must be interested in the technology and have the ability to pay for the technology (al).

Identification of sites. Suitable sites can be identified in cooperation with partner organisations (ap, al).

6.4.4.3 Economic/ financial factors

6.4.4.3.1 E1: Economic development

The economic development potential of renewable energies is generally twofold, namely, income generation and household savings. The cost of renewable energy technologies in Africa is kept to a minimum, and large profits are not planned for (k). At national level there is also potential for income and savings.

Income generation. Income is generated from being involved in installing (ao, i, ac, ab) producing (g, p, x, e, b, aa, u), maintaining (i, ac) or providing training for the renewable energy technology (p), or by utilising the product of the renewable energy technology to generate income. Most of the case study implementations focussed on creating a continuous market or sector for the renewable energy technology implemented which contributes to job creation (i, j, r, a, w, ac, am, g, p, ap, e, al, d, ai, ab). In the case studies, income is generated utilising the product of the renewable energy technology as follows: charging batteries (ac), selling fertiliser (ao), mobile phone charging (y, c), radio repair (c), raising chickens (c), packaging milk (c), fish egg aeration (c), cassette sales (c), guest house (c), shop lighting (c), barber shop (y, c), baking bread (am, n) and pasteurizing and selling milk (ac, ab). Improved agricultural production is also possible in the case of biogas and efficient tobacco barns (i, j, r, s, w, al).

Cost and time savings. Households and institutions save money in that they no longer need to buy wood, charcoal, kerosene, candles, batteries and where available, electricity (ao, i, j, r, a, ao, v, s, w, ac, am, e, q, d, u, t, f, ab, an). Women and children save time as they no longer need to gather as much wood (r, w, ai, z, aa, u, ab) and this saved time can be used for economic activities (w, ai, z). These savings are on a monthly basis as renewable energy technology normally has a once off payment and except for maintenance then is “free” (ak).

National income and savings. Countries benefit from renewable energy projects as carbon credits (k, r) can be sold and less expensive energy sources need to be imported (j). Countries further benefit as the renewable energy technology implementations in the case studies also contribute to skills development which is a priority in most African countries (i, j, m, ac, am, g, p).

6.4.4.3.2 E2: Availability of finance

Availability of finance was cited in most of the interviews and documentation as the main stumbling block to the implementation of renewable energy technologies in Africa. The main reasons for this are that the rural population in Africa is very poor, some renewable energy technologies have a high initial installation cost and the availability of firewood (ai) means that the rural population does not see the value of renewable energy technologies. Obviously the initial costs must be kept as low as possible (aj, t).

Payment methods. The main ways of payment were found to be cash (s, u), materials (s), produce (barter) (u) or labour (s, p). Cash is normally raised by selling produce (ak, o, r) or employment (r, n). The savings achieved using renewable energies can be used to pay off loans (v, d). Some of the institutional biogas facilities in Rwanda were funded by donors (an).

Finance methods. Methods used by the programmes to make finance available include subsidies (ao, i, j, a, e, ai), credit loans (k, o, i, j, r, a, m, w, ac, y, c, x, ai, al) and the giving of the renewable energy technology to the population for free (ap, d, u) or on loan (g). Subsidies are provided by donor agencies (ao, c, h) or government (ao). The government can subsidise renewable energy technology by providing financing or by removing duties and taxes (g, ai) on the technology. The rural poor do not normally have access to loans (s) and for this reason the implementing agency must negotiate with banks for favourable rates and payment periods (k, i, r, a, m, ac, y, c, ai). One of the problems that has not yet been solved is the provision of finance to households with seasonal income (ac, y, ab). Subsidies are carefully managed, in some cases subsidy is paid directly to the bank (k, c) and in other cases directly to the installer. Cash was raised through milk sales (ak).

6.4.4.4 Achievability by performing organisation

6.4.4.4.1 A1: Business management

Project management was identified during the focus group and Delphi study as a necessary skill for the performing organisation. During the case studies however it transpired that the skills required by the performing organisation are rather business management skills. In some of the case studies business management training (ab, an) had been implemented whilst in other case studies had been identified as an important requirement. Lack of business skills was identified as a reason why some businesses failed (ac).

Business management skills required. The following business management skills were found to be important during the case studies: market development (ao), marketing (j, ac, al. aa, d, u), entrepreneurship (ao, k, ac, ai), management (ao, k, m, al), personnel management (j), business development (c), price determination (d), financial management and organisational management (j, c, m)

Transfer of business management skills. Skills are transferred through formal training (c) and by doing the work with assistance and support (k, i).

Where skills are lacking. If the performing organisation does not have the required business management skills, the donor organisation or the government can help the performing organisation especially in terms of marketing and market development (p, x, e).

6.4.4.4.2 A2: Financial capacity

Financial capacity refers to the capacity of the performing organisation to finance the components and materials required for technology implementation. Especially when the performing organisation first starts up financial capacity can hinder the organisation from succeeding. With capital intensive technologies such as solar photovoltaics it was found that some performing organisations stop supplying the technology because of financial constraints (y, l).

Methods of dealing with financial capacity. The following methods were implemented to ensure that the performing organisations would have the financial capacity to implement the technologies: financial model of the project set up in such a way that the performing organisation has minimum capital outlay (ao, k, al, ab), subsidies (i, j, r, a, y, l), training to cluster work (k) and using technology that has very little capital outlay (ac, p, x, e, h).

6.4.4.4.3 A3: Technological capacity

Technological capacity of the performing organisation is of paramount importance (d) as poor quality products give renewable energy technologies a bad name in the community (aa, d). Technological capacity was found to be a problem as skills in Africa in general are problematic (y, l, ac, ai). In the case studies, the following methods were utilised to overcome these difficulties:

Quality assurance. Quality control is enforced (a, H, u) and is done by the implementing organisations (j, r, e, al) through monitoring and evaluation (j, u). Subsidies are linked to the quality control system (i, r, a).

Training. Training involves installation (k, v, m, w, ac) and maintenance (v, m, w, ac) training. Refresher courses (ao, r, x) are offered to correct mistakes and also to introduce adaption of processes (h). Training installers on quality is also important (j). Assessment of the skill level in the community was done before the project implementation (p, al, ab).

Support. Support is given by the programme implementers in the form of technical backstopping (ao, e, h, al) and supervision for a time during installation (r).

Regulation. Regulation is twofold, namely certification or registration of installers (ao, r, v, h) and dictating standards (j).

Technology selection. Technology was selected so that it could be installed by semi-skilled workers (i).

Client support. Clients were given technical guarantees (r, a, h) and after sales service (r, a, v).

6.4.4.5 Newly identified factors

The purpose of the case study was not only to confirm the factors identified during the Delphi study but also to determine whether some of the factors that were not rated “Feasible”, “Highly desirable” and “Highly important” during the Delphi study were also important for the case study. These factors were identified by asking the interviewees at the end of the interview to identify other factors which were important and then confirming the importance from the secondary data.

6.4.4.5.1 N1: Government support

In the cases examined, governmental support was stated as being important whether it was available for the specific project or not. Acceptance by the government of the specific renewable energy programme is important (k, g) as was one of the lessons learned in the solar photo voltaic implementation in Tanzania (ac). The government has to support policies to save the environment by banning the cutting of trees for example, and by ensuring that alternatives are available for the population (t, ab).

Governmental support is required in a number of areas including: regulations such as strategies (j), policies (w, l, c) and legislation (s, ai); standards (c); reduction in or elimination of duties and taxes (y); funding or subsidies (ac, y, ai, ab); licensing of technologies (g); setting up energy regulation agencies (l); partnering with donor organisations (r); building technical capacity (c, y, ai); public awareness (ai); market promotion (ai; forest law enforcement (ac, s, ai); health and safety; and monitoring and evaluation (ai).

6.4.4.5.2 N2: Environmental benefits

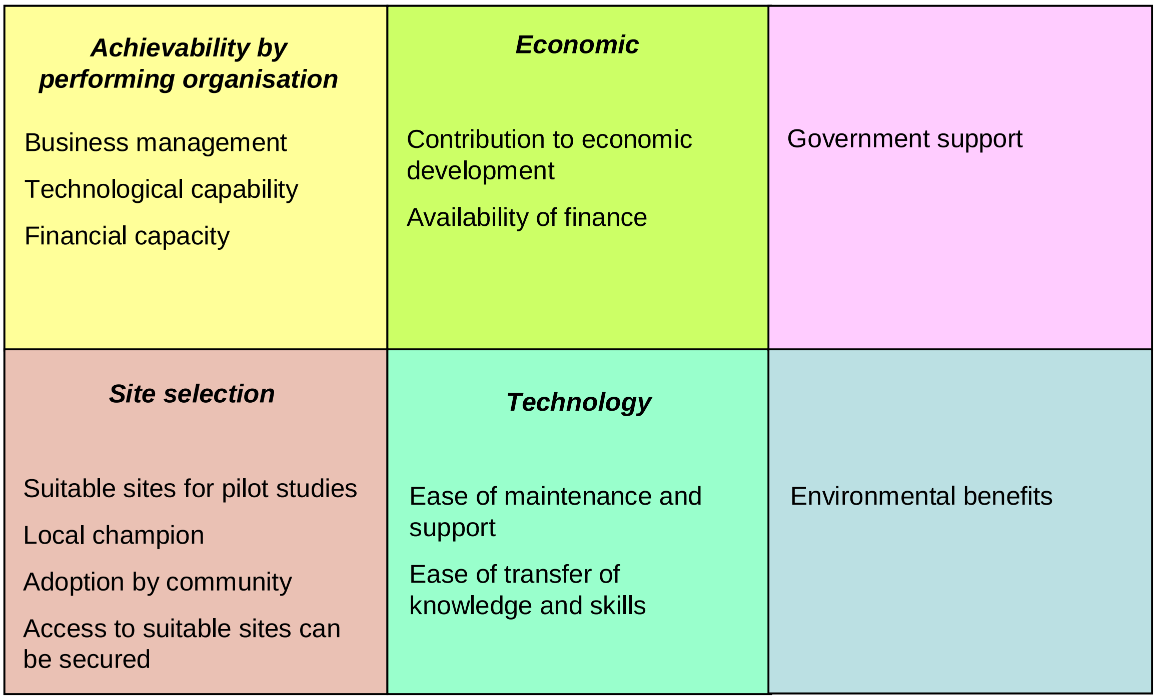
Environmental benefits were found to be important largely during the implementer interviews and in the supporting documents.

The main environmental benefit of renewable energy technology is that it halts deforestation (ao, i, j, r, s, am, g, e, al, ai, h, d, u, al, t). Other benefits include release of fewer greenhouse gasses (i, j, r, am, ai), protection of fragile ecosystems (am, ai) as well as halting soil erosion (i, am, d), desertification (am) and fresh water pollution (i, ai, d).

6.5 Conclusions

The case studies conducted in three developing African countries have confirmed that the all the factors identified in the Delphi study are important. The wording of one of the factors namely business management has changed from project management. Two new factors, government support and environmental benefitshave also been added to the list.

The final factors identified during the case studies are shown in Figure 6-6.

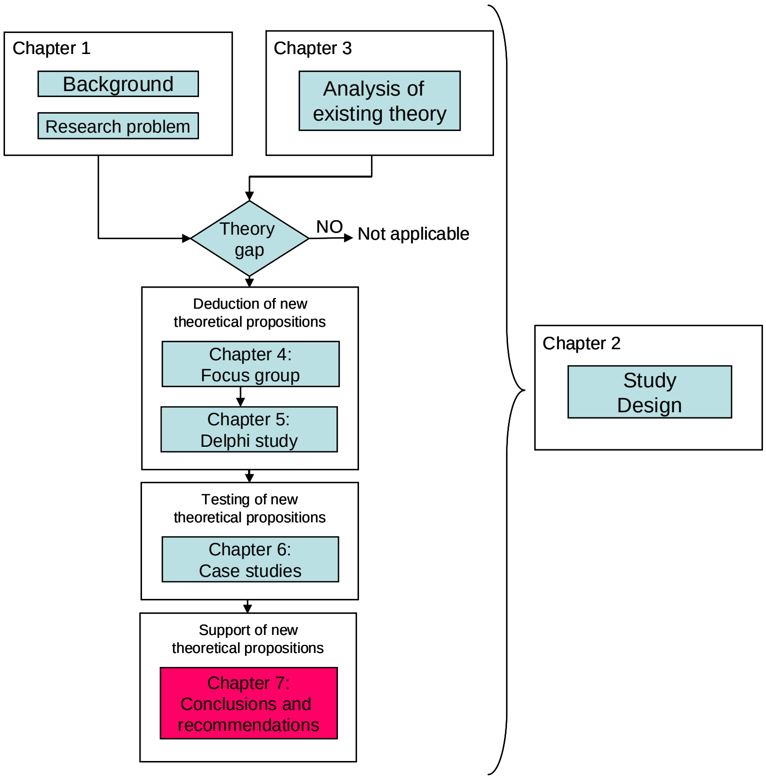


Achievability by performing organisation Business management Technological capability Financial capacity	***Economic*** Contribution to economic development Availability of finance	Government support
Site selection Suitable sites for pilot studies Local champion Adoption by community Access to suitable sites can be secured	***Technology*** Ease of maintenance and support Ease of transfer of knowledge and skills	Environmental benefits

Figure 6-6: Final factors as identified through the case studies

Chapter 7 will discuss these findings, and present conclusions and recommendations on the findings.

CHAPTER 7: Discussion, conclusions and recommendations



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7.1 Introduction

To date, implementation of renewable energy technologies in Africa has not been sustainable in the long term. Various methodologies for the selection of projects and technologies exist in the literature on the topic. A framework of factors for the selection of renewable energy technologies in Africa had not been summarised until this study was undertaken.

This chapter contains a discussion of the proposed framework for the selection of renewable energy technologies in Africa, followed by recommendations for future work. The data gathered during the focus group, Delphi study and case studies in consolidated in this chapter.

7.2 Discussion of the framework for the selection of renewable energy technologies in Africa

This section contains a discussion of the framework which is proposed as one which could be valuable for the selection of renewable energy technologies in the future. As stated in Chapter 3, the selection of technology requires: a selection methodology, a framework of factors, measures for the factors and rating scales for the factors. Essentially selection methodologies are populated with the framework of factors. This section is a brief discussion of the framework of factors as developed throughout this study from the focus group, through the Delphi study and the case studies (see Table 7-1) and suggestions are made as to the measures and ratings which can be applied for each factor.

Table 7-1: Changes in the factors from focus group through the Delphi study and case studies

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
Technology factors			
Ease of maintenance and support over the life cycle of the technology	Maintenance/ support	Security of supply is enhanced. It also implies that spares are affordable and can be easily acquired.	Quality of the installations, the maintenance plans, the training of technicians, maintenance training for users, keeping maintenance simple and adapting the technology to the specific environment
Ease of transfer of knowledge and skills to relevant people in Africa	Transfer of knowledge and skills	Transfer of knowledge and skills to the community involved. Dedicated personnel to run the facility are required.	Identification of stakeholders to train; methods of skills transfer applicable to the environment; quality of training; and formalization of skills transfer.

Factor description	Focus group identification	Delphi study definition	Important issues for each factor from case studies
Site selection factors			
Local champion to continue after implementation	Local hero – champion to continue after implementation	Facilitators of the technology exist which will ensure that the facility will continue after implementation.	Local champions must be identified during technology selection, their responsibilities must be clearly defined and they must be aware of the long term implications of their role
Adoption by community	Passion/ ownership/ buy-in/ adoption by community, responsibility	Community adopting the technology, accepting ownership, demonstrating buy-in and taking responsibility	A determination must be done of the capacity of the population to adopt the new technology, the benefits of the new technology must be determined and communicated to the community and that measures must be in place to ensure client satisfaction
Suitable sites ready for pilot studies	Pilot study site selection issues	Pilot studies are necessary to demonstrate technology to decision makers	Selection of pilot sites is very important and valuable; pilot sites must be selected in such a way that they will be accessible for demonstration purposes to the community
Access to suitable sites can be secured	Not applicable	Access for implementers to sites where the technology can be implemented must be secured up front	Determine priorities of population; set implementation targets; identify site criteria; and identify site
Economic/ financial factors			
Economic development	Economic development (community eventually able to pay), economic sustainability	Economic development translates into (a) the community being able to pay for services and (b) economic sustainability	Income generation, cost and time saving and national income and savings all contribute to economic development
Availability of finance	Available budget – the finances to support a project	The determination of the required budget and the availability of finance for this budget are addressed here. The type of finance whether debt, equity or grant must also be taken into account.	Finance can be facilitated by implementing payment methods which are applicable for the households, as for example, bartering and that finance methods must be in place before the technology can be implemented on a large scale

Factor description	**Focus group identification**	**Delphi study definition**	**Important issues for each factor from case studies**
Achievability by performing organization			
Business management	Proper project management	The performing organization having the business management capacity and procedures in place to ensure that the implementation of technology can be done successfully	Which business management skills should be transferred, how the skills are to be transferred and what to do in the short term when the skills of the organization are lacking
Financial capacity	Financial capacity	Both the administrative capacity to manage finances and the ability to deliver, given the payment conditions.	Financial capacity for performing organizations can be problematic at the outset but that various methods can be used to alleviate the financial capacity required by the performing organization.
Technological capacity	Capacity	The performing organization has the correct technology necessary for implementation of the project at their disposal.	Technological capacity is directly related to quality. Quality assurance must be enforced; regulation of performing organizations and the dictating of standards also contribute to quality installations.
Other factors			
Government support	Regulatory financial incentive, tax regimes must be supportive” and does it fit under national priorities	Governmental support has been obtained for the technology	In the first place, the government must be aware of the new technology and support its implementation. If the government is also prepared to assist in the implementation, success of implementation is further enhanced.
Environmental benefits	Environmental impact assessment	The implementation of the technology will have a positive impact on the environment	Environmental benefits may include: decrease in the release of greenhouse gasses; protection of fragile ecosystems; halting soil erosion; halting desertification; prevention of fresh water pollution.

7.2.1 Ease of maintenance and support over the life cycle of the technology

The definition of this factor, namely ease of maintenance and support over the life cycle of the technology, is as follows: *ease of maintenance and support means that the security of supply is enhanced. It also implies that spares are affordable and can be easily acquired.*

This factor was first identified in the focus group as “maintenance/support” and was expanded to the final description during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The case study showed that this factor relates to the quality of the installations, the maintenance plans, the training of technicians, maintenance training for users, keeping maintenance simple and adapting the technology to the specific environment. The first round of the Delphi study comments emphasised that spares must be affordable and available.

During the selection phase, it can be difficult to measure the quality of the proposed technology. One way of ensuring quality is to ensure that a high-level quality plan is in place before the selection decision is made. The quality plan must address: the standards that the installations must comply to; monitoring methodology of installations; evaluation to ensure that standards are being applied; types of corrective action required for non-compliance and a clear statement on the responsibility for quality processes.

Long term maintenance and support is also difficult to ensure when selecting the technology. Ensuring that an overall maintenance plan is in place before technology selection and comparing the quality of the various sections for different proposals can help in the selection decision. The maintenance plan must address operator maintenance, sustainable technical maintenance, responsibilities for maintenance and, very importantly, the maintenance funding model.

The training of technicians, maintenance training for users and keeping maintenance simple can be assessed by studying the training plan.

It is not always possible to implement renewable energy technologies that operate successfully elsewhere in a new setting without adapting the technology for the social, environmental and maintenance conditions in the new setting. The level of adaptation of technology can be determined by assessing whether it is: an off the shelf implementation; adapted for another developing country outside Africa; adapted for another country in Africa; or, adapted for the specific application within the country. It is also important to determine whether the adaptation has been verified.

The measures and rating methods proposed from the case study are summarised in Table 7-2.

Table 7-2: Measures and rating method for ease of maintenance and support over the life cycle of the technology

Measure	Method of measurement	Rating method
Quality plan	The quality plan addresses:	
	Standards defined	In detail; very generally; not at all
	Monitoring defined	In detail; very generally; not at all
	Evaluation defined	In detail; very generally; not at all
	Corrective action defined	In detail; very generally; not at all
	Responsibility for quality processes defined	In detail; very generally; not at all
	Warranty	Duration of warranty:
Maintenance plan	The maintenance plan addresses:	
	Simplicity of operator maintenance	Minimal operator maintenance; irregular operator maintenance; regular operator maintenance
	Sustainable technical maintenance	Technical maintenance dependant on external supplier; technical maintenance dependant on local supplier
	Responsibilities for maintenance	Maintenance responsibility mainly with operator; maintenance responsibility mainly with local supplier; maintenance responsibility mainly with external supplier
	Maintenance funding model	Cost of maintenance per annum after warranty expires: Responsibility for funding identified
	Availability of spares	Local off the shelf; in nearest town off the shelf; ordered from external supplier
Adaptation of technology	Off the shelf implementation:	Yes/ No
	Adapted for another developing country outside Africa	Yes/ No
	Adapted for another country in Africa	Yes/ No
	Adapted for specific application	Yes/ No
	Adaptation has been verified	Yes/ No

7.2.2 Ease of transfer of knowledge and skills to relevant people in Africa

The definition of this factor, “ease of transfer of knowledge and skills to relevant people in Africa” is as follows: *at macro level this refers to transfer of knowledge and skills to the African state involved. At micro level it refers to transfer of knowledge and skills to the community involved. At both levels, dedicated personnel to run the facility are required.*

This factor was first identified in the focus group as “transfer of knowledge and skills” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The case study research indicated that this factor relates to: identification of stakeholders to train; methods of skills transfer applicable to the environment; quality of training; and formalisation of skills transfer. The comments gathered in the first round Delphi study also emphasised that dedicated personnel are required if a large scale facility is under consideration.

Measuring the ease of transfer of knowledge and skills to relevant people in Africa can present challenges when selecting technologies.

The lack of skills in Africa hampers the transfer of knowledge and skills. The first step therefore is to determine the level of skills of all the stakeholders in Africa who are involved in the technology to ascertain the level of training which will be required for the specific technology.

Language diversity is another challenge. Operator and technical manuals may exist in the European language of the original developers of the technology. As a result of the colonisation of Africa by various European countries, there is no common European language which is understood by all the people of Africa. African countries are most often occupied by various tribes which means that even in the same country there may be more than one local language. Operator and technical manuals written in a language which is not understood by the operators and technicians will obviously hamper the transfer of knowledge and skills. In some cases the technical language required to describe the operation and maintenance activities required may not exist in the local language. The more technologically advanced the solution, the bigger the problem this will pose.

Operator and technical manuals must also be adapted to the specific environment in which the technology will be implemented. Operator and technical training must be of sufficient duration that the knowledge and skills can be successfully transferred. The method used to transfer knowledge and skills during the training is also very important. In the case studies hands-on methods were preferred.

Another consideration is the model for funding of training. Users, technicians and installers are not usually willing to pay for training. This is mainly because they cannot afford to do so. It is therefore important that a funding model for training be put in place at the outset.

Further, it is crucial to clearly assign an organisation which will be responsible for the training effort. This organisation will be responsible for developing the training material, presenting the training or ensuring that others are trained to present the training, monitoring and evaluating the training and ensuring that follow up training is arranged if required.

The life cycle of the technology when planning training activities is important. Previously trained individuals may leave the area for various reasons and retraining may be required.

Before selecting the technology the various stakeholders must be identified and it must be determined which of these stakeholders requires training. Training is not limited to operators and technicians but could also include financial institutions which will provide financing, field facilitators, local and national government.

In some cases skills peripheral to the technology must also be transferred. In the case of efficient stoves for example, people need to be taught kitchen management and how to adapt recipes.

The measures and rating methods proposed from the case study are summarised in Table 7-3.

Table 7-3: Measures and rating method for ease of transfer of knowledge and skills to relevant people in Africa

Measure	Method of measurement	Rating method
Training plan	The training plan addresses:	
	Skills levels of local people	Skills level has been determined and major training is required; skills level have been determined and minimal training is required; skills level has not yet been determined
	Operator training	Duration; method to be used
	Operator manual	Operator manual in European language; operator manual in local language Standard operator manual; operator manual adapted for specific environment
	Technician training	Duration; method to be used

Measure	Method of measurement	Rating method
	Technical manual	Technical manual in European language; technical manual in local language Standard technical manual; technical manual adapted for specific environment
	Training funding model	Cost of training per annum after warranty expires: Responsibility for funding identified
	Responsibility for training addressed?	Yes/ No
	Is training quality assured through tracking process of trainees as well as monitoring and evaluation? Is additional training provided if required?	Yes/ No
	Is the training plan sustainable over the life cycle of the technology?	Yes/ No
Identification of stakeholders to train	Are the following entities part of the training schedule: Users; installers or producers; financial institutions; field facilitator; national government; local government.	Yes/ No If any of the parties is not being trained, specify why.
Methods of skills transfer	What specific method will be used for skills transfer?	Hands on with follow up; hands on; workshop; presentation
Skills to be transferred	Are user-taught skills peripheral to the technology (e.g. cooking methods and recipes in the case of efficient stoves, slurry application in the case of biogas, hygiene)? Has a baseline study been done to determine the skills levels in the area of application? If the skills levels are lacking, has this been appropriately addressed?	Yes/No

7.2.3 Local champion to continue after implementation

The definition of this factor, “local champion to continue after implementation”, is as follows: *facilitators of the technology exist at governmental or local level, which will ensure that the facility will continue after implementation. The facility benefits most of the citizens.*

This factor was first identified in the focus group as “local hero – champion to continue after implementation” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that the proposing organisation would have to show whether there were facilitators and would have to conduct campaigns if and when necessary. The case study showed that local champions must be identified during technology selection, their responsibilities must be clearly defined and they must be aware of the long term implications of their role.

Local champions who will be able to continue promoting and supporting the technology after the implementation team has left must be identified at the outset. In the various case studies the local champions had diverse responsibilities. The responsibilities of the local champions must be clearly identified and communicated to the selected champions.

The measures and rating methods proposed from the case study are summarised in Table 7-4.

Table 7-4: Measures and rating method for local champion to continue after implementation

Measure	Method of measurement	Rating method
Identification of local champions	Have local champions been identified? Have the responsibilities of the local champions been clearly identified? Are local champions aware of their responsibility to continue their work after project hand over?	Yes/No

7.2.4 Adoption by community

The definition of this factor, “adoption by community”, is as follows: *this factor relates to the community adopting the technology, accepting ownership, demonstrating buy-in and taking responsibility. The implications of the proposed ownership structure must also be indicated in the proposal.*

This factor was first identified in the focus group as “passion/ ownership/ buy-in/ adoption by community, responsibility” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that addressing this factor properly would lead to smoother implementation. The case study showed that a determination must be done of the capacity of the population to adopt the new technology, the benefits of the new technology must be determined and communicated to the community and that measures must be in place to ensure client satisfaction.

The capacity for the implementation of the technology must be determined before the technology is selected. This is done in terms of the number of households which have the requirements for the installation of the technology. The current status of each household in terms of income, current expenditure on energy, time and cost and the possibilities for businesses in the area once the technology has been implemented must be determined. This baseline is required to determine whether the technology will benefit the community and also whether the community can afford to adopt the technology.

It is important that the technology be sustainable in the long term. The ownership of the product of the project must be identified at this stage.

The benefits of the specific technology to the population must be determined and information about these benefits must be communicated to the population. The use of the technology must also be explained to the population and a determination must be made of the interest in the technology. The closer the technology to be implemented is to what is currently being used, the higher the chance that the community will adopt it.

The measures and rating methods proposed from the case study are summarised in Table 7-5.

Table 7-5: Measures and rating method for adoption by community

Measure	Method of measurement	Rating method
Capacity determination	Has a detailed capacity determination been done in the area of deployment? Have household income, current expenditure on energy, current time spent on energy and possibilities for businesses been reviewed? Does the current analysis indicate long term sustainability of the technology? Is the ownership of the product of the project clearly defined?	Yes/No
Benefits determination	Have the benefits of the technology been determined? Do the benefits address the needs of the population?	Yes/No
Information distribution	Has information been distributed to the population regarding the use and benefits of the new technology? Did the population show an interest in adopting the new technology?	Yes/No

Measure	Method of measurement	Rating method
Adoption probability	How similar is the technology to that which is currently used by the population?	Very close; close but a change in mindset is required; completely different from what is currently used

7.2.5 Suitable sites ready for pilot studies

The definition of this factor, “suitable sites ready for pilot studies”, is as follows: *pilot studies are necessary to demonstrate technology to decision makers.*

This factor was first identified in the focus group as “pilot study site selection issues” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that this factor reinforces project acceptability and shows that a proper implementation process is being followed. The case study showed that the selection of pilot sites is very important and valuable.

Before the technology can be selected, it must be determined whether suitable sites are available for piloting the technology. The pilot sites must be selected in such a way that they will be accessible for demonstration purposes to the community.

The measures and rating methods proposed from the case study are summarised in Table 7-6.

Table 7-6: Measures and rating method for suitable sites ready for pilot studies

Measure	Method of measurement	Rating method
Selection of pilot sites	Have pilot sites already been selected for this technology?	Yes/No
	How many pilot sites have been selected?	Number
	Where have the pilot sites been selected?	In a public place; in a private place
	If the pilot site is under control of a private entity, is the proposed owner willing to allow demonstration at the site?	Yes/No
	Are any pilot sites already operational and ready for inspection?	Yes/No

7.2.6 Access to suitable sites can be secured

The definition of this factor, “access to suitable sites can be secured”, is as follows: *access for implementers to sites where the technology can be implemented must be secured up front.*

This factor was identified during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The case study showed that for access to suitable sites the following must be in place: determine priorities of population; set implementation targets; identify site criteria; and identify sites.

Securing access to suitable sites for implementation of the technology will be dependant on the priorities of the population and whether the technology contributes to those priorities.

Realistic and achievable implementation targets must be set in the implementation plan. Any technology-specific site requirements must be documented in the implementation plan. For example, for a biogas plant, access to water and location of the cowshed close to the kitchen is required.

The measures and rating methods proposed from the case study are summarised in Table 7-7.

Table 7-7: Measures and rating method for access to suitable sites can be secured

Measure	Method of measurement	Rating method
Determine priorities of the population	Have the priorities of the population been determined? Does the technology address the priorities of the population?	Yes/No
Set implementation targets	Does an implementation plan exist? In how many sites is technology to be implemented in the first six months? In how many sites is technology to be implemented in the first year? How many sites will be in place after five years?	Yes/No Number (a large number is preferred)
Identify site criteria	Are there any limitations or special requirements for the implementation of the technology? Limitations can include installation of the technology within a certain distance from the dwelling. Special requirements can include the availability of water.	List of special requirements List of limitations

7.2.7 Economic development

The definition of this factor, “economic development”, is as follows: *economic development translates into (a) the community being able to pay for services and (b) economic sustainability.*

This factor was first identified in the focus group as “economic development (community eventually able to pay), economic sustainability” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that, in the case of Africa, there is a higher premium on the benefit of the technology to the population and less emphasis on profit. The case study showed that income generation, cost and time saving and national income and savings all contribute to economic development.

Economic development can be achieved by job creation during the implementation of the new technology. Household income can also be improved if the cost for the new technology is lower than what is currently spent. The time spent by a household to collect fuel for energy can be spent in a productive way once the new technology is implemented.

At a national level renewable energy technologies can translate to income through the selling of carbon credits. Savings can also be made if the technology replaces an expensive resource, for example oil, which has to be imported and is subject to price fluctuations.

The measures and rating methods proposed from the case study are summarised in Table 7-8.

Table 7-8: Measures and rating method for economic development

Measure	Method of measurement	Rating method
Income generation	How many job opportunities will be created by implementing this technology?	Number (a higher number is preferred)
Domestic cost and time saving	How much time does a family currently spend on average per month to collect fuel for energy? How much money does a family currently spend on average per month for fuel for energy? How much time will the implementation of this technology save per month per family? How much money will a family save per month by implementing this technology? What is the initial installation cost of the technology?	Numbers (a higher number is preferred)
National income and saving	How many carbon credits will this project generate?	Number (a higher number is preferred)
	Does this technology replace an energy source which is currently imported?	Yes/No

7.2.8 Availability of finance

The definition of this factor is as follows: *the determination of the required budget and the availability of finance for this budget are addressed here. The type of finance whether debt, equity or grant must also be taken into account.*

This factor was first identified in the focus group as “available budget – the finances to support a project” and was refined to the current wording during the first round of the Delphi study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that the success of the technology (especially in poor areas) is dependant on the availability of funding at grassroots level. The case study showed that finance can be facilitated by implementing payment methods which are applicable for the households, as for example, bartering and that finance methods must be in place before the technology can be implemented on a large scale.

A financing plan must be in place before the technology is selected. The financing plan must address the question as to whether users can afford the initial investment required to implement the technology. If this is not the case, other measures must be investigated.

If users cannot afford the once off investment required to implement the technology, one of the methods to facilitate implementation is to adapt the technology to the environment so that users can supply material which is available but needs to be gathered, barter goods for the technology or provide labour for the implementation of the technology. An example of this is where farmers dig the holes required for biogas installations.

Financing schemes should be put in place before the technology is implemented. Financing schemes are however useless if the users will not be able to pay off the loans. It must therefore be determined whether users will be able to pay off loans, either by virtue of the income which they already receive, or because of the savings they make, or as a result of business opportunities or an environment more conducive to development becoming available to them when they use the new technology. These opportunities may be directly the result of using the new technology or indirectly as the time saved can be used productively, instead of gathering fuel. Also, if the technology, for example, provides lighting, they can be more productive for longer periods of the day.

The availability of donor funding can facilitate implementation of a new technology. It must nevertheless be clear from the outset what part of the implementation the donor funding will support, what is excluded from the support and also for how long the donor funding will be available.

Financial institutions should be approached up front to supply loans for the implementation of new renewable energy technologies if financing is required. It is important that allowance be made for households which have a seasonal income. The rates and payment periods should be negotiated on behalf of the users as especially users in rural areas do not have access to financing.

Government support of implementation of new renewable energy technologies is important and is consequently covered as a separate factor. In terms of financing however, it must be determined whether financial support for the technology will be forthcoming either in the form of subsidies or by the removal of duties and taxes.

The measures and rating methods proposed from the case study are summarised in Table 7-9.

Table 7-9: Measures and rating method for availability of finance

Measure	Method of measurement	Rating method
Financing plan	The financing plan must address the following aspects: Can the users afford the initial investment required for the technology in a once off payment?	Yes/ No
	If not, can the users contribute to the initial investment by means of providing materials that are freely available (such as rocks), by bartering goods or by providing labour for the implementation of the technology?	Materials can be supplied; goods can be bartered; labour can be supplied
	If financing is made available will the users be capable of paying off loans?	Yes, due to income which they receive; yes, due to the savings they make on other energy supply; yes, due to the business opportunities created by the technology; no
	Is donor funding available? If so for what part of the life cycle is the donor funding available?	Yes/ No To supply initial investment; to supply initial training; to support short term maintenance; to support long term maintenance
	Are financial institutions willing to provide loans for the initial investment required? Do loans make allowance for households with seasonal income? What rates and payment periods have been negotiated?	Yes/ No Yes/ No Numbers (lower rates and longer payment periods are preferred)
	Is government supporting the implementation of the technology? What percentage of the initial investment is the government supporting?	By providing subsidies for initial installations; by removing duties and taxes. Number (a high percentage is preferred)

7.2.9 Business management

The definition of this factor, “business management”, has been adapted as follows: *this relates to the performing organisation having the business management capacity and procedures in place to ensure that the implementation of technology can be done successfully.*

This factor was first identified in the focus group as “proper project management” and was refined to the current wording during the case study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that the performing organisation determines the success or failure of the implementation of the technology. The case study showed which business management skills should be transferred, how the skills are to be transferred and what to do in the short term when the skills of the organisation are lacking.

Business management skills to be transferred include: market development; marketing; entrepreneurship; general management; personnel management; business development; price determination; financial management; organisational management.

Before the performing organisation is given the go-ahead to implement the new renewable energy technology, the capabilities in terms of business management of the performing organisation must first be determined. In some cases an existing organisation may be up-skilled to do the implementation. In other cases new organisations would need to be created.

In the case where an organisation must be up-skilled, the organisation may already have some of the business management skills required. For example, in Tanzania shop owners who already had successful businesses were tasked with rolling out solar technology (with limited success). The organisation may also have some of the technical skills required but will need to learn the business skills.

The method of skills transfer is important. Formal training may not be sufficient especially if the basic skills of the personnel of the organisation do not meet minimum standards. Ongoing mentoring and coaching is preferred. During the implementation phase the performing organisation can be supported with the required skills but for long term sustainability, the required skills will need to be transferred.

The measures and rating methods proposed from the case study are summarised in Table 7-10.

Table 7-10: Measures and rating method for business management

Measure	Method of measurement	Rating method
Determine current organisations in place	Are there currently organisations in place that can be tasked with implementing the new technology? If not, are there organisations that have business management skills but in other applications? If not, are there organisations with related technical skills? Will a new performing organisation need to be created?	Yes/ No Yes/ No Yes/ No Yes/ No
Determine capabilities of the performing organisation	Does the performing organisation have skills and experience in the following areas of business management? • Market development • Marketing • Entrepreneurship • General management • Personnel management • Business development • Price determination • Project management (time, cost, quality) • Organisational management	Yes/ No
Business skills training	How will business skills be transferred to the performing organisation?	Formal training; informal hands on training; mentoring and coaching; do not know
	What interim measures will be put in place to compensate for lack of skills in the short term?	Performing organisation will be supported with business management; none

7.2.10 Financial capacity

The definition of this factor, “financial capacity”, is as follows: *financial capacity refers to both the administrative capacity to manage finances and the ability to deliver, given the payment conditions.*

This factor was first identified in the focus group as “financial capacity” and remained as that wording during the case study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that the performing organisation must exercise financial discipline when implementing the new technology. The case study showed that financial capacity for performing organisations can be problematic at the outset but that various methods can be used to alleviate the financial capacity required by the performing organisation.

Before the selection of a new technology it must be determined whether the performing organisation has the required administrative capacity to manage finances. If this administrative capacity is not in place, measures must be taken to address the administrative capacity.

Another important consideration about financial capacity of the performing organisation is the capital outlay required to implement the new technology. This capital outlay may be in terms of new equipment required to manufacture the technology, purchasing the components of the technology, purchasing the material for implementing the technology or infrastructure required to implement the technology. Lack of capital will hamper the ability of the performing organisation to deliver the new technology and so must be determined up front.

If the implementation of the technology will be hampered by the lack of capital, measures must be put in place which will alleviate the problem. These measures include the provision of subsidies or loans. Capital outlay can also be limited by clustering work.

The measures and rating methods proposed from the case study are summarised in Table 7-11.

Table 7-11: Measures and rating method for financial capacity

Measure	Method of measurement	Rating method
Financial capacity of the performing organisation	Does the performing organisation have the administrative capacity to manage finances? If no, how will this be addressed?	Yes/ No Formal training; coaching and mentoring; appointment of competent personnel; do not know
Capital outlay	What is the capital outlay required by the performing organisation?	Number (a lower number is preferred)
	Does the performing organisation have the financial resources for this capital outlay?	Yes/ No
	If not, are alternatives available to assist the performing organisation with capital outlay costs?	Subsidies; loans; none
	Can capital outlay be minimised by training the performing organisation to cluster work?	Yes/ No

7.2.11 Technological capacity

The definition of this factor, "technological capacity", is as follows: *the technological capacity of the performing organisation means that the performing organisation has the correct technology necessary for implementation of the project at their disposal.*

This factor was first identified in the focus group as "capacity" and was refined to the current wording during the first round Delphi study pilot study. In the second round of the Delphi study, it was found that it was feasible to consider this factor during technology selection and that it is also highly important and highly desirable.

The comments in the first round Delphi study also emphasised that technical knowledge can be bought in from specialists and need not be developed in-house. The case study showed that technological capacity of the performing organisation is important over the long term as it is directly related to quality. Quality assurance must be enforced; regulation of performing organisations and the dictating of standards also contribute to quality installations. Client support is important both in terms of technical guarantees as well as after sales service. The technological capacity of the performing organisation is assured by training and technical backstopping when required.

Before technology selection, organisations must be identified which have the technological capability to implement the technology. In the short term, technical backstopping can be done but to ensure long term sustainability detailed training and refresher courses are required.

A quality plan must be in place before the selection of the technology. The body responsible for quality assurance must be clearly identified. The linking of financial incentives to the sustaining of quality is recommended. Regulation of the industry by certification of performing installations is one measure which can improve quality. Another measure is enforcing standards for the technology. During selection, technologies which can be installed by semi-skilled workers should be given preference. The quality plan must also address client support in both the short and the long term.

The measures and rating methods proposed from the case study are summarised in Table 7-12.

Table 7-12: Measures and rating method for technological capacity

Measure	Method of measurement	Rating method
Technological capacity of the performing organisation	Does the performing organisation have the technological capacity to implement the new technology?	Yes/ No
	If not, how will the technological capacity be assured? Manufacturing training Installation training Maintenance training Refresher courses Quality training Technical backstopping	Yes/ No
Quality plan	A quality plan must be in place that addresses the following:	
	Who is responsible for quality assurance?	Performing organisation; government agency; third party; do not know
	Is there a financial incentive coupled to quality?	Yes/ No
	Is there any regulation in place for the technology?	Certification of performing organisations; standards; none
	Can the technology be installed by semi-skilled workers	Yes/ No
	How will clients be supported? Technical guarantees After sales service	Duration of guarantee Duration of after sales service

7.2.12 Government support

The definition of this factor, government support, is as follows: *Governmental support has been obtained for the technology.*

This factor was not explicitly defined in the focus group but lower level factors such as “regulatory financial incentive, tax regimes must be supportive” and “does it fit under national priorities” were identified. In the second round of the Delphi study, both factors were found to be feasible, desirable and important and were subsequently discarded as only feasible, highly desirable and highly important factors were finally considered.

The more generic factor of government support was however found to be important in Africa during the case studies; it was important in all eight cases investigated. In the first place, the government must be aware of the new technology and support its implementation. If the government is also prepared to assist in the implementation, success of implementation is further enhanced.

The measures and rating methods proposed from the case study are summarised in Table 7-13.

Table 7-13: Measures and rating method for government support

Measure	Method of measurement	Rating method
Acceptance by government	Is the government aware of the renewable energy technology which is being proposed?	Yes/ No
	Does the government support the renewable energy technology which is being proposed?	Yes/ No
Involvement of government	Is the government currently assisting or willing to assist the new technology with any of the following: • Energy policies • Energy legislation • Standards for the technology • Relief on taxes and/ or duties • Funding for the technology • Subsidies for the technology • Licensing of the technology	Yes/ No

7.2.13 Environmental benefits

The definition of this factor, “environmental benefits”, is as follows: *the implementation of the technology will have a positive impact on the environment.*

This factor was not explicitly defined in the focus group but “environmental impact assessment” was identified. This was changed to “degree of environmental impact of the technology” during the pilot of the first round of the Delphi questionnaire. This factor scored feasible, highly desirable and important during the second round of Delphi but was discarded as only feasible, highly desirable and highly important factors were finally considered.

Environmental benefits were however found to be important in all eight cases investigated.

It is important that the environmental benefits of a technology be considered during technology selection. Environmental benefits may include: decrease in the release of greenhouse gasses; protection of fragile ecosystems; halting soil erosion; halting desertification; prevention of fresh water pollution.

The measures and rating methods proposed from the case study are summarised in Table 7-14.

Table 7-14: Measures and rating method for environmental benefits

Measure	Method of measurement	Rating method
Environmental benefits of the technology	What are the environmental benefits of the technology? • Decreases release of greenhouse gasses • Leads to protection of fragile ecosystems • Will contribute to halting soil erosion • Will contribute to halting desertification • Will prevent fresh water pollution	Yes/ No

7.3 Limitations of the study

This section addresses the limitations of this study specifically due to the small sample size of the Delphi study, the use of a different model for selection of factors in future similar Delphi studies, the use of variability coefficients and hierarchical clustering for further analysis of the case study data and the need for change management when selecting renewable energy technologies in Africa.

When conducting a Delphi study it is important to note that Delphis must not be confused with conventional quantitative surveys (Mullen, 2003). Linstone and Turoff (1978) state the a suitable minimum panel size is seven and also that accuracy decreases rapidly with smaller panel sizes and improves more slowly with larger numbers. This study had a panel size of seven which means that the minimum requirement was met. A larger panel size might have ensured that all thirteen factors finally identified during the case studies were identified during the Delphi study and might also have generated more factors. In the final analysis however, due to the triangulation of methods, the final result of the study was not compromised by achieving the minimum panel size.

The decision to use Likert scales for feasibility, desirability and importance for the rating of factors during the Delphi study can also be seen as a contentious issue. In the study participants were informed on the definitions of scales and the scales were based on those used by Jillson (1975). Other definitions for example technology, economy and acceptability could also have been used and should be investigated in future Delphi studies of this nature.

The case study data was analysed using simplistic pattern analysis. The answered obtained during the interviews and in the secondary data was compared to the factors identified during the Delphi study in a binary manner i.e. either there was evidence available or there was not. The case study data can be further analysed using variability coefficients and hierarchical clustering as this might produce a more in depth view on the data.

The issue of change management has not been addressed in this study as the study deals with the selection of technologies and not *per se* the implementation of these technologies. Change management is “a structured approach to transitioning individuals, teams, and organisations from a current state to a desired future state”, and includes both organisational change management processes and individual change management models (Lewis et al 2002). In terms of this study, the entity to be transitioned will be the community and the desired future state is successfully implemented renewable energy technologies. Some of the factors identified here as being important for technology selection will also need to be addressed in the change management plan during implementation.

7.4 Conclusion

Africa faces great challenges in the next few decades to reach a maintainable rate of positive economic growth. Energy is essential for economic development in Africa. Given the projected electrification levels which Africa is expected to reach by 2030, the current concerns about global warming and the need to meet the Millennium Development Goals for Africa, the implementation of renewable energy technologies is required.

The objective of this research was to develop a structured framework of factors which has been empirically validated and can be used for the selection of renewable energy technology alternatives in Africa to ensure long term sustainability of the application of these technologies.

The following four research methods were used to empirically develop the framework of factors: analysis of the theory, focus group, Delphi survey and case study.

The analysis of existing theory is a summary of the different types of renewable energy technologies available, a discussion of the challenges of renewable energy technologies in Africa and an examination of the different selection methodologies, factors and measures used in the selection of project, portfolios, programmes and technologies.

The focus group used the nominal group technique to identify 38 factors that need to be taken into account for the selection of renewable energy technologies in Africa and classified these factors into six categories.

The Delphi study was conducted over two rounds with the purpose of confirming and prioritising the factors identified during the focus group. The Delphi questionnaires were sent to experts (both academics and practitioners) in the field of renewable energy, with the emphasis on Africa.

In the first round, respondents were presented with the factors identified during the focus group and then asked to: comment on the classification of factors; comment on the description of factors; provide additional factors that were overlooked during the focus group; and provide a preliminary rating of the factors identified during the focus group in terms of feasibility, desirability and importance of considering these factors during the selection of renewable energy technologies in Africa. At the end of the first round Delphi the factors were regrouped into four categories.

In the second round of the Delphi study, the respondents were presented with a summary of the comments and ratings supplied in the first round and were then asked to supply new ratings in terms of feasibility, desirability and importance. The results were analysed. Eleven of the factors were rated by the experts to be feasible, highly desirable and highly important when selecting renewable energy technologies in Africa.

The eleven factors identified in the Delphi study were then used to generate the framework for the eight case studies which were conducted in the following three African countries: Rwanda; Tanzania and Malawi. The sources of evidence used included interviews, documentation and observation. The case studies confirmed that the eleven factors identified during the Delphi study are important for the selection of renewable energy technologies in Africa. Two additional factors were also found to be important and the wording of one of the factors was changed.

In conclusion, the thirteen most important factors that need to be considered for the selection of renewable energy technologies in Africa have been collated into a framework. The framework is contained in Appendix Q and can be used to select renewable energy technologies in Africa.

The framework can be used at various levels and by various organisations to select the most appropriate renewable energy technologies for implementation in Africa. The questions in the framework are answered for each competing technology. The technology that performs the best in terms of providing positive answers for all the questions can then be selected.

By using the framework proposed in this study, selection of renewable energy technologies can be done with the assurance that the most important factors for the successful implementation of these technologies have been taken into account.

The successful implementation of renewable energy technologies in Africa will lead to the improvement of the lives of the population in Africa, will increase their productivity and quality of life, and will contribute towards the alleviation of poverty and the empowerment of women and children. African children who have sustainable access to energy will be better educated and thus be better future leaders.

7.5 Contributions and Recommendations

In this section some practical suggestions and recommendations for future research are made.

7.5.1 Contributions to practice

The main contribution to practice is the list of factors together with measures for these factors which is contained in Appendix Q of this study. A renewable energy practitioner, whether from an NGO, government agency or other agency, can use this list of factors to ensure that an holistic approach is followed when choosing between renewable energy technologies in Africa. The factors can be used in any comparative selection methodology.

This study consulted the opinions of experts in the field of renewable energy technology selection in Africa during the focus group and Delphi study. The findings of the focus group and Delphi study were confirmed during the eight case studies in three African countries. Considering factors the factors identified in this study when selecting renewable energy technologies in Africa will increase the long term success rate of these technologies.

7.5.2 Contributions to theory

This study contributes to the theory in that a better understanding of what it takes to ensure technological success in rural Africa has been defined and collected in a comprehensive, holistic framework of factors.

The framework of factors and how to measure factors during project/technology selection have been determined and these factors can now be further debated by academics and practitioners alike.

7.5.3 Recommendations for practice

A lack of skills is very evident in Africa. The uses and sources of energy are not adequately addressed in basic education. School curricula should be updated to address alternate energy technologies to raise awareness. This will also encourage school leavers to follow technical career paths.

Technical career paths in Africa should be encouraged by ensuring that school leavers have the correct level of mathematics and science to pursue these careers; by providing funding for students to continue their studies in technical areas and by establishing technical colleges and universities in areas where these are lacking.

Selection of renewable energy technologies in Africa should not be done based solely on the economic or environmental benefits of the technology but should take into account the framework of factors described in this study.

Involving the community in Africa before implementation of a technology is of paramount importance. The community must understand the benefits and uses of renewable energy technology before any implementation is planned.

The availability of finance will hamper the best planned implementation if not addressed at the outset. The population will not invest in new technology which is not affordable. If the choice is between food and technology, food will win.

Education and training of implementing organisations is of great importance to ensure the long term sustainability of renewable energy technologies. Badly implemented technologies give renewable energy technologies a bad name and hamper progress for future implementations.

Renewable energy technologies which have been successfully implemented elsewhere, even in other developing countries, will not necessarily be successfully implemented in Africa. There is a need to adapt the technologies for the specific environment in which they will be used.

Quality of installations and of technology is of utmost importance as disgruntled users will quickly revert to traditional methods if the application of the technology is not properly maintained and supported.

7.5.4 Recommendations for future research

This study has produced an empirically tested framework of factors for the selection of renewable energy technologies in Africa. The following work is recommended to improve the framework and make it more user-friendly:

The proposed framework of factors should be used in a pilot project to make a selection of a renewable energy technology in Africa to ensure that all the factors are clearly described and that the suggested measures address the needs of a framework.

In the pilot project the framework of factors should be implemented into one of the selection methods discussed in Chapter 3. The analytical hierarchy process or analytical network process is recommended because of the ease of use of these methods.

Weights must be assigned to the different factors. Research will be required to determine whether the weights will be applicable in all scenarios or whether the weights are application specific. It may also be found that during implementation in a similar environment, use can be made of the same weights but this will need to be confirmed by future research.

The proposed framework of factors includes measures for each factor. These measures must be confirmed by future research. It is recommended that the opinion of experts be gathered using the Delphi method to confirm the measures. Several case studies will then be required to confirm the measures.

This research has touched on the various stakeholders who are involved in the implementation of renewable energy projects in Africa. Further research is required to confirm whether the list of stakeholders identified here is exhaustive.

Note: The appendixes of this study are not in the bound copy but can be accessed at: http://phd-thesis.wikispaces.com/. Please create an account and request membership.

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