MCA4climate: A practical framework for planning pro-development climate policies

Case Study:

Towards a Low-Carbon Fuel Mix in the Electricity Sector in South Africa

Contribution to the MCA4climate initiative

Glynn Morris (AGAMA Energy)
Valerie Belton (University of Strathclyde)

Final Report

June 2011

Available online at: www.mca4climate.info

Acknowledgements

The authors are very grateful to all workshop participants and those involved in the development of this case study:

Frank Ackerman (Stockholm Environment Institute US)

Ariane de Bremond (University of Maryland)

Sophy Bristow (UNEP)

Zaid Chalabi (London School of Hygiene and Tropical Medicine)

Heleen de Coninck (Energy Research Centre of the Netherlands)

William Easterling (Penn State University)

Reinhard Mechler (International Institute of Applied Systems Analysis)

William Moomaw (Tufts University)

Erika de Visser (Utrecht University and Ecofys Netherlands)

Practical Note

This case study represents an illustration of how the MCA4climate initiative may be applied under more realistic settings. Though it draws on real data, it does not represent a proper pilot application of the MCA4climate approach, but only a snapshot of how this may be applied in practice (the case-study was mostly centred around a two-day workshop at UNEP offices in Paris). For an overview of the general MCA4climate initiative please see the main MCA4climate report and other associated documents available on www.mca4climate.info. For further information, please contact the UNEP team, Serban Scrieciu, Sophy Bristow, Daniel Puig or Mark Radka at unep.tie@unep.org.

Table of Contents

Acronyms and abbreviations

CCGT	Combined Cycle Gas Turbine
DEA	Department of the Environment
DoE	Department of Energy
DSM	Demand Side Management
FBC	Fluidised Bed Combustion
FGD	Flue Gas Desulphurisation
IRP	Integrated Resource Plan
OCGT	Open Cycle Gas Turbine
LTMS	Long Term Mitigation Scenarios
MCA	Multi-criteria analysis
NERSA	National Energy Regulator of SA
PF	Pulverised Fuel
PV	photovoltaic
REWP	Renewable Energy White Paper
SWH	Solar Water Heater / Heating

List of tables

List of Figures

1. Introduction

This case study is one of three case studies which form part of the UNEP MCA4climate project. These case studies are intended to illustrate and explore the potential to use multi criteria analysis to inform national or regional policy and decision making in the light of the potential climate change. This report documents the inputs to a MCA4climate case study workshop held over two days on 3rd/4th March 2011 at UNEP DTIE in Paris. The report focuses on the application of the MCA4climate tool to a policy and planning process which was undertaken in South Africa in 2010 to determine a more appropriate fuel (and technology) mix for electricity generation over the next 20 years – namely the Integrated Resource Plan 2010 (also called IRP 2010).

This IRP process is described in some detail in Section 3.1 below and is also comprehensively documented on a South African Department of Energy web site (http://www.doe-irp.co.za/). The outcomes of the IRP process were published in October 2010 in a draft report (DoE, 2010) and these were used as the reference for the MCA4climate workshop. Since the workshop, the document has been presented to and approved by the Cabinet in March 2010. The IRP 2010 document is currently going through the promulgation process and will be published in the Government Gazette on promulgation.

The case study draws on the energy modelling outputs for five scenarios in the IRP 2010 process and one scenario from a parallel energy modelling process in the Revision of the White Paper on Renewable Energy Policy (REWP). The case study uses these outputs in the MCA tool to provide an alternative and more dynamic decision-making framework than the multi-criteria decision making framework (MCDF) which is reported in the IRP 2010 draft report. A copy of the IRP 2010 MCDF outcomes is presented in Table 1. A copy of the similar multi-criteria matrix for the REWP is shown in Table 2.

Table 1: Matrix of criteria and scoring in the IRP 2010 multi-criteria development framework

Plans	CO_2 emissions	Price	Water	Uncertainty	Localisation potential	Regional development	TOTAL
Base Case 0.0	-	21.74	-	2.73	-	6.08	30.54
Emission 1.0	12.41	18.61	5.24	16.14	6.47	6.08	64.94
Emission 2.0	9.43	20.61	2.53	16.14	6.47	6.08	61.25
Emission 3.0	21.74	-	10.87	19.57	6.47	-	58.65
Carbon Tax 0.0	11.50	18.41	3.50	19.26	6.47	2.77	61.91
Region Development 0.0	0.67	21.53	0.37	-	-	10.87	33.44
Enhanced DSM	1.54	20.85	0.94	3.04	-	6.08	32.45
Balanced	10.46	20.24	2.74	16.71	11.02	1.85	63.01
Revised Balance	11.01	19.33	2.92	16.32	15.22	8.85	**73.66**
Swing Weighting (/100)	21.74	21.74	10.87	19.57	15.22	10.87	100.00

The MCDF outcomes in the matrix suggest that the optimal scenario for the IRP2010 would be the so-called Revised Balanced scenario. The high score for the Revised Balanced scenario in this example is influenced both by i) the quantified values for the criteria (whether derived from empirically based analysis or by more subjective judgements) and ii) the weighting of the individual criteria. The weighted MCDF outcome reflected in Table 1 is one of many overall outcomes which would all differ depending on the weightings applied to the respective criteria by different stakeholder interests. Similarly, the multi-criteria matrix for the REWP in Table 2 indicates relative rankings of the impacts of (two) scenarios on criteria which were considered to be useful in terms of the drivers which would shape the policy associated with either scenario. There is no weighting attached to these criteria in terms of stakeholder interests by different stakeholder interests.

Table 2: Matrix of criteria and scoring for two energy scenarios in the REWP

	Economic						Env	Social	
Scenario Description	Benefit Cost Ratio	GDP per R1 Total Expenditure	Taxes per R1m Total Expenditure	Foreign Exchange Outflows	Ave Electricity Price	Water Consumption	Environmental CO2 Emissions	Total Direct Jobs	Job Creation / TWh Dispatched Electricity
Reference scenario with energy efficiency	1.24	1.0	1.0	1.0	1.00	1.0	1.0	1.0	1.0
Policy scenario	1.12	0.9	0.9	1.3	1.05	0.9	0.8	1.2	1.3

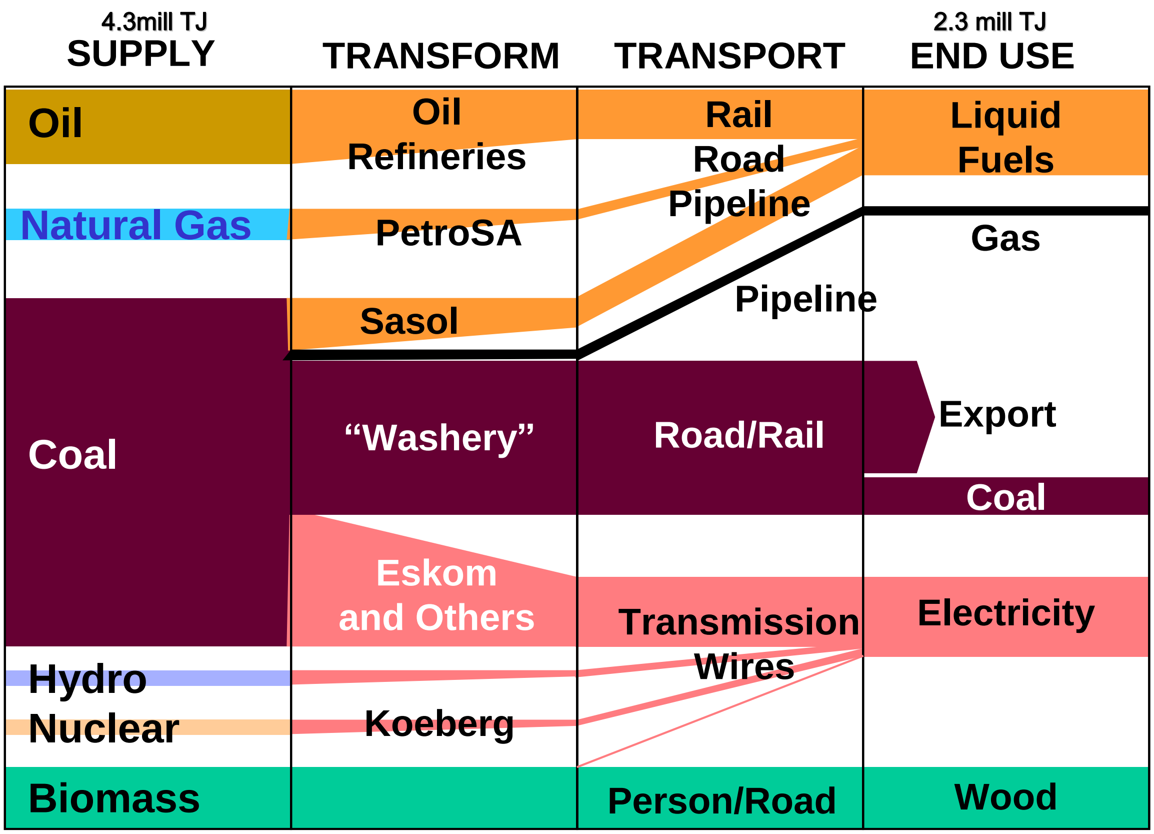
It is therefore very interesting to utilise a more dynamic and transparent (or accessible) MCA tool which could investigate and reflect the impacts on the overall relative outcome of different scenarios – based on different scoring and weightings of criteria.

The focus on the IRP 2010 process in South Africa for the MCA4climate case study workshop on fuel mix was considered particularly relevant to the application of the MCA4climate tool. As outlined below, the South African energy economy is heavily dependent on fossil fuels. This dependency on carbon intensive primary energy in South Africa invites strategic decisions to reduce this, diversify the fuel mix and simultaneously reduce the associated GHG emissions. The MCA4climate tool is thought to offer a dynamic and more easily understood framework for optimising the decision-making process for mitigating climate change by changing the fuel mix for electricity generation.

2. The policy context for energy in South Africa

2.1 The South African energy system

The South African energy system is heavily reliant on fossil-fuel primary energy resources with more than 87% of the primary energy derived from coal and oil. Although somewhat dated (being based on 1994 data), Figure 1 graphically illustrates the high proportion of fossil fuel in the primary energy mix. This picture has not changed significantly over the past decade and the overall proportions for 2006 are shown in Figure 2.



Source: DME, 1994

Figure 1: The energy flows in the South African energy system

The primary energy supply is dominated by coal with 65.7% (DoE, 2006) followed by crude oil with 21.6%, renewable and wastes with 7.6 % and gas with 2.8%. Nuclear, hydro and thermal solar constitute the smallest portions with 0.4%, 0.1%, and 0.1% respectively. As shown in Figure 3, the overall picture has not changed over the past decade for which national energy data are reported. Coal plays a vital role in South Africa's energy economy: it accounts for 70% of primary energy consumption, 93% of electricity generation and 30% of petroleum liquid fuels (Eberhard, 2011).

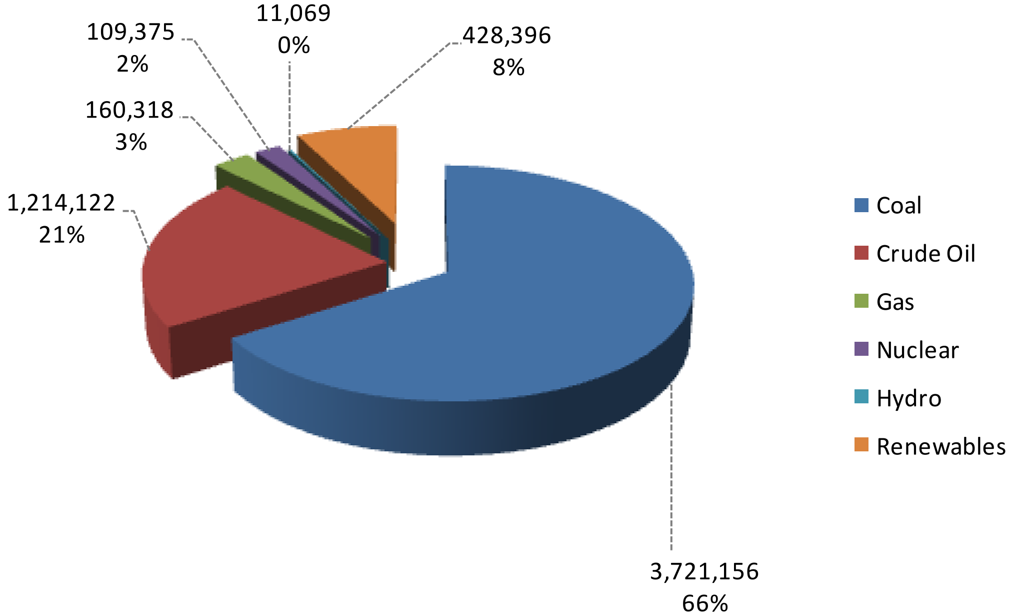


Figure 2: Primary energy balance for South Africa (source: DoE 2006)

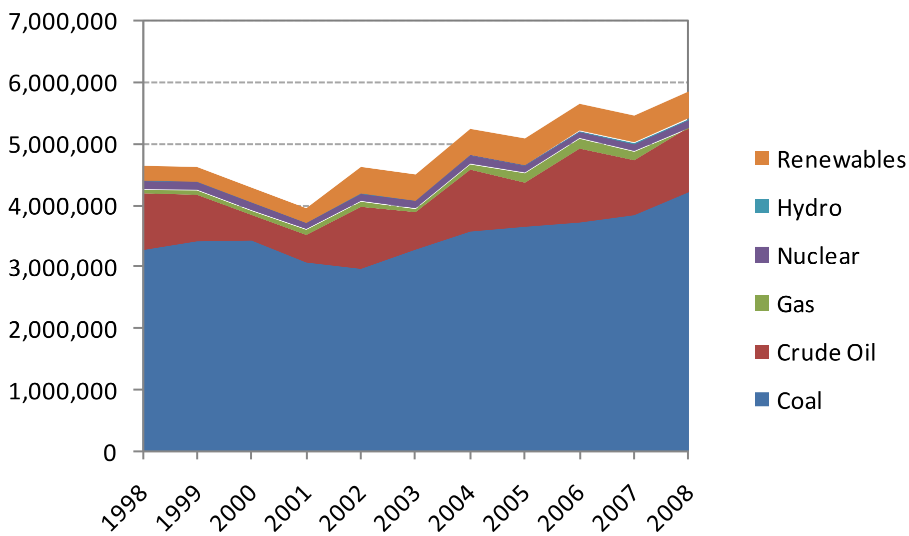


Figure 3: Primary energy mix for South Africa 1998 - 2008 (source: DoE, 2008)

In addition to the high dependency on fossil fuels, the South African economy is energy intensive. It is amongst the twenty most carbon-intensive economies in the world but does not yet face any binding international treaty obligations to reduce its greenhouse gas emissions (Eberhard, 2011). In the electricity sector, Eskom currently emits 225 Mt of CO_2 per annum which represents approximately 51% of the overall emissions for South Africa.

Apart from the inherent issues related to the dependencies and carbon intensity of the South African energy economy, the increasing risks of trade constraints for export oriented commodity and manufactured goods sectors present a case for addressing the fuel mix of the energy sector.

2.2 Greenhouse gas emissions in the energy sector

In 2009, the International Energy Agency listed South Africa as the thirteenth highest emitter of carbon dioxide in the world.

DEA is currently estimating emissions for 2000-2009, using IPCC methodology based on the 2000 inventory. Previous best estimates (from LTMS) were based on the 1990/1994 inventory. Significant data problems exist, especially for energy data, but emissions in 2010 are thought to be between 520 and 550 Mt Co2-eq (with some uncertainties remaining, e.g. coal mine methane). The energy sector is the largest contributor to greenhouse gas emissions, generating over 80% of South Africa's emissions. The emissions from the electricity sector represent roughly half of national emissions.

It is clear that successful climate change mitigation in South Africa must focus on the energy sector.

SA supports a 2 degrees / 450 ppm world and a top-down, legally-binding agreement (Marquard, 2011). South Africa has committed to its emissions peaking between 2020 and 2025, remaining stable for a decade and declining in absolute terms from around 2035. In December 2009 and in the context of this trajectory, South Africa committed at Copenhagen to reduce its greenhouse gas emissions by 34% by 2020 and 42% by 2025 below business as usual, on the condition that it receives the necessary finance, technology and support from the international community that will allow it to achieve this. A mitigation plan for the energy sector is key to achieving these objectives.

2.3 Generation in the power sector

The power sector in South Africa, which refers to the provision of electricity to customers from centralised generation, transmission and distribution systems, is dominated by the national electricity utility, Eskom. The state-owned company generates 232 TWh/annum (Eskom,2010) corresponding to more than 95% of the overall generation in South Africa. Eskom's installed nominal capacity is 44.125 GW (and a net maximum capacity of 40.87GW) which comprises 13 coal-fired power stations (38.0 GW); one nuclear plant (1.93 GW), four hydro and pumped-storage schemes (2.0 GW) and four gas turbine stations (2.4 GW). The balance of the generation capacity in the country is provided by a handful of municipal and private generators. In addition, generation capacity and electricity supply for South Africa is sourced from imports (predominantly from the 2 GW Cahora Bassa hydro plant in Mozambique). Approximately 85% of the net capacity in the country is based on coal-fired thermal generation (Eskom, 2011).

The key issue at stake currently in the power sector in South Africa is the persistent generation shortfall. This shortfall is indicated by the low reserve margins for generation capacity to meet the demand and the experience of electricity blackouts in 2006, in the Western Cape Province, and 2008, nationally. The reserve margin fell to 5.8% in March 2008 and has since been improved to 15% through operational improvements such as improved coal supply management.

In addition to the ongoing issue of reserve margins, the replacement of the existing capacity is a factor which invites questions regarding the choices for new infrastructure investments which may include cleaner energy technology options based on a less carbon intensive fuel mix. Figure 4 illustrates the installed capacity since 1955 and the requirement for replacement as the existing capacity is decommissioned over the period until 2060.

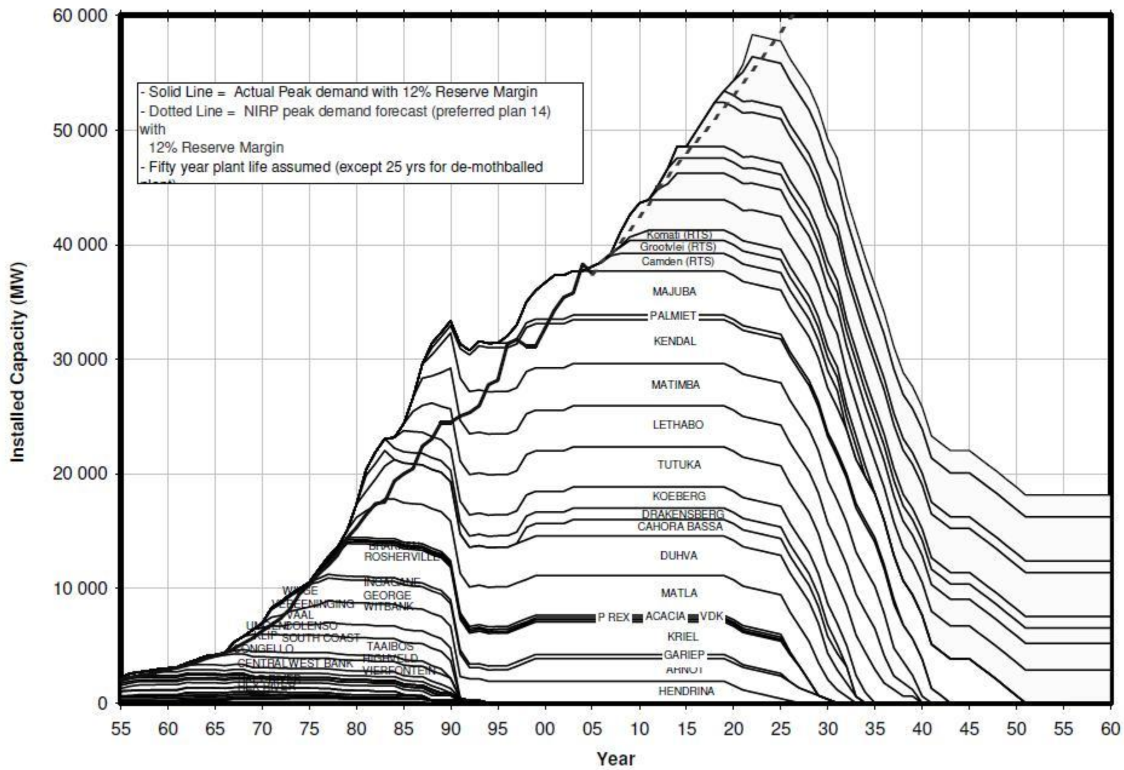


Figure 4: A schematic showing the electricity supply challenge in South Africa (source: Eskom, 2005)

In response to this challenge, Eskom is currently committed to building 17 GW of new generation capacity which is expected to be commissioned by 31 March 2018. This includes 5,032 MW already commissioned as at 31 December 2010. 10 896 MW of new capacity is to come from three projects namely:

- Medupi: 4 764MW coal-fired; first unit expected to be commissioned in 2012
- Kusile: 4 800MW coal-fired; first unit expected to be commissioned in 2014
- Ingula: 1 332MW pumped storage; expected to be commissioned in 2014

Based on this current build plan, the CO_2 emissions will continue to increase until at least 2020.

2.4 Energy services and a more integrated framework for understanding the energy system

It should be noted that the climate change implications of the investment decisions for new electricity generation infrastructure which are highlighted above are based on assumptions regarding the optimal supply chains for energy services. The main assumption is the emphasis (or focus) on the paradigm of centrally generated electricity for sale to customers as the primary supply chain for delivering energy services.

Figure 5 below illustrates three complementary supply chains which all provide energy services at levels of quality for which customers would buy the services. The prevailing emphasis on centralised grid-based electricity generation does not take into account the benefits (and costs) of direct on-site supply of energy services or of distributed energy conversion or generation. This narrow focus on centralised grid-connected electricity generation is understandable, given the historical development of the energy (and electricity) sector, but it is unlikely to address many of the policy drivers which are discussed in Section 2.5.5 below.

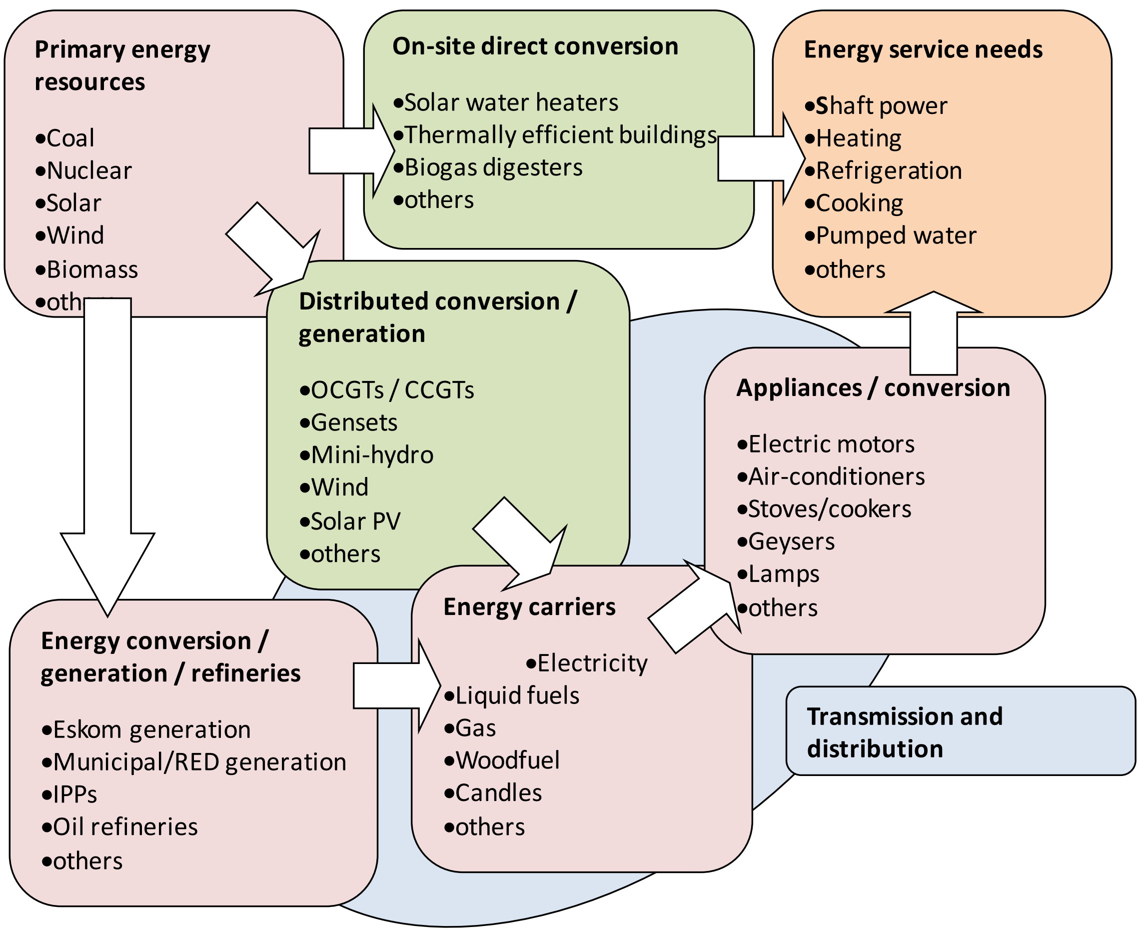


Figure 5: Schematic representation of energy supply chains for providing energy services

This case study attempts to broaden the scope of the challenge beyond the narrow emphasis on grid-connected electricity, as addressed by the IRP 2010 process, while acknowledging the data deficits and lack of energy modelling, planning and decision making tools which are available for a more holistic energy services approach to energy service provision.

As elaborated in Section 3 this case study draws on the data and energy modelling outcomes of the IRP 2010 process and adds a further set of data and modelling outputs which were developed under an unpublished study commissioned to revise the 2003 White Paper on Renewable Energy Policy for South Africa.

2.5 The current policy challenges relating to energy services

In considering the planning and decision making process, it is considered useful to identify and understand the key policy challenges faced in South Africa to provide a good framework for determining which criteria could be used to optimise the decision making. These policy challenges are similar to those experienced in many developing countries with emerging economies.

2.5.1 Social

South Africa is facing enormous challenges in terms of social issues. The reasons for these challenges are largely rooted in the historical legacy of the country's post-colonial development. Key challenges include:

- Poverty and high levels of income inequality
- Population growth
- Urbanisation
- High unemployment
- Low levels of skills / experience

2.5.2 Environmental

South Africa is has pressing environmental challenges. It also has a relatively robust and well developed framework of policy, legislative and administrative capacity. Among others, the two key challenges include:

- Water scarcity
- High per capita GHG emissions / waste

2.5.3 Economic

The country has an economy which has historically been built on, and depended on, export-oriented minerals extraction. The structure of the economy is changing and the emphasis is shifting towards a more diversified economy which maximises the following, among others:

- Economic stability (including predictability and efficiency in energy pricing)
- International competitiveness (including access to markets)

2.5.4 Political

South Africa emerged into an era of democratic multi-party government in 1994 which has re-framed the political context for energy infrastructure investments. The political dimensions of the policy challenges include:

- Service delivery in terms of supply, billing and administration of energy service provision

- Governance in the energy sector

2.5.5 Policy drivers

In summary, the policy issues highlighted above can be formulated in terms of the following policy drivers:

- Access to energy services
- Energy security and diversity of supply
- Greenhouse gas emissions
- Local economic development
- Employment and 'green economy' opportunities
- Maximising use of national resources
- Exploiting available climate change funds
- Take advantage of global technology advances

These policy drivers suggest the basis for identifying criteria which may be used to assess and understand the relative merits of different scenarios for investment decisions on the fuel or energy mix for the South African society and economy and environment.

2.6 A dynamic policy context

In addition to the policy issues highlighted above, the policy context is highly dynamic and evolving – especially in terms of the regulatory and administrative implications of the implementation of policies. Many existing policies have been developed and promulgated which have relevance to the energy (and electricity) sector. These include the National Environmental Management Act (No. 107 of 1998), the Air Quality Act (2004) and the Public Finance Management Act (No.1 of 1999 as amended by Act 29 of 1999) and Municipal Finance Management Act (No 56 of 2003). In addition, there are a number of policy and regulatory documents which are specifically relevant to the energy (and electricity) sector. Among these are the following:

- The Constitution and Bill of Rights, (Act No. 108 of 1996)
- The White Paper on Energy Policy (1998)
- The White Paper on Renewable Energy Policy (2003, revised in 2010)
- The Energy Act (Act No. 34 of 2008)
- The National Energy Regulator Act (Act No. 40 of 2004)
- Electricity Regulation Act (Act No 4 of 2006)
- Electricity Regulation Amendment Act (Act No. 28 of 2007)
- The Renewable Energy Feed-in Tariff (REFIT) guidelines(REFIT 1 and REFIT 2, 2009)
- Electricity Regulations on New Generation Capacity (Gazette No. No.32378,5 August 2009)
- Determination regarding the Integrated Resource Plan and New Generation Capacity (Gazette No. No.32898, 29 January 2010)
- Electricity Regulation Amendment Bill in Parliament for establishing the legislative framework for the Independent System and Market Operator (ISMO)
- Energy Efficiency Strategy (2005)
- Draft Industrial Strategy on Biofuels (2007)
- REFiT Guidelines I and II (2009)
- Domain Protocol for Renewable Energy Certificates (2009)

Key new policies which have bearing on the decision-making requirements for the energy (and electricity) include:

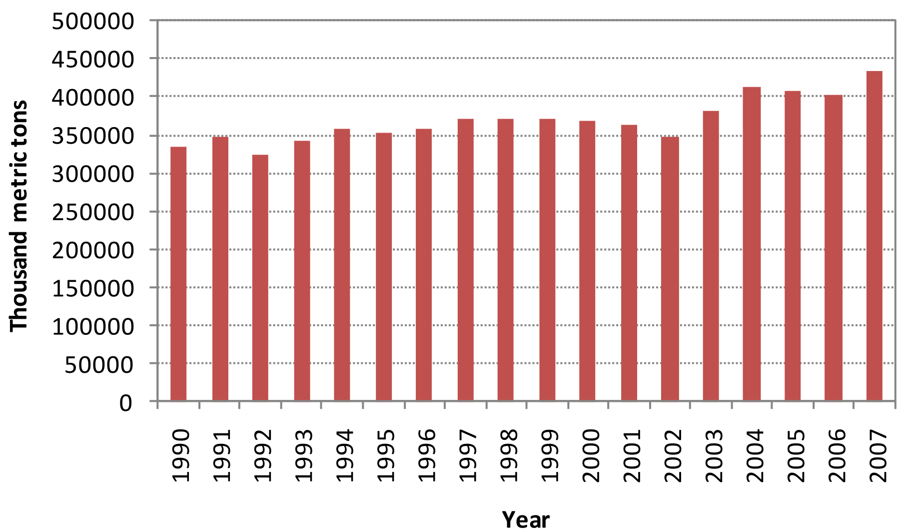
- The Industrial Policy and Action Plan, IPAP2 (2010)
- A draft policy on Climate Change (2010)
- An Integrated Energy Plan – under development
- The Integrated Resource Plan, IRP 2010, (2011)
- A carbon tax discussion document (2010)

2.7 South African GHG emissions and climate change commitments

South Africa has GHG emissions which are currently reported as 451,429 thousands of metric tonnes (2008) (Wikipedia, 2011). The historical emissions are shown in Figure 6 below. As shown in Table 3, more than 78% of the emissions arise from the energy sector (including for electricity generation). The electricity sector accounts for more than 50% of the overall emissions.

Figure 6: Annual emissions for South Africa (CO2e) (UNSTATS, 2011)

Table



3:

Aggregated emissions(13/11/2007)

Aggregated emissions of CO_2, CH_4 and N_2O in South Africa in 1990 and 1994

Greenhouse Gas Source	CO_2 Equivalent (Gg)							
	CO_2		CH_4		N_2O		Aggregated	
	1990	1994	1990	1994	1990	1994	1990	1994
Energy	252,019	287,851	7,286	7,890	1,581	1,823	260,886	297,564
Industrial processes	28,913	28,106	69	26	1,810	2,254	30,792	30,386
Agriculture			21,304	19,686	19,170	15,776	40,474	35,462
Waste			14,456	15,605	738	825	15,194	16,430
Total							**347,346**	**379,842**

Source: Department of Environmental Affairs and Tourism (2003)

Aggregated emissions for South Africa (DEA, 2011)

Projections have shown (LTMS, 2007) that without constraints, an almost four-fold increase in greenhouse gas (GHG) emissions can be expected – from 446 million tons of CO2–equivalent (Mt CO2-eq) in 2003 to 1 640 Mt CO2–eq by 2050. The largest part of the increase comes from the energy sector. Energy related emissions (CO2, CH4 and N20) are expected to almost quadruple by 2050.

As noted in Sections 2.2 and 2.5.2, South Africa is prominent internationally for the high carbon intensity of the economy but also for its engagement in international Climate Change negotiations. This participation in the UN Climate Change negotiations, as a non-Annex 1 country, has resulted in a conditional commitment to emission reductions and to hosting COP17 in Durban in November 2011.

The commitment by South Africa to GHG emission reductions was announced in Copenhagen in December 2009 and subsequently confirmed in January 2010 as reductions of 34% by 2020 and 42% by 2025 as determined against a baseline trajectory for emissions in a business as usual scenario.

This commitment is contingent on international commitments for i) technology transfer and ii) clean technology/investment funding. These commitments correspond to the 'peak-plateau-and-decline' scenario which arose from the emission trajectories described in the Long-Term Mitigation Scenarios (LTMS) process (DEAT, 2007).

Overall, regardless of the detail regarding the determination of the baseline and the monitoring of the emission reductions, the issue of significant emission reductions for the overall economy is clearly a high priority especially in terms of the emission reductions which are expected (or required) to be made in the energy sector.

2.8 Summary of the policy challenge

In essence, the overall policy challenge facing South Africa is how to extend the access to energy services to all South Africans (including the issue of energy poverty) in a manner which provides sufficient security of supply to all customers and which meets the environmental commitments of the Government – primarily the climate change commitments. This summarised by Trevor Manuel, the Minister responsible for the National Planning Commission: "we would have to make the transition to a less carbon-intensive economy"… "taking into account of the impact on the economy, on the poor and on employment" (Manuel, 2011).

3. The energy planning and decision-making process

The overall energy planning and decision-making process in South Africa has a long history stretching back to the original investments in power generation for the mining operations in the late nineteenth century. A large proportion of the effort has historically been focussed on the electricity (and especially the generation) sector. Some of this is described in more detail by Steyn (2006). More recently, since 1994, successive efforts have been initiated to undertake Integrated Energy Planning (IEPs), Integrated Resource Planning (IRPs) and energy policy development by the Department of Energy (DoE, formerly the Department of Minerals and Energy, DME), the National Energy Regulator of South Africa (NERSA, formerly the National Electricity Regulator, NER) and Eskom.

In terms of the focus of this case study, the outcomes of the most recent initiatives in the form of the Integrated Resource Plan for 2010 and the related energy modelling for the revision of the White Paper on Renewable Energy Policy are used to explore the benefits of the MCA4climate tool (and project).

3.1 Background to energy planning in South Africa

In the past, energy planning in South Africa has been undertaken within the context of a supply-side perspective which has focussed on commercial energy carriers such as electricity or liquid fuels which are supplied through centralised energy infrastructure. While this approach is understandable, based on historical imperatives, it is increasingly inappropriate as a basis (or framework) for addressing the pressing issues which South Africa faces in the 21st century.

As indicated in 2.5.5 above, the policy drivers now require an approach to energy planning which moves beyond the metrics of sufficient energy production to meet the expected demand for energy carriers (such as electricity or liquid fuels) in economic end-use sectors by means of a centralised energy system. For example, the criterion of access to energy services (which incorporates physical access as well as socio-economic dimensions such as energy poverty) requires a broader scope for modelling and planning and a more accessible framework and process for understanding the trade-offs between traditional criteria such as least-cost and human development criteria. Many households which are currently denied access to energy services (and the implicit subsidies which come with access to 'a connection') are beyond the reach of the national grid or distribution system. The precedent over the past decade of the off-grid concessions for rural electrification in South Africa highlights the need for a more holistic (and equitable) scope for energy policy and planning (Winkler et al, 2011).

Furthermore, as highlighted in 2.4, the energy modelling and planning process requires a more holistic and sophisticated approach and analytical tools. The key innovations which are required in the energy modelling and planning include:

- Extending the scope beyond the centralised energy or power sector to include both decentralised as well as stand-alone, or on-site, energy service provision
- Integration of all energy carriers and energy resources into a unified modelling and planning process
- Incorporation of spatial and temporal dimensions into the mapping of the demand for energy services (in terms of quantity, quality, location and patterns of use) to the energy service supply chains based on the location and availability of primary energy and the associated generation/ transmission/ distribution/ appliance options.
- Modelling tools which address centralised, decentralise and stand-alone energy infrastructure
- Reporting against criteria which are defined by stakeholders as the key drivers for the policy which is expected to shape the investment decisions for the energy sector as a whole
- Multi-criteria analysis to explore the trade-offs or co-benefits associated with different future energy scenarios

Furthermore, the process required for more inclusive and more informed policy development in the current political environment in South Africa needs to be more accessible (in terms of language and communication of the concepts and details) and flexible (in terms of process tools for discussion and decision making) than the more limited input/output modelling tools and policy development processes which have been available in the past.

In this case study, the most recent energy modelling and planning processes in South Africa have been used to explore the scope for improving these (along the lines suggested above) and particularly in terms of improving the outcomes of the multi-criteria analysis which is required for more optimal decision making. These are the IRP 2010 process and the Revision of the White Paper on Renewable Energy Policy. This case study then explores the inputs and outputs of these modelling exercises using the MCA4climate approach and the multi-attribute value analysis (MAVA) tool which has been used on the MCA4climate project.

3.2 Consideration of energy infrastructure investment scenarios

The case study explores the comparative characteristics and relative merits of energy infrastructure investment scenarios (or energy planning scenarios) rather than policy scenarios. The rationale for this level of investigation and analysis is that very specific outcomes are required in terms of the overall policy drivers and that these outcomes need to be understood in relation to different energy technology mixes prior to undertaking the policy development process which would be expected to deliver the preferred energy scenario.

3.3 The IRP 2010

The integrated resource plan – called IRP 2010 – is the second IRP which has been published by the DoE[1]. The IRP is mandated in terms of the Energy Act and published in terms of the Electricity Regulation Act (2006). The IRP 2010 was undertaken and managed by the DoE within the framework of an Inter-Ministerial Committee on Energy, chaired by the

[1] The first, called IRP 1, was published without consultation or any public participation on 31 December 2009 and again, in an updated format, on 29 January 2010

Minister of Public Enterprises. It drew on energy modelling undertaken by the Planning Division of the System Operator in Eskom and data which was determined through a process of public participation on the scenario-based energy modelling methodology and on parameter sheets for inputs to the energy modelling. A draft report was submitted in draft in October 2010 and a final version has been approved by the South African cabinet in March 2011 for promulgation in terms of the Electricity Regulation Act. The document was promulgated on 6 May 2011 and has been published in the Government Gazette.

More details are available on the IRP website, http://www.doe-irp.co.za/. Inputs and comments to the public participation process are available on http://irp2.wordpress.com/irp-2010-consultations/.

3.4 The Revision of the White Paper on Renewable Energy

In a parallel initiative, commissioned by the World Bank / GEF-funded Renewable Energy Market Transformation Project (REMT), the DoE undertook a review of the 2003 White Paper on Renewable Energy Policy. This REWP project also undertook energy modelling (and economic modelling) of scenarios for energy futures. Two important distinguishing characteristics of the modelling in the REWP process were:

- The consideration of decentralised and on-site energy service supply chains (in addition to the more traditional centralised energy service supply chain)
- Economic modelling of future energy systems scenarios to explore the cost benefit ratios and economic impacts of the different scenarios

3.5 Scenarios considered in the case study

Six energy mix scenarios were considered in this case study. Five of these were based on IRP 2010 modelling and the sixth was based on the modelling in the revision of the REWP. These six scenarios are briefly described below. Notably, only the sixth scenario, the REWP scenario, would meet the GHG commitments of the SA Government. The sixth energy scenario is added to indicate the scope for broadening the energy planning and decision making beyond grid-connected electricity. This broader scope of the overall energy modelling and planning process acknowledges and addresses the full range of energy service supply chains shown in Figure 5 and discussed in Section 2.4.

All these scenarios were based on a 20 year planning horizon extending to 2030.

The case study considered energy scenarios which reflect investment options in different technology/fuel mixes rather than policy scenarios. The energy scenarios represent outcomes of policy emphases which would guide these individual (and specific) energy portfolios without identifying or suggesting the respective policy scenarios. The energy scenario approach enables the use of more specific and quantified criteria than a policy scenario approach. Clearly, an appropriate combination of policies would still need to be identified (or developed) to shape the investment decisions which would result in the optimal energy scenario.

3.5.1 Base case scenario

The base case scenario provides for limited regional development options and makes no allowances for externalities (incl. carbon tax) or climate change targets. Key features of this scenario include:

- Committed build and decommissioning

- Some imported hydro
- CCGT
- Imported coal
- FBC
- PF + FGD
- OCGT for peaking

3.5.2 Emission limit case scenario

This scenario adopted the imposition of an annual limit for CO_2 emissions from the electricity sector of 220 Mt CO_2-eq, imposed from 2020. Key features of this scenario include

- Committed build and decommissioning
- Wind capacity (17.6 GW starting in 2015)
- Solar capacity (11.25 GW commissioned between 2017 and 2021)
- 9,6 GW of nuclear
- CCGT
- OCGT for peaking (6.5 GW)

3.5.3 Regional scenario

This scenario included additional regional projects as options, such as:

- Increased hydro imports
- Increased coal-fired imports
- Includes transmission upgrades

3.5.4 Enhanced DSM scenario

This scenario included a more aggressive demand side management programme with an additional 6 TWh/annum of electricity reduction imposed by 2015.

3.5.5 Balanced case scenario

The balanced scenario represents a trade-off between least-cost investment, climate change mitigation, diversity of supply, localisation and regional development. It includes solar, wind, cogeneration, nuclear and imported electricity generation capacity.

3.5.6 Renewable energy scenario

This scenario is based on energy modelling in the revision of the RE White Paper which includes RE options in addition to grid-connected electricity generation such as:

- 9.2 million solar water heating systems
- 330,000 solar home (PV) systems
- 60,000 household biogas digesters

Figure 7 illustrates the investment requirements of this scenario and the overall mix of energy supply options.

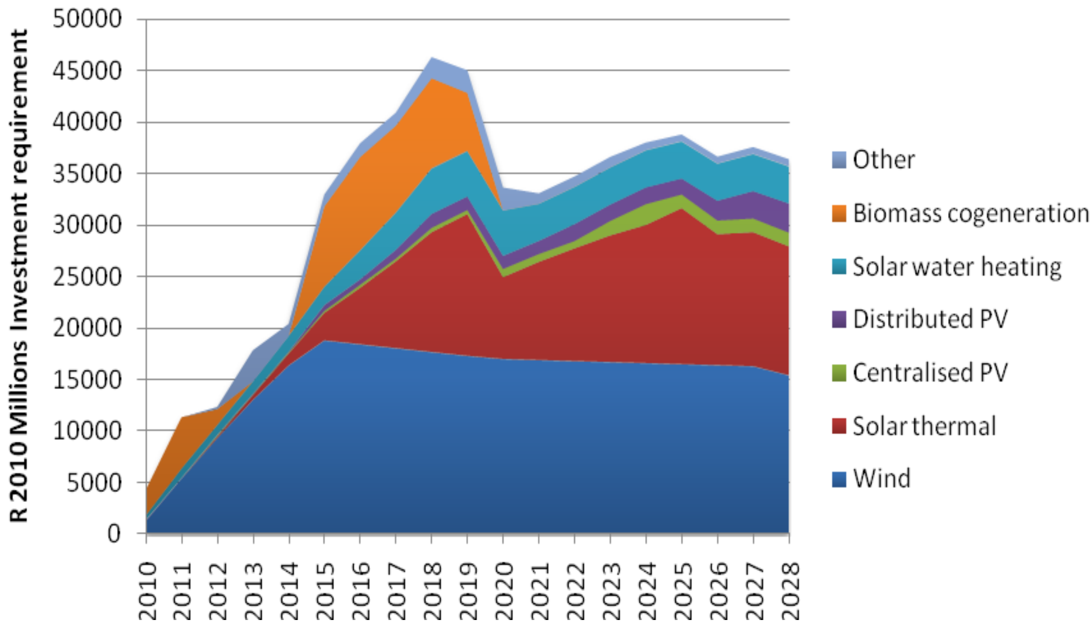


Figure 7: Indicative investment requirements

Figure 8 indicates the relative proportions of the investments required for different investment periods.

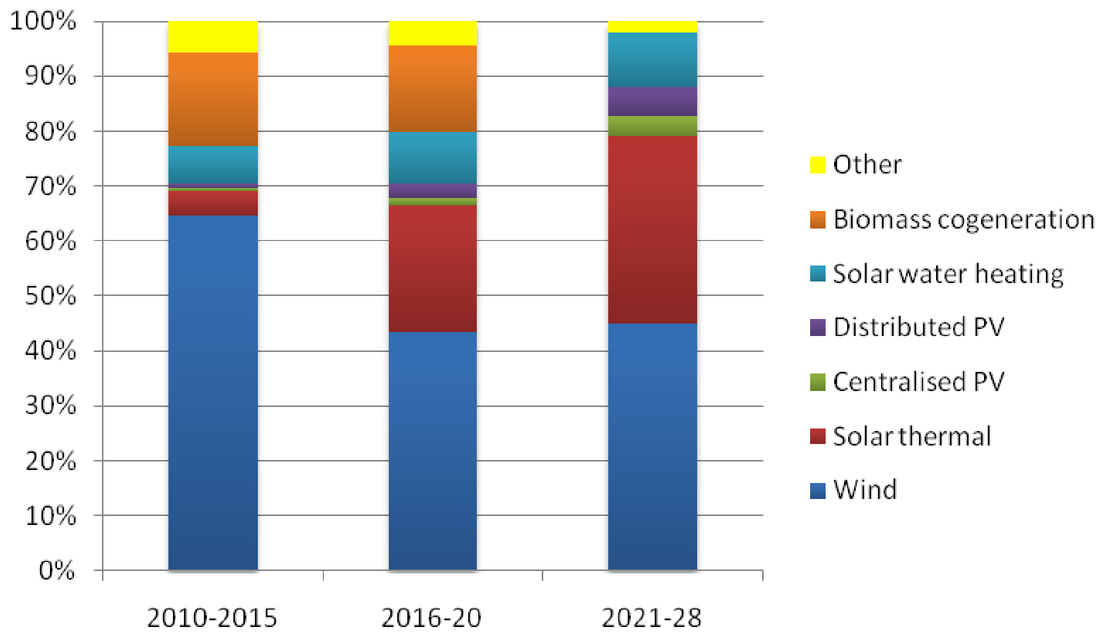


Figure 8: Indicative proportions of investment

4. Criteria, indicators and scoring of criteria

4.1 The MCA4climate criteria tree

The three-level criteria tree which had been developed for the MCA4climate project is shown in Figure 9 (this is an earlier version of the final generic criteria tree of the MCA4climate initiative available for download at: www.mca4.climate.info). This is a generic criteria tree which can be adapted for specific policy and decision-making processes.

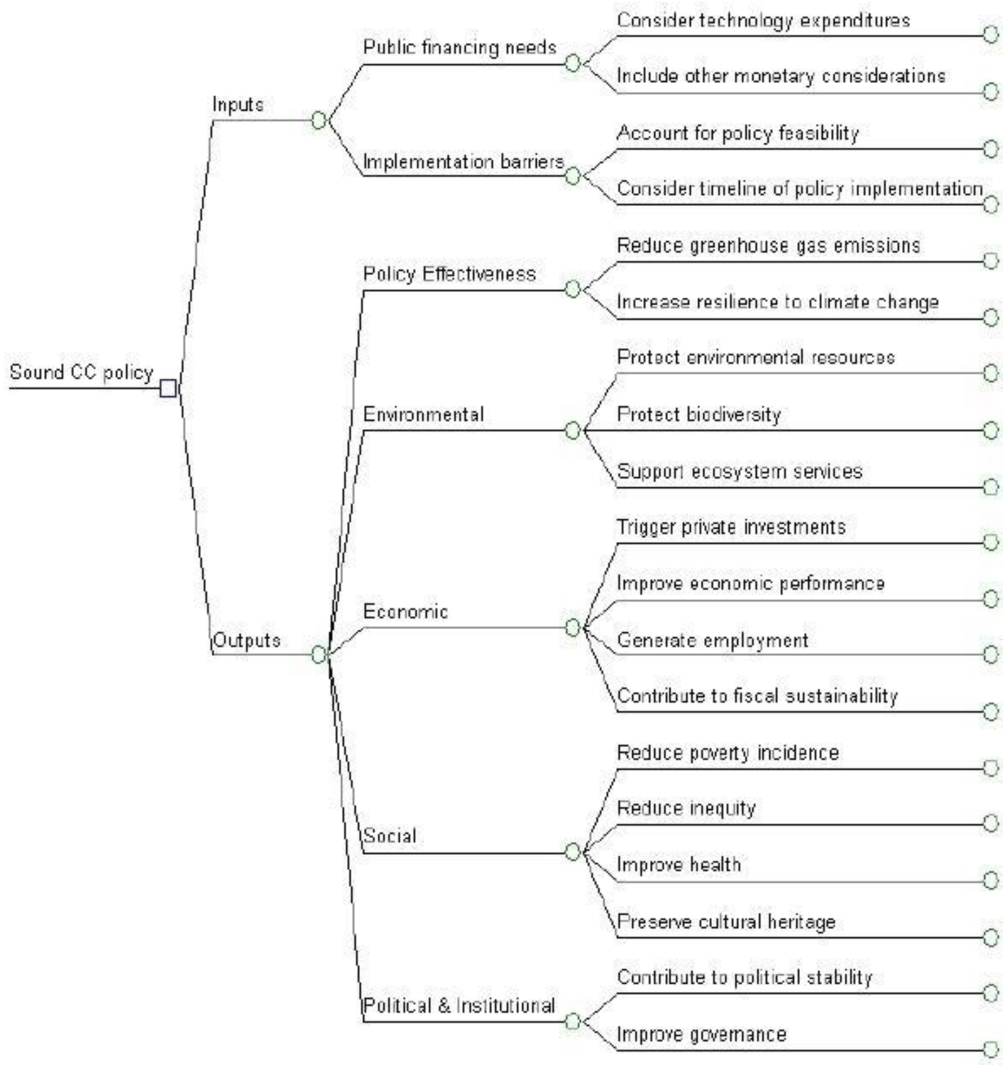


Figure 9: The generic MCA4climate criteria tree

4.2 Indicators and scoring of criteria

The application of the MCA tool requires that each of the criteria in the criterion tree should be defined in terms of indicators and a basis for scoring the degree to which the criterion is achieved.

In the case of the South Africa MCA case study the criteria that were used in the draft IRP 2010 document were mapped onto the Level 3 criteria in Figure 9 and then evaluated and scored against the considerations discussed below.

In some cases, quantified data are available from the energy modelling for particular criteria and in other cases data is not available. In these latter cases more subjective judgements are required to provide a basis for scoring the performance of different scenarios against these criteria.

It is clear in this MCA4climate case study that the criteria to be considered in the initial modelling of the IRP2010 and the REWP do not correlate directly with the nineteen Level 3 criteria in the MCA4climate criteria tree. Ideally, the modelling exercises would be undertaken on the basis of consensus among stakeholders on what the criteria should be for them to be useful within the context of a multi-criteria analysis framework such as the MCA4climate approach.

4.2.1 The criteria considered in the draft IRP 2010

The IRP identified six criteria for evaluating the scenarios under consideration. These are presented below. The first three and the last criteria were quantified based on the outputs of the energy modelling for the IRP 2010. The other two criteria were scored and ranked based on subjective assessments and judgements by experts.

The energy modelling and economic modelling in the revision of the REWP identified eight criteria (as shown in Table 2). Three of these criteria overlap with those identified and quantified in the IRP 2010, namely water, cost and emissions.

4.2.1.1 Water

The usage of water is quantified for each technology, according to the independent EPRI report and information from existing Eskom plant. The water consumption for each scenario is summed over the 20 year period of operation and averaged to provide an annual average water consumption in ML/annum.

4.2.1.2 Cost

The discounted present value of the summed direct costs associated with new generation capacity built under each scenario (including capital, operating and fuel costs) as well as existing plant (but excluding capital costs for committed plant).

4.2.1.3 Climate change mitigation

The GHG emissions from existing and planned generation capacity are quantified in the IRP modelling and compared between scenarios. As in the case of the water consumption, the emissions are summed over the twenty year operating period under consideration in the IRP 2010 and then averaged to provide an average emission per annum in Mt/annum.

4.2.1.4 Portfolio risk or uncertainty

The IRP modelling was unable to quantify risks on an objective and rational basis due to a lack of data and insufficient time and resources. Instead, subjective expert judgements were made for each technology which were weighted respectively to provide an overall risk factor for each scenario mix. The risks which were taken into account included:

- The validity of the cost assumptions for each technology;
- The validity of the lead time assumptions for each technology;
- The maturity of each technology;
- The security of fuel supplies for each technology; and
- Operational risks associated with each technology (including secondary life cycle effects), such as waste management, pollution and contamination.

4.2.1.5 Localisation benefit

A subjective rating was applied to each scenario portfolio to indicate the extent to which this portfolio supports localisation of specific technologies and supporting industries.

4.2.1.6 Regional development

This criterion acknowledged and rewarded increased imports of electricity from regional sources in the SADC region outside of South Africa. Thus a portfolio with the higher percentage of imports (to the total capacity) scores higher on the regional development criterion.

4.2.2 Indicators and scoring for MCA4climate

The mapping of the six indicators used in the draft IRP 2010, and the associated scoring, is shown in Table 4 below. It can be seen that modelling outputs were available for only three criteria.

For these criteria the quantitative scores were transformed to a 0 to 100 scale, where 100 represents the preferred performance, using a linear value function as illustrated below in Figure 10 for the criterion "consider technology expenditures" (if desired, the shape of the function can be changed to reflect non-linear values in relation to the specified criterion).

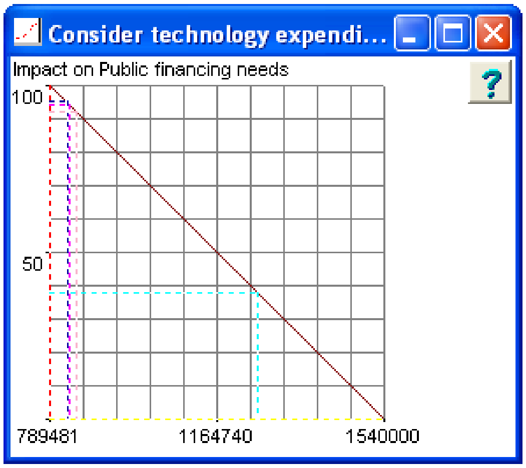


Figure 10: Scoring options against criteria – value function for "consider technology expenditures"

Table 4: Mapping IRP 2010 criteria onto Level 3 criteria and scoring of criteria

	Level 3 Criteria	Draft IRP 2010 criterion	Scenario units	1 Base Case	2 Emission Limit	3 Regional Development	4 Enhanced DSM	5 Revised Balanced Scenario	6 Renewable Energy
1	Consider technology expenditures	Present value of total cost	ZAR millions	789481	1257457	832388	826429	848906	1540000
2	Include other monetary considerations			0	0	0	0	0	0
3	Account for policy feasibility	Portfolio risk or uncertainty		687	521	699	686	611	699
4	Consider timeline of policy implementation			0	0	0	0	0	0
5	Protect environmental resources			0	0	0	0	0	0
6	Protect biodiversity			0	0	0	0	0	0
7	Support ecosystem services	Average annual water consumption	ML/annum	327	283	326	324	318	338
8	Trigger private investments	%	%	5	10	5	35	85	100
9	Improve economic performance	Peak price of electricity	c/kWh	100	172	101	104	111	115
10	Generate employment			0	35	25	55	75	100
11	Contribute to fiscal sustainability		%	35	85	35	55	55	95
12	Reduce poverty incidence			14	6	0	37	26	100
13	Reduce inequity			50	50	35	55	85	100
14	Improve health			0	75	45	65	85	100
15	Preserve cultural heritage			0	0	0	0	0	0
16	Contribute to political stability	Regional development		687	385	1040	687	863	0
17	Improve governance			50	55	45	65	55	100
18	Reduce greenhouse gas emissions	Average annual CO_2 emissions	Mt/annum	303	236	301	299	271	249
19	Increase resilience to Climate Change			0	65	55	80	75	100

Subjective judgement by experts is required to score and rank the unquantified criteria. This was achieved using a process of direct rating of the options against a 0 to 100 "locally defined" scale, whereby the "best" and "least good" of the options considered are positioned at 0 and 100 on the scale. The other options are scored according to their performance relative to these two reference points, the position of each being determined by relative difference between it and the reference points. Thus if option X is scored at 50 this means that the value added by moving from the least good option to option X (50 points) is judged to be equivalent to the value added in moving from option X to the best option. This is illustrated below in Figure 11 for the criterion "reduce poverty incidence".

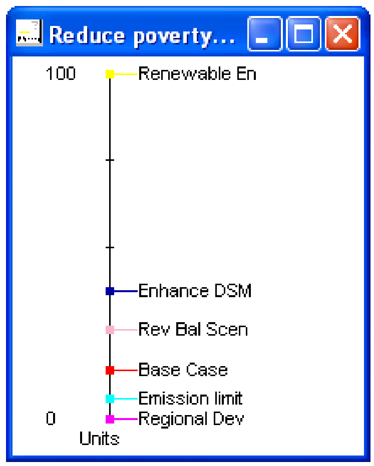


Figure 11: Scoring options against criteria – direct rating of "reduce poverty incidence"

Once the scoring process is complete, it can be helpful to reflect back the performance profiles of the options in visual form as seen in Figure 12. Each of the vertical bars corresponds to one of the criteria (moving down the criteria tree as we move from left to right in the figure) and a high score is always preferred (i.e. requiring less of an input or generating more of an output).

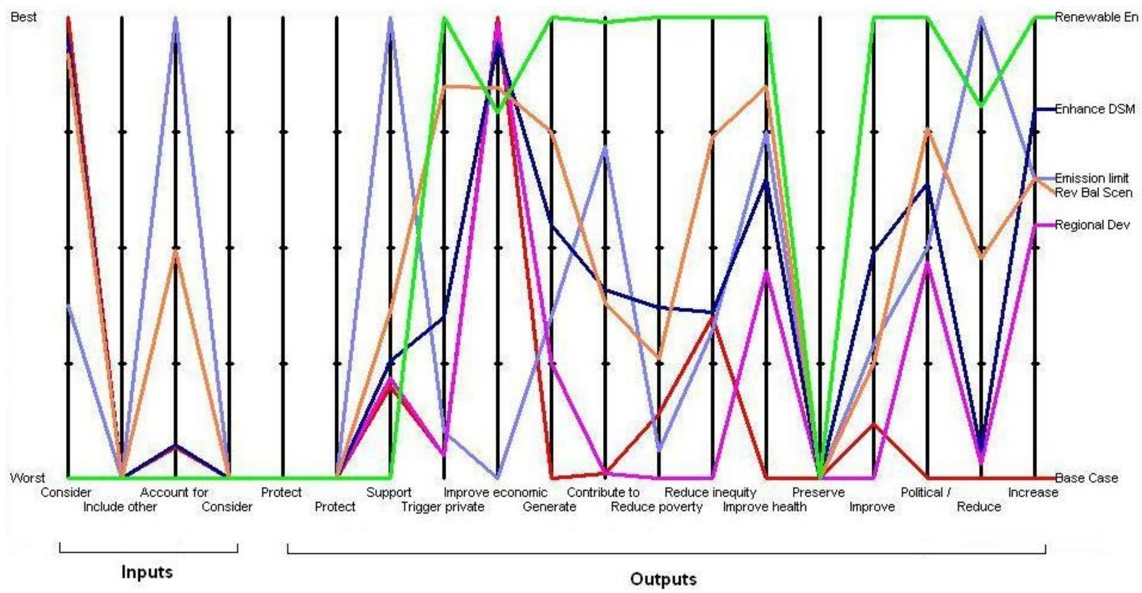


Figure 12: Option profiles (all options and criteria)

The number of options and the presence of five “unscored” criteria makes it difficult to pick out the patterns in the “full” picture, however, these are clearly highlighted by focusing on a selected subset of options as illustrated in Figure 13 (which also omits the bars relating to “unscored” criteria). In this display we see more clearly the strength of the Renewable Energy option with regard to outputs, but this is achieved at the expense of the highest level (and therefore the lowest score on) inputs.

Comparing Enhance DSM and Regional Development it can be seen that the former almost dominates the latter; whilst both have very similar inputs, Enhance DSM outperforms Regional Development on all but one of the outputs.

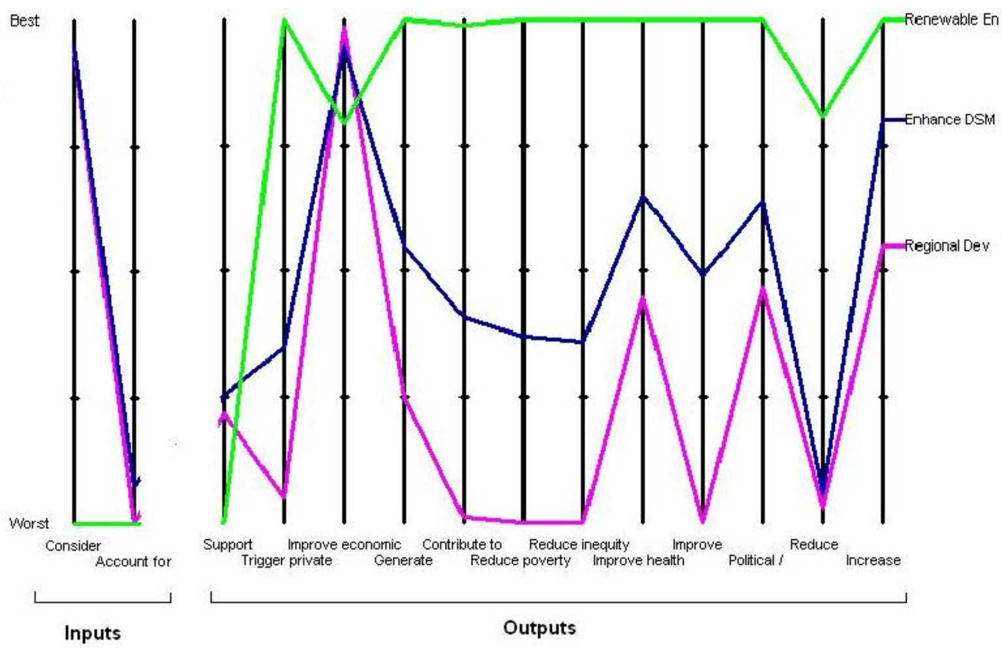


Figure 13: Option profiles – comparing three scenarios

Figure 14 and Figure 15 below show the score profiles across all the Level 3 criteria for all six scenarios considered in the case study. Level 3 criteria which had not been considered in the original modelling in the IRP2010 or the REWP are scored as zero.

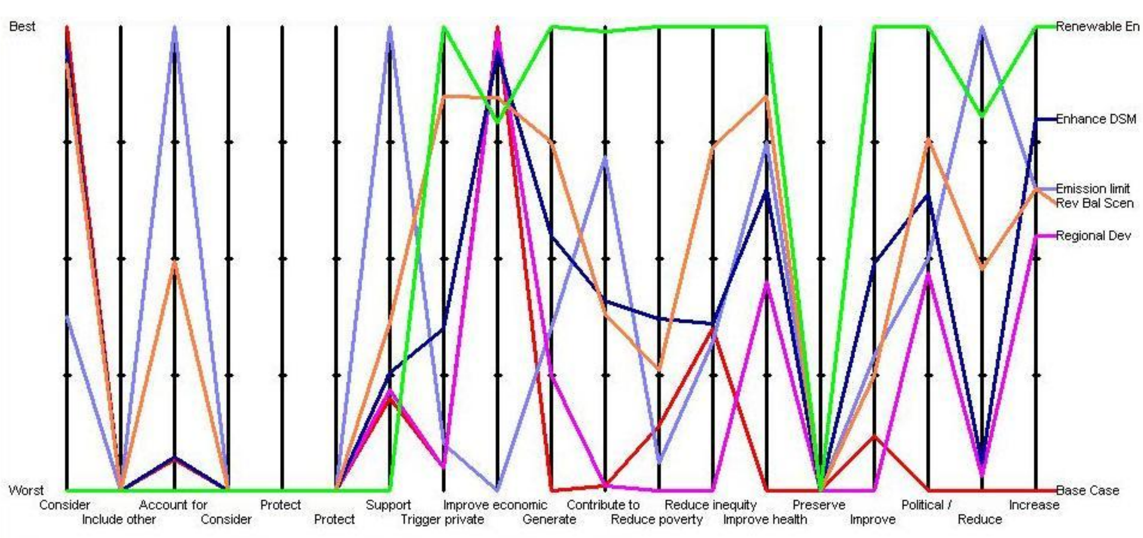


Figure 14: Score profiles for different scenarios across all the Level 3 criteria

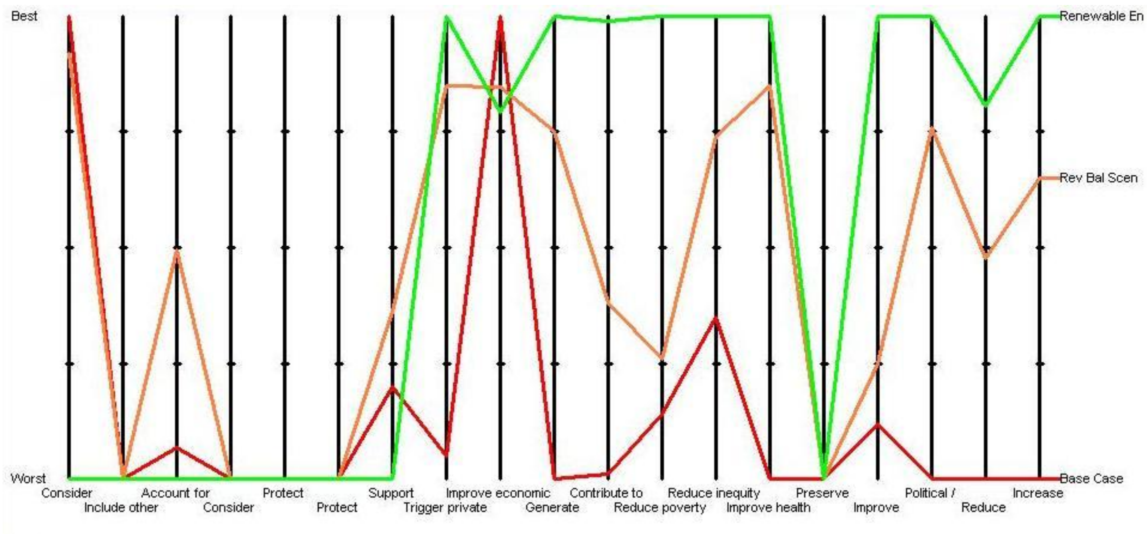


Figure 15: Score profiles for Revised Balanced Scenario and the Renewable Energy scenario compared to the Base Case scenario

Figure 16: Profiles for the Level 2 criteria for six different scenarios

4.2.3 Weighting of criteria

The scores discussed above capture the relative performance of options against each individual criterion at Level 3 of the tree and the profiles convey a holistic picture of strengths and weaknesses. Criteria weights are defined to enable the combination of Level 3 criteria scores to reflect the aggregate performance of options at higher levels of the value tree. The weights should reflect the relative "added value" obtained by increasing the performance of an option from the least preferred (score = 0) to the most preferred (score = 100) position on a criterion. These weights can be aggregated to reflect the relative values of families of criteria (e.g. Economic vs Social factors); these higher level weights reflect the relative "added value" obtained by increasing the performance of an option from 0 to 100 on all the Level 3 criteria which define that family. Thus the notion of the weight of a higher level criterion is quite complex, relating to the totality of everything below it, and direct assessment has been shown to be subject to bias. For this reason it is better to begin by assessing the criteria weights from the bottom of the tree up, rather than top-down.

The swing-weighting method is a common way to assess these weights across the bottom-level of a value tree. This approach first identifies the criterion which gives the greatest "added value" in moving from the least preferred (score = 0) to the most preferred (score = 100) and assigns a weight of 1 to that criterion. The relative added value associated with each of the other criteria is then considered, usually identifying the next greatest and assigning a weight (with value less than 1) which reflects the relative value of 100 points. When all weights have been determined the values are normalised to sum to 1 (simply as a mechanism to keep the aggregate scores at all levels of the tree within the range 0 to 100).

As the group did not have access to real decision makers this part of the analysis is only illustrative. The weights initially allocated at Level 3 of the criteria tree are shown in Figure 17; these reflect a stakeholder perspective which emphasises policy effectiveness. The aggregation of the Level 3 weights to Level 2 of the tree is shown in the right of Figure 17. Zero weight was assigned to the five criteria which were not scored (greyed out in Figure 17).

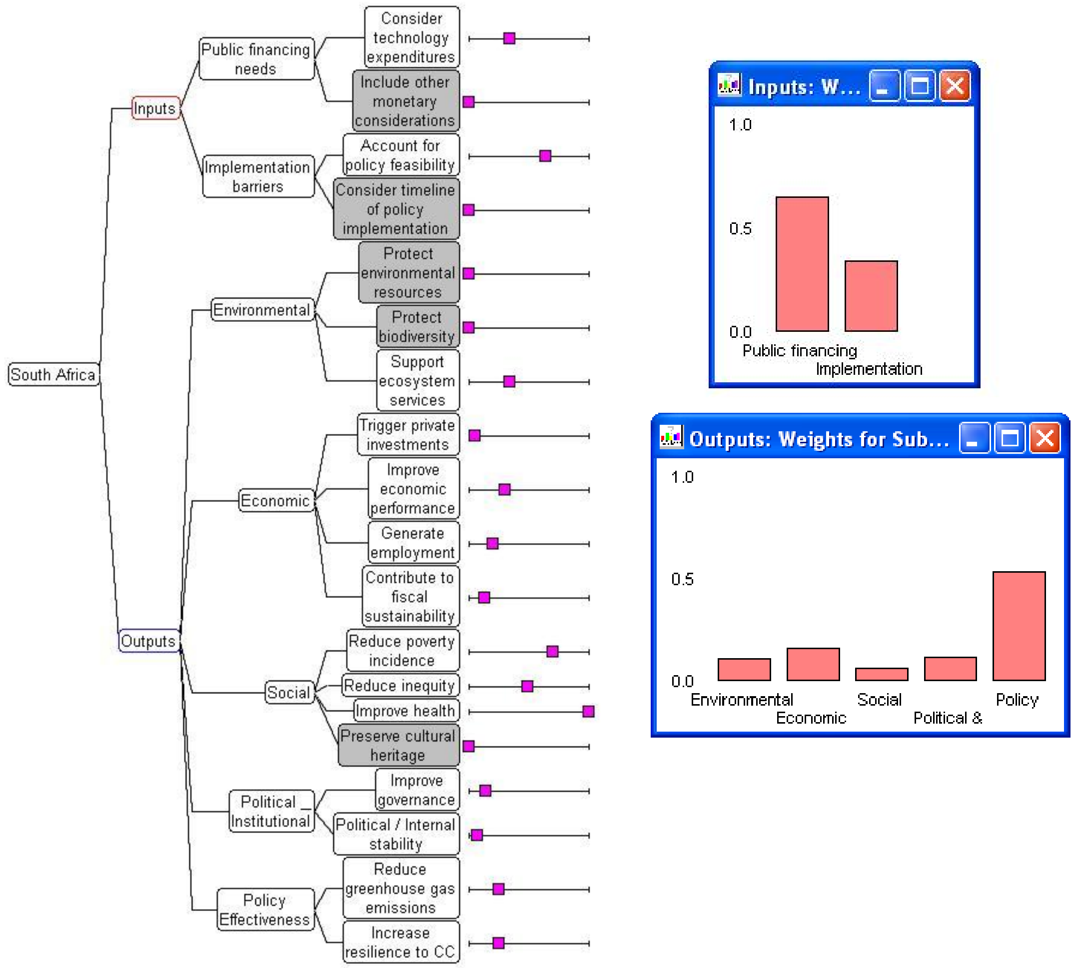


Figure 17: Initial Criteria Weights

It is now possible to aggregate the scores and weights assigned at Level 3 of the tree to determine the performance of the options at higher levels of the tree. Figure 18 shows performance profiles of the options at Level 2, clearly highlighting patterns of dominance. Note the Revised Balanced Scenario which performs relatively well on both inputs and outputs.

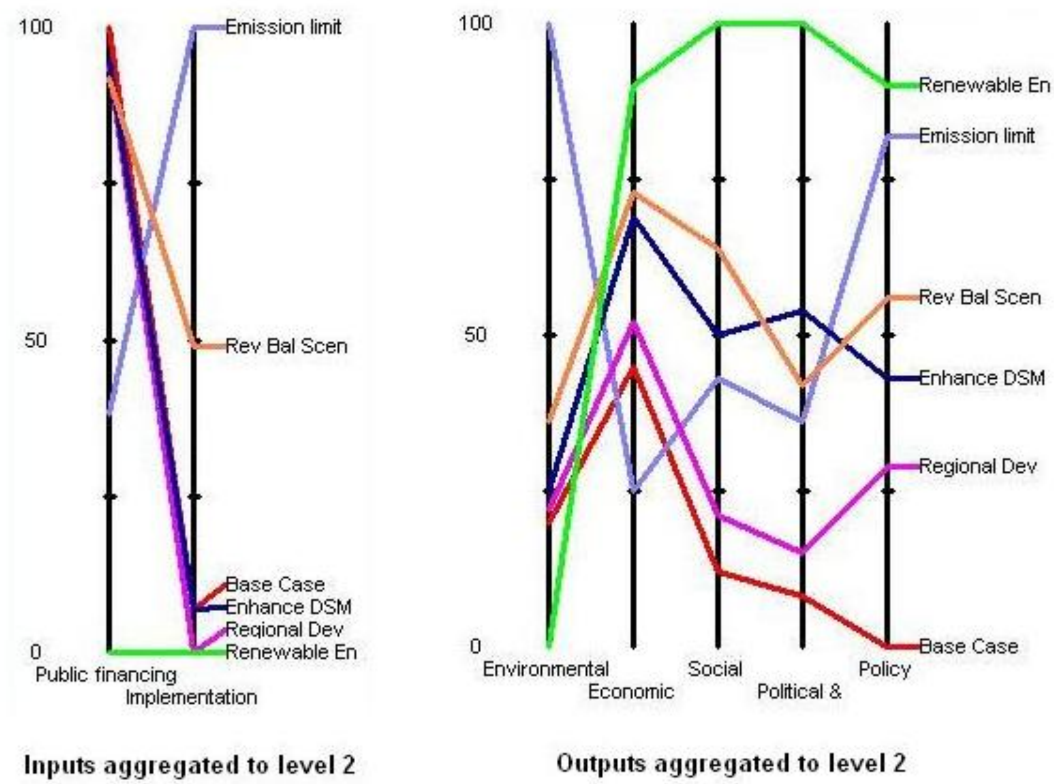


Figure 18: Option profiles at Level 2 of the criteria tree

4.2.4 Aggregated Scores – Efficiency Plots

Further aggregating scores using the assigned weights enables us to determine the performance of options against inputs and outputs as seen in Figure 19 and Figure 20 which graphs these aggregated scores against each other in an Efficiency Plot.

The Efficiency Plot enables us to identify those options which are "efficient" in terms of the level of output generated for a given input (i.e. there is no other option which generates a higher output for the same input or achieves the same output with a lower input). Efficient options appear on the "north-west frontier" of the plot, which in this case is defined by the three options Renewable Energy, Emissions Limit and Revised Balanced option. Each of these three options is a candidate for the overall preferred option. To determine which is the most preferred we should first consider if we believe that the additional inputs required by the Emissions Limit option in comparison with the Revised Balanced option merit the additional outputs; if the answer is yes, then the latter is preferred and we should ask the same question of it in comparison with the Renewable Energy option.

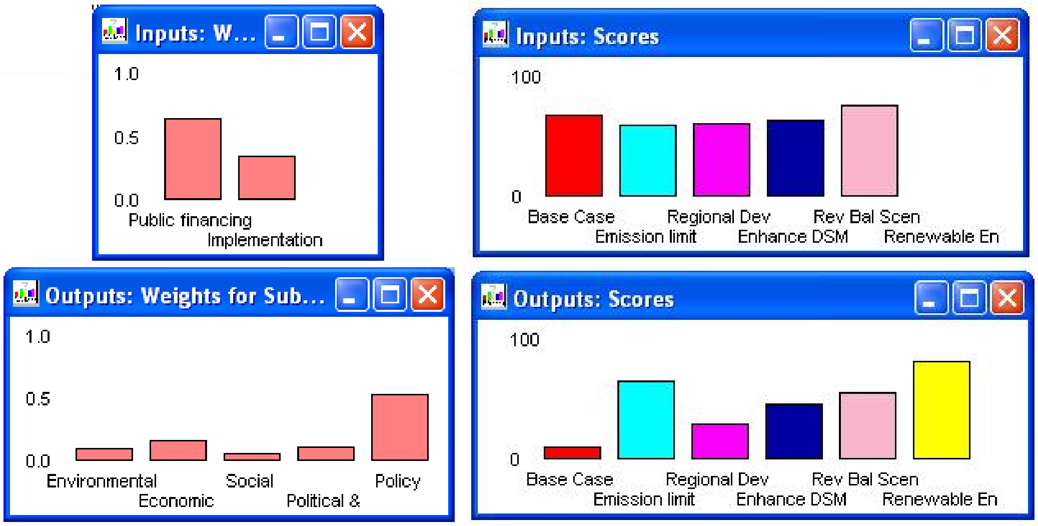


Figure 19: Aggregate scores at Level 1 of the value tree (Inputs and Outputs)

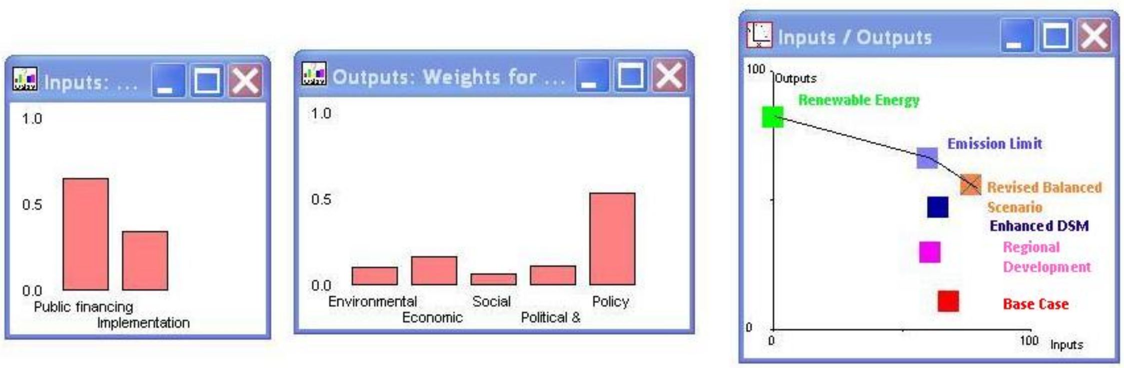


Figure 20: Efficiency plot of Outputs against Inputs – initial weights

4.2.5 Sensitivity Analyses

A real benefit of the use of the visual interactive software for analysis is the ability to "play" with the assigned criteria weights in order to understand the impact of changing these – small changes reflecting the consequences of imprecision in their specification and large changes potentially reflecting differing stakeholder perspectives. This process enables us to identify any "tipping points" - points at which the definition of the efficient frontier is changed. A static representation does not do full justice to the impact on understanding that can derive from the visual interactive analysis, but some of the observed effects can be seen in Figure 21, Figure 22 and Figure 23 which demonstrate the impact of changing the balance of weights across the five Level 2 output criteria whilst retaining the same weights across the input criteria "public financing needs" and "implementation barriers". The Revised Balanced scenario remains efficient whichever input criterion is weighted highly. When Economic or Social factors are weighted more highly, the Renewable Energy scenario also remains on the efficient frontier but the Emission Limit scenario moves away from it. If environmental factors are emphasised then the situation is reversed and the frontier is defined by the Emission Limit and Revised Balanced scenarios, with the Renewable Energy scenario moving off it.

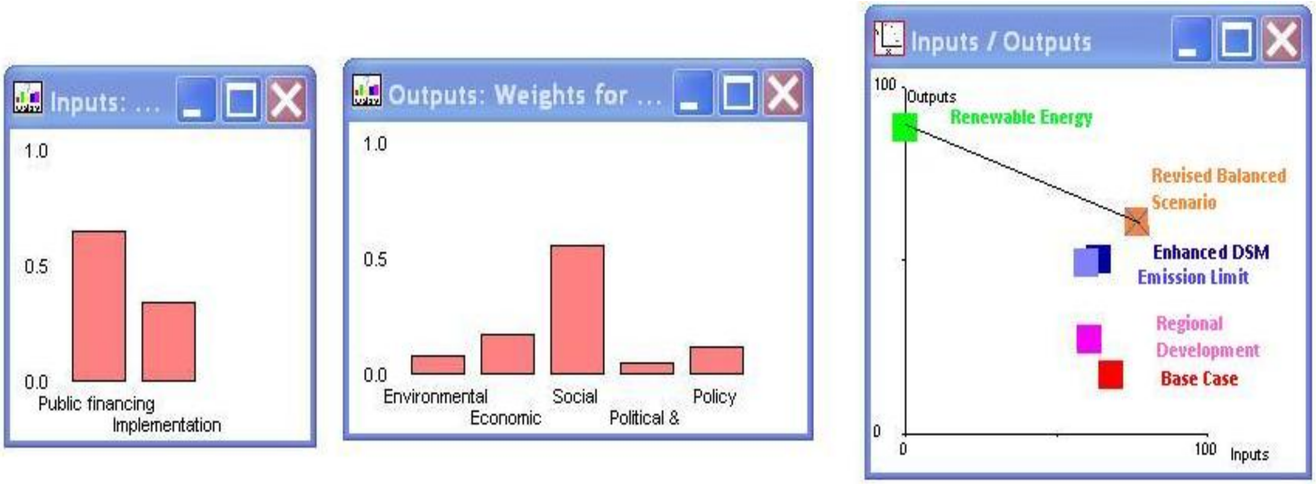


Figure 21: Efficiency plot of Outputs against Inputs, increased weight on Social

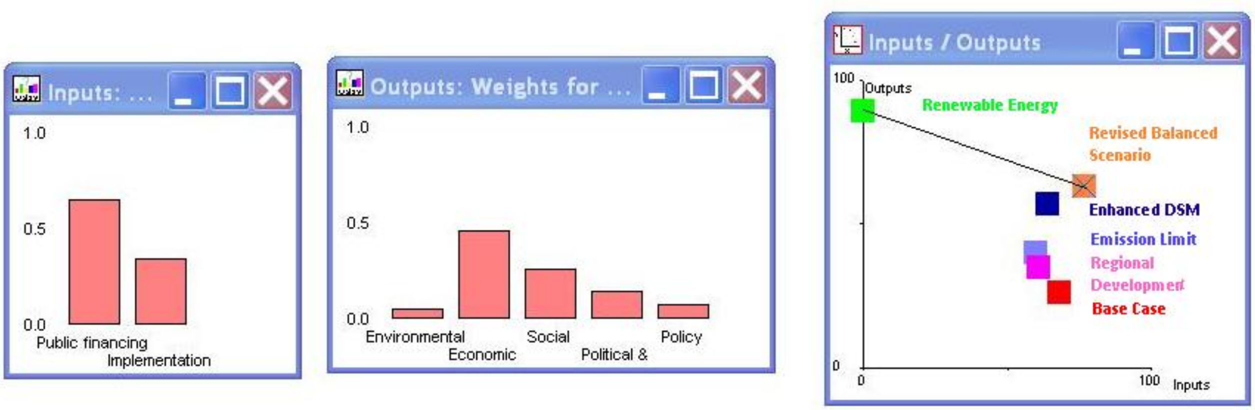


Figure 22: Efficiency plot of Outputs against Inputs, increased weight on Economic

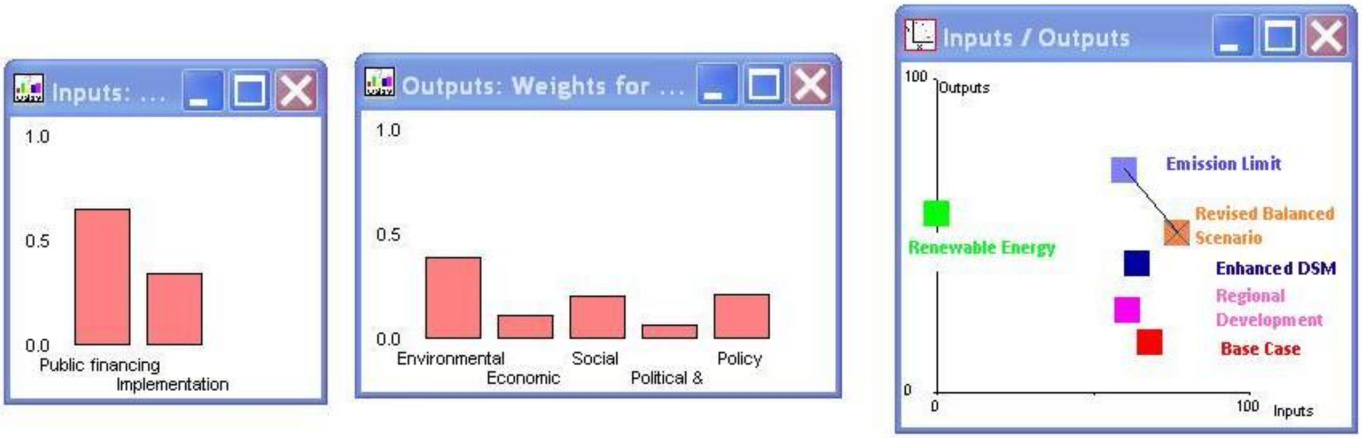


Figure 23: Efficiency plot of Outputs against Inputs, increased weight on Environmental

Figure 24, Figure 25, Figure 26 and Figure 27 below demonstrate the effect of changing the balance of weight on the input criteria, allocating a higher weight to Implementation Barriers than Public Financing needs, for the same four sets of output weights considered above. As before, it is the same three scenarios, or a subset of these, which define the efficient frontiers. When Environmental factors are weighted highly Emission Limits is the only efficient scenario, dominating all other options at this level of aggregation.

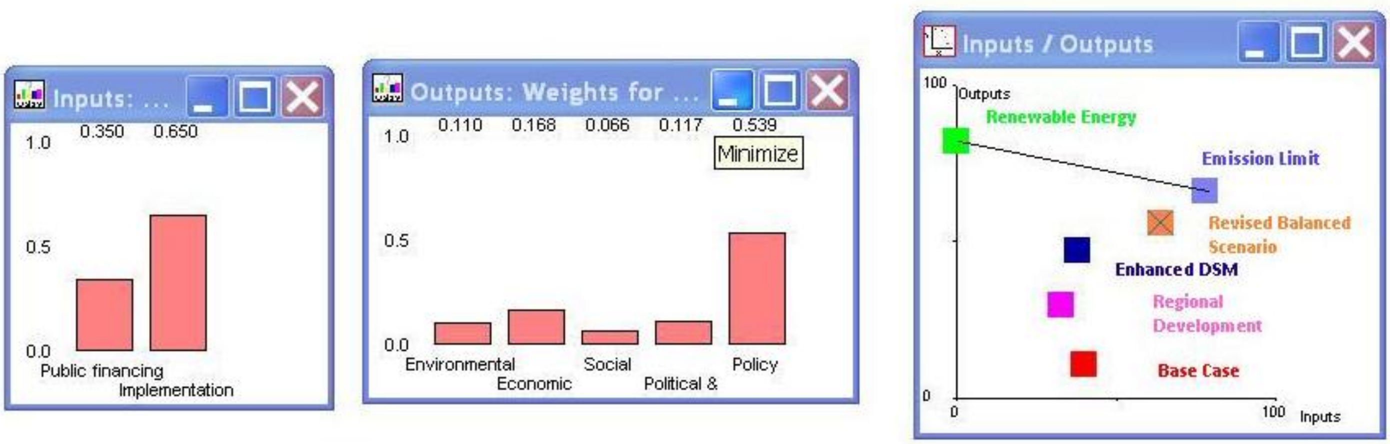


Figure 24: Efficiency plot of Outputs against Inputs, increased weight on Policy

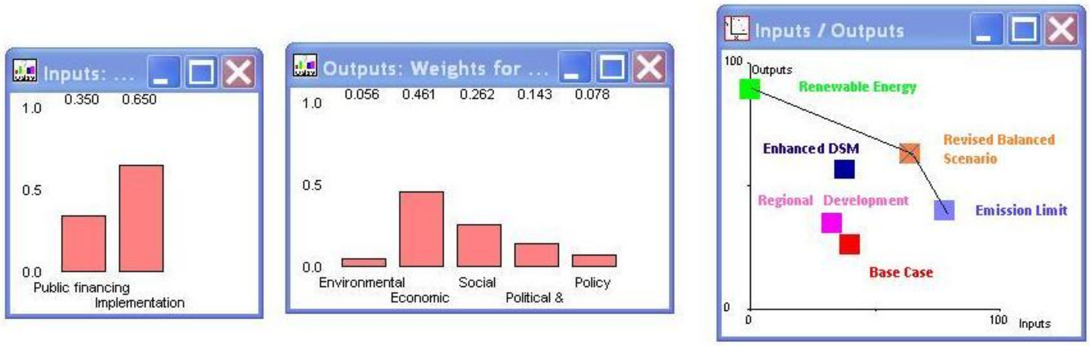


Figure 25: Efficiency plot of Outputs against Inputs, increased weight on Economic

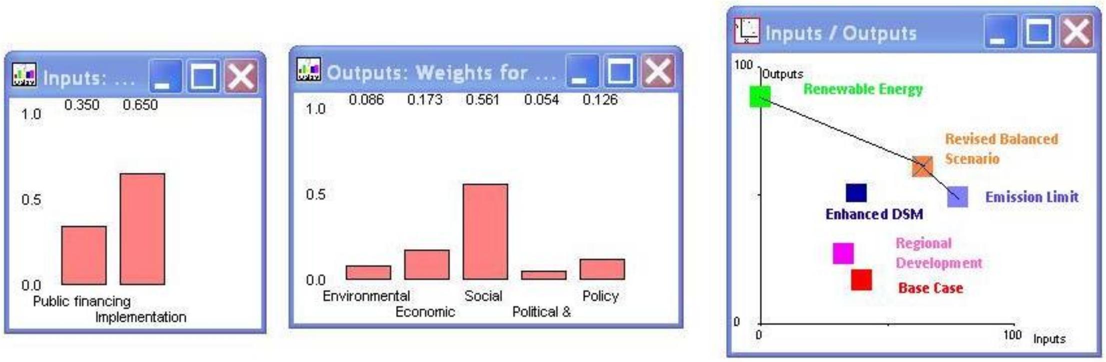


Figure 26: Efficiency plot of Outputs against Inputs, increased weight on Social

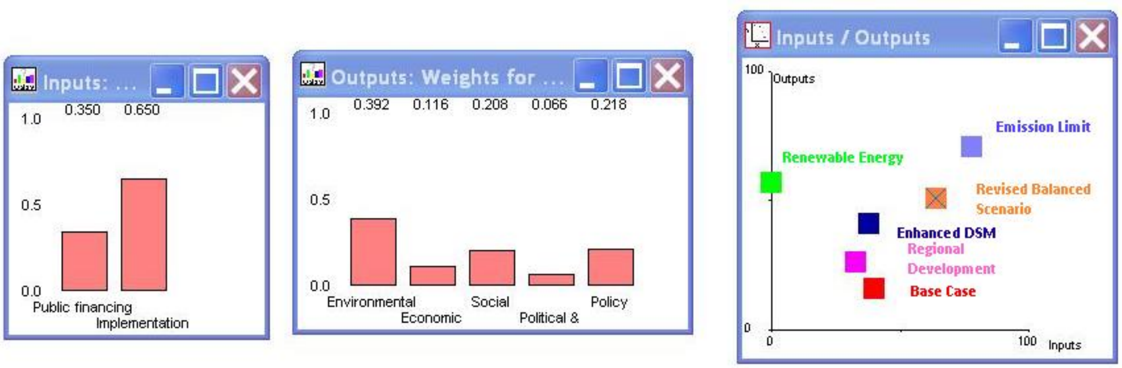


Figure 27: Efficiency plot of Outputs against Inputs, increased weight on Environmental

5. Conclusions

Key conclusions arising from the application of the MCA4climate tool for the case study of the electricity (preferably energy) planning in South Africa include:

- Apart from the analytical value of the MCA4climate tool it also provides a very powerful process tool which enables a wide range of stakeholders to engage in the complex decision making process which is required for investment decisions in the energy sector. In practice, good policy development requires thorough and meaningful stakeholder participation and consequently tools such as the MCA4climate approach are exceedingly useful in ‘working through’ the issues with stakeholders to ensure a common understanding of the dimensions of the policy which is required.

- The case study for the fuel-mix mitigation options in South African energy system clearly illustrates the sensitivity of the technology mix scenarios to both i) good inputs and outputs in the energy and economic modeling of the scenarios and ii) the weighting of the criteria in terms of the perspectives of different stakeholders.

- The value of the MCA4climate approach is evident in this case study despite the fact that there were gaps in the mapping of the modeled input and output criteria to the Level 3 criteria in the generic MCA4climate approach.

- It would clearly be useful to identify and agree on criteria (and scoring) for all the criteria before undertaking the energy (and economic) modeling activities in an energy planning process to ensure that the outputs of the modeling can be useful in the MCA4climate tool (or an equivalent MCA tool).

- Criteria identified in the level 3 criteria tree do map onto the policy drivers identified in Section 2.5.5 but more work would be required to confirm the correlation and the appropriate scoring for these criteria.

- The MCA4climate approach is furthermore interesting from the perspective of energy service delivery (as opposed to traditional least-cost supply-side energy planning) in that it can address scenarios which are framed by an energy services perspective – including onsite (or standalone) and distributed energy service supply chains.

6. References

DEAT (2007) Long Term Mitigation Scenarios: Strategic Options for South Africa, Department of Environment Affairs, South Africa.

DoE (2010). Integrated Resource Plan (2010 Rev 2) - Draft Report, Department of Energy, October 2010.

DoE (2008). Commodity Flow and Energy Balance 2008 ver 3, http://www.energy.gov.za/, accessed March 2011.

Eberhard, 2011. *The Future of South African Coal: Market, Investment and Policy Challenges*. Working Paper #100, prepared for The Program on Energy and Sustainable Development (PESD), Stanford University. January 2011

Eskom (2010), Corporate governance and statistical tables, http://www.eskom.co.za/annreport10/corp_tables_statistic.htm, accessed March 2011.

Eskom (2011). Presentation to the Parliamentary Portfolio Committee on Energy, http://www.pmg.org.za/report/20100315-department-energy-its-strategic-plan-201011-201213-and-budget-201011, accessed March 2011.

Manuel T (2011) In search of win-win solutions. Article in the Mail & Guardian, June 10 to 16 2011

Steyn (2006) Investment and uncertainty: Historical experience with power sector investment in South Africa and its implications for current challenges, Working Paper prepared for the Management Programme for Infrastructure Reform and Regulation, Graduate School of Business, University of Cape Town.

Winkler et al (2011). Access and Affordability of Electricity in Developing Countries, World Development, Vol. 39, No. 6, pp. 1037–1050, 2011

Winkler H (ed) (2007). Long-term mitigation scenarios, Energy Research Centre, University of Cape Town.