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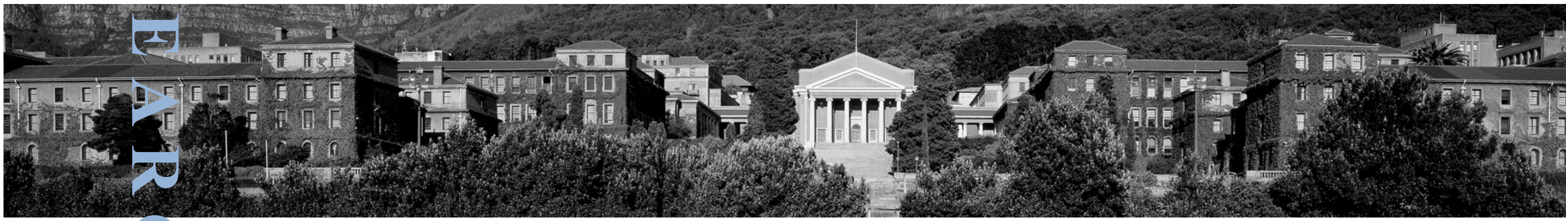

# Water considerations in selecting energy technologies

**Amos Madhlopa, Samantha Keen, Debbie Sparks, Mascha Moorlach**

May 2014

## Key points

- Water is scarce in South Africa.
- Exploitation of energy technologies requires water.
- Water requirements are not well integrated into decision-making processes for selecting energy technologies.
- This workshop was organised to evaluate methods for selecting renewable energy technologies.
- Water needs to be considered within the existing methods for decision-making without creating new methods.
- Some criteria have been proposed for prioritising energy technologies.
- Financial modelling, with adequate water consideration, can play an important role in the prioritisation of energy technologies.

**This project was commissioned by the Water Research Commission**

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# Contents

# 1. Introduction

## 1.1 Water-energy nexus, climate change and renewable energy technology

Water plays a vital role in the socio-economic development of any nation. It is exploited in different economic sectors, including the energy sector. Water and energy are inextricably related, and this relationship is usually referred to as the water-energy nexus. Water is used for energy production in the abstraction, growth and preparation of some fuels as well as in some power plants. It is also used in the raw materials for plant infrastructure, manufacturing of plant components, and the construction of power generating infrastructure. The volume of water used in the raw materials will vary widely, not only with the technology, but also the material type and plant design. Furthermore, these materials can be imported from any location and the associated water use is not limited to any water catchment, water management area or local authority.

The production of electricity may demand a significant quantity of water, and growth in the energy supply poses a challenge in regions where water is scarce. Consequently, there is a need to exploit water resources sustainably. Already, most of the catchment areas in South Africa use more water than is available on an annual basis (Figure 1).

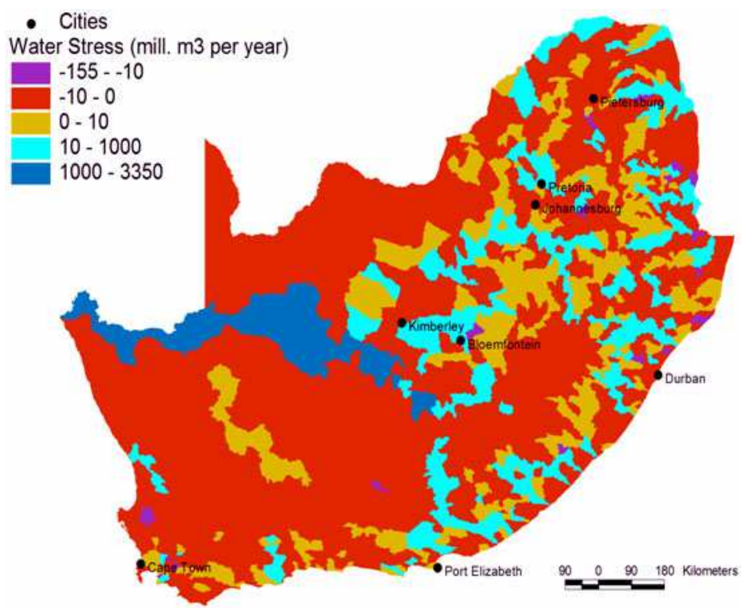


**Figure 1: 2005 annual water balance in South African catchments**
*Based on data from the Department of Water and Forestry (Colvin et al 2009)*

South Africa is divided into nine water management areas: Limpopo, Olifants, Inkomati-Usuthu, Pongola-Mzimkulu, Vaal; Orange, Mzimvubu-Tsitsikamma, Breede-Gouritz and Berg-Olifants (see Figure 2). Each local authority is allowed to regulate the abstraction and use of water within its boundaries. Large-scale water abstraction and use, for example by mining and some industry, is regulated and licensed by the national government. Water resource management in this country faces various challenges, which may be compounded by its vulnerability to climate change and consequent increased stress on water resources. The impact of climate change is complicated, with some areas likely expected to be more affected than others. In this regard, six climate zones were identified in South Africa as part of the Water Sector Climate Adaptation Strategy process, reflecting institutional boundaries defined by Water Management Areas (Figure 3). These zones are grouped based on their climatic and hydrological variables.

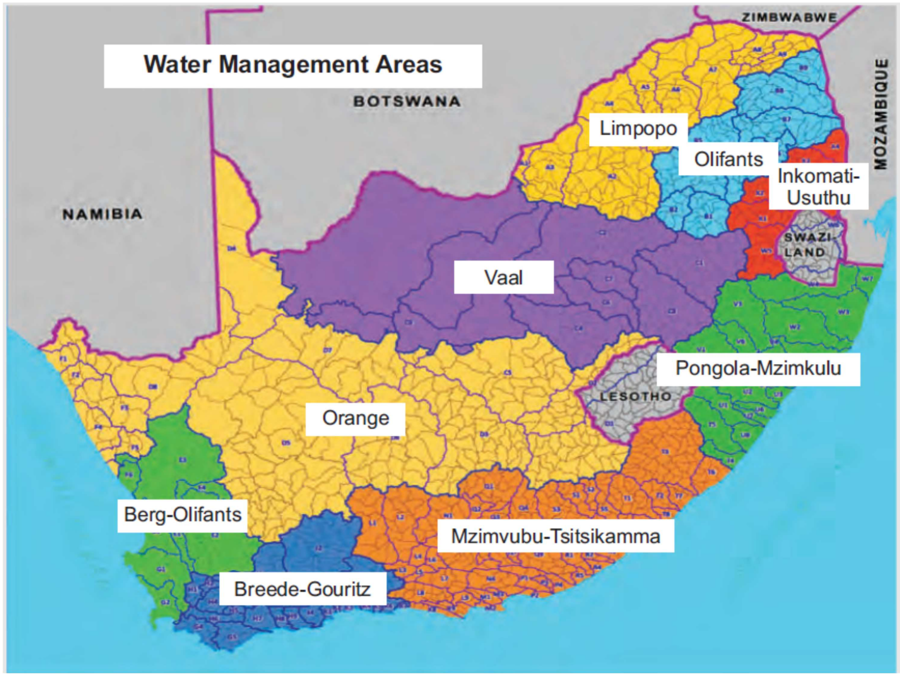


**Figure 2: Water management areas**
*Source: DWA (2013)*

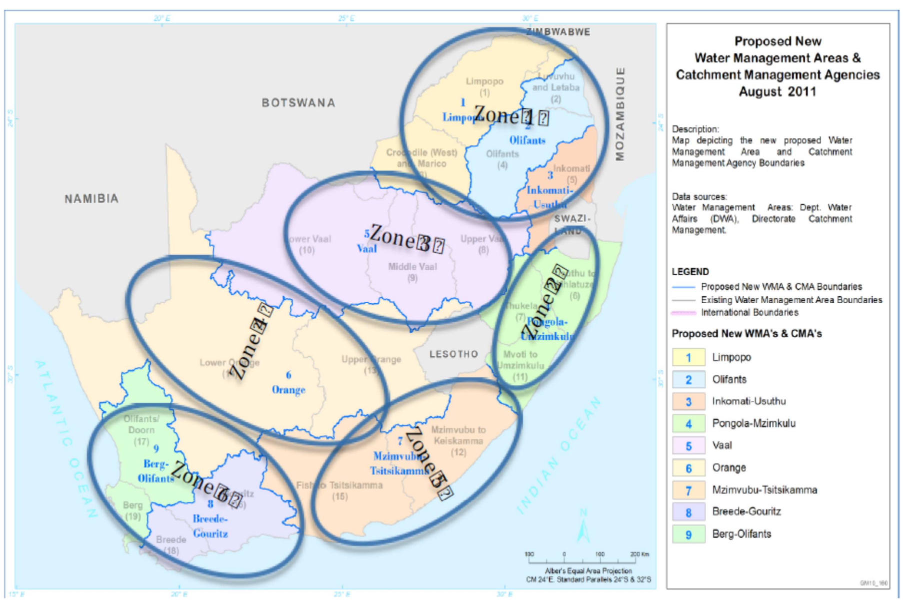


**Figure 3: Climate water zones in South Africa**
*Source: DWA (2013)*

On the other hand, energy is needed to pump, treat or distribute water. At present, the main source of primary energy in South Africa is coal, and overreliance on this energy resource is significantly contributing to climate change. The advent of climate change may result in a decrease in the amount of rainfall. Moreover, the growing economy and social development are increasing demand for water (DWAF 2013), so that it is likely that most areas will require more energy for the provision of water services. Water conveyance and treatment to meet stringent drinking regulations require energy from often distant locations. There are growing concerns about the increase in greenhouse gas (GHG) emissions as a result of the intense use of fossil fuels (including coal and petroleum) for energy supply, and applying renewable energy technologies can assist in the mitigation of climate change as well as increase the security of the country's energy supply.

Climate change is expected to augment the strain on water provision due to projected changes to seasonal and regional temperature and patterns of precipitation (Hoekstra *et al.* 2011; Wilson *et al.* 2012). In the light of this, the Department of Energy (DoE) developed an Integrated Resource Plan (IRP) (DoE 2010), embodying a national strategy to meet both the growing electricity demand and international commitment to reduce GHG emissions by 34% below business-as-usual by 2030. The IRP strategy diversifies the energy mix from the current primary reliance on coal-fired electricity to an energy mix in which a third is generated from renewable sources (DoE 2010). To meet this goal, the government is currently offering incentives for investment in renewable energy technologies under the Renewable Energy Independent Power Procurement Programme (REIPPP), with a bidding process. So far, three rounds of bidding have been successfully implemented. However, the impact of deploying renewable energy technologies on water resources needs to be considered properly and this study contributes towards efforts in this direction.

## 1.2 The water-energy nexus project

The Water Research Commission (WRC) commissioned a project on the water-energy nexus in South Africa in 2013. The aim of this project is to investigate trade-offs between water use efficiency and renewable energy in South Africa, and it comprises a series of nine tasks.

### 1.2.1 Completed tasks

***a) Task 1***

The first task focussed on renewable energy choices and water requirements. Research results show that there are limited data on all aspects of water usage in the production of energy. There is a need to take into account all aspects of the energy life cycle to enable isolation of stages where significant amounts of water are used. Conventional fuels (nuclear and fossil fuels) withdraw significant quantities of water over the life-cycle of energy production, especially for thermoelectric power plants operated with a wet-cooling system. The quality of water is also adversely affected in some stages of energy production from these fuels. This investigation has also shown that solar photovoltaic and wind energy exhibit the lowest demand for water, and could perhaps be considered the most viable renewable options in terms of water withdrawal and consumption.

***b) Task 2***

*Energy policy and regulation in South Africa and its consideration or implications for water* were investigated in the second task. Findings show that it is helpful to examine energy and water policy from the perspective of individual energy sources or technologies but also at a systemic level – including how energy demand is managed and planned for, the water efficiencies of the energy mix, and the incentives to decision makers when responding to future national energy needs. The IRP takes water scarcity into account and demonstrates an awareness of the trade-offs but, beyond that awareness, there is little information indicating the water impacts over the full lifecycle of energy production, and there are no tools available for analysis, in order to assist decision makers. As a result, the awareness of trade-offs is not efficiently translated into decision-making practice.

***c) Task 3***

Impacts of current energy choices, and the challenges and opportunities involved in adapting to climate change were investigated in the third task. It was found that water impacts vary in the energy generation cycles of different energy technologies. Planning for energy supply now and in the future necessitates that South Africa's policy makers take into account the water impacts and associated risks of the energy generation technologies available, particularly in areas where there is severe water stress.

***d) Task 4***

The aim of the fourth task was to develop a policy framework that can enhance harmonisation of policies linked to water and energy. The formulation of this framework took into consideration the following key points:

- South Africa faces concomitant imperatives to secure a supply of clean water, protect water resources, and provide a secure supply of energy.
- It is important to use water resources efficiently in the energy production chain.
- Legal and policy instruments developed direct the management of water, energy and other sectors.
- Harmonisation of policies is required for effective management of the water-energy nexus.

This framework can help in the development of new policy (legal) instruments or review existing instruments.

### 1.2.2 Present task

The aim of this task was to evaluate methods for prioritising renewable energy technologies and water catchments in South Africa. To this end, a workshop was organised and took place on 13 May 2014 at the Stone Cottages, Kirstenbosch in the City of Cape Town. It was perceived that sharing insights of practitioners in the energy-water nexus can assist in tackling the water-energy challenge.

## 1.3 Workshop objectives

The workshop was aimed at providing an opportunity to gather insights into managing the water-energy nexus from business, national and provincial government, and water and energy practitioners and researchers. It was also an invaluable opportunity for networking between various groups interested in the water-energy nexus. The focus of this forum was on water use (withdrawal and consumption) for renewable energy technology, especially in areas already perceived to be water stressed. The three objectives of the workshop were to:

- discuss and evaluate means of prioritising water concerns in energy planning / proposals / projects;
- evaluate methods to prioritise technologies and catchment areas for case study; and
- elicit feedback on the Policy Framework for water for energy that was drafted in an earlier task of the project, for the purpose of refining the Framework.

The workshop also gave the opportunity to test the hypothesis that water requirements are not well integrated into decision-making that requires a selection between renewable energy technologies. The workshop activities were planned with assumptions that:

- project developers select one of two or more appropriate renewable energy technologies;
- the process of developing renewable energy projects may be initiated with a site already in mind or with an already selected renewable energy technology; and that
- there may be means to prioritise the consideration of water resources in the selection of renewable energy technologies.

# 2. Approach

## 2.1 Stakeholder representation

Stakeholders were invited from different groups of organisations: civil society/non-governmental organisations), South African National Energy Development Institute (SANEDI), REIPPPP, the business sector, DoE, Department of Water Affairs (DWA), Department of Environmental Affairs (DEA), other government departments and academia. Due to other official commitments, there was unfortunately no representation from the DWA, DEA and the WRC. A list of attendees is presented in Appendix B of this report.

## 2.2 Workshop process

Participants were welcomed to the workshop by ERC and a facilitator, and the aims and anticipated outcomes of the workshop were explained. Self-introductions were conducted to provide a perspective of the stakeholder representation and expertise. An overview of the day's programme was also outlined (see Appendix C).

PowerPoint presentations were made on the renewable energy and water resource maps (see Appendix D), and methods for decision-making. The presentation on renewable energy and water resources was aimed at providing insights into the spatial distribution of these resources. Various methods of decision-making were presented to give a starting point for the discussion. After the prelude, participants were divided into three random groups and requested to discuss, evaluate and select appropriate methods for prioritising renewable energy (RE) technologies. The objectives set out by WRC pertaining to the water-energy nexus were clarified. In this regard, the discussion was to focus on project-level considerations. The workshop participants could contribute by drawing from their experience and exposure to look at how this could be done (methodologies/approaches). To start the discussion, three methods for selecting energy technologies were suggested:

- multiple criteria;
- decision tree; and
- incorporating strategic assessments in current guidelines for energy projects.

Groups examined the methods in detail and recorded their points on paper. After group discussions, participants re-convened in a plenary session to consolidate ideas. A representative from each group presented their findings by putting up their points and explaining them (see Figure 4.

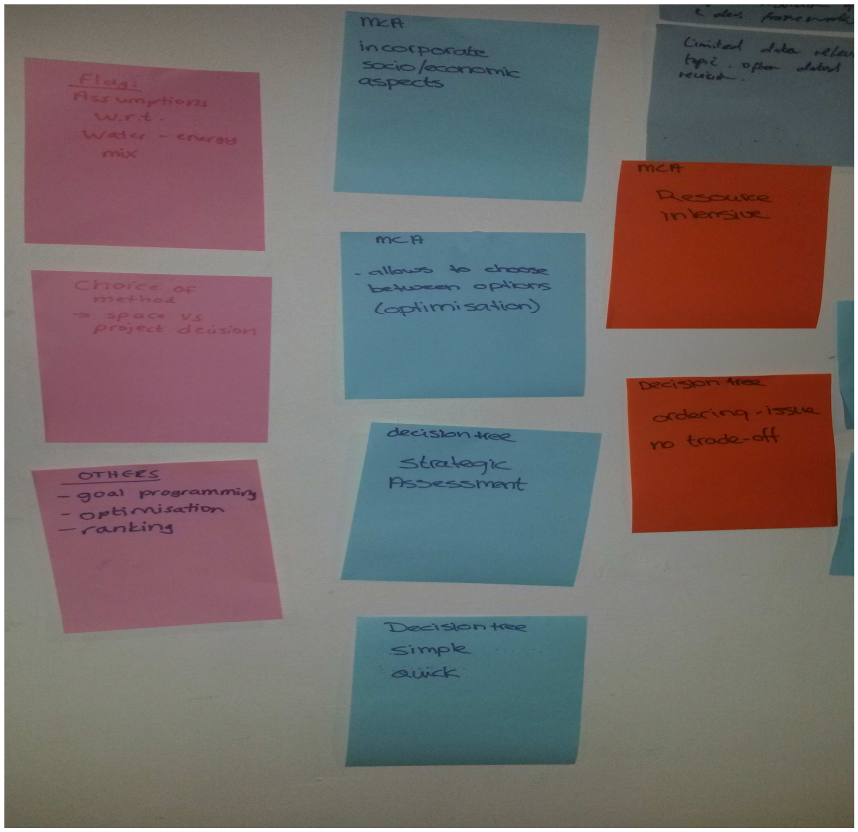


**Figure 4: A record of some points on methods for prioritising energy technology**

# 3. Key issues and findings

## 3.1 Distribution of renewable energy and water resources

- South Africa is endowed with various renewable energy resources (solar, wind and other resources).
- Water is scarce in some areas with good renewable energy resources. For instance, there is abundant solar radiation in the Northern Cape (Figure 5) but water is scarce in this region (Figure 1).
- Choices of energy technologies and where to exploit them need to take into account local water scarcity.

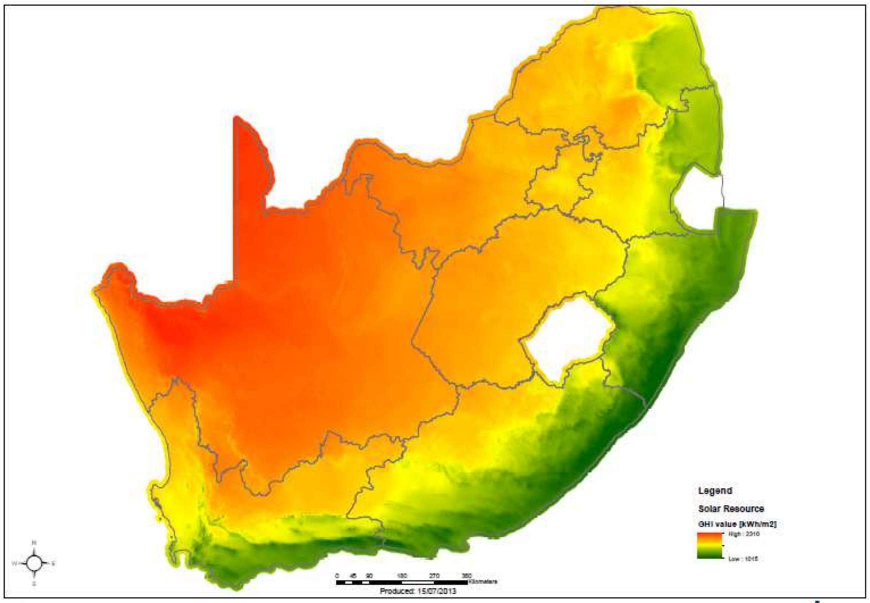


**Figure 5: Global horizontal solar radiation distribution in South Africa.**

## 3.2 Methods for prioritising energy technologies

- There are risks associated with each criterion for prioritising energy technologies. These should be modelled through sensitivity studies to determine thresholds.
- Participants noted that it is important to look at existing prioritisation frameworks. A lot of work has previously been done for prioritising water, so there is not much need for developing new methods. Instead, the importance of the water resource in energy decision-making processes should be augmented.
- Financial modelling precedes all renewable energy projects. In view of this, it was suggested that relevant information that would affect all projects be made freely available. This information would include updated assessments of water availability and analysis on the likely future price of water, taking into consideration competing demands on water, likely changes to water availability and quality (as a result of water use and climate change). The benefit of this approach is that assessments of project sustainability would be made on the basis of the best available and most recent information.
- It was suggested that the setting of benchmarks as guidelines (e.g. an amount of water consumption per unit of energy production) could be used for more 'fair' allocation of water amongst different types of energy projects.
- The spatial and temporal disconnection regarding water was mentioned as a key constraint in quantifying the amount of water used. In this vein, the workshop participants shared the concern that there is a lack of coordination between project licencing by the various relevant departments. Projects are required to apply to the DWA, DEA, and DoE for various permissions and licences. However, there is a time lag in this process and there would be a risk that any department's assessment of an application might not have full information as to the other permissions granted or the aggregate impact on water resources of recently-given permissions. Workshop participants felt there is a lack of transparency on how changes are made to water allocations and that this might be a complicated process. Some participants felt that, in their experience, allocations were not always done centrally and the methods for prioritising licences were not always clear.

- A country could choose to focus on a specific technology and create incentives to make it work. However, the incentives should be considered along with the costs of employing one technology rather than another. So, the costs related to the water demand would be weighed against the incentive. If, for example the cooling system being considered for electricity generation is water-intense or energy-inefficient, then the benefit of the incentive might be nullified.
- On the localisation policy (jobs, water trade-offs), it was observed that local production provides jobs but places a water burden within the country.

## 3.3 Proposed criteria

The list of criteria drawn up and discussed by participants included:

- costs of water (including the opportunity cost of alternative uses);
- water availability, current and future;
- water quality;
- intensity of water use;
- incentives / taxes;
- socio-economic factors (benefits and costs to society and the local community);
- climate change resilience;
- knowledge capital (commonly available data and analysis around water resources);
- infrastructure;
- location;
- technology;
- environmental concerns;
- type of user (strategic or priority);
- local / regional / international content of production;
- non-equivalence of technologies (base and peak load);
- prospects for onsite water storage or recycling facilities;
- seasonality of precipitation;
- compatible technologies, ie smart grids;
- risk and uncertainty.

It was acknowledged that some of these criteria are difficult to quantify – for example, knowledge capital, socio-economic factors and climate resilience. However, qualitative analysis can also be used to make a decision. The localisation criterion was held to present a trade-off in water scarce areas between providing jobs and placing a burden on water resources.

## 3.4 Suggested case study catchments to evaluate methods and criteria to prioritise renewable energy technologies

Workshop participants agreed that the recently published Strategic Environmental Assessment (SEA) for the rollout of wind and solar PV energy in South Africa (CSIR 2013) provides ideal potential case studies for the WRC project. The report highlights eight wind and solar PV SEA focus areas, among which water concerns vary; two of the focus areas are in the Western Cape (where the workshop was held).

## 3.5 Draft policy framework

- Specific suggestions for inclusion in the Policy Framework (see Appendix D) were to include Strategic Infrastructure Projects (SIPs), the New Growth Plan, the Green Economy Accord, and Industrial Action Plans.
- The draft policy framework should be circulated to participants for comprehensive feedback.

# 4. Concluding remarks and recommendations

## 4.1 Concluding remarks

- Choices of energy technologies should take into account water scarcity in South Africa.
- Different methods already exist for prioritising energy technologies. These methods have associated risks.
- Water requirements are not well integrated into decision-making processes that require a selection of energy technologies.
- Existing methods should be modified to include variables for efficient use of water in the energy sector.
- Some criteria have been proposed for prioritising energy technologies.
- It appears that financial modelling can play an important role in prioritisation of energy technologies.

## 4.2 Recommendations

a) The interdisciplinary nature and complexity of the water-energy nexus requires further consideration with respect to what has already been done, and how this can be used in order to achieve the set objectives. So, there is a need to build on the 'knowledge capital' surrounding energy and water use by making information available to practitioners, researchers, developers and project managers.

b) Workshop participants recommended that further study make reference to the following in order to map trade-offs and to draft scenarios in further tasks within this project:

   - IRP scenarios (IRP 2010 and the draft IRP 2013);
   - Strategic Environmental Assessment (SEA) for the rollout of wind and solar PV energy in South Africa (available at www.csir.co.za/nationalwindsolarsea);
   - Industrial Policy Action Plan;
   - Strategic Infrastructure Projects;
   - New Growth Path / National Development Plan;
   - DWA Climate Change Adaptation and Mitigation Plan; and
   - DWA climate change adaptation and mitigation plan.

c) Participants recommended the following as potential resources in further research inquiries:

   - Developers of renewable energy projects.
   - Respected stakeholders in industry with relevant expertise.
   - Look at the locations suggested by the DEA for different RE technologies and consider using those as case studies.
     - Contact project developers to get a sense of what they are thinking about, what challenges they face and how they plan to overcome them ( for example: Martin Ginster, Sasol, Nanda Govender, Eskom,Musi Chonco, SABMiller).
   - Look at Eden Project, co-founded by Sanlam; this may be useful for modelling logic – incorporating water into the financial model.
   - The University of KwaZulu-Natal and Eskom study on climate change and water use in Waterberg.
   - The South African National Biodiversity Institute Long Term Adaptation Scenarios Flagship Research Programme for South Africa.
   - The DEA LTAS water studies.
   - Council for Scientific and Industrial Research water projects and Integrated Assessment Modelling.
   - DWA outputs.

- The National Water Resources Strategy.

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# Appendices

### Appendix A: Workshop invitation

**The UCT Energy Research Centre invites you to participate in a workshop:**

## Evaluation of methods for prioritization of renewable energy technologies and water catchments in South Africa

**13 May 2014** | **Stone Cottages, Kirstenbosch, CT** | **09:30-15:00**

## Rationale

This aim of the workshop is to consult a range of expert stakeholders and decision-makers who will assist the team to propose, evaluate and select method(s) that will enable governing bodies at different levels to select the most appropriate RET for a particular site or prospective sites for RET installation, in terms of least water demand/pollution, and also to assist in selecting sites in which the selected method(s) can be tested.

## Travel Costs

This project is funded by the Water Research Commission (WRC). Travel costs to this workshop will be met by the Energy Research Centre for participants who live outside Cape Town. Lunch and refreshments will be provided to all participants.

## Background

ERC and Pegasys are working on a project that proposes methods for selecting renewable energy technologies (RETs) that take into consideration the water requirements and associated water impacts of the technology, the water availability and resilience of the area, and other important criteria. Given the increasing scarcity of water in South Africa, and the threat that climate change may further stress water supply, heightened by South Africa's targets of having 3 725 MW of renewable energy online by 2016, it is imperative to factor water demand and impacts into future plans for renewable energy generation.

**Please RSVP to**
**wrcworkshop2014@gmail.com**
**by 25 April 2014**

ERC ENERGY RESEARCH CENTRE University of Cape Town

**For further information, please contact:**
**Mr Pieter Krog, Ms Mascha Moorlach or Dr Debbie Sparks**
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WRC WATER RESEARCH COMMISSION

## Appendix B: Participant list

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| Stephanie Midgley | stephanie.midgley@gmail.com | |

## Appendix C: Workshop agenda

**Programme for workshop on the evaluation of methods for prioritization of renewable energy technologies and water catchments in South Africa**

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**Date:** **13 May 2014**
**Venue:** **Stone Cottages, Kirstenbosch**

| | |
|---|---|
| 09.30-10.00: | Tea/coffee and registration |
| 10.00-10.15: | Welcome, aims of the workshop, questions |
| 10.15-10-30: | Introductions |
| 10.30 -10.40: | Process overview |
| 10.40-11.15: | Small group activity on categories and criteria for designing a decision-making method |
| 11.15-11.45: | Report back and sorting exercise |
| 11.45 -12.00: | Presention of decision making tools and decide on "commissions" |
| 12.00-13.00: | Work in "commisions" groups |
| 13.00-13.45: | LUNCH |
| 13.45-14.30: | Presentations and discussion in plenary |
| 14.30.15.00: | Site selection for method testing and case studies |
| 15.00 – | Closure and farewell |

## Appendix D: Proposed policy framework

It is important that Water, Energy and other Acts should be harmonised with regard to the efficient use of water. In turn, these Acts should influence the vertical development of relevant strategies/policies which are horizontally synergetic. Similarly, national water and energy plans/programmes should emanate from national strategies/policies. These plans should also be aligned. There is need to capture elements of water use efficiency at all the levels of this framework.

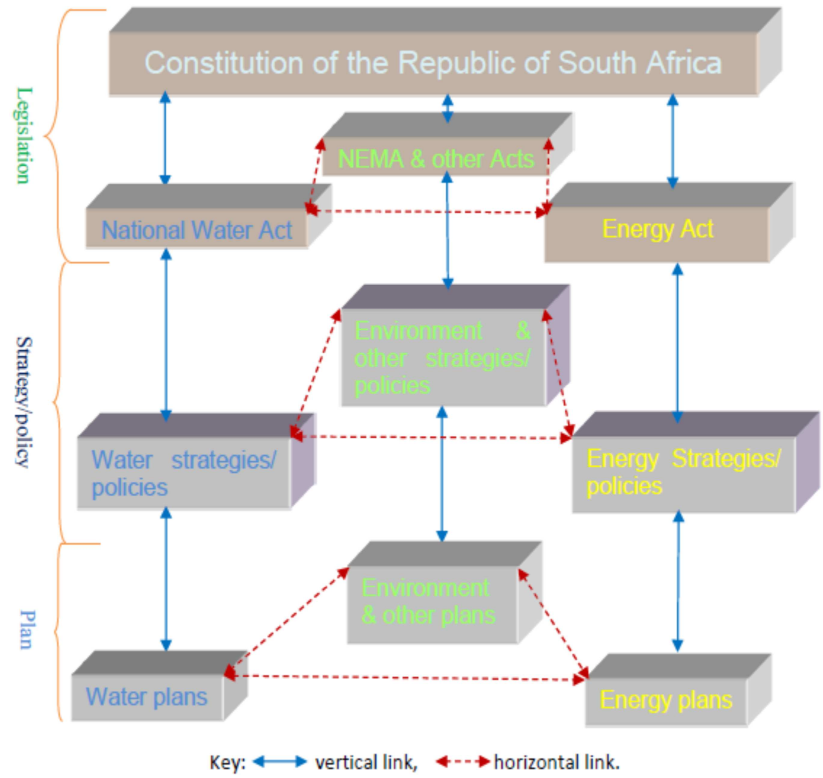


**Figure A1: Diagrammatic view of the framework for harmonising legal and policy instruments for water use in the energy sector**

## Appendix E: Maps of renewable energy resources

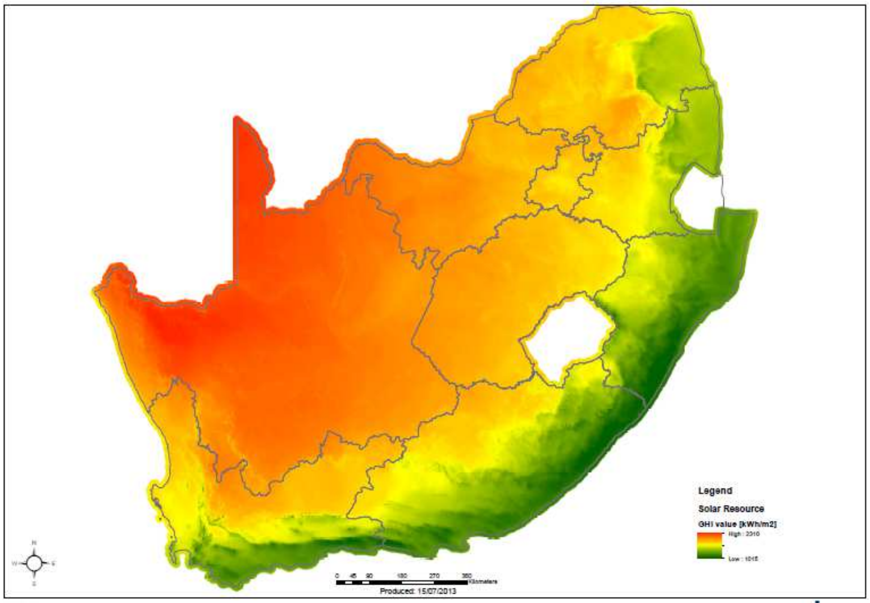


**Figure A2: Global horizontal solar radiation.**

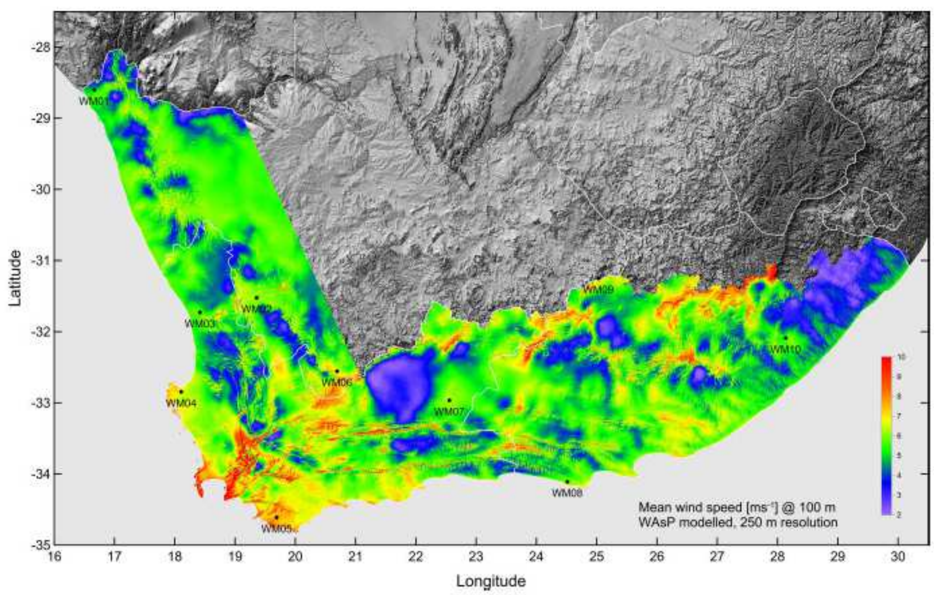


**Figure A3: Wind resource**

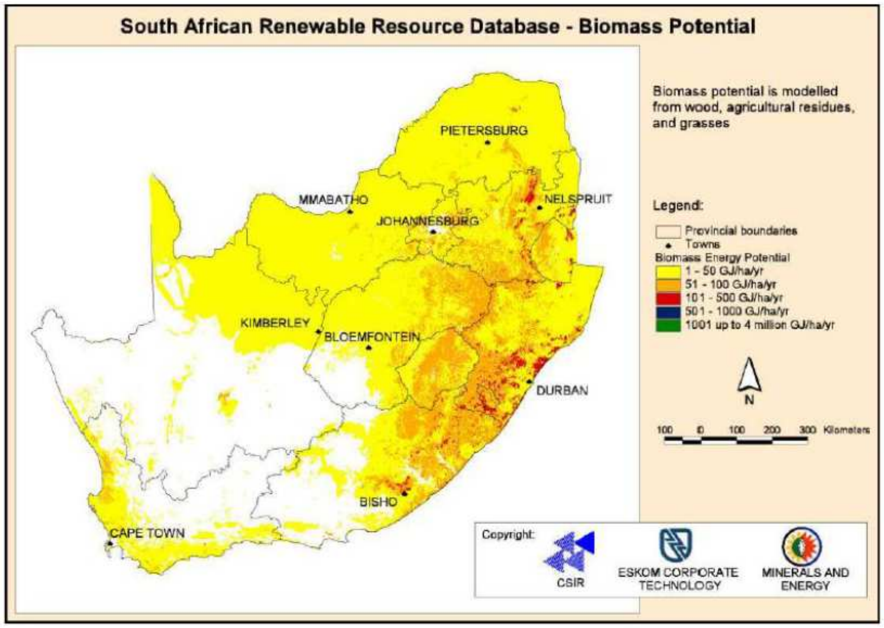


**Figure A4: Biomass resource**

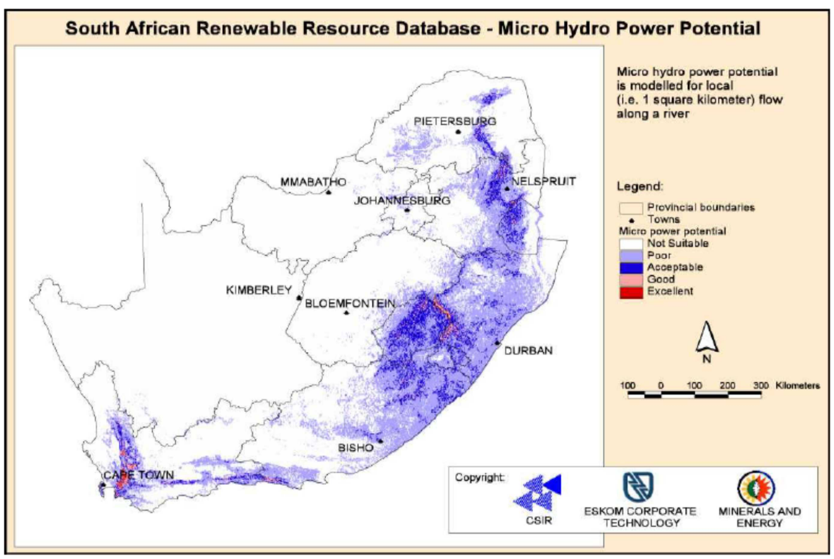


**Figure A5: Small hydro resource**

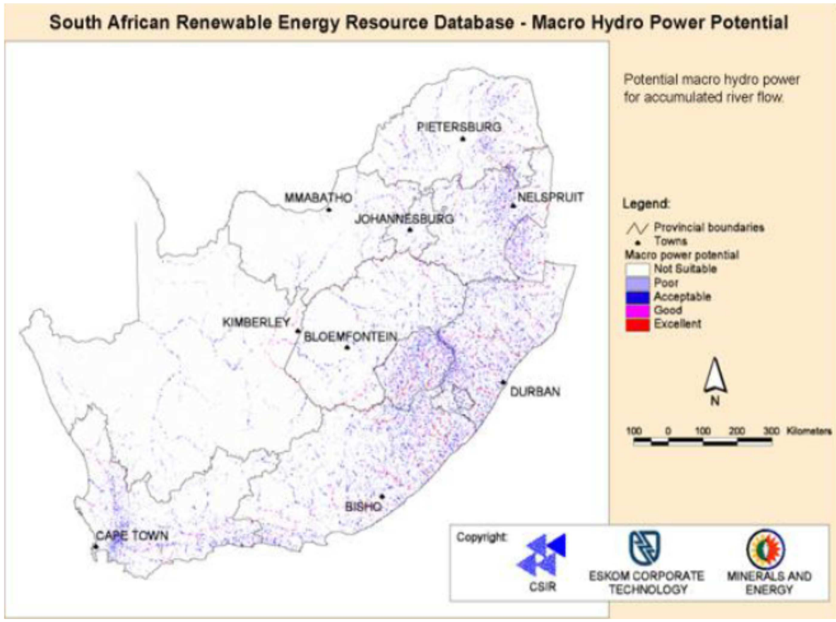


**Figure A6: Large hydro resource.**