Energy, water and climate change in Southern Africa

What are the issues that need further investment and research?

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Photos on cover page

Left: Barren fields at Bethel in Lesotho; hot and dry - perfect weather for solar applications, but not farming).

Right: Storm water diverted to the Bethel Business and Development Centre campus where it will slow, spread and sink. A lush fruit and vegetable garden has developed.

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Executive summary

Regional climate change projections in Southern Africa, based on GCMs comparing 2080-2099 to 1980-1999, indicate that global warming will most likely lead to greater than the global annual mean temperatures for all seasons, 3.1°C for summer warming and 3.4°C for winter warming (Christensen et al, 2007).

Warming in Southern Africa will lead to increasing rainfall intensities, decreasing frequencies of low intensity (soft soaking) rainfall and longer dry period between rainfall events. This will result in more severe draughts, floods and heatwaves, which will lead to greater food insecurity. In historic times, draughts and floods had already major impacts on Southern African populations. Around 1200 to 1500, droughts led people to abandon settlements in the Kalahari Desert. The Lifaqane wars, starting in about 1815, were characterized by a 25-year period of famine and violent conflict between peoples in Southern Africa. During the 1991-1992 draught, 20 million people in the region (15% of SADC population) needed food relief (Dejene et al 2011).

Many parts of Southern Africa face two critical resource constraints on development, namely energy and water. Energy and water are closely linked at different levels and scales. Water drives the turbines of hydroelectric power plants. Processing of coal and cooling in thermal and nuclear power plants requires water and energy is required to lift, treat and distribute water. Even at the household level, we observe water-energy linkages. When using water-saving showerheads, for example, we not only save water, but also electricity for heating the water. This complex interconnection is called the water-energy nexus.

At the same time, coal-based power plants emit large amounts of greenhouse gases (GHGs) into the atmosphere, contributing to climate change and climate variability which then leads to floods and droughts. In times of drought little water flows into hydroelectric dams, affecting electricity generation. For rural communities the greater frequencies and severity of droughts and floods caused by climate change leads not only to crop failure and subsequent hunger but also interferes with water supply technologies when, for example, the water levels in boreholes rise or fall beyond the specification of the pump. Thus climate change critically impacts the water-energy nexus.

The International Development Research Centre (IDRC) in Canada commissioned the Energy Research Centre (ERC) at the University of Cape Town to assess the water-energy nexus in the context of climate change. 'The goal of the exploratory project is to analyse the way energy and water services can be combined and improved to enhance resilience and adaptive capacity of communities to climate variability and change'.

After an introduction to the water-energy nexus in Southern Africa (Chapter 1) and a brief review of the four countries studied as well as climate change scenarios for the Southern African region (Chapter 2), the study reports on the following four major research topics identified by the Southern African team:

1. The state of integrated planning of water and energy resources in the context of climate change (Chapter 3).
2. Opportunities and barriers for renewable energy technologies for rural water services in Namibia, Botswana and Mozambique (Chapters 4 and 5).
3. The water-energy nexus in policies of South Africa (Chapter 6).
4. An investigation of water supply adaptation technologies and strategies in a case study from Lesotho (Chapter 7).

The assessment is based on secondary data through a cross-disciplinary desktop study, discussions with experts and two workshops. The countries covered in this report are Botswana, Lesotho, Mozambique, Namibia, and South Africa.

1. The state of integrated planning of water and energy resources in the context of climate change

Access to clean drinking water and modern affordable energy sources are primary goals of most developing countries' policies. Southern African countries have opted to expand infrastructure, industrial development and agricultural production to create badly needed jobs for a growing

population. However, the region faces two critical resource constraints on development, namely water and energy. Both sectors will compete for scarce water resources in the region. The energy sector is growing and is still largely fuelled by coal-based power plants in South Africa, Zimbabwe and Botswana. Coal-based electricity generation consumes more water than any other power plant except nuclear. National development plans focus upon energy plans and water plans separately often not integrating the other sector's resource use.

Using renewable energy technologies for water services in developing countries is able to address both the need for energy and the need for water services in the most vulnerable areas. Wind and solar photovoltaic renewable energy technologies use hardly any water and are therefore the energy technologies of choice in water-scarce remote areas which are not connected to the national electricity grid. Further research on planning and water and energy resources, climate change and the role of renewable energy resources in integrated development is required.

2. Opportunities and barriers for renewable energy technologies for rural water services in Namibia, Botswana and Mozambique

This part briefly describes the different technologies currently used in rural sub-Saharan Africa to access, treat, distribute and use water (see Chapter 4). The selection of the appropriate technology depends on many factors, from intended end-use of the water (for agricultural irrigation or for providing hot water in a clinic, for example) to the availability of components and local technical skills. Furthermore, the way these technologies are designed must also be able to adapt to climate variability. Examples include rainwater harvesting systems that can accommodate varying rainfall patterns or pumps that can respond to changes in water tables, or applying conservation tillage in agriculture which slows down the movement of water and conserves on fuel use and reduces soil erosion. Considerations for assessing technology choices are given in tables. Issues around the introduction of new technologies and technology transfer are discussed.

Case studies of energy technologies in rural water supply are described and analysed in Chapter 5. Three Southern African countries, Namibia, Botswana and Mozambique, are selected for the case studies. As an example the NAMREP I and II project in Namibia are given here; detailed descriptions and analyses of projects in Botswana and Mozambique are reported in the main body of the report. NAMREP I provided technical assistance to government, NGOs, finance and other sectors to remove barriers to and facilitate the wide-scale introduction of solar technologies. NAMREP II delivered solar energy services to rural and off-grid households using effective financing schemes. To address the barriers, NAMREP sought to achieve five outcomes: capacity building in the public and private sectors and NGOs, establishing a framework of policies, regulations and actions to supporting renewable energy and off-grid electrification, increased public awareness and social acceptability of renewable energy technologies, appropriate financing and product delivery schemes, as well as learning, evaluation and adaptive management.

NAMREP achieved high levels of success in building capacity, putting in place policy, laws and regulations to support RETs, and setting up appropriate financing and product delivery schemes. It managed to raise the status and awareness of the potential of renewable energy technologies in Namibia, increase acceptability amongst stakeholders and achieved considerable success in introducing RETS commercially in the country. It has also facilitated the development of new standards for RETs in the country. However, the project encountered a number of challenges during the implementation of objectives. The global goal, to increase affordable access to sustainable energy services thus contributing to climate stabilisation by reducing or avoiding CO_2 emissions and improving livelihoods and income generation of rural people, was not fully achieved. The development objective, to promote the delivery of commercially, institutionally and technically sustainable solar energy services, was also not fully achieved. Support for decentralised RET companies was not very satisfactory. The objective of capacitating vocational and training centres and providing technical training on RETs were prevented by changes in legislation.

A major concern of NAMREP was the fact that it bypassed the off-grid and rural communities which were the intended beneficiaries of the project. The loan facility was mainly utilised by urban households and commercial farmers and thus the fund was rapidly depleted. These households were better equipped to make use of the loan facility as they had more experience with financial procedures, had access to banking facilities, had regular income and therefore were able to make regular repayment of loans, and already had access provided with basic services (Schultz, 2011).

It appears that a common aspect of the unsuccessful components of NAMREP is the lack of follow-up. Most of the unsuccessful areas were not subject to the most reliable measurements of the levels of success achieved. In particular there were no supplier or end-user surveys for assessing emissions reductions and increase in the usage of RETs. This means that conclusions were based on preliminary studies or secondary research rather than verifying the outcomes of these objectives on the ground. This does not mean that actions were not implemented but it is difficult to accurately quantify levels of success without measuring progress on the ground. One of the principle factors behind lack of evaluation may be the 'end-of-project study' not being completed. The contracts with the funding agency expired upon completion of the project and it was not established who would be responsible for continuing the project after NAMREP was completed. This meant that no-one took responsibility for completing the end-of-project study and therefore certain elements of an accurate and comprehensive project evaluation process were neglected. Furthermore, by not properly evaluating initiatives on the ground, problems can be overlooked and initiatives will continue to be implemented in an inappropriate manner. Addressing this problem would help to improve the degree of success of NAMREP.

The barriers, opportunities and gaps of the case studies were analysed using a framework of seven categories; market failure, market distortions, economic, financial, institutional, technical, social cultural and behavioural barriers. An example of market failure is described in the Mozambican project of WaterAid in Niassa province. Many RE technologies and spare parts could not be manufactured locally as the market demand is too low, which made the cost of production too high, so these technologies had to be imported, which made them unaffordable. A particularly significant and known element of market failure is the non-consideration of externalities in the pricing of conventional energy as well as hidden and not-so-hidden subsidies. This makes it difficult for RETs to compete economically and many of the described projects cite these as barriers for the widescale use of RET. Economic and financial barriers are the high initial cost of RETs which make them unaffordable in the poor rural areas where they are most needed. The high cost of capital, lack of access to capital and lack of financial institutions further compound the problem. Government funds in the Southern African countries are limited and external donors play a key role. This fosters dependency and creates sustainability problems once the foreign project funds have come to an end. Projects need to adopt a framework that enables communities to generate funds using RETs.

National institutions do not have the capacity to generate and disseminate information, and this task is left to an already overloaded provincial government or municipality which lack the resources to carry out these important functions; they are as a result often neglected. The lack of stakeholder involvement is a concern in many of the projects. The lack of private sector participation, which is evident, is caused by the risk in investing in these projects and the fact that better opportunities lie in other investments. The lack of consistency in government policy causes uncertainty and further reluctance to invest.

A major element of technical barriers is the lack of skilled personnel. This is linked to capacity in communities especially in rural communities. There is also a lack of entrepreneurs in the renewable energy sector in the countries of the case studies.

Social, cultural and behavioural barriers, expressed in the lack of consumer and social acceptance, are raised in all projects. The main reason for these is the inadequate information and education about the product. Products are then seen as alien and inferior and a preference for traditional energy remains.

There are a number of other barriers that cannot be grouped under the previous six headings but are still prevalent. Uncertain government policies are one of these. Un-supportive policies for RETs, lack of government capacity and lack of faith in RETs from the government were all evident to some degree in the projects in Botswana, Mozambique and Namibia.

Lack of infrastructure is another significant concern in all these countries. Roads, connectivity to the grid and communications infrastructure all became a problem especially in the remote settlements. These are difficult conditions under which to implement a project based on new renewable energy technologies and also make achieving sustainability in these projects challenging. Emphasis on supporting infrastructure is acknowledged but difficult to address without huge investment.

Opportunities

The success of some of the projects highlights the opportunities they present. The projects show how good planning, management, and education can make a significant difference, and how to use limited resources as effectively as possible. Communities taking an active role in the project and leadership from local government were essential in nearly all the successes. Without these influential players the projects would have lacked the initiative they provided. This is important because it is not merely lack of funding that is a constraint to projects, and this is visible in the many other barriers encountered in the case studies provided. It is important for communities and local governments to develop other components that projects depend on so that, when they do manage to receive the required finance, the necessary conditions exist to support the funding and make the project a success. This kind of mindset needs to be applied to all projects in order to move away from a dependency mindset, and presents an opportunity to communities and local governments. In order for countries in Southern Africa to achieve progress this change in mindset is imperative.

The projects in the three countries show a large variety of outcomes and we need to develop an analytical framework to compare the different elements in the projects. Such a framework or frameworks would present a guide to upscaling of the successful elements and avoiding mistakes when deploying RETs to other regions in Southern Africa.

3. The water-energy nexus in policies of South Africa

This chapter analysed water and energy policies and planning in South Africa. It was found that in comparison to the USA, where laws and policy documents recognize and address the linkages between water and energy, policies in South Africa seldom cross sectoral boundaries when raising issues.

The Local Municipal Spatial Development Framework (LMSDF) is the principal planning tool of local government and it was analysed for the case study of the rural Elundini Municipality. Water was quite extensively addressed in the LMSDF and the coverage of energy was restricted to electricity. The LMSDF combines water and energy issues only in the plan for building a hydroelectric power plant. In conversation with representatives of the Elundini Municipality this plan could not be confirmed. Neither the water, nor the electricity department's superintendant knew about a planned hydropower plant.

The integration of technologies like solar water pumps or solar water heaters has the potential to benefit municipal service delivery. GHG mitigation opportunities, poverty alleviation contribution and expenditure savings are possible benefits government is missing out on.

The suggested set of research questions aims to stimulate the academic and political debate in the country around these issues. Research is suggested to investigate whether there is any specific planning/policy for the water-energy nexus in the context of climate change and what such policy could look like in the South African and regional context. The level of awareness of the water-energy nexus in the context of climate change needs to be explored further at all government levels. Technology options in terms of renewable energy technologies and their potential for adaptation to climate change in particular in the water -energy context remain largely unexplored. This is particularly important in the context of rural development.

4. An investigation of water supply adaptation technologies and strategies in a case study from Lesotho

Lesotho is an arid to semi-arid country with higher rainfall in the mountainous eastern parts. While droughts and poor degraded soils are major constraints on agriculture, floods do occur and it is argued that much better water utilisation and storage strategies can be pursued. At present agriculture is in decline and the contribution of agriculture to the economy is small.

In contrast to agriculture stand the Lesotho Highlands Water Authority which transfers water from the mountains in Lesotho to Gauteng, the economic hub of South Africa. Phase I is completed and transfers $30m^3$/sec of water to South Africa. In addition, 70 MW of lectricity are generated and sold in Lesotho. Phase II is under way and will further increase water transfer and electricity generation. Lesotho greatly benefits from the water sales and the electricity distribution. However, more remote and dispersed villages are lagging behind the rate of progress in urban areas and high levels of unemployment and poverty remain in the rural areas.

It is suggested that work in the following will have significant impact particularly in rural areas.

i. intensive landscaping for storm water retention;
ii. technology for water supply and sanitation;
iii. general adoption of renewable energy technology; and
iv. environmental education.

Taken together, these four broad courses of action will increase resilience to weather-related stress while generating wealth and improving human welfare. Will this all happen naturally at its own pace, or chaotically as much technological and cultural diffusion does, or is there a role to play for targeted interventions, specific policies, regulatory mechanisms, institutional reform?

1. Integrated water-energy planning in the context of climate change

   This would need the following:

   - To identify relevant existing data sources and collection/collation of data where not readily available, possibly including utilisation of expert judgement.
   - To establish critical problem areas, future policy alternatives, regional and national goals and appropriate scenarios for external pressures such as climate change and global economic conditions.
   - To construct a general model (or models) to provide an overview of the energy-water – climate change system: Experimentation with such models would serve to identify sensitive 'pressure-points' that would require the most careful data needs and/or policy variables; the validity of the models should be explored in stakeholder and expert workshops to integrate local knowledge in communities as well as understanding of interdisciplinarities.
   - To develop more detailed models arising out of the general model. These may or may not include some of the following features:
     - Regional modelling for defined regions in Southern Africa - individual countries, regions and communities within countries; metropolitan areas such as the City of Cape Town and remote rural communities such as Elundini in the Eastern Cape Province;
     - Explicit representation of multiple scenarios;
     - Modelling of multiple societal goals and objectives as part of the process of developing national strategies for water/energy planning in the context of climate change.
   - Experiment with models to identify key areas of sensitivity or pressure, e.g. potential magnitude of water/energy cross-effects; potential magnitude of climate change effects; where local interventions may have greatest impacts in the broader system; where are greatest data sensitivities.
   - Design of refined and more extensive model in the light of these experiments. Support of local intervention studies by more detailed models of community-level actions (subject to global constraints)

2. Develop a bottom-up research methodology integrating case studies as well as top-down planning for basic infrastructure development.
   - Case studies will include the analysis of factors limiting or promoting decentralized renewable energy technologies, eg., drivers and barriers.
   - We need a research framework to analyse and compare case studies and draw conclusions. This would include community participation and an integrated approach to infrastructure planning in communities.

- In which way is the social embedding of technologies planned? More attention has to be paid to analysing the interaction between educated technology providers and rural users.

3. Support policies, regulations, information and training enhancing efficiency and equity of water and energy services. A comparative study of integrative development policies and plans and their impact on the water-energy nexus and climate change is recommended.

   - The water-energy nexus is an outstanding issue for the South African government to address. The implications of the nexus in particular in the context of climate change appear to be present on the systemic agenda-setting level. But it requires considerable awareness raising and more detailed research in order to bring the issue closer to government's attention.
   - Problem-oriented, multi-disciplinary policy analysis is suggested in order to zoom in on the water-energy nexus and draw expertise from the water, energy and development sectors. The potential benefits of alternative technologies like solar powered water pumps and solar water heaters need to be known in government and its implementation mainstreamed in service delivery.
   - The barriers for governments to address inter-/ multi-departmental challenges with appropriate collaborative solutions have to be studied and eventually overcome. Finally, a comprehensive understanding needs to be developed of appropriate cross-sectoral policy formulation, budgeting, implementation and evaluation in the field of energy and water taking the national circumstances into consideration.

4. Adapting to climate change: Risks, opportunities and context in Lesotho

   To guide the interventions the following research areas are suggested.

   i. Intensive landscaping for storm water retention
      - What practices have the most impact and what do they cost?
      - What are the gaps in adoption, financial, technical, or motivational?
      - What remote and local sensing technology is available to monitor change and how can it be deployed?
      - What potential business models exist that can utilize markets to collect water, construct roads, and landscape on a sustainable for-profit basis?
      - What role can focused and managed public works programs play in contributing infrastructure for climate change and adaptation?

   ii. Technology for water supply and sanitation
      - What low cost water treatment technology is available to ensure safe supply of potable water in households.
      - What water storage and reticulation options exist for rapid roll out and deployment?
      - What watershed enhancement strategies exist, that will both buffer threats from climate change and at the same time provide water for irrigation and household use?

   iii. General adoption of renewable energy technologies
      - What basic mechanisms exist for Lesotho to forge its own low-carbon footprint development agenda?
      - What technologies are available now, not only to reduce global carbon emissions, but to reduce urban island pollution?

- What frontier technologies should be tested and nurtured? For example solar powered central pivot irrigation wheels and EVs.
- What potential exists for Lesotho to become a market leader, rather than a market follower?

iv. Environmental education

- How can response to the risk of climate change and action for adaptation be generated? Dull speeches, documents, billboards or Pop Stars and concerts? All options should be considered.
- What mix of modern experiential marketing and plodding institutional analysis is best suited to tackling climate change and responsiveness?
- Where can basic knowledge on climate change and adaptation be assembled in Lesotho, and utilized to inform public/private policy/practice and drive change.

5. IDRC Energy and Water Workshop in Brazil

The IDRC Energy and Water Workshop in Porto Galinhas, 23-24 September 2011, presented an opportunity to compare results of the Southern African study with similar work in Latin America. Similarities and differences between the two regions emerged. In Latin America a far larger part of energy is generated from hydropower while in Southern Africa most energy generation is coal-based. This is why awareness of the water-energy nexus in Latin American countries is greater than in Southern African countries. A significantly higher percentage of the population in Southern Africa (40–75% in the countries studied) than in Latin America (about 20–30 %) is rural and dependent on agriculture for a livelihood. Climate change and climate variability is consequently directly affecting a largr proportion of people in Southern Africa.

Issues raised in the Latin American case studies are very similar and often identical to those raised in the Southern African case studies. A collaborative effort would enhance particularly the validity of the results of the proposed research topic 2 below: Developing a research framework for a bottom-up research methodology integrating case studies as well as top-down planning for basic infrastructure development.

1. Introduction

a. Background

Water-scarce countries, globally, face two critical resource constraints on development, namely energy and water. Southern Africa is no exception.

Energy and water are closely linked at different levels and scales. Water drives the turbines of hydroelectric power plants. Processing of coal and cooling in thermal and nuclear power plants requires water and energy is required to lift, treat and distribute water. Even at the household level, we observe water-energy linkages. When using water saving shower heads, for example, we not only save water, but also electricity for heating the water. This interconnection is called the water-energy nexus.

At the same time, coal-based power plants emit large amounts of greenhouse gases (GHGs) into the atmosphere, contributing to climate change and climate variability which then leads to floods and droughts. In times of drought little water flows into hydroelectric dams, affecting electricity generation. For rural communities the greater frequencies and severity of droughts and floods caused by climate change leads not only to crop failure but also interferes with water supply technologies when, for example, the water levels in boreholes rise or fall beyond the specification of the pump. Thus climate change critically impacts the water-energy nexus.

The Energy Research Centre (ERC) at the University of Cape Town was commissioned to assess the water-energy nexus in the context of climate change. 'The goal of the exploratory project is to analyze the way energy and water services can be combined and improved to enhance resilience and adaptive capacity of communities to climate variability and change'. More specifically, the objectives of the assessment study are:

- To explain when and why decentralized renewable energy technologies for water services are not used, are not used in the proper way, or not as much as they could be;
- To determine the challenges and opportunities to inform policies and initiatives aiming to enhance the climate change adaptation capacity of people living in areas under climate related water stress by using renewable energy technologies;
- To formalize the results for communication in an international workshop; and
- To define clear and practical entry points for further investment and research.

Access to clean and modern energy is a primary goal of many developing countries' energy policies. It is acknowledged that access to energy will improve the livelihoods of people in the region, promote economic growth and help alleviate poverty. Access to clean, more modern forms of energy is and will continue to be an important component in addressing not only the UN Millennium Development Goals (MDGs), but also climate change, the social and environmental impacts on the most vulnerable sectors of our society, and ensuring economic growth and sustainable development.

Southern African countries have opted to expand industrial development and agricultural production to create badly needed jobs and reduce poverty. However, the region faces two critical resource constraints on development in the coming decades, namely water and energy. Both sectors will compete for scarce water resources in the region. The energy sector is growing and is fuelled by coal-based power plants mainly in South Africa as well as in Zimbabwe and Botswana and coal-based electricity generation consumes more water than any other power plant except nuclear (Figure 1).

The same parts of society that lack access to modern forms of energy also tend to lack access to water resources for domestic (e.g. sanitation), agriculture and industrial use as well as a safe water supply for drinking purposes. National development plans focus upon energy plans and water plans often not fully including the other sectors resource use. The use of renewable energy technologies for water services in developing countries is able to address both the need for energy and the need for water services in the most vulnerable areas. Wind and solar photovoltaic renewable energy technologies use hardly any water (Figure 1) and are therefore the energy technologies of choice in water scarce remote areas which are not connected to the national electricity grid.

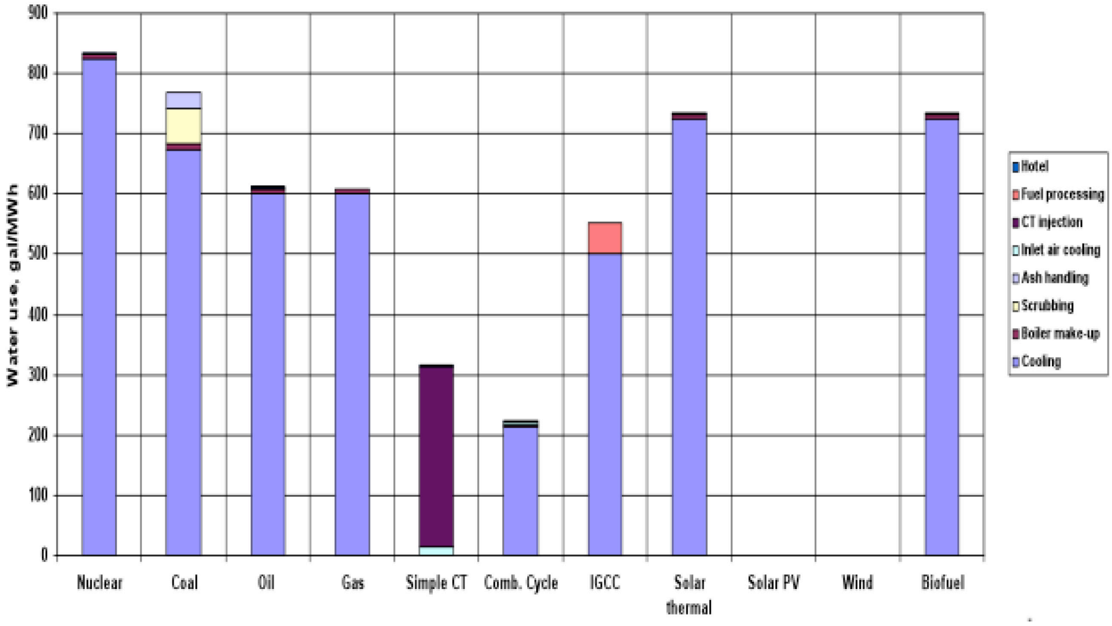

Figure 1.1: Water use by plant type of energy technology

The change in climate will impact the viability and availability of all natural resources, but more specifically water resources. Increased flooding and droughts, for example, will threaten water security and national development (Global Water Partnership, 2010). Droughts are already reducing electricity supply from hydroelectric power plants in Kenya (Afrepren, 2009). With an ever growing population there will be an increased demand for water for domestic use, sanitation, food production, and biofuels as well as commercial and manufacturing purposes. Limited or degraded water resources which are further impacted by climate change will affect those most vulnerable in this scenario – the poor, the elderly, women and children. In Southern Africa and internally in South Africa there are already a number of water transfer schemes (Figure 2). One of the largest schemes is the South Africa-Lesotho Highlands Water Scheme which transfers water from the Senqu/Orange River in the Lesotho Highlands to the Vaal River system in South Africa to supply the metropolitan area of Gauteng. Water needs in the Gauteng/Johannesburg area continue to rise and a second phase of the Senqu/Vaal transfer project has just been signed.

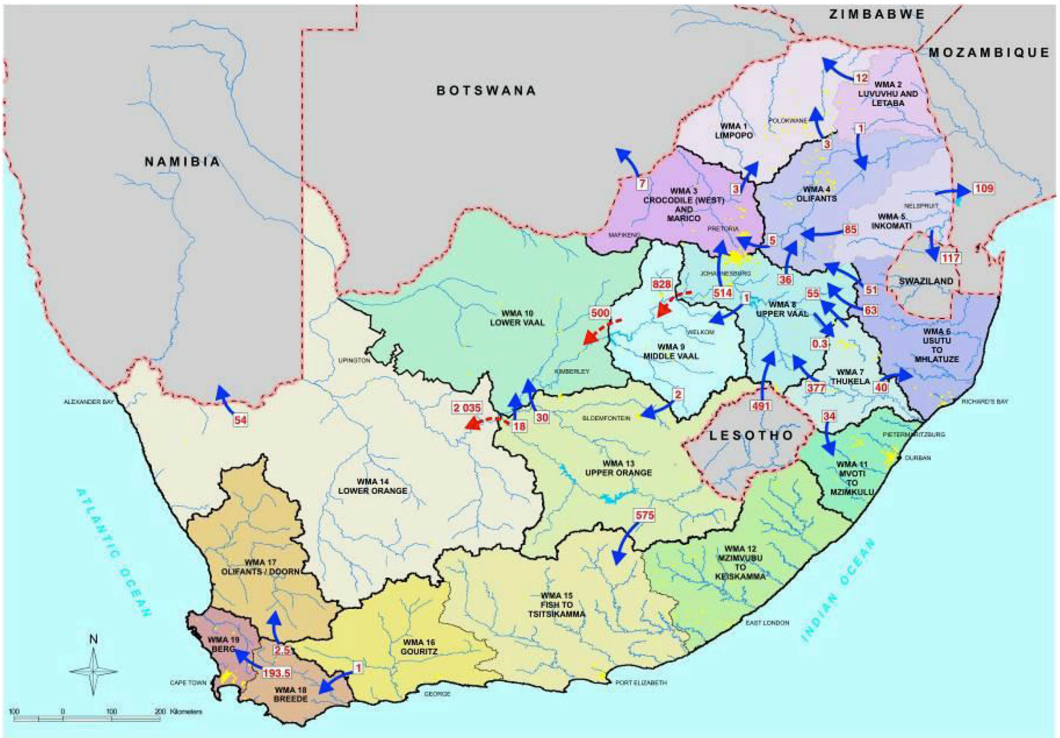

Figure 1.2: Water transfers in South Africa and to and from neighbouring countries

The ERC chose five countries in the Southern African region for this research, namely Namibia, Botswana, Lesotho, Mozambique and South Africa. Reasons for their selection include their location within a region known to be particularly vulnerable to climate change and their high levels of poverty. According to the Human Development Index (2010), Mozambique is ranked #165 out of 169 countries listed, Lesotho #141, South Africa #110, Namibia #105, and Botswana #98 (UNDP, 2010). Also, these countries share significant trans-boundary water (Figure 2) and energy resources, namely the Okavango and Senqu/Orange Rivers and associated basins, and South Africa imports hydroelectricity from the Cabora Bassa dam in Mozambique. South Africa was included in the mix as a middle-income country, with a larger population than the other countries studied and an important economic role in the region, which is also vulnerable to climate change. Environment Statistics ranks South Africa as the 28th most water-stressed country out of 140 countries listed while Namibia was ranked 54, Botswana 58, and Mozambique 60 of water stressed countries globally. [1]

b. Methodology

The assessment is based on secondary data through a cross-disciplinary desktop study. Supporting documentation details are highlighted in each section and a reference list is given at the end of this document. In addition colleagues and professionals from the energy and water sector have been consulted by email, telephone and in person. A seminar and a workshop have been held to discuss the issues involved in the water-energy nexus in the context of climate change. The programme for the workshop is included in Appendix 1. A list of consulted persons is given in Appendix 6.

Comparing water and energy data can be challenging due to the difference of spatial planning for energy distribution and water basins. Water planning is carried out at the river-basin level and these basins can be in the same country or they can be in two or more countries, such as the Senqu/Orange River which has its source in the Highlands of Lesotho, crosses South Africa and flows into the Atlantic Ocean on the South African and Namibia border. The Limpopo River is another transboundary river between South Africa and Zimbabwe. Energy planning is undertaken at a centralized national level, for example in national power generation companies and then the electricity is distributed to regional and local electricity departments.

[1] Source: http://www.nationmaster.com/graph/env_wat_sev_wat_str-environment-water-severe-stress.

2. Brief country reviews including climate change scenarios for the region

a. Brief country reviews

An overview of some country statistics and climate is given in Table 2.1. The climate regime ranges from desert in Namibia, arid to semi-arid in Botswana, temperate cold in Lesotho to tropical and subtropical in parts of South Africa and Mozambique.

Table 2.1: Comparative data on population, land, rainfall, irrigation potential, HDI and climate regimes of the selected countries; Botswana, Namibia, Lesotho, Mozambique and South Africa
Sources: [1]UNDP (2010), [2]FAO (Aquastat), [3]IMF (2010), [4]The World Fact Book (2009)

	Botswana	*Namibia*	*Lesotho*	*Mozambique*	*South Africa*
[1]Population (1000 inhab)	1 921	2 130	2 049	22 383	49 668
[2]Percent (%) with access to water (2002)	95	80	76	42	87
[1]Rural population (% of total)	775 (40.4)	1 346 (63.2)	1 528 (74.6)	14 134 (63.1)	19 504 (39.3)
[1]Population density (inhab/km^2)	3.302	2.584	67.49	28	40.74
[2]Land area (1000ha)	58 173	82 329	3 036	78 638	121 447
[2]Cultivated land area (1000ha)	252	808	359	4 750	15 450
[2]Percentage (%) of total country cultivated	0.433	0.98	11.8	5.9	12.67
[2]Rainfall (mm/yr) – 2008	416	285	788	1 032	495
[2]Irrigation potential (1000ha) – 2003 – 2007	13	47.3	12.5	3 072	1 500
[3]GDP *per capita (2008 PPP US$)*	13 462	6 474	1,605	929	10 140
[1]HDI (2010)	0.633	0.606	0.427	0.284	0.597
[1]Adult (+15yr) literacy rate	84.8	88.9	82.2	46.2	89.3
[4]Terrain	Predominantly flat to gently rolling table land	Mostly high plateau; Namib Desert along coast; Kalahari Desert in east	Mostly highland with plateaus, hills, and mountains	Mostly coastal lowlands, uplands in center, high plateaus in northwest, mountains in west	Vast interior plateau rimmed by rugged hills and narrow coastal plain
[4]Climate regime	Arid to semi-arid, warm winters and hot summers with low rainfall and high rates of evapotranspira tion. Periodic droughts	Desert; hot, dry; rainfall sparse and erratic. Prolonged periods of drought.	Temperate; cool to cold, dry winters; hot, wet summers with periodic droughts	Tropical to subtropical in the north and central parts, and dry semiarid steppe and dry arid desert climate in the south. Periodic floods.	Mostly semiarid; subtropical along east coast; sunny days, cool nights. Prolonged droughts and floods.

Botswana

Botswana is an arid to semi-arid country with low rainfall and high rates of evapotranspiration. The country experiences periodic droughts. It is land-locked with no point closer than 500km to either the Atlantic or the Indian Ocean. The average rainfall is 416mm per annum. Only .4% of the land is cultivated. In comparison to the four other countries Botswana has the highest GDP (13 462 US$ per capita) mainly based on mining. Forty five percent of the population has access to electricity (UNDP and WHO, 2009) and 95% have access to water (FAO/AQUASTAT, 2011).

Namibia

Namibia is second in aridity only to the Sahara Desert and 92% of the land area is defined as hyper-arid, arid or semi-arid (FAO/AQUASTAT, 2011). It has the lowest rainfall, 285mm per year among the selected countries and less than 1% of the land is cultivated. It is one of the world's most sparsely populated countries with a population density of 2.4 inhabitants/km^2. The population is widely spread across country, making investments in public centralized infrastructure like water, sanitation and electricity very expensive. Renewable energy technologies are the most suitable choice under these conditions (See Namibia case study in section 5).

Lesotho

Lesotho is a small mountain kingdom entirely surrounded by South Africa. It has a temperate climate with cool to cold dry winters and hot wet summers with periodic droughts. The average rainfall is 788mm per annum. Seventy five percent of the population live in rural areas mainly as subsistence farmers. Only 16% of the population have electricity access (UNDP and WHO, 2009) and 87% have access to water (FAO, 2011).

Mozambique

Mozambique is tropical and subtropical in the north and central parts, and dry semiarid steppe and dry arid desert climate in the south (FAO, 2005), has low population density, coastal development which is flood prone, and is one of the poorest countries in the world - ranking 165 out of 169 countries on the Human Development Index (UNDP, 2010). Only 12% of the population have access to electricity (UNDP and WHO, 2009) and 42% have access to water.

South Africa

South Africa is the largest and economically most developed country in the region. The western part is mostly semi-arid while the east coast bordering the Indian Ocean is subtropical. The average rainfall is 495mm per year. Prolonged droughts and floods occur. Commercial agriculture is well developed but its contribution to GDP has declined in the last 10 years. Electricity access stands at 75% (UNDP and WHO, 2009) and 87% of the population have access to water.

b. Climate change in the Southern African region

Climate change will affect temperatures and rainfall patterns in Southern Africa. Regional climate change projections in Southern Africa, based on GCMs comparing 2080-2099 to 1980-1999, indicate that global warming will most likely lead to greater than the global annual mean temperatures for all seasons, 3.1 degrees for summer warming and 3.4 degrees for winter warming (Christensen et al, 2007).

Warming in Southern Africa will lead to increasing rainfall intensities, decreasing frequencies of low intensity (soft soaking) rainfall and longer dry period between rainfall events. This will result in more severe draughts, floods and heat waves which will lead to greater food insecurity. In historic times, draughts and floods had already major impacts on Southern African populations. Around AD1200 to AD1500, draughts led people to abandon settlements in the Kalahari Desert. The Lifaqane wars, starting in about 1815, were characterized by a 25-year period of famine and violent conflict between peoples in Southern Africa. During the 1991-1992 draught, 20 mill people in the region (15% of SADC population) needed food relief (Dejene et al, 2011).

The impact of climate change will be felt by the majority of the population in Southern Africa who depend on rainfed agriculture. Seasonal climate forecasting will play a major role in climate change adaptation for farmers.

c. The impact of climate change on water and environmental resources in the region

Climate change in Southern Africa is expected to increase the variability of rainfall, as well as the occurrence of extreme events such as droughts, floods and heat waves. Climate change will add another layer of complexity to the already stressed and high risk water sector and amplify the parameters of the hydrological system (Water Research Commission, 2005). In Southern Africa, climate model-based downscaling tools suggest higher precipitation in the east, a shorter winter season in the southwest and less rainfall in the far west (Hewitson, 2005). Runoff and recharge are sensitive to changes in precipitation. In Southern Africa the variability of rainfall amplifies the hydrological response with serious implications for floods and droughts (Schulze, 2005).

Many countries are developing measures and policies to reduce the vulnerability to climate change and this is closely linked to planning for sustainable development. UNFCCC invited National Adaptation Plans of Action (NAPAs) from Least Developed Countries. NAPAs indicate priority activities to respond to urgent and immediate needs to adapt to climate change and further delay would increase vulnerability and/or cost at a later stage. Two countries included in this study responded. Lesotho submitted 11 projects out of which only one included energy activities. It is to promote wind, solar and biogas energy use as a supplement to hydropower energy. The four projects proposed by Mozambique do not contain any energy component (UNFCCC, 2010). No project includes the need for energy in the water sector and water in the energy sector.

At a municipal level Mukheibir and Ziervogel (2007) developed a Municipal Adaptation Plan (MAP) for the City of Cape Town illustrating some of potential climate change threats and resource mobilisation issues but energy issues were not recognized.

So far energy has been scarcely or not at all considered when looking at water and climate change.

3. Competing water needs for industrial and agricultural development and integrated water and energy planning

a. Competing water needs

The relative use of water in the four major sectors in South Africa shows that by far most water is used for irrigation and afforestation (DWAF, 2003). The sector uses 61% of the total available water. Mining and large industries use 8% but approximately 2% could be added to this figure if some of the commercial sector which is included in urban and domestic is added to indutrial water use (DWAF, 2003).

Table 3.1: Water usage in South Africa

Irrigation and afforestation	61%
Environment	20%
Urban and domestic	11%
Mining and large industry	8%

The water allocated for irrigation in South Africa still reflects the unequal access to water of the apartheid era. White large-scale farmers consume 95% of the irrigation water and mainly black smallholders have access to the remaining 5% (Cullis and Van Koppen, 2007).

b. Integrated water and energy planning in the context of climate change

The water needs in all the above sectors are going to rise as the economy grows, and careful integrated planning of the water and the energy sector is required to use and save the water resources so that they do not constrain development and economic growth. Climate change is another possibly constraining variable in this context.

Integrated water and integrated energy plans have been have been prepared and these plans are updated from time to time. For example, the Department of Energy in South Africa published an Integrated Resource Plan on Electricity in 2011 (Department of Energy, 2011). But, so far, little attention has been paid to integrated water and energy planning and modeling, although in the water-scarce countries of Southern Africa it is not really possible to separate water and energy planning. There is competition of these sectors for the existing water resources and there are multiple interrelationships of water and energy.

There is one important modeling challenge at the outset: water resource planning is often carried out at the regional level of river-basins, even though inter-basin transfers are potentially available policy actions, but energy planning typically needs to be undertaken at a national or even supra-national level.

In August 2011, the Department of Energy in South Africa invited bids for its Renewable Energy Feed-in tariff (REFIT). These renewable energy resources will add resources to the national level planning. Any modelling will need to take such distinctions and changes into account. The approach would need:

- To identify relevant existing data sources, and collection/collation of data where not readily available, possibly including utilisation of expert judgement;
- To establish critical problem areas, future policy alternatives, regional and national goals and appropriate scenarios for external pressures such as climate change and global economic conditions;

- To construct a general model (or models) to provide an overview of the energy-water system: Experimentation with such models would serve to identify sensitive ‘pressure-points’ that would require the most careful data needs and/or policy variables;
- To develop more detailed models arising out of the general model. These may or may not include some of the following features:
  - Regional modelling for defined regions in Southern Africa - individual countries and regions within countries;
  - Separation into descriptive (possibly systems dynamics) and normative/prescriptive (mathematical programming) models;
  - Explicit representation of multiple scenarios;
- Modelling of multiple societal goals and objectives as part of the process of developing national strategies for water/energy planning in the context of climate change.

c. Additional water and energy resources from water conservation, waste and sewage, water recycling, desalination, inter-basin transfers

Water conservation saves water and energy

Large amounts of water are needed in the production of energy, and a notable amount of energy is used to treat water and transport it to consumers. Savings in energy will translate into water savings, and vice versa. With the expansion of cities comes the need for more power. This in turn requires more water for its generation, hence impacting on water as well as energy resources. This emphasizes the importance of saving water and practising energy-efficient measures. Every kilowatt of energy saved also translates into water savings. In Southern Africa, where water is a scarcity and where water is used primarily in agricultural production, and where energy to meet the needs of the future population is in short supply, savings in either or both of these two resources are critical.

In South Africa water is recognized as a key constraint and risk in the Integrated Resource Plan 2010-2030 (Department of Energy, 2011) which is an electricity plan, and water usage is included as one of the criteria in all the scenarios.

Energy from waste and sewage

Extracting energy from waste is a widely applied technology in other parts of the world but it is not yet widely practised in Southern Africa. There is a great need to reduce the amount of waste, particularly in urban areas, where suitable dump sites are filling up fast. The City of Durban captures methane gas, burns it and generates electricity for 6000 homes. The project recovers some of its costs through CDM registration. The University of Cape Town has recently inaugurated a biogas digester in which food waste from a student cafeteria is used to generate gas which is used for cooking the meals in the cafeteria.

Waste water recycling

Recycling waste water is not yet widely practised in Southern Africa and could contribute to the available water supply. Energy is required for recycling. Many municipalities in Southern Africa have plans to recycle because the demand for potable water is continuously increasing. The first private recycling plant in South Africa started operating in Durban in 2001. The plant treats 47.5 million litres of domestic and industrial waste water to a near potable standard. The water is sold to industrial customers for direct use in their processes, saving treated potable water for about 300 000 people. The two largest customers are the Mondi Paper Mills and the Sapref refinery owned by Shell and BP. The industries benefit from a lower tariff as compared to the normal tariff for potable water (Ethekwini Municipality, nd).

Desalination

Desalination is an option for areas near the sea and in regions with saline groundwater. However, the energy requirements for the desalination process are high, making this technology choice viable only if water is very scarce and desalination becomes an economic option. The largest desalination plant using reverse osmosis in South Africa is owned by Albany Coast Water Board, Ndlambe municipality in the Eastern Cape. The original plant has served the Ndlambe municipality for 10 years. It was recently upgraded and has now a throughput of $1800m^3$ per day. The national grid supplies the electricity for the plant. There is also a plant at Saldanha Bay on the South African South coast

In Namibia groundwater is frequently saline and two desalination plants in the villages of Akutsima and Amarika in the Omusati Region respectively provide 3500 litres and 4500 litres of drinking water daily. Two different solar-powered technologies are used: at Amarika a reverse osmosis membrane system is installed while at Akutsima a multi-effect humidification evaporation process is used. Terra-water provides technical support and training for local people and the project was funded by the German government.

Inter-basin transfer

Inter-basin water transfer is an inviting policy option, taking water from areas of surplus to areas where it is in critically short supply, and thus limiting industrial and other developments. Several Southern African countries already transfer water across borders (Figure 1.2).

The largest water transfer scheme in the region, the Lesotho Highland Water Project (LHWP), transfers water from Lesotho to South Africa. Water is transferred from the upper reaches of the Senqu (Orange) River in Lesotho to the Vaal River basin in South Africa where the water is needed for the industrial and urban expansion and development of the Gauteng region. With an expected $70m^3/s$ total water capacity by 2020, this is one of the largest civil engineering projects currently under way. The Lesotho Highland Development Authority and Trans-Caledon Tunnel Authority are the implementing agencies for Lesotho and SA respectively. The Joint Permanent Technical Commission monitors and oversees project implementation on behalf of the two governments. A phased implementation of the project is planned, incorporating phases IA, IB, II, III and IV. Phase IA and IB are completed and the agreement for Phase II was signed in August 2011.

Phase IA of the LHWP is designed for a yield of 18·3 m^3/s and also includes a hydroelectric power plant at Katse Dam with a generating capacity of 70MW (Table 3.2). Most of the electricity is sold in Lesotho. Phase 1B increased the project yield by a further 11.7 m^3/s. Phase II is expected to increase the project yield to 55 m^3/s. Phase II with a second hydropower station will increase the power capacity by a further 110 MW. Phases III and IV, are yet to be signed and are envisaged to increase the project yield to $64.6m^3/s$ and 70 m^3/s respectively.

Table 3.2: Water, energy and sales data for the completed Phase IA, IB and Phase II of the Lesotho Highlands Water Project

	Phase IA	*Phase IB*	*Phase II*	*Source*
Reservoir	Katse Dam: 1950 x 10^6 m^3 (1)	Mohale: 90 million m^3 (2)	Polihali Dam 2.2 billion m^3. (3)	www.lhwp.org.ls, Katse Dam Technical Description Nthako & Griffiths www.lhda.org.ls - LHDA, Press release (Zuma state visit)
Speed	Katse Dam: 18.3 m^3/s (1)	Mohale Dam: 9.5 m^3/s Matsoku: 2.2 m^3/s (1)	Mashai: 25.4 m^3/s (1)	(1) Nthako & Griffiths 1997
Power	Installed: 72 MW Available: 70 MW (1)		110MW (1)	(1) Nthako & Griffiths 1997
Total energy (cummulative until 2010)	Total (LEC + Exports): (5 065 701 + 153 016) = 5 218 717 MWh			www.lhda.org.ls (Electricity Sales)

	Phase IA	*Phase IB*	*Phase II*	*Source*
Energy Sales (cummulative up to 2010)	Total (LEC + Exports): (668 783 404.19 + 7 008 010.63) = M 675 791 414.82			www.lhda.org.ls (Electricity Sales)
Water sales (volume) (cummulative until 2010)	7 957.02 MCM (million cubic meter)			www.lhda.org.ls (Water Sales)
Watersales (cummulative until 2010)	M 3 347 051 689.72 [M0.42/CM (1)]		**M14 billion (2)**	www.lhda.org.ls www.lhda.org.ls - LHDA, Press release (Zuma state visit) – 09 September 2012

d. Water needs of renewable energy technologies

Thermoelectric power generation uses significant amounts of water. In the USA 41% of all freshwater withdrawals were used for thermoelectric power (NREL 2011). In South Africa, only 8% of the available freshwater is allocated to the mining and large industry sector (DWAF 2003). Figure 3.1 gives the water consumption factors for operational water requirements of electric generating technologies, and Figure 3.2 indicates the water withdrawal factors (Macknick, 2011). Most water is used for cooling and steam. Renewable energy technologies that require cooling such as concentrated solar power (CSP) trough and CSP Fresnel technologies use up to 1000 gallon/MWh (Figure 3.1) for cooling (Macknick, 2011). Wind, photovoltaic and CSP dish sterling technologies do not need any cooling and require minimal amounts of water for cleaning (Figures 3.1 and 3.2).

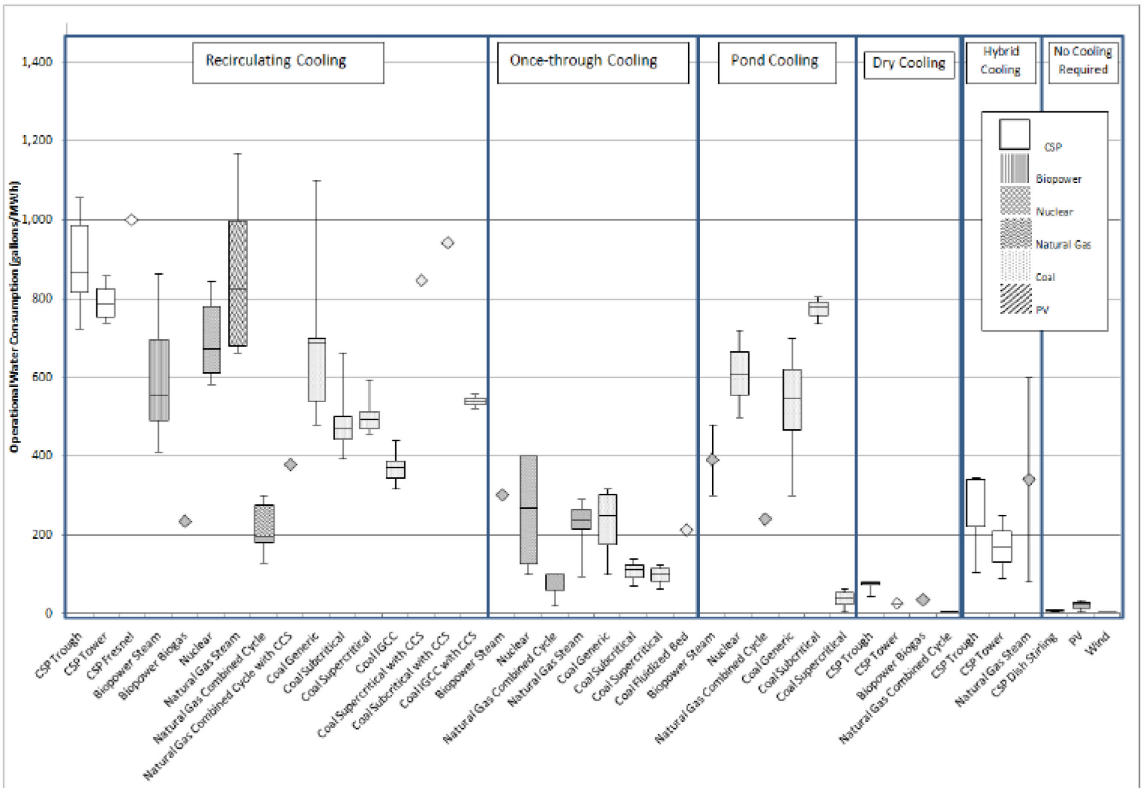

Figure 3.1: Operational water consumption factors for electricity generating technologies
IGCC: Integrated gasification combined cycle. CCS: Carbon capture and sequestration. CSP: Concentrating solar power. Whiskers ends represent maxima and minima. Upper and lower end of boxes represent 75th and 25th percentile, respectively. Horizontal lines in boxes represent medians.

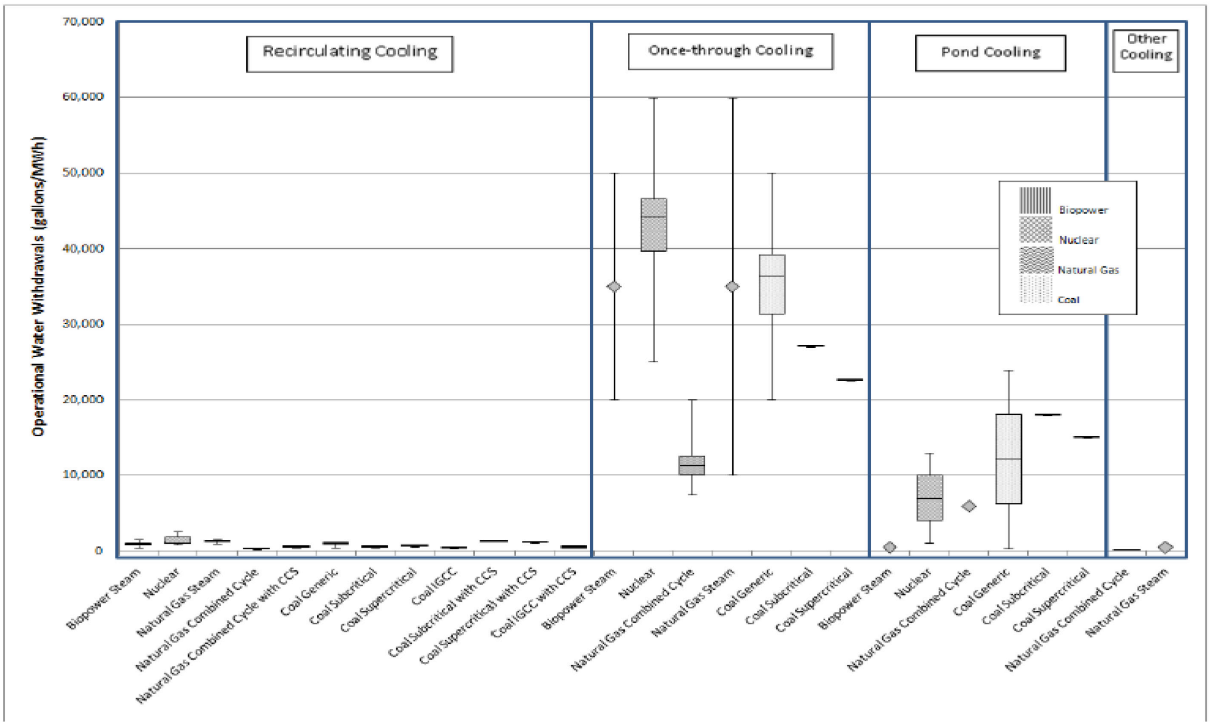

Figure 3.2: Operational water withdrawals for electricity generating technologies
IGCC: Integrated gasification combined cycle. CCS: Carbon capture and sequestration. CSP: Concentrating solar power. Whiskers ends represent maxima and minima. Upper and lower end of boxes represent 75th and 25th percentile, respectively. Horizontal lines in boxes represent medians.

4. Energy technologies in rural water supply

The large majority of the Southern African population lives in rural areas. Most rural dwellers depend on subsistence farming and they have lately seen their crops destroyed by more severe and more frequent droughts, floods, heat waves and devastating cyclones. The changing climate pattern adds another level of problems to rural livelihoods and rural water supply.

a. Energy technologies employed in rural water supply

Water use in many rural areas relies on suitable technologies to access, treat and distribute the available water in a sustainable and efficient way. This could be through pumping borehole water, setting up rainwater collection systems or efficient irrigation systems for existing water sources. The technologies used to achieve this will rely on energy input such as manual energy, photovoltaic panels or diesel. Offering more affordable and sustainable energy sources for water provision is essential, as demonstrated by the case of heating water where traditional fuel sources such as firewood and charcoal are becoming scarce and expensive (Nieuwoudt and Mathews 2004).

There are a variety of technologies that are currently in use in different parts of Africa to access, treat, distribute and use water efficiently. Some case studies outlining examples of rural water supply initiatives in Namibia, Botswana and Mozambique are presented and discussed in more detail in Section 5. The selection of the appropriate technology depends on many factors from intended end use of the water (for agricultural irrigation or for providing hot water in a clinic, for example) to the availability of components and local technical skills. Furthermore, the way these technologies are designed must also be able to adapt to climate variability. Examples include rainwater harvesting systems that can accommodate varying rainfall patterns or pumps that can respond to changes in water tables, or applying conservation tillage in agriculture which slows down the movement of water and conserves on fuel use and soil erosion.

Southern Africa as well as Africa as a whole lags behind other regions in regard to practices of conservation agriculture. The estimated areas (hectare) under conservation agriculture in some Southern African countries are as follows (FAO, 2010);

- South Africa 368 000
- Zambia 40 000
- Mozambique 9 000
- Zimbabwe 7 500
- Tanzania 6 000

The major types of conservation practices are basins, ripping and direct seeding. Direct seeding is the most common practice as shown in Table 4.1.

Table 4.1: Conservation agriculture practices employed in Africa
FAO (2010)

Country	*Basins*	*Ripping*	*Direct seeding*
Malawi		•	•
Lesotho		•	•
S. Africa			•
Madagascar			•
Zimbabwe	•	•	•
Angola			•
Zambia	•	•	•
Mozambique	•	•	•

Table 4.2 shows just some of the potential technologies, which will be used as a starting point to start thinking about the appropriateness of a technology, in terms of end use, socio-economic impacts and improving productivity in livelihoods.

Table 4.2: Available technologies for water supply in rural areas

Energy/fuel source	*Technologies*	*End use*
Small renewables: • Photovoltaics • Wind • Mini hydro • Biogas Diesel Gravity fed system Manual input	Pumps • Hand pump • Animal pump • Ram pump • Solar pump • Suction pump • Centrifugal pump Solar water heaters (modified SWH's- brick batch or blacksmith solar water heating) Solar still Gravity fed pipe Rainwater tank • Surface & subsurface	Water harvesting and recycling Purification Desalinisation Sanitisation Motive power – water mill to grind grain, pumping water, transport water, mechanical ploughing Irrigation Hot water: domestic use, schools, clinics

There are many more innovative localised, modified and adapted technologies. One example is the mobile solar water heater for rural housing in South Africa (Nieuwoudt and Mathews 2004).

It is essential to select appropriate technologies for a particular area. For example, one of the outcomes of an ADB 2010 study was that the priority for the PRONASAR rural water supply programme in Mozambique, was for low maintenance solutions and renewable energy options (ADB 2010) (See section 5). The appropriate choice of technology will depend on many factors such as those shown in Table 4.3.

Table 4.3: Overarching considerations when assessing technology choice

Water source	Water provision methods: spring, dug well, drilled well, dam, catchment (Roark et al, 1989)
End use	Is the water required for: irrigation, drinking water, hot water
Energy access	Which energy sources are available for powering these technologies: sun, diesel, manual energy?
Distance from water source	Transportation of water source to end use is energy intensive, time consuming and costly
Scale: community or household level	Suitability of the technology depending on the user
Development benefits	How will this technology offer: livelihood benefits, clean drinking water
Waterborne disease	There are many health risks from waterborne diseases particularly in stagnant water.
Governance	Successful adoption and long term sustainability of a technology requires integration with existing governance structures & initiatives.
Sustainability:	
Environmental	Efficient use of available water? Is it possible to re-use water (i.e. biogas)? Is the use of renewable energy possible?
Social	Absorptive capacity & social acceptance
Economical	What are the capital and running costs? Is the energy required available i.e, access to diesel? Affordability of renewable energy technologies

Technical	Ensuring a long-term design life & avoid low quality components (see Table 3)
Adaptation to climate variability	Consider the affects of climate variability on sizing of tanks for rainfall patterngs and designing lifting gears of pumps for changing water levels

As can be seen in Table 4.4, there are many technical and non-technical issues affecting the technology choice. Below are highlighted some of the technical factors that must be taken into consideration when selecting the appropriate technology.

Table 4.3: Technical considerations for selecting appropriate water supply technology

Technical & skills capacity (locally & nationally)	What skill level is required for construction, operation & maintenance? Is it available locally? Nationally? Will ongoing training be available if necessary?
Technology suppliers/ technology supply chain	Is the necessary technology supply chain in place to support replacement of components, manufacturing of parts etc.
Maintenance	What level of maintenance will be required? And has a maintenance plan been put in place?
Access to parts	Without access to parts, technologies can be left dysfunctional and become obsolete
Commissioning	Low post-construction and maintenance support at the local level and lack of community ownership of water points are among the main reasons for dysfunctional technologies (ADB, 2010)
Lifetime/lifecycle of components	To ensure long-term sustainability of the project, appropriate components resilient in the local environment are required
Designing for adaptation	Designs for technologies will need to be modified for climate variability (i.e. sizing storage tanks and lifting gears), depth of water table, innovative approaches & flexibility in design are needed
Safety	Safety considerations depend on the exposure of the technology i.e. is it sunken in the ground, or above ground and accessible to children
Vandalism	Technologies are vulnerable to vandalism, where possible design against this with appropriate component selection, cover important components

The World Health Organisation undertook a study in which it considered the resilience of certain technologies used for water supply. The major climate-related threats that affect water and sanitation technologies are grouped under three broad scenarios: increased likelihood of flooding or increased run-off, decreased rainfall resulting in declining surface and renewable groundwater availability, increased rainfall leading to long-term increases in groundwater levels (WHO, 2010).

The technologies analysed in the WHO report include piped and non-piped water supply options and sanitation technologies including pit latrines and septic tanks. These have been assessed against a resilience matrix and categorised into low, medium and high resilience (Figures 4.1, 4.2, 4.3). The matrices below are taken from this report and provide resilience for scenarios of decreased rainfall, increased rainfall and increased intensity of rainfall.

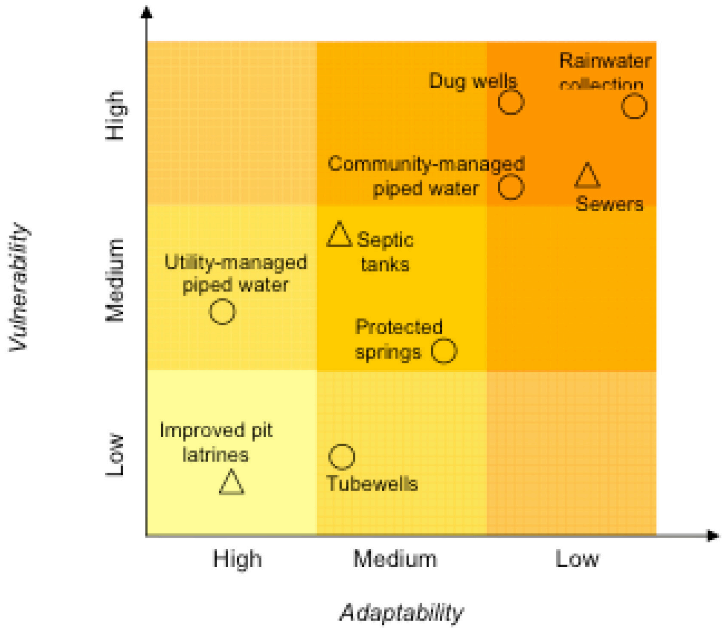

Figure 4.1 Resilience matrix: vulnerabilities and adaptability of improved water supply and sanitation facilities under conditions of decreased rainfall

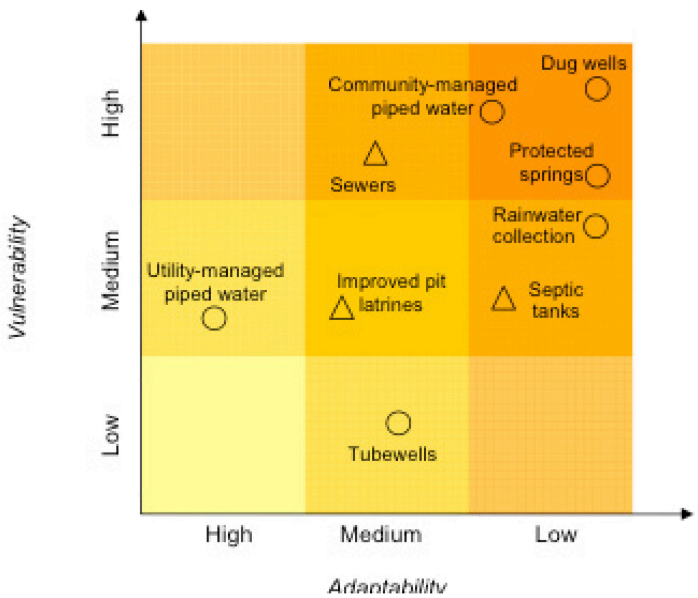

Figure 4.2: Resilience matrix: vulnerabilities and adaptabilities of improved water supply and sanitation facilities under conditions of increased rainfall

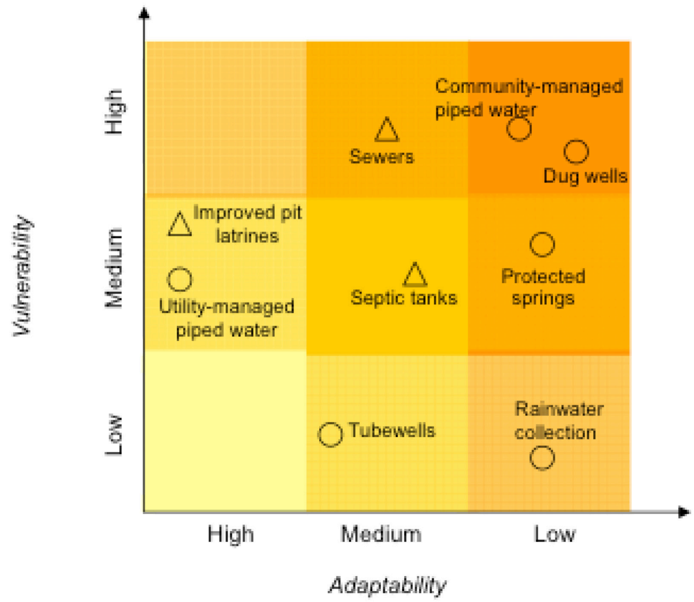

Figure 4.3: Resilience matrix: vulnerabilities and adaptabilities of improved water supply and sanitation facilities under conditions of increased intensity of rainfall

The main findings from this report highlighted that research is required to improve those technologies currently considered to have only medium resilience. There is also an urgent need to improve the knowledge and monitoring of water resources if future demands are to be met within a changing climate – particularly in relation to groundwater and non-piped water supplies for households (WHO, 2010).

In the past technical options were designed on the basis of water consumption per rural household, the number of households, depth of wells and the availability of energy sources (Biswas, 2010). Therefore it is evident that many of the issues relating to appropriate technology choice highlighted in this report are already known. However an additional dimension to how we select technology, is to design for adaptation to climate variability. Outlining the considerations for selecting appropriate technologies in Tables 4.1, 4.2 and 4.3 provides an essential baseline to understand how technology choices could be modified in the context of adaptation to climate change and sustainable use of energy and water.

Technology transfer

Tables 4.2 and 4.3 introduced some of the more localized issues, but there are also technological issues related to the introduction and transfer of existing or new technologies from outside the country - for example in the case of Botswana where windmills are sourced from South Africa, as they are already widely used by the country (Muswere, 2010). However beyond importing the physical technology, there must also be the necessary technical and non-technical capacity in place at a national and local level to support the construction, operation and maintenance of a water supply technology.

There is much literature on technology transfer of climate friendly technologies, and there are reoccurring themes, which are also relevant to the successful implementation and uptake of water supply technologies, such as

- appropriate enabling environments;
- innovation;
- intellectual property rights;
- knowledge sharing; and
- skills training.

A suitable enabling environment, such as appropriate policy incentives or training programmes and human capacity development from a national level, will assist the uptake of technology. It is recognized that a successful enabling environment works together with technical and human capacity (Bazilian et al, 2008).

It remains a contentious issue as to whether intellectual property rights (IPRs) and the cost of patents are in fact a barrier to technology transfer. For example, in the context of biogas technology in South Africa there was no evidence in empirical data or published literature of examples of technology projects that were prevented due to financial or other constraints related to IPRs and its associated issues (Boyd, 2010; Gerstetter, 2009; Bazilian, 2008), rather than due to a lack of knowledge or information sharing (see also South African study in section 6). However, when considering decentralised water supply technologies, particularly in the context of modifying them for adaptation, the most relevant 'intellectual property' is likely to be information and knowledge sharing. Furthermore, innovative modification of existing technologies and approaches to efficiently tapping into existing water reservoirs are required.

Training and education is key at all levels of technology transfer from research and development to manufacturing through to local implementation and operation of a technology.

In the next section opportunities and barriers to sustainable community water supply are discussed using case studies from Namibia, Botswana and Mozambique.

5. Energy technologies in rural water supply – case studies from Namibia, Botswana and Mozambique

Relevant issues

- Lack of funding was identified as a problem; the limited government funding was put into large centrally-managed projects. External funding was essential for most of the projects, but problems have arisen with sustainability after completion of the project
- Perceptions and acceptance about the cost and performance of renewable energy technology was a significant barrier in remote rural areas
- Lack of participation of local communities in the planning and implementation of projects resulted in lack of ownership of projects
- Over-centralisation of skills, resources and finances posed a problem for projects in remote areas and placed a constraint on their effectiveness
- Lack of reliable data on water services was identified as problematic as the status of services in the country could not be assessed
- Lack of leadership in government and local communities
- Lack of coordination between government departments
- The lack of income generating opportunities even after a successful project is a significant problem in these communities
- The status of a settlement given by the government showed to have an effect on water service provision levels

Research questions

- How is a project maintained and sustained once the project has been completed and no more donor funding is available? Who is responsible for the maintenance of the installed system?
- How can projects encourage and achieve decentralisation of resources, skills and funds so that remote areas are assisted?
- What is the most effective way to educate affected communities about new and renewable technologies to break down false perceptions and create acceptance?
- How are the problems of over-centralisation of resources, skills and finance overcome to achieve upscaling of successful small scale projects?
- How does a project achieve meaningful participation of the community in the project, to ensure ownership over the project and long term sustainability?
- How can policy barriers be addressed to ensure that specific communities are not prevented from receiving improved service provision?

Rural water supply is an area of serious concern in many southern African countries. Many rural communities in the region are not connected to the grid and have no reliable water supply network (Mazvimazi & Mmopelwa, 2006). As a result they rely on unsafe and inaccessible water sources which are not sufficient to supplement their demands. Consequently, water consumption levels per capita are lower than the recommended allowance and sickness is common. The World Policy Institute identifies the water-energy nexus as a significant global problem (Glassman et al, 2011). The water-energy nexus refers to the co-dependency of the two. Conventional energy production requires water, and water provision requires energy. This problem is further compounded by the fact that water and energy are both in shortage in most southern African countries. This is certainly the case in Namibia, Botswana and Mozambique, and in the face of climate change and population growth the problems are expected to become even more severe. This section looks at case studies from these countries and focuses on the role that renewable energy can play in improving rural water supply. Many renewable energy technologies (RETs) do not require water for energy generation and therefore have the ability to save water where conventional energy generation would consume it. Furthermore RETs can serve off-grid communities that will not be connected to the grid in the foreseeable future and are most in need of energy and water services. This section aims to identify barriers that exist to the implementation of renewable energy projects for rural water supply and also to identify opportunities there may be for these technologies to address the existing problems.

a. Namibia

i. Barrier Removal to Namibian Renewable Energy Programme

In a country like Namibia the water-energy nexus is of particular importance. Namibia is one of the driest countries in sub-Saharan Africa, receiving on average 260mm of rainfall a year (van den Bosch, 2011). Along with this it has very high evaporation rates, which deplete the already meagre surface water resources. Furthermore, it is forecast that with the effects of climate change the conditions will worsen in future years (van den Bosch, 2011).

According to Reid et al (2007) the effects on climate change on Namibia are already very evident and only set to get worse. Over the course of the twentieth century Namibia showed an increase in mean temperature three times that of the global mean increase. By 2100 it is forecast that temperature will increase by between 2°C and 6°C. Linked to this is the expected 5% increase in evaporation rate per degree of warming. In a country as arid as Namibia, this will have a devastating effect. On top of this, rainfall is predicted to decrease and become more variable, which in conjunction with increased evaporation will have a crippling effect on the country. The frequency and intensity of extreme weather events is also expected to increase along with desertification (Reid et al., 2007).

Considering these conditions, providing a safe, reliable and adequate water supply to the population is a significant challenge. This is made even more difficult by a power supply sector that cannot meet the demands of a growing economy (UNDP, 2007). According to the United Nations Development Programme (UNDP) only one third of Namibia's population has access to electricity. In urban areas as much as 67% have access whereas in rural areas as little as 10% have access. In a country with an area of 824 269km^2 and a population of only 1.8 million, the low population density especially in rural settlements makes grid electrification impractical and unrealistic and as a result communities residing in rural areas will have to wait decades before being electrified (UNDP, 2007). The Rural Electricity Distribution Master Plan has designated 27 000 households as off-grid, which means they will not be accessed by the national grid within the next 20 years.

The above mentioned factors display the severity of the problem in Namibia. Renewable energy can play an important role in providing part of a solution to the problem. Because of Namibia's favourable solar regime, solar energy technologies (SETs) can prove a reliable and cost-effective energy supply technology. The water-saving benefit delivered by using RETs has been discussed. Additionally, stand-alone SETs are more suitable and feasible with the low population density of the country. Because of this, settlements that are not forecast to be grid-electrified in the foreseeable can be supplied with alternatives. With such technologies in place water provision in these areas can significantly improve and communities previously dependent on rain-fed agriculture can become more resilient to the effects of climate change. The co-benefits of saving water, improving water supply, and adding power to a struggling power sector are all essential for the future development of Namibia.

The National Rural Electrification Programme was launched in 1990 and since then the project has electrified 8330 households (Ministry of Mines and Energy, 2005). The aim of the project set out in Namibia's 1998 White Paper on Energy Policy was to assist in achieving 25% rural household access to electricity by 2010. However, it became clear after a number of years that this target would be missed and that by 2010 roughly only 17% of rural households would be grid-electrified (Emcon, 2008). With the low density of some settlements grid extensions are unfeasible and the programme acknowledged the need for off-grid electrification options (Emcon, 2008). As a result of the Namibian Renewable Energy Programme (NAMREP) the Off-grid Energisation Master Plan (OGEMP) was developed to promote off-grid solutions, and will be discussed at a later stage in Section 5.

The Home Power Programme was set up by the Namibian government in 1996. The programme aimed to increase the number of solar home systems (SHSs) by offering loans with a pay-back period of five years at an interest rate of 5% (MME, 2005).

The Ovitoto Fee-for-Service project installed 100 SHSs in the village of Ovitoto on a fee-for-service basis. The logistical support required to make such an approach work was considerable and it was eventually accepted that capacity in Namibia is insufficient to support such a scheme (MME, 2005) Because of this, in 2004 the installed systems were converted to the ordinary SHS where residents were required to pay a monthly fee and, once the system is paid off, it belongs to the household (MME, 2005).

The Ministry of Mines and Energy (MME) was also responsible for setting up three solar villages. Systems were provided free of charge to households, clinics, schools and community halls and solar water pumps and streetlights were also installed (MME, 2005). Residents only had to make small monthly contributions to support the maintenance of the systems. Despite the systems still running today, there has been no investment in similar projects (MME, 2005).

The AccuPower Project was installed by the University of Namibia. The project provided SHSs but not the PV panels. Instead they provided a battery charging station where residents could exchange flat batteries for charged batteries at a fee (MME, 2005). The purpose of this was to reduce the cost of rural electrification by not having to provide PV panels to all the households but instead just to the charging station. The transporting of the 12kg batteries proved problematic. Consequently, PV panels were supplied to households and the project came to an end in 2002 (MME, 2005).

NAMREP was designed to remove the barriers to the wide scale introduction of renewable energy technologies, barriers that were so prevalent in the aforementioned projects. Namibia with an average daily solar radiation of 6kWh/m^2 has a highly favourable solar regime for SETs (von Oertzen, 2008). Because of this SETs were identified as having the highest potential and SHSs, solar water heaters, and solar photovoltaic-powered pumps were selected as the most appropriate technologies for the project (van den Akker & Heita, 2006).

The project was set up and funded by the UNDP and Global Environment Facility in collaboration with the Namibia Government's Ministry of Mines and Energy (MME) with co-financing from the MME and the Danish Government. The MME also setup a Project Management Unit. The project progress was monitored by the Project Steering Committee, made up of representatives from the MME, UNDP and the Ministry of Environment and Tourism (van den Akker & Heita, 2006). Appendix 2 shows how funds were allocated for the different components of the project. It shows the breakdown of the GEF funds as well as sources of cofinancing and there expected and actual contributions. Appendix 3 gives a detailed breakdown by sector of the different stakeholders involved in NAMREP.

The NAMREP was an important project for the development of renewable energy in Namibia. It was introduced as a country-wide initiative with the following aim (MME, 2005):

a) Through providing off-grid solar technologies, improve livelihoods and create income generating opportunities for rural communities

b) To reduce the dependence on imported fossil fuels by promoting solar water heating and solar water pumping

An expected additional outcome of the project was to contribute to climate change mitigation efforts by reducing GHG emissions by 233 700 tCO_2 over a 15 year period (Deenapanray, 2011).

The project included two phases of implementation:

- NAMREP I: The focus of this phase was to provide adequate technical assistance to government, NGOs, finance and other sectors to assist in the removal of barriers to implementation. The aim of this phase was to put in place the necessary foundation to facilitate the wide-scale introduction of solar technologies.
- NAMREP II: The second phase focused on delivering sustainable solar energy services to rural and off-grid households by making use of effective financing schemes.

Five main barriers to SETs in Namibia were identified in a baseline study conducted by the MME for NAMREP: capacity, institutional, public awareness and social acceptability, financial, and technical (MME, 2005). In order to address these, five outcomes were defined that NAMREP sought to achieve (MME, 2005).

1. Capacity building in the public and private sectors and in NGOs.
2. Establishing a framework of policies, regulations and actions for support of renewable energy and off-grid electrification.
3. Increased public awareness and social acceptability of SETs.
4. Appropriate financing and product delivery schemes.
5. Learning, evaluation and adaptive management.

Major findings
The set of tables included in Appendix 4 provide a detailed summary of the performance indicators drawn up for NAMREP and the degree to which they were successfully achieved, as assessed in the terminal evaluation of the project. It is evident from these tables what elements of the project were successful and those that were not. Successes provide important evidence of what can be used in future interventions, whilst less successful outcomes indicate which components require more attention. The main barriers and opportunities are discussed at a later stage in Section 5 and along with Appendix 4 this provides a detailed evaluation of the project.

NAMREP achieved high levels of success in building capacity, putting in place policy, laws and regulations to support RETs, and setting up appropriate financing and product delivery schemes. It managed to raise the status and awareness of the potential of renewable energy technologies in Namibia, increase acceptability amongst stakeholders and achieved considerable success in introducing RETS commercially in the country. It has also facilitated the development of new standards for RETs in the country.

However, the project encountered a number of challenges during the implementation of objectives.

Global goal: To increase affordable access to sustainable energy services thus contributing to climate stabilisation by reducing or avoiding CO_2 emissions and improving livelihoods and income generation of rural people. Unsatisfactory.

Development Objective: To promote the delivery of commercially, institutionally and technically sustainable energy services by solar energy. Unsatisfactory.

1.2. Decentralised RET companies are adequately supported. Marginally unsatisfactory.

1.3. Vocational and training centres are capacitated and providing technical training on RETs - Changes in legislation have prevented this target to be achieved.

An additional concern of NAMREP was the fact that it bypassed the off-grid and rural communities which were the intended beneficiaries of the project. The main reason behind this was that the loan facility was mainly utilised by urban households and commercial farmers and thus the fund was rapidly depleted. These households were better equipped to make use of the loan facility as they had more experience with financial procedures, had access to banking facilities, had regular income and therefore were able to make regular repayment of loans, and already had access provided with basic services (Schultz, 2011).

It appears that a common aspect of all the unsuccessful components of NAMREP is the lack of follow-up. Whilst the objectives clearly state the aims that are relevant to the different areas of the project, most of the unsuccessful areas have not had the most reliable ways to measure the levels of success achieved. In particular no supplier or end-user surveys for assessing emissions reductions and increase in the usage of RETs, mean that conclusions were based on preliminary studies or secondary research rather than verifying the outcomes of these objectives on the ground. This does not mean that actions were not implemented but it is difficult to accurately quantify levels of success without strategies to measure progress on the ground. One of the principle factors behind lack of evaluation may be the 'end-of-project study' not being completed, as indicated under outcome 5.1.

5.1. Adaptive management, monitoring and evaluation. End-of-project study. Unsatisfactory
The reason why the end of project study was not completed was that the contracts of the PMU expired upon completion of the project and it was not established who would be responsible for completing the project after NAMREP was completed and whether it would be completed. Not having this responsibility designated meant that no one took responsibility for completing the end-of-project study and therefore certain elements of an accurate and comprehensive project evaluation process were neglected. Furthermore, by not properly evaluating initiatives on the ground, problems can be overlooked and initiatives will continue to be implemented in an inappropriate manner. Addressing this problem would help to improve the degree of success of NAMREP.

ii. Demonstration Gobabeb of Renewable Energy and Energy Efficiency

The Gobabeb Training and Research Centre was established in 1962 and is located in the central Namib Desert. It was electrified in 1972 by two diesel generators provided and financed by the Ministry of Work (gobabebtrc, nd). By 1990 the functions of the centre needed to be expanded outside the setting of the Namib Desert and for this purpose the Desert Research Foundation of Namibia was formed. In 1998 Gobabeb took over the responsibility of operating the generators and therefore had to begin paying for the electricity. In 2004 the implementation of the DANIDA-funded Demonstration Gobabeb of Renewable Energy and Energy Efficiency (Degreee) project began (Tuinenburg & von Oertzen, 2007). The project developed a modern hybrid electricity system using the two existing diesel generators, four solar panels, batteries, and a bi-directional power converter. In order for the new system to be able to cope, electricity demand had to be significantly reduced in Gobabeb. To achieve these reductions a number of energy efficiency measures were introduced as part of the project. These included: replacing electric stoves and kettles with gas stoves, replace incandescent light bulbs with compact fluorescent lights (CFLs), energy efficient refrigerators, energy saving settings on computers, and educating users to make them aware of system constraints, with usage tips to make behavioural changes. Prepaid electricity meters were also installed. As a result electricity demand was reduced from 230kWh/day when it was a diesel only system to 135kWh/day for the hybrid system. Between April and November 2006 electricity demand was met 99% by solar (Tuinenburg & von Oertzen, 2007). This figure is representative of how effective such systems can be.

As part of the project a life cycle cost assessment was conducted for different energy generation techniques. Table 5.1 shows the favourable performance of a hybrid system.

Table 5.1: Life cycle cost assessment of different power generation techniques
Tuinenburg & von Oertzen (2007: 15)

	Diesel (N$)	*Grid (N$)*	*Solar PV (N$)*	*PV hybrid (N$)*
Initial costs				
System	86 000	1 925 000	2 375 000	1 200 000
Upgrade	0	0	50 000	50 000
Conversions	0	0	14 000	14 000
Total initial capital costs	86 000	1 925 000	2 439 000	1 264 000
Future expenses				
Operating, maintenance & replacements	2 773 000	1 655 000	190 000	1 189 000
Gas	224 000	224 000	581 000	581 000
Total future expenses	2 997 000	1 879 000	771 000	1 770 000
Life cycle costs	3 083 000	3 804 000	3 210 000	3 034 000
Annual costs	247 000	305 000	258 000	243 00

iii. Tsumkwe Energy Project

The Tsumkwe Energy Project aims to improve access to modern energy services to the population of Tsumkwe through developing a solar diesel hybrid energy supply system. Tsumkwe is the largest off-grid settlement in Namibia and is not scheduled to be grid electrified within the next 20 years. Before the project ,which is currently in its final stages of construction, the settlement was supplied electricity through a mini-grid powered by two diesel generators. However fluctuating voltage and interrupted power supply are common in the town and two out of the three suburbs in the settlement are not electrified. In 2005 NAMREP commissioned an observation trip to assess the necessity and feasibility of a hybrid system in the settlement (Schultz, 2007).

Tsumkwe has very little economic activity, with only a police station, clinic, primary and secondary school, a Namibia Broadcasting Corporation studio, NamPost branch, administrative offices for government ministries and NGOS, a small tourist lodge and guest house, Tsumkwe Craft Centre, Community Development Centre, two small shops and several shebeens. Because of this there are few employment opportunities and out of the population of 700 residents there is only a small high-income group made up of public servants and NGO staff. The majority of the population is made up of San people who either have very low or zero income. Alcohol abuse is a problem and residents have raised concern about safety at night due to lack of lighting because of fused streetlights from the fluctuating voltage of the power supply. Interruptions in water supply are also a significant problem as the pumps are also powered by the central diesel generators. The only sources of income in the town are limited tourism, state pensions, and salaries of public servants. The low-income groups rely on the government's drought relief programme, collection of veldkos, and occasional game hunting. There are no banks or petrol stations due to unreliable power supply and as a result the settlement is dependent on the town of Grootfontein which is 300 kilometres away (Schultz, 2007). The inadequate power supply has been identified as the single biggest barrier to economic development in the area.

The Tsumkwe Energy Project was approved in 2008 and construction is forecast to be completed by the end of September 2011 (Adetona, 2011). The project is being implemented by the Desert Research Foundation of Namibia (DRFN) in partnership with NamPower and the Otjozondjupa Regional Council, with funding from the European Commission African Carribean Pacific-European Union Energy Facility (DRFN, 2008).

The hybrid electricity supply system will utilise and refurbish the existing diesel generators and add a 100-150 kWp solar energy system and storage batteries. The aim of the upgrade is to improve electricity service reliability, and provide 24 hour supply to essential loads such as water pumping, street lighting and clinics (Adetona, 2011). The new system also aims to connect all unelectrified households in the settlement and to introduce energy efficiency measures. Upon completion of construction, along with the new mini-grid, the project will have replaced over 80 electric stoves with gas stoves, installed 80 solar water heaters, pre-paid electricity meters and CFLs and provided access to alternative fuels (Adetona, 2011). Currently the price of electricity from diesel generation in Tsumkwe is estimated at N$6 per kWh, and the Otjozondjupa Regional Council is selling at N$1.20 per kWh, making it very expensive for them to subsidise. With the introduction of the new hybrid system and energy efficiency measures the price is expected to drop to N$3.50 per kWh, saving the council a considerable amount of money (Adetona, 2011).

As part of the project, the Tsumkwe Energy Supply Company will be established and fulfil the role of independent power producer. The Tsumkwe Energy Trust will also be setup, made up of community representatives and agencies. The trust will be responsible for managing the new system and ensuring revenue generated is re-invested into the system and for the social and economic upliftment of the community (DRFN, 2008). In order fund and maintain the project, the project aims to gradually introduce cost-reflective tariffs and move away from subsidisation fossil fuel energy supply/grid extensions. This will be challenging and the community needs to be consulted and closely worked with.

The project also aims to integrate parts of the OGEMP through integrating an energy shop approach. As the system is so dependent on diesel and LPG it could act as a distribution point for these fuels as none currently exist in the settlement (Schultz , 2007). Integrating with the national initiatives is an important part of the project.

b. Botswana

Botswana is an arid country where water scarcity is a major environmental problem. The country not only experiences low rainfall but also a highly uneven distribution of rainfall varying from 250mm per annum in the south west to 650mm per annum in the north east. The country is dependent on a shared water resource and mainly ephemeral rivers with the exception of the Okavango and Chobe Rivers. As a result of the low rainfall, high evaporation rates and high seepage the country has limited surface water resources and is heavily reliant on groundwater. It is estimated that in 2005 80% of the country's water consumption was supplied by groundwater. This brings an added layer of complexity to water provision in Botswana. Due to the growing demand, abstraction rates have started to exceed recharge rates and boreholes and wells are beginning to dry up. Pollution of groundwater reserves is of increasing concern, and the cost of provision is rising with the increasing depths from which water needs to be pumped (Wingqvist & Dahlberg, 2008).

These conditions suggest what a challenge it is to provide a safe and reliable water supply to all in Botswana. Those in remote rural settlements are particularly vulnerable to fluctuations in rainfall as many rely on rivers for their water supply. It is not only these communities that are vulnerable to the effects of water scarcity. The performance of the economy of Botswana is closely linked to the climate (Wingqvist & Dahlberg, 2008). Climate change and its effects have started to receive more attention, and clearly this issue is particularly relevant to Botswana.

According to Wingqvist and Dahlberg (2008), severe rainfall fluctuations, El Nino and La Nina have already had a significant impact on Botswana. The worsening effects of climate change are expected to make these impacts more acute in the region. Temperature is forecast to increase by 1–3°C by 2050, rainfall is expected to decrease, rainfall events will intensify, and desertification, land degradation and water scarcity are set to become more prevalent (Wingqvist & Dahlberg, 2008). Because of the above-mentioned factors and its fragile ecosystems Botswana is considered to be highly vulnerable to climate change. According to Wingqvist and Dahlberg energy and water will be the two constraints to future social and economic development in the country.

When discussing renewable energy and rural water supply in Botswana, it is imperative to take cognisance of these factors in order to realise how important a solution is, and what strategies will be appropriate. Policy in Botswana has started to recognise this but often fails to translate into successful practice. The reasons behind this failure need to be investigated and addressed.

i. Challenges of supplying water to small, scattered communities in Ngamiland, Botswana

The proportion of a country's population with access to safe and reliable water is a serious problem especially in many sub-Saharan African countries (Mazvimazi & Mmopelwa, 2006). In the case of Botswana considerable progress has been made and only 12.1% of the population lacks access to safe drinking water (Swatuk & Kgomotso, 2007). Whilst this achievement is commendable, disparities at local levels need to be addressed. The North South Water Carrier is a multi-billion dollar development and is responsible for supplying water to the majority of the population. This is made possible by the fact that it was built along the Lobatse-Francistown road and 80% of the country's population reside within 50 kilometres of this road (Swatuk & Kgomotso, 2007). This water supply network is the main reason for the high levels of water access in the country, however strategies for water supply of remote, rural areas such as settlements in the Ngamiland district require attention.

In Botswana water is public property and is controlled and allocated by the state. The Botswana National Settlement Policy is a spatial development policy with the aim of concentrating limited government finance in settlements with the highest development potential (Swatuk & Kgomotso, 2007). A settlement needs to be gazetted by the government in order for water to be provided to the settlement. For a settlement to be gazetted it must fulfil the following criteria: have a population of at least 500 people; it must be at least 15 kilometres from the nearest village; and must have a headman and a Village Development Committee (Swatuk & Kgomotso, 2007). In the Ngamiland district the majority of settlements have fewer than 249 people and therefore cannot be gazetted. This means they are not eligible for water supply or any other service provision from the government (Swatuk & Kgomotso, 2007). This is evident by the different existing levels of water provision between gazetted and ungazetted villages. Village water supply is one of the main functions of the Ministry of Local Government, but this is only for recognised villages, which means water supply for ungazetted areas is a problem. Households in gazetted settlements get their water from standpipes provided by the government. These standpipes are within 400 metres of households and the water is provided free of charge (Swatuk & Kgomotso, 2007). Contrastingly, 89% of households interviewed in the Ngamiland district depend on the Boteti River to satisfy their water needs. The remaining 11% travel to the closest gazetted village to collect water (Mazvimazi & Mmopelwa, 2006). In the Ngamiland district the mean annual rainfall is less than 400mm (Mazvimazi & Mmopelwa, 2006). During the dry season it is no longer possible for people to extract water directly from the river and these settlements become reliant on hand-dug wells. Households are forced to travel between 0.5 to 4 kilometres to get water (Mazvimazi & Mmopelwa, 2006). Water sources over one kilometre away are considered inaccessible by the WHO and will negatively affect consumption levels. Because of these conditions water use is on average less than 20 litres per capita per day, which is insufficient for food preparation, adequate hygiene and drinking (Mazvimazi & Mmopelwa, 2006). The Department of Water Affairs (DWA), in response to concerns that are being raised state that they develop systems but hand them over to the District Council to manage. The District Council is unable to keep up with the increased demand due to lack of financial and human resources.

According to Matshameko (2004), the Government of Botswana recognises the potential that SETs possess for providing energy services to rural communities not connected to the grid. In the National Development Policy 9 the Government included a number of policy objectives to promote the use of SETs in Botswana (Matshameko, 2004: 2):

i. To promote increased use of photovoltaic/solar electrification in an orderly manner with adequate coordination, institutional support, financing and technical standards.

ii. To take advantage of regional and international developments in research and development.

iii. Promote the use of solar energy for both power generation and water heating where economically feasible.'

ii. Renewable energy projects in Botswana

The Manyana Pilot Project, National Photovoltaic Rural Electrification Programme (NPVREP), and the Photovoltaic Rural Electrification Master Plan, are all examples of solar energy initiatives in Botswana (Matshameko, 2004). Although they achieved some success there have been numerous barriers that will be discussed later in this chapter. In spite of these challenges, the initiatives showed the potential of solar energy services in Botswana. Considering the conditions in the Ngamiland district that have been discussed, SETs could play a prominent role in providing energy services and improving water provision in communities like these. However, whilst the technical potential is there, issues such as the status of settlements and whether they are gazetted still needs to be addressed - without that, no intervention, no matter how suitable, will be successful.

The Botswana Vision 2016 has been introduced to propel socio-economic and political development and bring prosperity to all in Botswana (Presidential Task Group, 2011). The Vision places emphasis on the need to address water provision for remote settlements (Presidential Task Group, 2011). The following statement indicates the areas of concern identified by the strategy:

> Botswana must develop a national water development and distribution strategy that will make water affordable and accessible to all including those who live in small and remote settlements. (Presidential Task Group, 2011: 34).

In addition to this the vision highlights the need to develop technologies for remote water supply (Presidential Task Group, 2011). This is significant progress for Botswana and may lay the foundation for addressing remote, rural water supply in the country - an area that has been neglected by past policy, as discussed above.

The Botswana National Decentralised Rural Electrification Programme is an initiative focussed on providing energy to areas that will not be grid electrified in the foreseeable future. In July 2010 the Botswana Power Corporation (BPC) awarded the project to Electricité de France (EDF). The project aims to electrify 50 000 to 70 000 homes over a period of ten years. Products provided by the programme include PV panels, LED lamps, and improved woodstoves (EDF, 2010). For the bigger villages PV plants will be connected to mini-grids to provide a more substantial power supply network. In order to make these products available, the programme utilises local franchises. EDF are also responsible for training of local personnel to ensure a transfer of skills to the local community. Franchises are responsible for installing and maintaining installed equipment and generate revenue through a monthly service charge, electricity tariffs, recharging lanterns, and selling equipment (EDF, 2010). There is a pressing need for this programme and it has the potential to address the problem of poor energy provision in remote settlements in Botswana. Considering that water provision in remote areas experiences similar problems to energy there should be more integration between the National Decentralised Rural Electrification Programme and water provision in remote settlements. Decentralised energy solutions have enormous potential to improve water supply and when something like the above-mentioned programme puts in place the necessary technologies all that needs to be done is to identify the link between the two and the possibility that exists. Projects such as those discussed in Namibia make use of solar hybrid mini-grids for water pumping. The Botswana National Decentralised Rural Electrification Programme identifies the possibility of solar-powered mini-grids for larger villages. Such mini-grids could be used for water pumping and could play an influential role in addressing the problems of poor water supply for remote rural settlements in Botswana.

c. Mozambique

Mozambique has made considerable socio-economic progress since the end of the civil war. Stability has been added to the political landscape, poverty rates have been reduced and GDP is growing. Despite this progress the country remains one of the poorest countries in the world, with a population heavily dependent on natural resources (World Bank, 2007). Because of this extreme weather events have had a devastating effect on the country. For these same reasons, Mozambique is considered to be extremely vulnerable to the impacts of climate change.

According to Erhart and Twena (2006), by 2075 in Mozambique temperature is forecast to increase by between 1.8°C and 3.2°C, accompanied by a 2-3% increase in solar radiation, and 9–13% increase in evapotranspiration. It is also predicted that rainfall will decrease by 2–9% and this decrease will be particularly prevalent in the growing season which will have a significant effect on crop yields. The frequency, intensity and unpredictability of floods, droughts and tropical cyclones are all expected to increase. Furthermore the 96 centimetre sea level rise that is expected by 2100 will have a disastrous effect on the 2700 kilometre coastline of the country where over 66% of the population resides and commercial centres are located (Ehrhart & Twena, 2006).

Considering these possible impacts and how much the population and especially the rural population in Mozambique is dependent on the land, developing a reliable and adequate rural water supply is essential for increasing the adaptive capacity of rural Mozambique to climate change. It is with this in mind that the feasibility of RETs for improving rural water supply should be assessed.

i. National Rural Water Supply and Sanitation Programme in Nampula and Zambezia Provinces, Mozambique

The National Rural Water Supply and Sanitation Program (NRWSSP/PRONASAR) is aimed at improving rural water supply and sanitation in Mozambique and especially making use of RETs in appropriate settings to improve functionality of water points and to provide a more reliable service. The project aims to do this over the period 2006-2015 and will be implemented by the Government of Mozambique, NGOs, development partners, private sector and community members (Ministry of Public Works and Housing, 2009). The programme will be implemented in two phases, Phase I: 2009-2011, Phase II: 2012-2015. In order to improve rural water supply and sanitation the project aims to: increase rural water coverage from 48.5% to 70% through providing new or rehabilitated water points and small supply systems, and increase sanitation coverage from 39% to 50% through the construction of improved latrines, by 2015 (Ministry of Public Works and Housing, 2009). By doing this, the project will attempt to satisfy basic human needs and address rural poverty in Mozambique.

The Programme consists of four components (MOPH, 2009: 8):

1. Support to sustainable increase in rural water supply and sanitation (RWSS) coverage.
2. Development of appropriate technologies and management models for RWSS.
3. Capacity-building and human resource development in the RWSS sub-sector.
4. Support to decentralized planning, management, monitoring and financing of RWSS activities.

A Programme Steering Committee and Programme Implementation Teams were set up to guide the project and monitor project activities (Ministry of Public Works and Housing, 2009).

The African Water Facility, funded by the African Development Bank conducted a study that looked at the problem of inadequate rural water supply in Mozambique. This study formed the basis of the PRONASAR (African Development Bank, 2010).

PRONASAR is based on two policy frameworks, the Strategic Plan for the Rural Water Supply and Sanitation Sub-sector (PESA-ASR) and the Action Plan for the Reduction of Absolute Poverty (PARPA) (2009-2012) (AfDB, 2010: 10). It is aimed at all rural areas in Mozambique and is estimated to benefit 3.8 million people out of the total rural population of 16.9 million. The African Development Fund (ADF)-funded projects are to be implemented only in the Nampula and Zambezia provinces. These two provinces were identified as priority areas for the project due to the fact that they are densely populated and the rural water coverage is roughly only 40% (AfDB, 2010). The project has placed priority on low maintenance solutions and focused on making use of renewable energy options that have the ability to improve functionality. The aim of the water schemes was to provide a reliable supply of water of at least 25 litres per capita per day a maximum of 500 metres away from the targeted households. Areas where hand pumps were not delivering satisfactory performance were identified as areas that would need power-driven pumps to be installed to ensure a reliable supply. It is estimated that around 800 000 of the rural population in the two provinces will benefit from the project (AfDB, 2010). SETs are being made use of already to improve performance of existing systems (Ministry of Public Works and Housing, 2009).

The projects were divided into seven main components: decentralised planning support (includes plans, equipment and staff), capacity building, rural water supply infrastructure, rural sanitation, technical assistance and consultancy, testing alternative options, and program management (AfDB, 2010)).

In order to track the progress of projects and evaluate how successful they were a number of key performance indicators were developed (AfDB, 2010). They are the following:

- Number of people with access to improved drinking water sources, and the percentage of them which are female.

- Number of people with access to improved sanitation facilities, the percentage of which are female, as well as the number of new on-site sanitation measures.
- People educated through hygiene programmes, the percentage of which are female
- New committees with approved associations, the percentage of which include women as members.
- Public and private sector staff trained in project implementation.
- Number of districts RWSS plan; and number of joint sector reviews carried out.

ii. Sustainability of rural water supply projects in the Niassa province, Mozambique

WaterAid conducted a study looking at the sustainability of rural water supply projects in the Niassa province of Mozambique. The aim was to establish how well services last over time and, if they do not, why this is the case. The study found a number of factors contributing to poor sustainability. Spare part availability was a problem especially as many of these settlements are in remote areas; because they cannot access spare parts, service provision is interrupted (Jansz, 2011). Unsuitable community management models and poor capacity in local communities was identified as another contributing factor. The need for education and skills development of all stakeholders was identified as an essential component to increase capacity in communities, and also to make use of a process that encourages community participation (Jansz, 2011). Inadequate finance and poor management of finance led to project funds running out before achieving all intended project outcomes. Sector coordination, better planning and including communities in the planning process, and supporting policy were all identified as areas that require further attention (Jansz, 2011).

iii. Clean energy and water

The Government of Mozambique has attempted to improve rural water provision by drilling more boreholes, the majority of which are served by hand pumps which are unreliable and unsuitable for the tasks that are required of them (SSN, 2007). The Action Group for Renewable Energies and Sustainable Development (GED) a local NGO in Mozambique implemented a project to address these problems and contribute to climate change mitigation and adaptation. Other partners in the project were: the Energy Fund (FUNAE), the National Directorate of Water (DNA), the National Disaster Management Group (INGC), the National Directorate of Environmental Management (DNGA), The National Directorate of Rural Development (DNDR), southsouthnorth (SSN), Energy Environment and Climate Research Group (SSN, 2007). The project was funded by DANIDA.

It was decided that PV-powered water pumps were the most suitable solution (SSN, 2007). These pumps are suitable as they can replace existing hand pumps which do not operate with the high level of the water table and are not sufficient to supply adequate water for large numbers of people. PV-powered pumps can also be used instead of diesel-powered pumps. This reduces emissions and fuel costs. The project proposed to install a system in six provinces, namely: Maputo, Inhambane, Gaza, Sofala, Manica and Tete (Action Group for Renewable Energies and Sustainable Development, 2007). All these provinces are arid or semi-arid and with the impacts of climate change becoming more evident, these projects would be a crucial adaptation and mitigation strategy to improve water services in rural areas. Each project was to include a solar PV pump, a tank for water storage, basins and taps, clothes-washing facilities, and troughs for water for livestock. Each system was intended to serve 500 people and 100 livestock in the project vicinity (Action Group for Renewable Energies and Sustainable Development, 2007).

The project implemented in the Maputo province has realised much success. The local community is satisfied with the project and expressed that the project has improved security of water supply and provided them with increased resilience to possible future climate change impacts (Cuamba, 2011). The local community and municipality have taken responsibility for the project. In the setting up of the project, the community was required to contribute their labour to help with the construction of the project, but were not required to make an upfront financial contribution. Once the project was completed, households were required to make a monthly financial contribution to help with the maintenance of the system (Cuamba, 2011). Despite the overall success of the project, various barriers have been identified. The flow of information was identified as one of the major constraints.

The lack of staff and time of GED was another factor that needed to be overcome. Inadequate technical capacity in the communities necessitated training workshops (Cuamba, 2011). The projects in the other five provinces were not implemented due to a lack of funding. However some other water pumping projects have started in the Inhambane province.

Issues such as the need for decentralised planning and skills, lack of capacity in government and at the local level, inadequate funding, poor infrastructure and governance issues are prevalent in all projects in Mozambique.

d. Barriers, opportunities and gaps for energy technologies in rural water supply

A framework for analysis

Although it is evident that the aforementioned projects encountered challenges, a further step needs to be taken, first to identify the exact barriers and why they have occurred, and then to highlight what can be learnt and what opportunities exist. In order to identify barriers and group them, a framework developed by Painuly (2001) was used to analyse the barriers to renewable energy penetration in these projects. This is necessary, because although RETs are commercially available and in many cases economically viable they have failed to meaningfully penetrate the market. This framework aims to analyse why this is the case with reference to the case studies. The framework makes use of seven categories for barrier identification: market failure, market distortions, economic and financial, institutional, technical, social cultural and behavioural, and other barriers (Painuly, 2001).

The issue of market failure is prevalent in many of the projects that have been discussed and this is evident when investigating the elements that contribute to market failure. Lack of awareness and information was a significant obstacle for many of the projects as shown in the water pumping project in Maputo, Mozambique (Action Group for Renewable Energies and Sustainable Development, 2007). This was mainly brought about by the lack of agencies equipped to provide information to the public. This is particularly important for increasing acceptance of RETs as most of the communities were unfamiliar with them (van den Akker & Heita, 2006). The lack of the necessary agencies was also evident in the poor flow of information to stakeholders. Poor market infrastructure in the form of under-developed supply channels was responsible for lack of availability and product visibility in many of the projects; this was especially the case in remote rural settlements (Fagbenle, 2001). According to Jansz (2011), the cost of spare parts and where to source the technologies from, made them less accessible. Many RETs could not be manufactured locally as the market demand was too low which made the cost of production too high, therefore these technologies had to be imported. This made them unaffordable. The project implemented by WaterAid in the Niassa province of Mozambique is an example of one encountering these challenges.

Market distortions are the second sources of barriers as identified by Painuly (2001). A particularly significant element of this is the non-consideration of externalities in the pricing of conventional energy as well as subsidies. This makes it difficult for RETs to compete economically and as seen in many of the projects is cited as a substantial barrier to their wide scale use.

Economic and financial barriers often receive much attention. The high initial cost of RETs often makes them prohibitive, especially as many of the target areas are low-income rural areas (Deenapanray, 2011). The high cost of capital, lack of access to capital, high up-front capital costs for investors and lack of financial institutions further compound this problem. Moreover, government funds in these countries are limited and external donors play a key role. This is the case in all the projects and can be problematic due to the degree of dependency it fosters. The result is often a lack of ownership over the projects. Because of this, many projects have started to enforce communities making a monthly financial contribution to the maintenance and upkeep of the projects to ensure local stakeholders are actively participating in the project and contributing to its sustainability (Action Group for Renewable Energies and Sustainable Development, 2007).

According to Deenapanray (2011), one of the main aims of the NAMREP was to address the lack of government investment in rural areas. The limited available government funds are mainly invested in grid extensions, which are unlikely to access the remote rural communities. Furthermore as seen in most of the projects, government funds are put into areas with the most potential, therefore communities that are most in need are often neglected (Swatuk & Kgomotso, 2007). Private investment into renewable energy technologies is discouraged by institutional and regulatory barriers and by small market demand (Deenapanray, 2011). The NAMREP project put in place an effective financial planning structure. This ensured that existing financial resources were utilised optimally and resulted in high delivery rates of the project (Deenapanray, 2011). In spite of the relatively low maintenance required by most renewable energy technologies, the issue of the price and access to spare parts was problematic (Jansz, 2011). In addition to this the pricing of water or how to collect revenue remained an obstacle. This was particularly evident in the effort to upscale the Manyana Pilot Project to the National Photovoltaic Rural Electrification Programme (NPVREP). Consequently, costs could not be recovered, delivery was poor and the project was terminated (Fagbenle, 2001).

Institutional barriers often found in developing countries pose a serious challenge. The lack of institutions to generate and disseminate information is a serious concern and responsibility is left with an already overloaded provincial government or municipality. Governments and municipalities lack the resources and capacity to carry out these important functions and they are as a result often neglected. The lack of involvement of stakeholders in decision making has received some attention in all the projects and has to a degree been successful in projects such as NAMREP. Despite this, it still remains a barrier and a culture of consultation and participation needs to be created. The lack of private sector participation, which is evident, is caused by the risk in investing in these projects, and the fact that better opportunities lie in other investments (Fagbenle, 2001). Additionally, the lack of consistency in government policy causes uncertainty and further reluctance to invest. The capital and efficiency that the private sector can offer has the ability to improve projects, and therefore their participation needs to be incentivised. The status of a settlement according to the government dictates whether a settlement will receive an intervention. As was evident in the Ngamiland district of Botswana, ungazetted areas were not eligible for government water provision, and because of this access to water in these settlements was poor (Swatuk & Kgomotso, 2007).

Painuly (2001) further identifies technical barriers as factors inhibiting the potential of RETs. One of the major elements of this is the lack of skilled personnel. This is linked to the lack of capacity in communities especially in rural settlements. As alluded to in the projects, these communities are unfamiliar with the technologies and therefore struggle to maintain and repair systems once implemented (Jansz, 2011). This makes communities reliant on skilled technicians often travelling from distant urban centres. This means delays in service provision are common and repair is costly. More effort is being placed on training individuals in the community so that they can take responsibility of their own projects as shown in the project implemented in Maputo, Mozambique. Product reliability has also received some attention in the projects. Poor quality, lack of quality control and inadequate standards means that quality of products is sometimes sub-standard. Consequently, reliability becomes a problem. System constraints also pose a problem such as the integration problems of RETs with the existing grid. Linked to the previous barrier of lack of private sector investment is the lack of entrepreneurs in the renewable energy industry in these countries. The risks and low profitability discourages them and results in the lack of competition that is present in the sector.

Social, cultural and behavioural barriers, expressed in the lack of consumer and social acceptance, are issues that are raised in all the projects. The main reason behind these is the lack of information and education about these products. Products are then seen as alien and inferior, and a preference for traditional energy remains (Deenapanray, 2011). Although such views are often unfounded, they still significantly affect the attitude towards RETs in these areas, which influences the level of success of projects. Increasingly people are becoming aware of how important it is for projects to address these areas and projects are starting to take them more into consideration in planning and implementation. The Manyana Pilot Project focused on increasing the acceptance of solar energy technologies and consequently the project showed high levels of success and there was an effort to upscale it within the NPVREP. Even though the Manyana Pilot Project had achieved high levels of success, the upscaling effort was less successful.

Closely linked to social acceptance is community ownership and participation. One of the most successful outcomes of the NAMREP was the strong sense of ownership by the country due to the process used by the project. However, some key stakeholders were not included or could have been included at an earlier stage in the project. Significantly more input from these stakeholders in the design phase of the project could have been contributed. The fact that NAMREP missed its intended beneficiaries is a clear indicator that there was not sufficient participation from all stakeholders at all levels of the project (Deenapanray, 2011).

There are a number of other barriers that cannot be grouped under the previous six headings but are still prevalent. Uncertain government policies are one of these. Un-supportive policies for RETs, lack of government capacity and lack of faith in RETs from the government were all evident to some degree in the projects in Botswana, Namibia and Mozambique.

Lack of infrastructure is another significant concern in all these countries. Roads, connectivity to the grid and communications infrastructure all became a problem especially in the remote settlements. These are difficult conditions under which to implement a project based on new renewable energy technologies and also make achieving sustainability in these projects challenging. Emphasis on supporting infrastructure is acknowledged but difficult to address without huge investment.

e. Lessons learned

There are a number of lessons to be learned from the case studies that have been discussed. These not only highlight the problems that were encountered but provide areas of focus for future projects.

Properly equipped agencies need to be set up to provide information about RETs and campaigns and activities need to be run to increase visibility and promote the use of RETs to the targeted communities. The REEEI at the Polytechnic of Namibia is an example of an institute that has been earmarked as having potential for NAMREP.

A cost-benefit analysis to compare SETs and fossil fuels is important for the marketing of SETs. The benefits of SETs also need to be effectively communicated to the public to bring about social acceptance. Financial instruments are needed to help end-users overcome the high capital costs of the technologies. The government could also impose pricing of energy that reflects externalities. This would help to make RETs more competitive and improve affordability for the poor.

As funds are such a problem, projects need to adopt a framework that enables them to generate some revenue. Monthly financial contributions from communities to help with the maintenance of the projects have started to be used in various projects and are an effective way of recovering costs. Good financial planning is essential for managing and optimising the use of existing funds. The planning structure used in NAMREP showed what a difference this can make to project delivery rates. Expanding loan schemes is also needed to encourage the growth of these technologies.

Government policies need to support the introduction of RETs and promote better service delivery for all settlements, especially those in remote rural locations.

Training local personnel and setting up local artisan associations is needed to ensure that communities can take full responsibility for their own projects and do not remain dependent on donors after completion of the project.

Running workshops to educate and actively engage communities in projects is an essential component. These can build capacity, raise awareness and increase participation in projects. The planning phase of projects also needs to include public consultation to further increase participation in projects and to create ownership over them.

f. Opportunities

The following section describes how a UNICEF project implemented in Guro district, Mozambique effectively dealt with many of the barriers mentioned above. It is a good example of how obstacles can be overcome, and the opportunities that exist for future projects.

In order to improve rural water supply in the Guro district of Mozambique, the community developed a model for the sustainability of water supply infrastructure. The model allocated specific roles to different stakeholders and appointed a water committee, made up of community members.

The committee was responsible for the operation and maintenance of the water points, and decided on and collected water charges. Each household was also obliged to make an upfront financial contribution to the project to help recover the costs of the installations. This also showed a level of commitment and meant each household had a stake in the project (Godfrey, 2010).

Local artisan associations were set up. Local artisans were trained to maintain the systems and be responsible for the spare part supply chain and for fitting the spares. Additionally they were given the responsibility of carrying out compulsory maintenance checks every three months. This not only addressed the problem of the availability of spare parts but ensured installations were maintained using local skills, were monitored and provided a source of income for the local artisans (Godfrey, 2010).

Because of the active role, community members took in the project a sense of ownership was inherent in the project. To add to this, a series of sustainability workshops were run to educate the public about the costs and maintenance of renewable energy technologies and raise awareness about their potential benefits. These workshops were also used to give the opportunity for all stakeholders to meet together and come up with ideas about how to create a locally driven framework for the project and for the maintenance and repair of water points. By doing this it allowed the community to design the project (Godfrey, 2010). As a result, the project was tailored to the local community and mishaps such as missing the intended project beneficiaries were avoided.

Lastly, a database of the water points in the district was created. This was done to monitor the status of water points, to minimise breakdowns and to prevent delays in the repair of faulty water points. This database was important in building up data for water services in the district (Godfrey, 2010). Many of the other projects encountered a lack of data and inaccurate data as a problem. Creating such a database is a way of combating this challenge.

Figure 5.1 below provides a graphical representation of the model that was used in the project and the stakeholders active at the different levels.

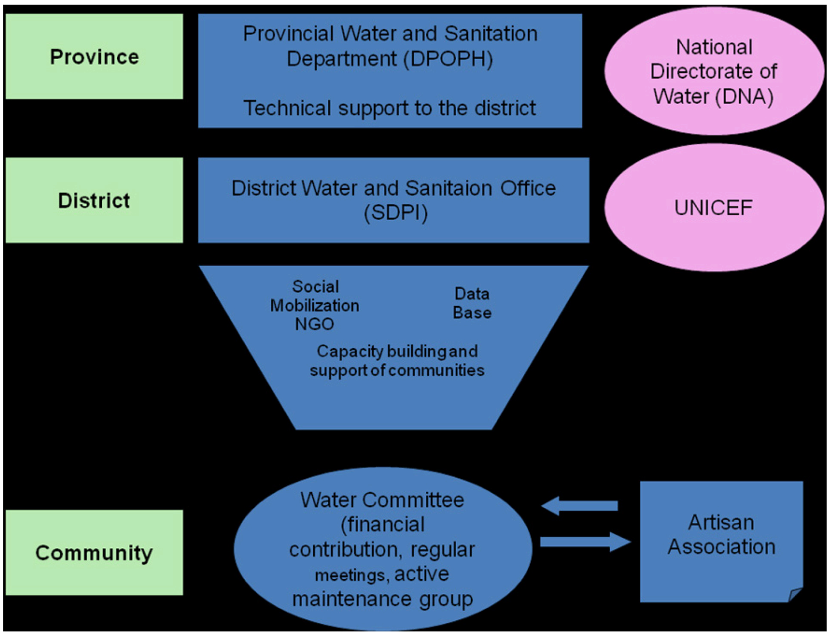

Figure 5.1: Model for sustainability of water supply infrastructures
Godfrey (2010: 2)

Because of the project, non-functioning water points in the Guro district fell from 30.3% to 0%. Not only were non-functioning water points repaired but an additional 46 new water points were installed from 2007 to 2010. The project also identified the potential of utilising the improved water supply to support the cultivation of vegetable gardens and use this activity as a possible source of income (Godfrey, 2010).

The provincial and national government and UNICEF played an important facilitative role in offering support for the project. The district administrator also took an active leadership role in the project and was helped by APRODES, which was the NGO responsible for community workshops and social mobility activities (Godfrey, 2010).

The UNICEF project in Guro, Mozambique and the Manyana Pilot Project in Botswana were both successful projects. However, neither has been upscaled successfully. There may be a number of factors contributing to this, but the problem of over-centralisation of resources and skills was identified as a problem in other projects implemented on a national scale, and could be the reason behind the unsuccessful up scaling attempts. Decentralising skills, finance and responsibilities has been shown to improve effectiveness of projects and should be considered in the implementation of large centrally managed projects. The lack of coordination between government departments is an additional factor to consider. When projects are implemented on a larger scale that require a number of government departments, their inability to effectively deliver a coordinated approach results in a fragmented project, and ultimately the effectiveness is compromised.

The case of Guro is a good example of a project as it was solely dedicated to developing a sustainability model. However, elements of the other case studies also represent opportunities that can be built on to realise greater levels of success in future projects.

Workshops, distribution of pamphlets, training programmes, and cost-benefit analyses played a particularly important role in NAMREP to increase public awareness, capacity and knowledge about RETs and to shift perceptions. New policies and laws were also established to support the introduction of RETs and which led to the creation of strategies such as OGEMP and vocational training centres. Government ministries also began to integrate SET plans in their strategies. Standards for SETs were established as a result of the project. Furthermore effective financing and product delivery schemes were developed by and utilised in the project. Adaptive management, monitoring and evaluation was another strong component of the project (Deenapanray, 2011).

The Off-grid Energisation Master Plan (OGEMP) and the Solar Revolving Fund (SRF) were initiated by NAMREP and are the initiatives responsible for promoting the uptake of renewable RETs. These play a crucial role in continuing the work of NAMREP now that the project has been completed.

The OGEMP is based on an Energy Shop approach. Energy shops are located within a reasonable distance from the targeted communities and supply energy products, services and the accompanying appliances. The shops also act as payment collection points for a national off-grid energy financing mechanism. The need to outsource the management of the OGEMP fund was identified as being necessary due to the lack of previous experience of the MME with such matters (Schultz & Schumann, 2007).

The SRF was previously administered by private fund administrators but in April this year the Ministry of Mines and Energy took over responsibility and launched a new SRF as part of the OGEMP (Namibia Economist, 2011). Loans are made available to households wanting to purchase SWHs, SHSs, or PVPs. The period of the loan can be up to 60 months at 5% interest. As the fund is based on an ownership model, once the system has been purchased the household becomes the owner of the system and is responsible for the maintenance of it (MME, 2011). The SRF will be expanded in the future to include cook stoves, LPG stoves and lighting devices. The aim of the fund is to provide access to modern renewable energy technologies to rural areas (MME, 2011).

The Gobebeb and Tsumkwe energy projects displayed the potential of hybrid mini-grids and how to address the challenges of revenue collection and energy efficiency to operate within the limits of the systems (Adetona, 2011). Programmes such as the Botswana National Decentralised Rural Electrification Programme indicated that all the necessary technologies and strategies for RETs are available and that linkages need to be made with issues like water provision, like was done in Tsumkwe using the hybrid mini-grid to provide a reliable water supply. Strategies such as the Botswana Vision 2016 are playing an important role in identifying such linkages as well as identifying areas that have been neglected in the past and require attention. The acknowledgement by Vision 2016 that water supply for small and remote settlements requires attention is a good example of this and is fundamental in improving the conditions of these types of areas in the future.

The Manyana Pilot Project and the GED project in Maputo illustrate the potential of social acceptance to act as a catalyst to the success of projects. They also show how the contribution of labour from the community in construction and subsequent monthly financial contributions can be fundamental to sustainability of projects.

The successes in the above projects show how although projects encounter many challenges there are many opportunities for new projects. Many of the challenges encountered were avoided or addressed to some extent. These projects show how good planning, management, and education can make a significant difference, and use limited resources as effectively as possible. Communities taking an active role in the project and leadership from local government were essential in nearly all the successes shown in the projects. Without these influential players the projects would have lacked the initiative they provided. This is important because it is not merely lack of funding that is a constraint to projects, and this is visible in the many other barriers encountered in the case studies provided. It is important for communities and local governments to develop other components that projects depend on so that when they do manage to receive the required finance the necessary conditions exist to support the funding and make the project a success. This kind of mindset needs to be applied to all projects in order to move away from a dependency mindset, and presents an opportunity to communities and local governments. In order for countries in southern Africa to achieve progress this change in mindset is imperative.

g. Integrated systems of several infrastructure services improve benefits to communities

Infrastructure and the services it can provide are important for growth and to improve the well-being of communities. One of the major reasons behind the recent improved growth performance in Africa is the development of infrastructure (Foster & Briceño-Garmendia, 2010). Despite the improving conditions, infrastructure in Africa still lags behind most other developing regions in the world. The economic geography across Africa is varied and makes it difficult to address the needs of the different parts of the population. Power is one of the biggest infrastructural challenges. Most countries in Africa have an inadequate power supply to serve the population, and low population densities especially in rural areas make it difficult to expand the supply network. Lack of funds and underinvestment has hampered further growth and because of this infrastructure is far below the level required by the growing population and to support growth (Foster, et al., 2010

Another feature of the infrastructure landscape of Africa is the expense of infrastructure services. Due to the diseconomies of scale in production and lack of competition, prices of these services are high and unaffordable too much of the population. In addition to this, further institutional, regulatory and administrative reform is required in Africa to promote development of infrastructure rather than acting as a constraint (Action Group for Renewable Energies and Sustainable Development, 2007; Swatuk et al, 2007)

The above mentioned factors mean that communities in many African countries lack the access to the necessary system of infrastructures to improve their quality of life. New projects are needed to address this problem, but the environment in which they are implemented in is often a limiting factor as the necessary pre-existing conditions to make the project successful are often not in place. These challenging conditions often contribute to the lower than expected levels of success in projects (Foster & Briceño-Garmendia, 2010). Improvements in infrastructure can help to create a network that increases the quality of life of communities and facilitates the introduction and success of new projects.

As is evident in the above-mentioned case studies, infrastructure in water provision and energy supply is lacking in Namibia, Botswana and Mozambique. Resultantly, significant portions of the populations in these countries, especially rural communities, lack access to these services. The poor levels of basic infrastructure make it difficult for new projects to succeed. The role that RETs can play in providing energy and water services to these communities is clear. Such technologies are less dependent on well-established infrastructure and therefore offer a more feasible solution than strategies such as grid-extension. Because of this potential that RETs possess, they are beginning to play a larger role in African countries and may be fundamental to providing solutions in energy and water provision as well as other services in the future.

h. Outstanding research areas

This section has outlined barriers and opportunities to renewable energy projects for rural water provision. What still remains is the need to identify areas that require more research in order to contribute to furthering progress in future projects.

Despite education and training being focused on, more emphasis needs to be placed on them as their lack is a fundamental barrier in most developing countries. Through improving education and training, capacity can be built at a local and national level. Government officials and community members will be equipped to take leading roles in projects, and it fulfils a necessary condition to enhance acceptance and ownership. This has the potential to aid decentralisation of skills and resources and to make a more attractive environment for private sector investment and participation. Effective ways to achieve this especially in remote, rural communities still need to be established.

The lack of up-scaling is an area that has received much attention, but little progress has been made in increasing the number of successful examples. More work is needed to investigate what is needed to facilitate successful up-scaling attempts or to reveal an alternative model to follow to achieve similar effects of up-scaling but through following a different path.

What is required to create an environment that ensures policy is formulated through consultation with the community? What is needed to ensure that successful policies and strategies access and benefit the people that are most in need?

Policy issues related to the water-energy nexus will be discussed in the next section. Examples for the policy analysis are taken from South Africa where, generally, very good policies exist in the separate sectors of energy, water and climate change.

6. Policy issues: Reflection on the water-energy nexus in the context of climate change in South Africa

a. Introduction

Issues

- The water-energy nexus is not sufficiently recognised in policies, regulations and laws in South Africa.
- Mining companies, Eskom and banks are pushing the nexus on the political agenda; their focus is on water quality and quantity needed for mining coal for the generation of electricity.
- Research needs to inform and assist government in making the right decisions around renewable energies.
- Especially poorer municipalities which lack capacity and skills as well as small-scale farmers need to be enabled to adapt to changing weather conditions (droughts, floods, water quality) including impacts on service delivery.

The water-energy nexus in policy and planning documents - local municipal case study:

- Elundini, a small municipality in the rural Eastern Cape Province, supplies citizens with water from dams and boreholes operated by diesel engines. Increasingly water shortages create an additional supply challenge. The Integrated Development Plan of the municipality speaks about a hydropower plant, but municipal managers are not aware of this plan. The reality of rural service delivery in the example of water and energy supply in the context of climate change provides a case for an investigation of the planning processes and broader research into political processes, awareness and acceptance of the water-energy nexus amongst policy makers.
- Is there specific planning/policy for the water-energy nexus? What could it look like?
- Is there awareness of the water-energy nexus at government levels and is the climate change impact on this nexus appreciated?
- To what extent are policymakers aware of renewable energy technologies and the potential role they can play in adaptation to climate change in particular in the water – energy context?
- What are the barriers for governments to address inter-/ multi-departmental challenges with appropriate/collaborative solutions and how could they be overcome?
- What does appropriate cross-sectoral policy formulation, budgeting, implementation and evaluation in the field of energy and water look like, taking national circumstances into consideration?

At present, governments all around the world are trying to grapple with the challenge of energy security in a changing world climate. In countries concerned about poverty alleviation, this matter is closely linked to development decisions being important for the economic growth. Whilst new energy policies are being formulated and re-written, there is an opportunity for linkages between energy production and its consumption, water and climate change to be brought onto the agenda (The World Policy Institute, 2011). In this regard, the role of renewable energy in sustainable water supply is especially important in the context of rural development.

Energy, water and development policies need to be aligned on this matter, and cross-checking to be mainstreamed in the formulation and evaluation of such policies. The implications of the linkage between water consumption and GHG emissions need to be understood and taken into consideration (Hoyle, 2008). Generally, all policies need to be assessed against its potential implications on water. In brief, 'The water-energy nexus, along with its wide-ranging impact and the challenging questions that result, has earned a rightful place on the global policy agenda' (The World Policy Institute, 2011).

Policy is 'a long series of more or less related choices, including decisions not to act, made by governmental bodies and officials' (Dunn, 1981). A comprehensive policy process analysis is necessary to make out the national status-quo and identify gaps. Compared to developments in countries such as the United States of America, the water-energy nexus it is a new topic in the South African context, not yet reflected in laws, policies and regulations. The current debate around the water-intensive extraction of natural gas through hydraulic fracking in the water-scarce Karoo is a good example of the direct relationship between water and energy decisions. This case may present a good learning opportunity for national, provincial and local governance and policy making. Relevant policies need to be formulated and the appropriateness of these tested.

Working towards mainstreaming the consideration of water in energy and development policy making and decisions, the World Policy Institute has developed an analytical framework 'to evaluate the water energy relationship and policies to balance competing needs and identify policy options that address various trade-offs' (World Policy Institute, 2011). The framework (see Appendix 5) suggests improving the collection and analysis of a whole range of data related to water and energy. Subsequently, cost analysis and a review of governance mechanisms is recommended.

Exploring the South African policy environment further, comprehensive research taking the whole policy circle into consideration, is advised. Even when following a simple policy circle, several research questions arise.

For a new issue, like in this case, the water-energy nexus to be integrated into policy, first of all it needs to find its way onto the political agenda. Agenda-setting being 'the process by which problems and alternative solutions gain or lose public and elite attention' (Birkland, 2005), the recognition of the water-energy nexus by policy makers and the different groups in society is crucial. The competition for attention, however, is fierce due to limited space on the agenda and the fast rotation of topics. The model in Figure 6.1 categorises four levels in the agenda-setting process.

The agenda universe stands for 'the list of all the possible ideas that could ever be advanced in any society' (Birkland, 2005) and compares to the systemic agenda which 'consists of all issues that are commonly perceived by members of the political community as meriting public attention and as involving matters within the legitimate jurisdiction of existing governmental authority' (Cobb & Elder cited in Birkland, 2005)). Issues, problems or ideas which made it into the systemic agenda are believed to be accepted within well-established social, political, ideological and legal norms. Successful elevated matters move into the institutional agenda where they are placed on the 'list of issues that is currently being considered by a governmental institution, such as an agency, a legislature, or a court'. From here, relatively few issues will reach the decision agenda which 'contains items that are about to be acted upon by a governmental body'. The underlying consideration of this model is that the carrying capacity of the agendas towards the inner circle is limited and competition therefore inevitable.

In the United States, policy decisions have already been made on the water-energy nexus, but the topic appears to be fresh on the systemic agenda in South Africa. No policy-related decisions have been made, nor do the media or academic literature indicate any developments on the institutional agenda. The situation in the other Southern African countries appears to be similar. No linkages have been found so far, and further research is required.

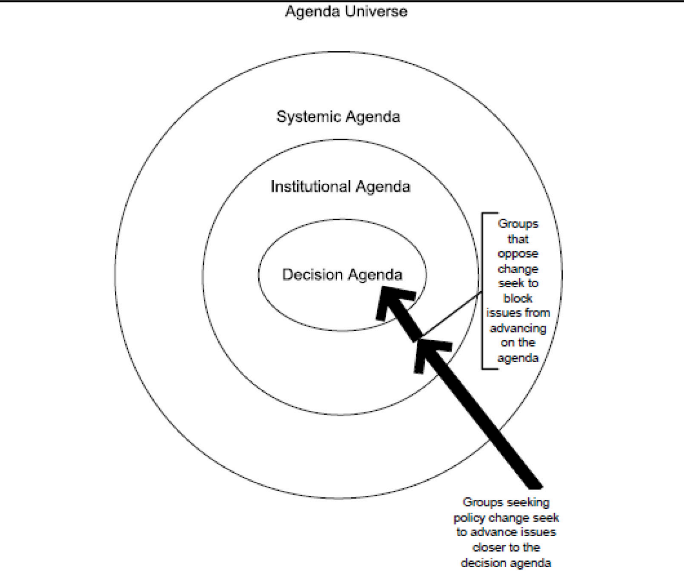

Figure 6.1: Levels of the agenda
Fischer (2007)

Early in 2011, the first publicly announced local event linking water and energy was held in Johannesburg. A mining company, the state controlled electricity company Eskom and a private bank organised a two-day event called the South African Water-Energy Forum. Despite the announcement 'to examine the water/energy/food security nexus with a view to developing tangible goal-oriented outcomes in the form of PPP's or collaborative solutions' the presentations focussed on the water needs in terms of water quality and quantity of the energy producing industry (South African Water and Energy Forum, 2011). The connection between water and energy has been made, to the extent to which it is of concern to the mining industry, Eskom and the banking sector. The water-energy nexus affects, however, by far more aspects of the economy and society in South Africa. The policy process in South Africa is still in an early stage. Research of the policy process has therefore a high potential to influence the policy outcome. Figure 6.2 suggests research questions to be asked in the policy arena.

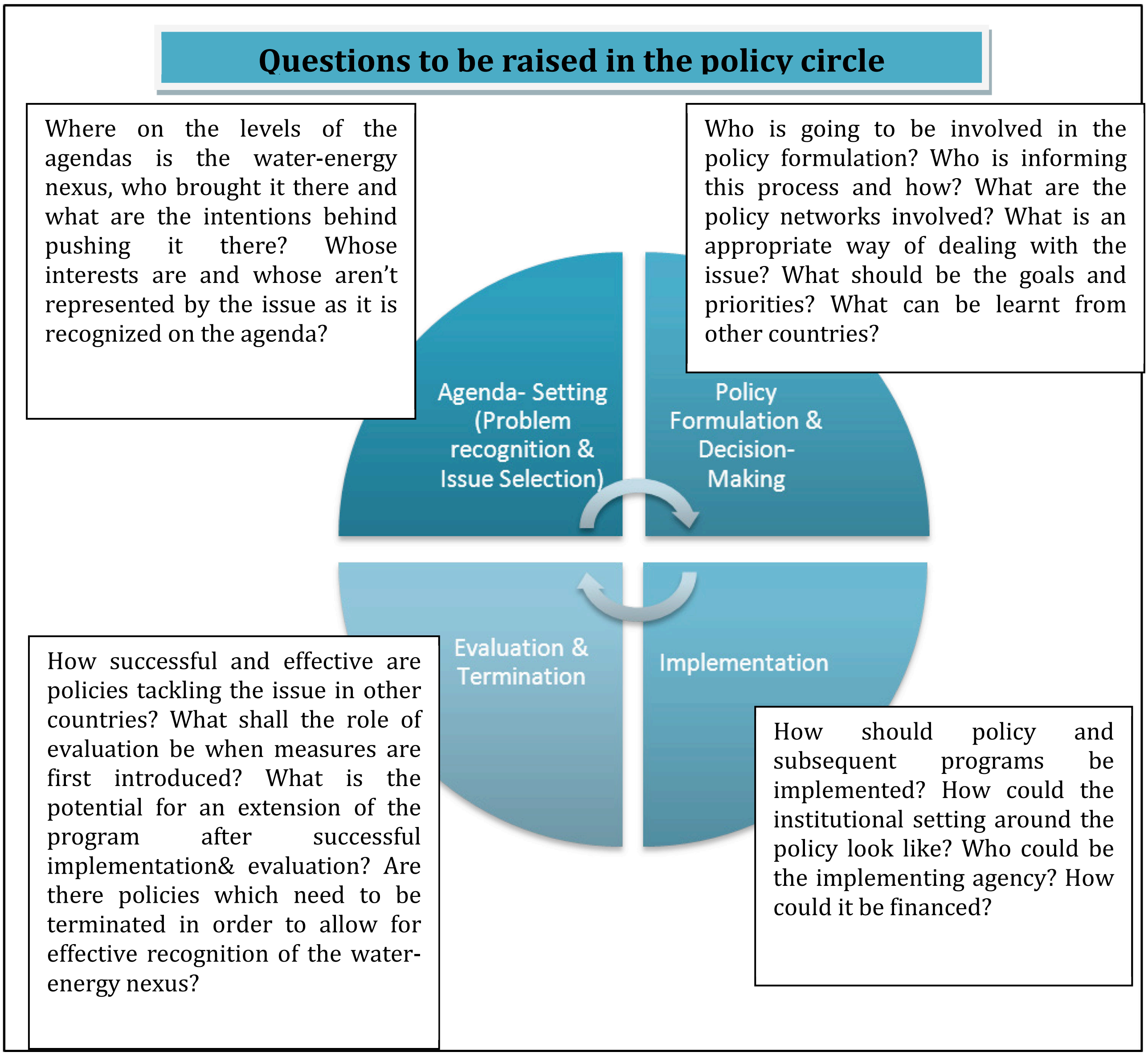

Figure 6.2: Questions to be asked in the policy circle

b. International policies and regulations

In the international arena, two examples are outstanding. Under the UNFCCC, two water and energy related methodologies have recently been approved for the development of projects under the CDM. Both allow for the development of GHG emissions saving projects: demand-side energy efficiency activities for the installation of low-flow hot water saving devices and water pumping efficiency improvements are innovative in such they link water saving devices and GHG emissions. With the methodology for demand-side energy efficiency activities for the installation of low-flow hot water saving devices also being approved with the Gold Standard organisation, the procedures to obtain carbon emission credits (CERs, GS CERs, or GSVERs) are now in place.

In 2010, the Conference of the Parties in Cancun, Mexico decided to establish a Technology Executive Committee. The committee represents the first component of the Technology Transfer Mechanism, under which also a Climate Technology Centre and Network is going to be created. The Climate Technology Centre is supposed to facilitate a network of national, regional, sectoral and international technology networks, organisations and initiative. It is suggested that the Technology Centre for Southern Africa should be located in Pretoria. Under the UNFCCC, all Non-Annex-I states are encouraged to undertake assessments of country-specific climate change technology needs. The South African technology needs assessment report does not mention topics related to the water-energy nexus, but more generally speaks about water efficiency and renewable energy for electricity generation (Department of Science and Technology, 2007).

c. National and district policies

In South Africa, policies and laws do not yet mention the water-energy nexus. Compared to international developments, for example in the USA where laws and policy documents recognize and address the linkages between water and energy, policies in South Africa seldom cross departmental boundaries when raising issues. While the major energy related policy documents do mention water, this is mainly done when addressing solar water heating or the lower water demand of renewable energy technologies. The country's National Water Act from 1998 merely mentions power generation in connection with waste water management (Republic of South Africa, 1998). The National Water Resource Strategy suggests applying different water charges for municipalities, mining/energy/industry, agriculture and stream flow reduction activities. The strategy (Figure 6.3) presents the alignment of policies including energy policies and the Department of Water Affairs and Forestry taking national responsibility to integrate the different sectors (DWAF, 2004).

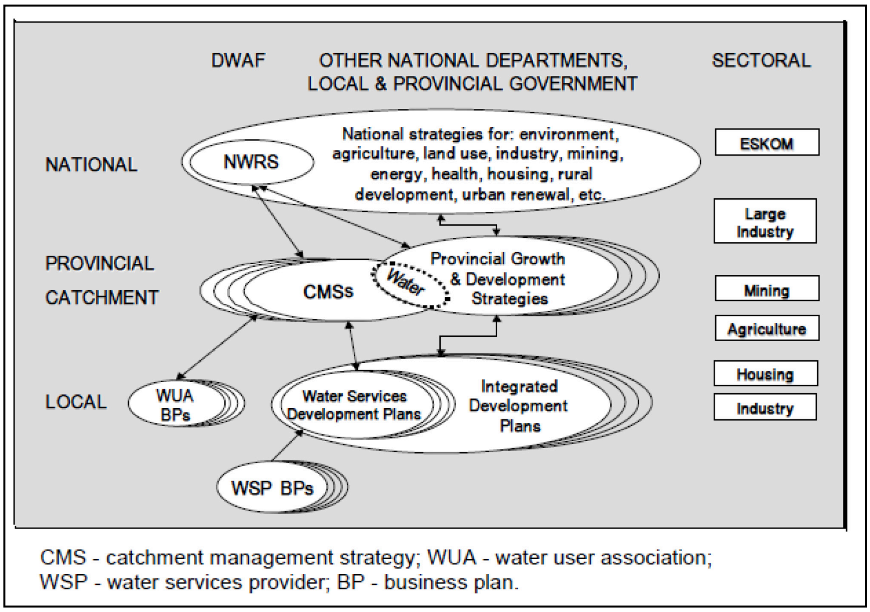

Figure 6.3: Water-related planning in the national planning framework
Department of Water Affairs and Forestry (2004)

The Department of Rural Development which is tasked with the initiation, facilitation, coordination, catalysation and implementation of an integrated rural development programme is addressing water as well as electricity in its framework document. Implemented pilot projects from the department include the distribution of tanks for rainwater harvesting only (Ministry of Rural Development and Land Reform, 2009). None of the publicly available documents identifies, for example, photovoltaic water pumps or mini-grid for energy provision as opportunities.

The level of inclusion of innovative approaches to service delivery has proven to be higher in cities and metropolis governments and documents. On local and district levels, the Integrated Development Plans (IDP) and, within these, the Spatial Development Frameworks/Plans are the guiding documents on district and local level. While these documents require the integration of all IDP priorities (water, roads and storm water, sanitation, electricity, housing, health, sport and recreation and solid waste disposal), the connection between water and energy has been made by local governments in Johannesburg and Cape Town, but not by the rural municipality of Elundini for example.

The off-grid electrification programme of the Department of Energy (DoE) can be looked upon as an example of the challenge government is facing in linking water and energy. The provision of basic services, including the supply of water and energy, plays a crucial role in government's efforts to alleviate poverty. Within the DoE, the off-grid unit is working on electrification of houses in remote rural areas. This unit implements only one programme, whereby small PV-systems are subsidized in a number of allocated areas and installed and maintained by appointed concession companies. Despite this commitment by government to provide an alternative to the grid-based electricity service for households which are unlikely to be connected in the short to mid-term future, the off-grid unit lacks capacity and knowledge to extend its activities beyond this one programme.

Within the DoE, the energy efficiency unit and the off-grid unit are expected to work collaboratively on solutions for households which are remote and not connected to water or the electricity grid (Sebastian Khoza, 2010). For example, equipping houses with solar water heaters which can be filled manually and solar home systems would provide residents with an immediate sustainable source of energy. In addition, RETs such as solar pumps and wind technologies, suitable for rural application, could complement such an approach. These opportunities need to be piloted and integrated into policy and programmes. The barriers hindering even mature and simple technical solutions from entering government's approaches are manifold. The analysis of barriers to the success of projects in Southern Africa presented in section 5 of this report offers the groundwork for further research. The lack of funding, leadership and coordination in government, lack of reliable data on water services and participation of local communities in project planning and implementation and negative perceptions and acceptance of renewable energy technology by networks within government are identified as challenging to the success and up-scaling of pilot projects tackling the water-energy nexus.

Building on these findings, possible pull factors holding policy development back, and also potential push factors towards more sustainable and integrated policy making, should be studied. How does policy making need to be changed in order to eliminate the pull factors and elevate the push factors? In the following, the recognition and integration of water and energy and the linkages thereof are explored in a few policy examples on different levels of governance. Examined are documents of a provincial spatial development plan, a local/municipal spatial development framework, and a water service management plan which was developed as well on the municipal level. In addition, national level policies on water and energy are checked in regard to their integration of the water-energy nexus.

i. Case study: Provincial Spatial Development Plan, Eastern Cape

The Spatial Development Plan is a key document on provincial and local level in South Africa. Provincial spatial Development Frameworks (PSDFs) are far less detailed than the local municipal plans. The case study PSDF provides an overview of the main characteristics and challenges the different areas and towns within the district are facing. While remaining fairly general, missing coordination, poor integration and sectoral separation are identified as problems. By aiming for 'shared impact' between all stakeholders through identified focus areas and multi-sectoral programmes, these problems shall be addressed.

Activities relevant to the water-energy nexus are found either in the water or in the energy chapter. The province is motivating future projects to engage in mapping exercises of environmental sensitive areas and resource areas including among others also renewable energy potential.

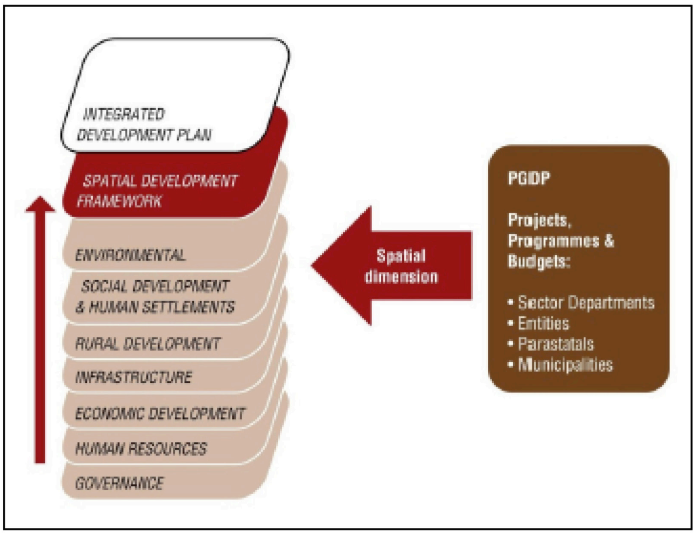

Figure 6.4: Integration of Spatial Dimension
Eastern Cape Government (2010)

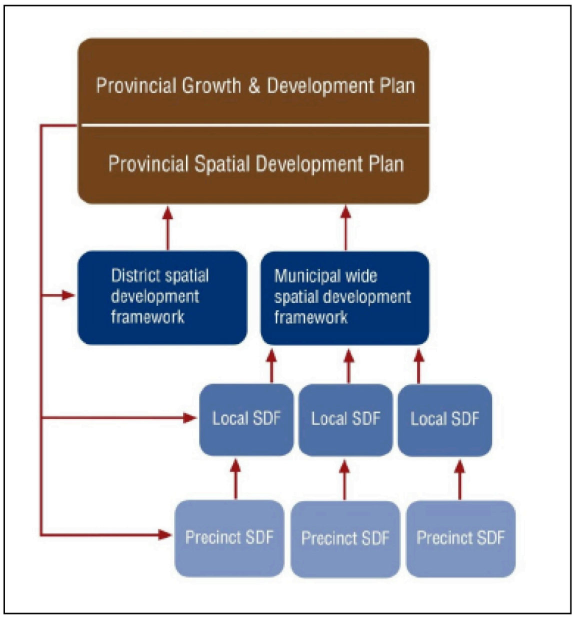

Figure 6.5: Relationship between provincial growth and development plan in relation to other plans
Eastern Cape Government (2010)

d. Local/municipal policies

The Local Municipal Spatial Development Framework (LMSDF) as part of the Integrated Development Plan (IDP) is, according to the Municipal Systems, Act the principal planning tool of local government. As outlined in Figure 6.6, the IDP informs all planning and development, and all decisions with regard to planning, management and development in a municipality.

The key aspect of the Act is the requirement that every IDP include a spatial development framework, which must include provision of basic guidelines for a land use management system for the municipality. It is clear that the Spatial Development Framework fulfils the role of being a forward plan describing the intended nature of spatial development in a Municipal area. (Elundini Municipality, 2007).

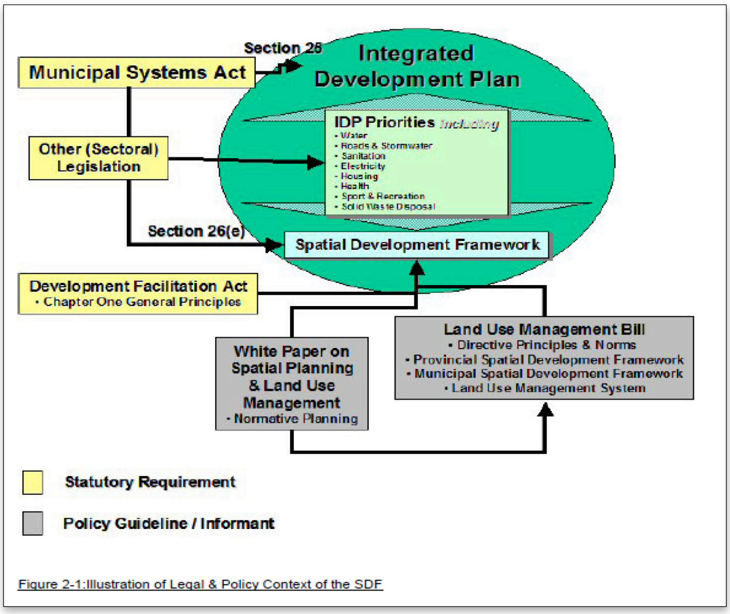

Figure 6.6: Illustration of legal and policy context of the SDF
Elundini Municipality (2007)

The case study document reviewed for this chapter mentioned the policy documents listed in Figure 6.7 as the main pieces of legislation considered in the drafting of the Spatial Development Plan. This list does not include any energy policies, but policies on water, forest, heritage, environmental management, conservation and agricultural resources.

LEGISLATION
The Conservation of Agricultural Resources Act (No. 43 of 1983)
The Environment Conservation Act (No. 73 of 1989)
The National Environment Management Act (NEMA – No. 107 of 1998)
The National Heritage Resources Act (No. 25 of 1999)
The National Forests Act (No. 84 of 1998)
The National Water Act (No. 36 of 1998)

Figure 6.7: Main pieces of legislation that need to be considered in the drafting of a Spatial Development Framework
Elundini Municipality (2007)

i. Case study: Water-energy nexus in the LMSDF of the Elundini Municipality

Water

The Elundini Municipality is located in the north of the province of the Eastern Cape in South Africa and shall provide the case study for this analysis. The municipality's mission is to strive for 'a viable, effective and efficient management institution in order to alleviate poverty and ensure sustainable service delivery to the community'. The Elundini Municipality presents its LMSDF in a 74-page document. The document includes demographics and socio-economic characteristics of the Elundini population, the economic profile of the municipality, indicators of well being (including access to service and social infrastructure), physical attributes of the area and institutional challenges in terms of land use management and staffing capacity.

The Elundini Municipality perceives its rivers, areas of sensitive vegetation types, grasslands, rock paintings sites, heritage sites, nature reserves, plateau, endangered fauna and flora and wetland areas as its most important natural and cultural endowments. The area benefits from relief water and rainfall.

> Some of the higher mountain peaks have between 800mm – 1200mm rain per annum. The rest of the area receives 600-800mm per annum. Elundini forms the catchment for the Umzimvubu River, which bisects the region and supplies large volumes of water down to the Indian Ocean. Much of Elundini has slopes steeper than 1:8 as it forms part of the southern Drakensberg range. (Elundini Municipality, 2007).

Elundini's LMSDF estimates the total yield of the surface water resources in Elundini based on the percentage of exploitable mean annual rainfall at 2 924 million m^3 per annum. Only 21% of households in the Elundini Municipality have access to piped purified water within 200m of their dwelling.

> The main source of water for the majority of the municipal population is raw water from natural sources such as rivers, springs, streams, dams etc. The abstraction points are in most cases not properly protected and are shared with livestock, leading to contamination and poor water quality. The health risks of this are a concern. (Elundini Municipality, 2007).

The water supply in the three towns in the Elundini area depends mainly on dams and boreholes with a river water supply project for bulk water supply under implementation. The largest town, Maclear, is supplied by water from the Maclear Dam on the Wildebees River. The yield from this dam is, however, insufficient and a new, smaller dam is being constructed. The lack of bulk water supply in Maclear is a critical factor that limits the development of the town. The town of Ugie is supplied by water from the Ugie Dam on the Mooi River. Water supply in the town is inadequate - a new dam and two reservoirs have been proposed to increase Ugie's water supply. The current water treatment plant is being upgraded and expanded. The village of Mount Fletcher is supplied from four boreholes, which are seen as inadequate. A project of R148m to provide bulk water supply to Mount Fletcher and surrounding villages is currently being implemented, where water will be accessed from the Tena River (Elundini Municipality, 2007).

The key planning informants include sustainability, meaning

> that the provision of services and infrastructure should not be undertaken at a level that is likely to undermine the longer-term financial and environmental sustainability in the area. Natural resource management is acknowledging that there has been extensive land degradation through inappropriate management and planning, and this has lead to a depletion of natural resources and agricultural land. The natural resources, scenic assets and prime agricultural land that exist in the Elundini LM area need to be carefully managed in order to ensure their appropriate development and sustainable use. The tourism and agriculture sectors have been highlighted as sectors for potential growth. These sectors are dependent on Natural Resources and therefore it is essential that these resources are properly managed in order for these sectors to function. (Elundini Municipality, 2007).

Energy

Energy is addressed only in the form of electricity, where the LMSDF reports that Eskom distributing electricity to all the rural areas and some sectors of the towns. The municipality supplies the other sectors. Only 12% of households in the Elundini Municipality have access to electricity, with candles being the most common fuel for lighting (62%). The towns enjoy a relatively high level of access to electricity while the rural settlement areas have very limited, if any, access (Elundini Municipality, 2007).

Elundini's LMSDF mentions renewable energy opportunities in two chapters, of which one brings water and energy issues together. Firstly, the document defines guidelines for land development in limited development areas. Such areas include lands which are generally considered to be of moderate ecological sensitivity and which do not fall within no-development areas or the defined urban edges. Although limited development areas may be degraded or transformed agricultural lands in which little natural vegetation remains, future development within these areas should demonstrate strong linkages with socio-economic upliftment and skills development and net environmental gains. Electricity generation through solar shall therefore be considered and also further alternative energy opportunities (Elundini Municipality, 2007).

Secondly, the chapter on alignment of the SDF with other planning initiatives includes plans on the district level. The Eastern Cape Development Corporation is said to be driving the Umzimvubu

Catchment Scheme, an ‘anchor’ project of the initiative which is still in the concept stage. A network of dams aimed for water storage and hydropower is envisaged to produce 600-million cubic metres of water to the Orange, Fish and Sundays Rivers, as well as Nelson Mandela Bay, and ‘at least’ 2000MW of hydroelectric power to the national grid. Secondary initiatives within this project include irrigation schemes covering estimates of 112 000 ha which will address approximately 50 000 ha of degraded agricultural land, forestry and agriculture projects (244 000ha will be earmarked for forestry, 346 000ha for arable agriculture) and tourism initiatives around the dams. Although there will be economic stimulation in the project area through job creation, the direct impacts are of the project on the Elundini Local Municipality and its residents is unclear, as the project was in a very early stage at the time of publishing the SDF (Elundini Municipality, 2007).

Water-energy nexus

The reviewed LMSDF combines water and energy issues only in the plan for the building of a hydroelectric power plant mentioned above. In conversation with representatives of the Elundini Municipality this plan, however, could not be confirmed. Neither the water, nor the electricity department’s superintendant knew about a planned hydropower plant. In line with the information given in the LMSDF, the municipal area is suffering water stress. Currently water has to be distributed by trucks. The 44 boreholes in the municipal area are operated by diesel engines.

In this study, it became obvious that the situation described in the SDF does not necessarily reflect reality to its full extend. While the process leading to the development of the spatial development plan remains unclear to the authors at this stage, the level of inclusion of the water-energy nexus in the plan reflects the level of awareness and knowledge of the water-energy nexus in the context of climate change within the municipality. Invited to a workshop on the linkages between water and energy, the municipal manager sent the electricity and water managers. During the course of the workshop, it became obvious that the issues surrounding the nexus are not understood very well within the municipality. The presentations on the linkages between water and energy in the context of climate change functioned as ‘eye openers’ for many participants.

e. Conclusion and outstanding research areas

The water-energy nexus is an outstanding issue for the South African government to address. The implications of the nexus in particular in the context of climate change appear to be present on the systemic agenda-setting level. This requires considerable awareness raising and more detailed research in order to elevate the issue closer to government’s attention.

The level of awareness of the nexus in local, rural government is concerning. The integration of technologies like solar water pumps or solar water heaters has the potential to benefit municipal service delivery. GHG mitigation opportunities, poverty alleviation contribution and expenditure savings are possible benefits government is missing out on.

Problem-oriented, multi-disciplinary policy analysis is suggested in order to zoom in on the water-energy nexus and draw expertise from the water, energy and development sectors. The potential benefits of alternative technologies like solar powered water pumps and solar water heaters need to be known in government and its implementation mainstreamed in service delivery.

The suggested set of research questions aims to stimulate the academic and political debate in the country around these issues. Research is suggested to investigate whether there is any specific planning/policy for the water-energy nexus and what such could look like in the South African and regional context. The level of awareness of the water-energy nexus in the context of climate change needs to be explored further at all government levels. Technology options in terms of renewable energy technologies and their adaptation to climate change potential in particular in the water - energy context remain largely unexplored in particular in the context of rural development.

Subsequent, the barriers for governments to address inter-/ multi-departmental challenges with appropriate collaborative solutions have to be studied and eventually overcome. Finally, a comprehensive understanding needs to be developed of appropriate cross-sectoral policy formulation, budgeting, implementation and evaluation in the field of energy and water taking the national circumstances into consideration.

7. Adapting to climate change: risks, opportunities and context in Lesotho

a. Background

This chapter opens with an overview of Lesotho's landscape and environmental history over the last 100 years. This history will also include a discussion of the important institutional drivers of land use and development in Lesotho over the period. It will establish a context for considering policy and practice for climate change adaptation at present. The chapter will conclude by outlining potential strategies and areas that need further research. These are pragmatic and optimistic, and will concentrate on favourable outcomes that will achieve significant impact effectively in conjunction with broad-based consent and buy-in by citizens of Lesotho.

Vast stretches of Southern Africa are arid to semi-arid, and this includes Lesotho. While drought and poor growing conditions generally prevail, floods do occur and it will be argued that much better water utilisation and storage strategies can be pursued. While radiation is constant, the availability of water in a landscape enables radiation to perform work through photosynthesis. As well, oasis effects recycle water and energy benignly, redistributing energy and water between night and day, and winter and summer. Water and energy quality within a landscape are not zero sum games. Adapting to climate change is not only possible but an opportunity for long-term transformation and enrichment of arid lands. Radiation, water, carbon and life acting in harmony can create wealth. At this point in the discussion, it is necessary to review Lesotho's particular geo-political situation and trajectories.

Just over 100 years ago as a result of the Boer Wars, the Basotho came to occupy an enclave of relatively undesirable land marked by its present borders. Earlier, the Basotho, who were cattle herding pastoralists, ranged over an extensive area of South Africa, shifting camps between summer and winter, along with the vicissitudes of grass and fuel wood availability. A strip of arable but arid land flanks the western border, while steep and rugged mountainous terrain characterizes most of the country. Lesotho's first leader, Moshoeshoe I, invited Christian missionaries to Lesotho and by the 1950s mission stations penetrated even the most remote regions. Missions invariably operated small-scale farming operations that included grain crops, gardens and orchards. From these, settled farming practices spread to the wider community. Once the modern borders of Lesotho were drawn, settlements became permanent, and herding and rearing of animals began to put landscapes on the perimeter of settlements under accelerated stress. As patterns for shifting between summer and winter grazing areas began to break down, even more stress was placed on farm and range land near to settlements. Through the 1920s and 1930s, virgin grasslands were ploughed in the lowlands along the western border, and corn and wheat exported to South Africa where growing urban populations, mining and manufacturing, created a ready market for cereal grains. The natural fertility of a thin layer of top soil was soon exploited and depleted, however, and yields began to decline along with soil quality. The last time that Lesotho was self-sufficient in grains was 1970, and since that time declining yields and growing population result in a food import proportion of 90% at present. Episodic drought and short brief monsoons began to incise the landscape with the characteristic deep cutting ravines and gullies locally known as dongas. While measures were taken to mark out fields along terraces and contour lines, this was not matched by progressive farming practices related to protection of soil quality or water use efficiency. The basic practice of ploughing has not changed, nor have simple crop rotations. The amount of agricultural land under irrigation in Lesotho at present is insignificant.

b. Agriculture and water developments in Lesotho

At this point, it is necessary to understand Lesotho's present position in relation to soil and water, through two significant bodies in Lesotho over the last 40 years, the Ministry of Agriculture (MOA) and the Lesotho Highlands Development Authority (LHDA).

Like many African nations, following independence in 1966, Lesotho saw the state as the primary vehicle for driving and managing development agendas. While Basotho held traditional tenure of land, Lesotho began to assemble a formidable organisational bureaucracy to control and deploy the capital assets required for modern farming operations. A huge network of offices, stations, and personnel was established to operate tractors, plough fields, plant them and harvest them. At the same time, several huge irrigation schemes were developed around the country, which on paper demonstrated to technocrats food self-sufficiency. These irrigation schemes failed and lie abandoned. They were financed and managed not only by well-meaning and dedicated Basotho, but a host of international agencies and governments. Today, driving along the main corridor of highway through Quthing, Mafeteng, Maseru, TY, Leribe and Butha-Buthe, fields on either side of the highway are largely abandoned, with pastoralists having their day again. While strips are planted here and there by individual farmers, no semblance of efficient or profitable agricultural operation is apparent. There have been remarkable and heroic achievements by individual innovators in soil and water conservation, and crop production, but overall the contribution of agriculture to the national economy is small. For a variety of reasons, the constellation of forces assembled to guide agricultural production in Lesotho were subject to systemic failure. Lesotho as a nation faces serious choices and decisions about what to do with fragments of the MOA that continue to operate and exist, along with issues related to incentives and markets for land use. Delay will continue to be costly, while piecemeal reforms are probably irrelevant. The colossal nature of this failure has still not been publicly acknowledged in Lesotho.

Both soil and water are important. Indeed, in arid environments water is the critical variable required to buffer and mobilise radiation intensity for positive ends. In stark contrast to endeavours in agriculture in Lesotho, stands the LHDA. Over a period of approximately 20 years, world class infrastructure was installed by the LHDA to construct roads and aqueducts, and barrier dams at Katse and Mohale. The LHDA mobilized formidable technical and financial resources to achieve its objectives and meet plan. Over two decades a highly structured organisation produced astonishing results. The LHDA is an unqualified success story. Another dam is currently under construction at Metelong for supply of water, and it is an effort patterned along the same lines used by the LHDA. Recently Lesotho and South Africa signed an agreement to pursue Phase II of the LHDA, which will be a project worth 15 billion USD and slated to achieve an additional 4000MW of hydroelectric output, along with 6000MW of wind energy from the Letseng plateau (the best wind resource region in Southern Africa). More barrier dams will be constructed on the upper reaches of the Senqu River for hydro-electric production and to supply water to the Vaal Triangle in South Africa.

Therefore, in view of adapting to climate change in Lesotho, one faces a contrasting situation of failure with regard to broad-scale agricultural land use, against one of extraordinary success with respect to large-scale water supply. Of course, the benefits of the LHDA have been uneven, and many small villages and settlements in Lesotho have been bypassed; this is a more complex issue. At the same time as agriculture has floundered, other sectors of the economy have continued to flourish, with growth apparent in new houses, highways, public administration, health services and education. Phases I and II of the LHDA give Lesotho immense water storage and hydroelectric generating capacity.

Aspiring Basotho want what others elsewhere on the planet have: automobiles, travel, spacious houses, well-appointed interiors, packaged food and so on. With economics and technology as usual, this translates into CO_2 emissions of 10–20 tons per capita per annum. To what extent can individual practices change, and how can society respond to general conditions that may impart additional stress and risk to humans? A sense of shared responsibility and resolve to act differently cannot be imposed by outsiders or social engineering. Education and better practices need to be introduced through innovation and change agents. Against this backdrop, what climate change and adaptation programs should be considered, and how can they be implemented in order to achieve impact and sustainability?

c. Opportunities of adaptation

Phase II of the LHDA will certainly proceed as planned, without fundamental changes to the basic parameters of its operations, and this issue is not contentious. Dispersed settlements and villages, however, have lagged behind the rate of progress in urban regions and have high levels of unemployment and relative poverty. It is here that stress related to drought or episodic monsoon rains that produce flooding and further soil erosion will be severest. The greatest opportunity for proactively facing the challenge of climate change in Lesotho relates to general humidification of the arid and drought prone belts of Lesotho. Arid lands suffer from poor landscape energy quality, which means that daytime radiation acts very much as a pollutant, producing excessive heat. During the night, an absence of atmospheric water vapour means that long wave radiation leaves so rapidly that frost occurs before dawn. Hot–cold temperature swings are typical of desert climates. It is worth reviewing the basic numbers involved. Under clear skies, solar radiation intensity is approximately 3.6 $MJ/m^2/hour$. The amount of energy required to change one litre of water from a liquid to a vapour is 2.4 MJ (the latent heat of vaporisation). These two basic values are close partners. Life cannot exist without water. Water enables photosynthesis to occur, and allows energy to perform useful work, and is the superstructure for all food webs. The condensation of one litre of water spills 2.4MJ of heat energy into the air at night, as the air temperature falls through the dew point. Powerful oasis effects result when water is available in an arid environment: cooler days and warmer nights; cooler summers and warmer winters; higher water use efficiency; higher net primary productivity. Areas sheltered from wind and turbulence enable water to cycle frequently over many transpiration and condensation phases. Each molecule of water vapour in night air acts as a mirror, reflecting precious long wave radiation back to earth, where its presence is all that stands between a tomato plant and a killing frost. Forest stands that bear immense quantities of water as part of their vascular structures also enhance landscape energy quality. Life persists and thrives by slowing down all forms of energy and delaying entropy. As stated earlier, Lesotho's arid lands need to begin accumulating more water from the earth's oceans, and letting it work through life to eat the air, build soils, stabilize micro-climates and feed people. How can this process be nurtured?

The most significant impact will result from the following:

i. intensive landscaping for storm water retention;
ii. technology for water supply and sanitation;
iii. general adoption of renewable energy technology;
iv. environmental education.

i. The need for intensive landscaping and village roads

First, intensive landscaping is needed in and around settlements, and this means investment in an array of individual and collective assets. Contour bunds need to be rebuilt and maintained, or newly surveyed and built (swales), along with terraces, ponds, groundwater dams in streams, wells, and also good roads. Designed roads have not been built in most rural villages and settlements. While main transportation arteries exist, they normally bypass a village. Surfaced roads do not reach every household. It is difficult to imagine a modern economy which is not served by wheeled transport. Human settlements without road networks are characterized by gullies, wheel tracks, paths and barren ground that exacerbate and accelerate runoff and stream velocity and horsepower. Roads are needed that serve two purposes: the first is to enable efficient wheeled and even pedestrian transportation to every household, and secondly to divert, channel and control stormwater flow. A road can be badly built in relation to water, or it can achieve the opposite effect and at the same time serve a vital human cultural and economic purpose. Villages need good roads that channel, divert and harness storm water flows. Pilot programmes can be used to demonstrate, test and generate new knowledge in this regard.

ii. Household water supply

Lesotho needs a second round of investment in household water supply that delivers water to every household. The Metelong dam is one component of infrastructure needed to do this in the lowlands. Competent watershed management and reticulation of water is required throughout the country. Rural water supply programmes installed communal taps in villages to supply relatively small amounts of potable water to every household. This infrastructure has decayed and failed to keep pace with economic requirements or social aspirations. A significant water supply is required in a household for irrigation, washing, cleaning and also for small-scale enterprises. Reticulated sanitation systems are cost-effective, reliable and simple, and enable wastes to be rapidly recycled. Small woodlots, orchards and forage plantations can absorb nutrient-rich black and grey water indefinitely. Furthermore, there are modern systems for extracting high quality biogas from stages of a water purification system.

iii. Harnessing renewable energy technologies

Renewable energy must be harnessed to raise living standards and enhance economic opportunities. Fossil fuels are increasing in price and Lesotho does not have any natural deposits of coal, oil or gas. Renewable energy technology has improved significantly in recent years, and indicates an attractive convergence of falling real prices and improved performance. While Lesotho's net contribution to global carbon emissions is small, it has nothing to lose by piggy-backing on recent innovations and avoiding spending of foreign exchange on increasingly pricey fossil fuels.

iv. Public policy and private practice

Adapting to climate change cannot proceed without questions, discussions, and debate within circles of learning and education. Which numbers matter, how are they generated and what will be their iterative consequences? In this chapter we have mentioned some basic numbers related to atmospheric ecology. Public policy and private practices must be underpinned by sound reasoning. It has been said that morality is based on the rational coordination of means and ends. Whose voice will be heard, and how can we ensure that we are guided by timely persuasion rather than reactions of panic, helplessness or blame? Social media and experiential marketing can generate and spread enthusiasm for best practices. How can this be encouraged?

1.4 Conclusions and outstanding research areas

Conclusions

Taken together, the four broad courses of action outlined above will increase resilience to weather-related stress while generating wealth and improving human welfare. Will this all happen naturally at its own pace, or chaotically as much technological and cultural diffusion does, or is there a role to play for targeted interventions, specific policies, regulatory mechanisms, institutional reform? The issue of land use and land rights is a difficult one, and has no easy fixes given Lesotho's traditional practices and culture. We pointed out that the MOA has been a miserable failure, with no clear direction on land use or agricultural policy available at the present or even open admission that there is a fundamental problem. On the other hand, the LHDA led a successful programme, with solid achievement and public confidence in Lesotho, and has created the foundation for Lesotho to spread prosperity and good living standards to most of its citizens. There is no doubt that Phase II of the LHDA will propel Lesotho to developed nation status. How then should Lesotho create a framework and policies, for adapting to climate change? Is there a role for formidable, focused and consolidated organisations, or should this be a task for networks of small organisations, agencies and institutions, sometimes collaborating and sometimes working on their own?

Decentralisation, markets, public administration and institutional reform are all needed to make things happen. Local governments in Lesotho are just getting on their feet and have considerable capacity. We spoke about landscaping and village roads. How much can be achieved if some international finance is leveraged alongside tax payer's money? As well, innovative business models and methods can as easily be used to construct roads as to make pizzas or hamburgers, or to supply water. One of the dividends of globalisation is rapid diffusion of intellectual capital and best practices. Broad band information technology is becoming commonplace in Lesotho.

In terms of climate change and mitigation, whatever Lesotho can do to conserve, store and retain water on its landscapes, replenish carbon in its soils, and encourage its biomes to work harder year after year, it will serve itself well along with the rest of humanity.

Outstanding research areas

The most significant impact will result from the following areas and addressing the related research questions.

1. Intensive landscaping for stormwater retention

- What practices have the most impact and what do they cost?
- What are the gaps in adoption, financial, technical, or motivational?
- What remote and local sensing technology is available to monitor change and how can it be deployed?

- What potential business models exist that can utilise markets to collect water, construct roads, and landscape on a sustainable for-profit basis?
- What role can focused and managed public works programs play in contributing infrastructure for climate change and adaptation?

2. Technology for water supply and sanitation

- What low cost water treatment technology is available to ensure safe supply of potable water in households.
- What water storage and reticulation options exist for rapid roll out and deployment?
- What watershed enhancement strategies exist, that will both buffer threats from climate change and at the same time provide water for irrigation and household use?

3. General adoption of renewable energy technologies

- What basic mechanisms exist for Lesotho to forge its own low-carbon footprint development agenda?
- What technologies are available now, not only to reduce global carbon emissions, but to reduce urban island pollution?
- What frontier technologies should be tested and nurtured? For example, solar-powered central pivot irrigation wheels and EVs.
- What potential exists for Lesotho to become a market leader, rather than a market follower?

4. Environmental education

- How can response to the risk of climate change and action for adaptation be generated? Dull speeches, documents, billboards or Pop Stars and concerts? All options should be considered.
- What mix of modern experiential marketing and plodding institutional analysis is best suited to tackling climate change and responsiveness?
- Where can basic knowledge on climate change and adaptation be assembled in Lesotho, and utilised to inform public/private policy/practice and drive change.

8. Conclusions

Southern Africa is a water-scarce region. Like other developing countries Southern African nations aspire to the living standards of industrialised countries. To achieve these standards more water and energy resources are needed to support economic growth, industrial expansion and food security for a growing population. Most rural people in Southern Africa struggle to acquire basic necessities and the four countries described in this report are food importers. Lesotho, for example, expects to have to import food for 90% of its population in 2011, and even South Africa has been a net food importer since 2008. Water management and food security are major challenges because a relatively high percentage of the available water is used for food production. In South Africa 61% of the available water is allocated to irrigation as compared to 40% in the USA. Growing water, energy and food security needs have to be carefully balanced and planned considering climate change.

This study looked at the water-energy nexus in the context of climate change in Namibia, Botswana, South Africa, Lesotho and Mozambique. National planning was investigated in South Africa and the absence of integrated water and energy planning was noticeable at all governance levels and is of concern. No integrated water and energy plans were found in the other countries. It is suggested that a modelling framework of the water-energy nexus be established, using the following approach.

a. Modelling framework for planning water-energy interactions and climate change

To develop a basis for integrated water and energy planning taking climate change into consideration, modelling tools and scenarios should be developed. The following five actions are proposed:

- Development of a prototype systems-modelling framework for energy/water planning in the context of climate change. Policy options to include national impacts and constraints on local actions (e.g. implementation of community-level renewable energy technologies as a policy).
- Use of the framework in stakeholder and expert workshops to integrate current knowledge and understanding of inter-dependencies.
- Experiment with model to identify key areas of sensitivity or pressure, e.g. potential magnitude of water/energy cross-effects; potential magnitude of climate change effects; where local interventions may have greatest impacts in the broader system; where the greatest data sensitivities are.
- Design of a refined and more extensive model in the light of these experiments. Support of local intervention studies by more detailed models of community-level actions (subject to global constraints)

b. Addressing barriers and opportunities in rural water provision

Rural water supply systems and their energy technologies used for water pumping and distribution were investigated in Namibia, Botswana and Mozambique and barriers and opportunities for rural water provision were analysed. Lack of funding was identified as a problem; the limited government funding was put into large centrally-managed projects. External funding was essential for most of the projects, but problems have arisen with sustainability after completion of the project.

Funding, education, training and information were identified as major barriers throughout the study and at all levels. Government officials and community members need to be equipped to plan projects and take leading roles, and community members and local leaders have to be involved and consulted in the planning policies and programmes that affect their area. This will enhance acceptance and ownership. It will also contribute to the decentralisation of skills and resources and make the environment more attractive for private sector investment and participation. None of the successful projects studied has been upscaled to a region or the entire country. The following action is suggested:

- Find out how to maintain and sustain projects once they have been completed and no more donor funding is available.
- Develop effective ways to better inform all stakeholders about suitable and new renewable energy technologies to break down unrealistic perceptions and create acceptance.
- Better educate and train all stakeholders, particularly at the local level, to facilitate decentralisation of resources, skills and finance.
- More work is required to motivate national governments and communities to invest resources to upscale and adapt successful projects
- Policies and strategies must ensure that the most needy people in remote areas are included and get access to and benefit from water- and energy-supply schemes?

c. The water-energy nexus and climate change in policy and planning

The water-energy nexus is not sufficiently recognised in policies, regulations and laws in South Africa. Mining companies, Eskom and banks are pushing the nexus on the political agenda; their focus is on water quality and quantity needed for mining coal for the generation of electricity. Research is needed to inform and assist government in making the right decisions around renewable energies. Especially poorer municipalities which lack capacity and skills as well as small-scale farmers need to be enabled to adapt to changing weather conditions (droughts, floods, water quality) including impacts on service delivery. The following outstanding questions have to be addressed:

- Is there specific planning/policy for the water-energy nexus? What could it look like?
- Is there awareness of the water-energy nexus at government levels and is the climate change impact on this nexus appreciated?
- To what extent are policymakers aware of renewable energy technologies and the potential role they can play in adaptation to climate change in particular in the water–energy context?
- What are the barriers for governments to address inter-/ multi-departmental challenges with appropriate/collaborative solutions? How could the barriers be overcome?
- What does appropriate cross-sectoral policy formulation, budgeting, implementation and evaluation in the energy and water sectors look like, taking national circumstances and climate change into consideration.

1.4 Adaptation to climate change – case study Lesotho

In recent years, agricultural yields in Lesotho have declined and many fields are left fallow, because inputs are higher than the harvest. Changing and variable rainfall patterns are the reason why farmers are reluctant sow crops. It is estimated that 90% of Lesotho's food requirements have to be imported in 2011. The following questions have to be addressed;

- What nodes of leadership exist at the present time, whether public, private or institutional, that represent vision and best practice in regard to climate change and adaptation?
- Who are the innovators in Lesotho doing the work that needs to be done?
- What institutional mechanisms exist to improve critical policy analysis and environmental education for climate change adaptation?
- What means exist to sequester carbon, improve soils and reduce evaporation of water through better and modern farming methods?
- Why are simple and beneficial strategies (such as swales) not replicated in neighbouring communities and/or not scaled up?
- How can these adaptation strategies become part of the national plans and action for Lesotho under the UNFCCC?

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Appendix 1: Programme for WRC/ERC workshop on Water-Energy nexus in the context of Climate Change

Venue: Energy Research Centre, UCT, Upper Campus, Menzies Building, 6th Floor, Room 648

Tuesday 23 August 2011

Final Programme

10.00 Tea/Coffee

10.30 Introduction of participants

10.35 Introduction to workshop: Gisela Prasad

10.50 Discussion and Questions

11.00 Theme 1: Case studies

Renewable energy technologies for rural water services. Opportunities and barriers: Michael Boulle

11.15 The water-energy nexus in policies of South Africa: Holle Wlokas

11.30-11.45 Tea Break

11.45 Adaptation technologies and strategies in water supply – opportunities and barriers. A case study from Lesotho: Sebataolo Rahlao.

12.00 Theme 2: Impact of Climate Change on Water Resources of SA: Roland Schulze

Current status of reseach on water, energy and climate: Chris Moseki

The need for integrated planning of water and energy resources in the context of climate change: Theo Stewart

12.40 Theme 3: Water, energy supply and climate change challenges in municipalities
Elundini rural municipality: Luyanda Rozani and Thembelani Ngceba

City of Cape Town

13.00-13.45 Lunch

13.45 Discussion

14.15 To discuss clear and practical entry points for further investment and research

15.30 End of workshop

Appendix 2: Sources of financing included in the project framework

From Deenapanray (2011)

Project component	GEF financing (US$)		Cofinancing (US$)	
	Approved	Actual	Promised	Actual
1. Capacity building	210 00	210 000	315 000	523 000
2. Policies, laws and regulations	181 000	181 000	538 750	538 750
3. Public acwareness and social acceptability	275 900	275 900	222 500	430 500
4. Financial and product delivery model	1 302 000	1 302 000	5 500 000	5 500 000
5. Learning, evaluation and adaptive management	302 100	302 100	433 750	643 750
6. Project management	329 000	329 000		
Total	2 600 000	2 600 000	7 010 000	7 636 000

Sources of co-financing	*Type*	*Project implementation*	
		Expected	*Actual*
Danish Government	cash	1 155 000	1 155 000
Finish Government	cash	3 626 000	5 726 000
RE financing schemes with banks	cash	2 000 000	
MME	In-kind	100 000	755 000
MME	cash	755 000	
Total		7 636 000	7 636 000

Appendix 3: Stakeholders participating in NAMREP

from Deenapanray (2011: 40)

Government Ministries and Institutions	NGOs and Parastatals
Ministry of Mines and Energy	Desert Research Foundation of Namibia
Ministry of Environment and Tourism	Gobabeb Training and Research Centre
Ministry of Agriculture, Water and Rural Development	Namibia Nature Foundation
Ministry of Works, Transport and Communication	Ibis
Ministry of Education	Namibia Wildlife Resorts
Regional Councils (13)	NamWater
National Planning Commission	Telecom Namibia
Namibian Development Corporation	Habitat Research and Development Centre
Ministry of Finance	Agribank
Ministry of Trade and Industry	Electricity Control Board
Ministry of Women Affairs and Child Welfare	NamPower
Solar Revolving Fund	Regional Electricity Distributors
	National Housing Enterprise
Capacity Building Institutions	**Donor Agencies/Development Partners**
University of Namibia	UNDP
Polytechnic of Namibia	DANIDA
Windhoek VTC	
Financial and Private Sector Institutions	**End-users/Beneficiaries**
Premier Electric	Off-grid communities
Bank Windhoek	Regional Councils
First National Bank Namibia	Households
SMEs (suppliers, installers, technicians of SETs)	Building owners
Private housing developers	Communal farmers
Namibian breweries	Commercial farmers
Engineering and consultancy bureaus (CSA, EmCon, Craddle)	

Appendix 4: Analysis of outputs measured against NAMREP indicators

Objectives, outcomes, outputs	*Final Indicator*	*Verification*	*Performance Rating*
GLOBAL GOAL Improve accessibility to sustainable energy services, reduce CO_2 emissions, and improve quality of life and create income generating activities for rural communities	Kerosene for lighting reduced in houses with PV	No supplier or end-user surveys distributed to assess reduction in use of fossil fuels	Unsatisfactory
	Diesel consumption on farms reduced due to uptake of PVPs	Secondary research used to establish reductions	
	Houses with SWH reduce grid electricity consumption	SHS reduced use of kerosene by ~50%	
	233 670 tCO_2 forecast to be reduced because of the project	Annual diesel consumption decreased by 21 320L because of PVP uptake	
		SWH installation increased by a factor of 3.5 between 2008 and 2010	
		Avoided emissions over 15 years ~243 900 tCO_2	
DEVELOPMENT OBJECTIVE To promote the delivery of commercially, institutionally and technically sustainable solar energy services	Number of systems sold in 2009 is 10x that of the baseline year	End-user survey was not completed	
	Impacts on end-users	REEEI preliminary survey show following stats for 2009	Unsatisfactory
	Number of households affected	3120 SHS	
	Number of social services affected	385 PVP	
	Number of people with increased income	195 SWH	

Objectives, outcomes, outputs	*Final Indicator*	*Verification*	*Performance Rating*
OUTCOME 1 Build capacity in private and public sectors and NGOs	1000% increase in RET businesses outside Windhoek	End-user survey not completed	satisfactory
	End-user satisfaction with installation and service increased by 50%	RET businesses outside Windhoek increased from 24 in 2008 to 30 in 2010	
	Reported system faults decreased by 30%	Complaints and system faults dropped to zero	
1.1 Training programmes have been executed and established	25 government and NGO personnel trained, as well as 35 solar technicians	155 persons trained, 55 out of which were technicians	Technicians and staff are willing to be trained
1.2 Decentralised RET companies are adequately supported	50% of technicians that participated in training workshops set up or improved small RE businesses	No surveys carried out but 20 technicians participated in NTCRE accreditation training which made commercial financing schemes available to them	Marginally unsatisfactory
1.3 Vocational and training centres providing training on RETs	Two training centres established	Changes in legislation prevented this target from being attained	Satisfactory
		It is expected that the WTVC will be able to offer training	
OUTCOME 2 New policies, laws and regulations and actions in support of RETS	Three new policy measures have been introduced	In 2007 this included the introduction of the Solar Water Heater Cabinet Directive, Off-Grid Energisation Master Plan, National Regulatory Framework on Energy	Highly satisfactory
		In 2008: National Technical Committee on RE, and the RE Strategic Action Plan	
		In 2009: OGEMP Fund, and RE Division within the MME	
2.1 Policy and regulatory frameworks for RE and off-grid electrification	Policy measures have been introduced	SWH Cabinet Directive and OGEMP	Highly satisfactory
	Guidelines on standards and codes of practice	The NTCRE has identified standards which will become the Namibian standards for SETs	
2.2 Government ministries and public institutions finance and implement SETs and projects	SET projects integrated in future plans of two ministries	SET plans integrated in four government ministries	Highly satisfactory
	Inter-sectoral coordination on RET	REEEI could play coordinating role for RETs between sectors	
2.3 REEEI has been	The REEEI has taken	REEEI is setting up	Highly satisfactory

established	over some non-core functions from the MME	energy shops and conducting energy research, and has started to become involved in the core functions of the MME such as engaging in policy dialogue	
OUTCOME 3 Increased public awareness and social acceptability	Number of sales and loan applications for SETs	Loans issued under the SRF and Bank Windhoek SHS: 694; SWH: 169; PVP: 155.	Highly satisfactory
3.1 Comparative information on demand for energy services and costs and benefits of SETs	Cost-benefit analyses on SETs	Cost-benefit analyses for SETs have been updated and leaflets on affordable RETs have been distributed	Highly satisfactory
3.2 Increased knowledge among decision-makers and end-users	6000 people reached by campaigns	18000 printed materials distributed by the project	Satisfactory to highly satisfactory
	40 on-site demonstrations conducted	Workshops attended by more than 200 people	
		34 on-site demonstrations	
		160 decision-makers have been briefed on SETs	
3.3 Active networks or associations in place	SENSE is fully functional	SENSE has over 200 members	Highly satisfactory
	SET suppliers participating in SENSE	REoIA that regroups around 80% of RET suppliers has been formed	
<u>OUTCOME 4</u> Appropriate financing and product delivery schemes	Number and type of lending schemes	The Bank Windhoek granted 177 loans, First National Bank scheme issued 116 loans, SRF being transformed into OGEMP Fund	Satisfactory
	Number of loans granted and lending volume; repayments	Loan repayment rate of the three scheme was 85%	
	A strategy to reduce first cost is in place	A strategy for first cost reduction is not in place	
4.1 SRF has been scaled up and expanded	300 loans awarded per year	SRF loans for 2008-138, 2009-149, no loans issued in 2010 due to transition to OGEMPF	Satisfactory
4.2 Financing schemes through commercial financing institutions have been set up	Existing schemes have been scaled up	BW scheme-177 loans; FNB scheme-116 loans	Satisfactory
	New schemes have been established	Local banks independently issuing loans for RETs	
	At least one scheme with a development bank to develop RETs and productive		

OUTCOME 5 Learning, evaluation and adaptive management	Number of staff in REEEI and MME working on RETs	RE division increased staff from 4 to 6, REEEI created position for Energy Shop Coordinator	Successful implementation of all the activities in the previous components
	Lessons learned	Lessons learnt were reported	
5.1 Adaptive management, monitoring and evaluation	PMU staff absorbed in MME or REEEI	One of the PMU staff integrated in MME, and one applied for position	Satisfactory
	End of project study	End of project study has not been completed, and no one has taken responsibility to complete it	Unsatisfactory
	Project progress reports	Project progress reports completed	Highly satisfactory
	Terminal evaluation	TE report expected to be finished within months of the project completion	Highly satisfactory
5.2 Lessons learned have been documented and disseminated	NAMREP quarterly and other publications	Standard progress reports produced quarterly, 15 publications from NAMREP II	Highly satisfactory
	Experiences shared with other countries	Six countries benefited from experience of NAMREP	
		Lessons learned reports were being put together	

Appendix 5: Analytical framework to evaluate the water energy relationship and policies to balance competing needs and identify policy options that address various trade-offs

Source: The World Policy Institute (2011)

1. Update and improve the quality of the data underlying analysis of water consumption in energy production. The most recent US Geological Survey on water consumption, for example, was published in 1998. Some examples of improvements to the data include adding the full range of emerging technologies to the analysis of existing technologies; updating and filling in holes in data on hydraulic fracturing and Canadian oil sands; and incorporating data about aggregate water consumption according to type of energy technology and industry sector.
2. Carry out complementary analyses of water withdrawal and quality by energy type, including breakdowns by technology including aggregate data and details by industry sector.
3. Identify possible portfolios of traditional and alternative energy sources designed to meet projected future water needs for an array of water scarcity hot spots.
4. Create a cost analysis of water efficient technologies. Attempt to quantify or monetize their impact on water, business, and elsewhere. Recognize and identify the impediments these can pose.
5. Identify technologies that both maximize water efficiency and minimize carbon dioxide emissions.
6. Assess the impact of energy choices on water availability for agriculture and forests.
7. Analyze how the state of the existing power grid in a given area affects cost implications of water-efficient energy choices—i.e., the capacity to get clean, water-efficient energy to users.
8. Analyze how well existing governance mechanisms support the process needed to develop water-efficient, cost-effective, and carbon minimizing policies, and how to harmonize regulatory bodies at the local, national, regional, and global levels (for example, the UN General Assembly Law of Transboundary Aquifers, the Water Cooperation Committee of the Gulf Cooperation Council, and so on).
9. Focus these analyses on water-scarce border regions where water and energy decisions affect stakeholders of different nationalities or jurisdictions.

Appendix 6: List of persons consulted

Arthur, Fatima	Electricidade De Mocambique E.P., Mozambique
Cuamba, Boaventura	Energy Physics Group, Eduardo Mondlane University, Mozambique
Hughes, Alison	Energy Research Centre, University of Cape Town, South Africa
Ngceba, Thembelani	Water Superintendant, Elundini Municipality, Eastern Cape, South Africa
Gashi, Khaya	Municipal Manager, Elundini Municipality, Eastern Cape, South Africa
Ginster, Martin	SASOL, South Africa
Klintenberg, Patrik	Desert Research Foundation, Windhoek, Namibia
Letete, Thapelo	Energy Research Centre, University of Cape Town, South Africa
Moseki, Chris	Water Research Commission, South Africa
Paulo, Julieta Felicidade	Rural Water Department, Mozambique
Reinecke, Josh	Master Student, Energy Research Centre, University of Cape Town
Rozani, Luyanda South Africa	Electricity Superintendant, Elundini Municipality, Eastern Cape,
Schulze, Roland	University of KwaZulu-Natal, Pietermaritzburg Campus, South Africa
Schultz, Robert	Tsumkwe Energy Project Coordinator for Desert Research Foundation Namibia
Scott, Kirsten	University of Cape Town, Environmental Evaluation Unit
Sparks, Debbie	Energy Research Centre, University of Cape Town, South Africa
Stewart, Theo	Department of Statistics, University of Cape Town, South Africa
Swatuk, Larry Waterloo	School of Environment Enterprise and Development, University of
Trollip, Hilton	City of Cape Town, South Africa
van der Merwe, Steyn Manager	former Nelson Mandela Bay Municipal Renewable Energy Project
Ward, Sarah	City of Cape Town, South Africa
Winkler, Harald	Energy Research Centre, University of Cape Town, South Africa