Western Cape Government
Environmental Affairs and Development Planning

Western Cape Climate Change Mitigation Scenarios for the energy sector

FINAL REPORT

SEPTEMBER 2015

EXECUTIVE SUMMARY

This study is a first representation of the climate mitigation potential of the energy sector in the Western Cape. It is founded on an analysis of energy use in the Province using a set of models which allow for energy demand to be projected into the future, based on a set of variables which influence demand. On the energy supply side the analysis includes electricity and fuel supply options. The energy demand and supply analysis then leads to an assessment of energy-related greenhouse gas emissions. Starting from a base position (Reference) the study has then applied a set of mitigation measures aimed at reducing these emissions. A starting point for identifying these measures was the national Mitigation Potential Analysis (MPA) undertaken by the national department of Environment Affairs. The list of measures applied as part of the MPA was then amended through a stakeholder engagement process to get the final list of 100 measures to be applied for the Province. The models then allowed emission projections to be made for two core climate mitigation scenarios: 1) All Possible Measures (APM) and 2) APM with the addition of fuel switching from coal and liquid fuels to natural gas. The study also identified measures over which the Province and municipalities within the Province have influence, with the associated ability of these organisations to influence emissions.

The primary conclusion from this study is that, with all possible measures applied, other than fuel switching, there is the potential to reduce emissions substantially from a rate of increase of 2.3% per annum under the Reference case scenario to an average annual increase in emissions of 1.1% per annum over the period up to 2040 (Figure 1: Modelled scenario comparison – emissions (in ktCO2eq) and Figure 2: Modelled scenario comparison – emissions by fuel type in 2040 (in ktCO2eq)). Further, should the province simultaneously implement all possible measure with fuel switching, there is an even greater opportunity to reduce emissions, with the average annual increase in emissions reduced to 0.9% per annum. While it is shown that it is not feasible to avoid an increase in emissions associated with energy use in the Province this is a substantial reduction. In this regard it needs to be kept in mind that the analysis excludes non-energy related emissions which, if included, will reduce emissions further.

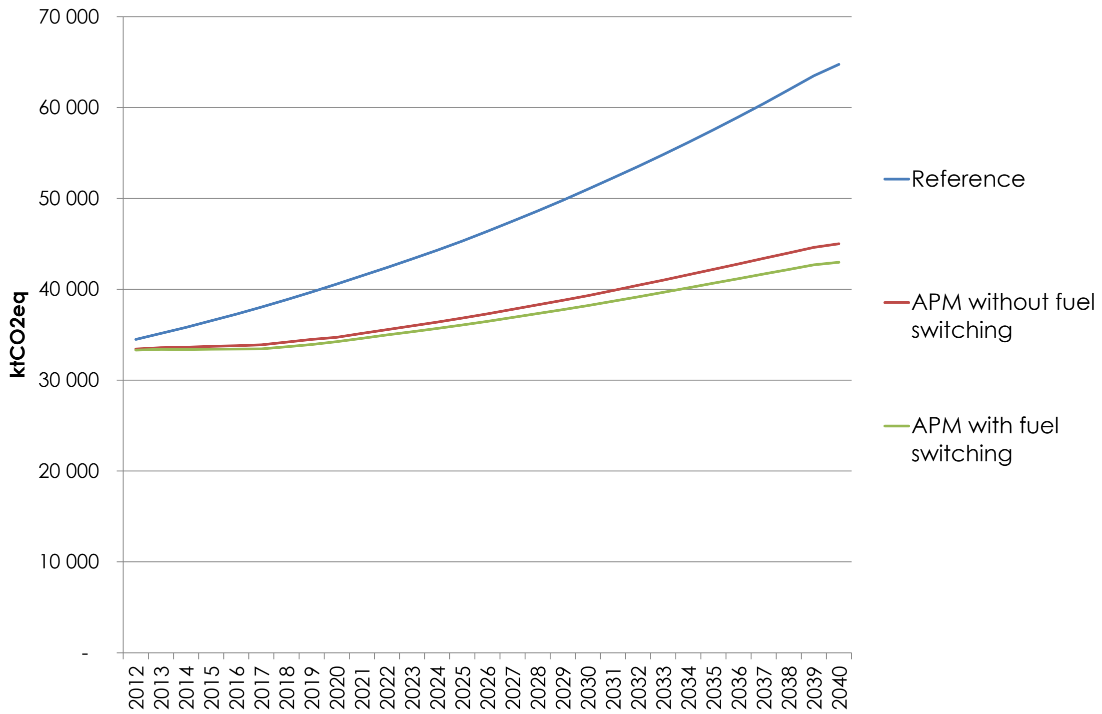

Figure 1: Modelled scenario comparison – emissions (in $ktCO_2eq$)

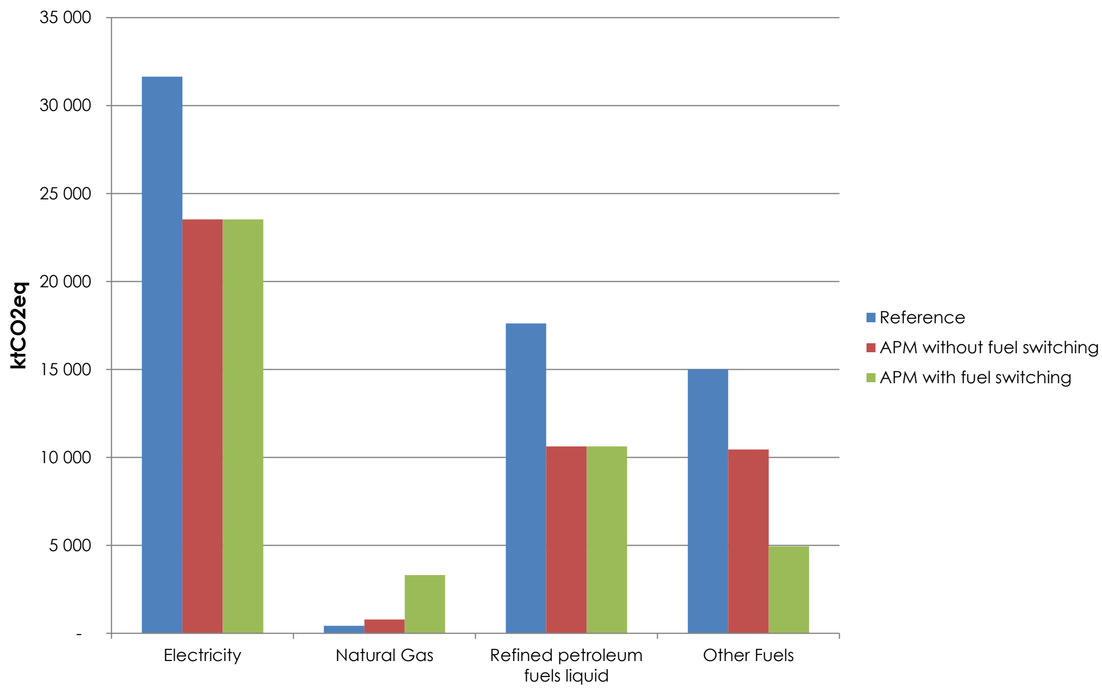

Figure 2: Modelled scenario comparison – emissions by fuel type in 2040 (in ktCO2eq)

However, the implementation of all measures will be an onerous task requiring a full commitment of energy providers and energy users in the agriculture, industrial, commercial, residential and transport sectors. The measures have various degrees of difficulty in being implemented in terms of cost and institutional obligations and they have various degrees of benefit other than through emissions reduction. In order to assess the relative costs, ease of implementation and benefits, a Multi-Criteria Analysis (MCA) was applied based on methodology used for the DEA MPA. This allowed for a ranking of measures to be provided with the implication that the highest ranked measures have the best balance between cost, implementability and benefits (Table 1: Multi-criteria analysis rank by overall weighted score top 20 mitigation measures). It is important to note that, given the time and budget limitations for this study, this ranking needs to be seen as a provisional guide only and there is much room for refinement.

Table 1: Multi-criteria analysis rank by overall weighted score top 20 mitigation measures

Rank	Sector	Sub-sector	Mitigation measure	Overall weighted MCA score	Total Emissions Abated (ktCO2eq)	% of Total emissions abated
1	Transport	Freight	Road - Shifting freight from road to rail (modal shift)	86.55	2 867	0.6%
2	Transport	Road	Road - Shifting passengers from cars to public transport	68.44	29 701	6.3%
3	Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	66.33	26 450	5.6%
4	Electricity	Electricity	Solar Photovoltaics (Concentrated)	63.97	29 069	6.1%
5	Buildings	Residential	Solar water heating	63.50	9 004	1.9%
6	Buildings	Commercial	Solar water heaters	63.39	7 255	1.5%
7	Electricity	Electricity	Biomass	63.36	10 224	2.2%
8	Buildings	Commercial	Behavioural changes	62.52	6 324	1.3%
9	Buildings	Commercial	Efficient Lighting	62.01	14 932	3.1%
10	Industry	Pulp & Paper	Energy recovery system	61.93	2 360	0.5%

Rank	Sector	Sub-sector	Mitigation measure	Overall weighted MCA score	Total Emissions Abated (ktCO2eq)	% of Total emissions abated
11	Buildings	Residential	LPG for cooking	61.30	438	0.1%
12	Industry	Petrochemicals	Energy monitoring and management system	61.30	838	0.2%
13	Agriculture	Agriculture	Reduced tillage	61.24	3 905	0.8%
14	Industry	Pulp & Paper	Convert fuel from coal to biomass/residual wood waste	61.23	10 111	2.1%
15	Industry	Petrochemicals	Improved electric motor system controls and Variable Speed Drives (VSDs)	61.22	225	0.0%
16	Industry	Petrochemicals	Improve steam generating boiler efficiency	60.81	320	0.1%
17	Industry	Petrochemicals	Improve process heater efficiency	60.79	149	0.0%
18	Industry	Chemicals	Improved electric motor system controls and VSDs	60.51	375	0.1%
19	Buildings	Residential	Efficient Lighting - CFLs	60.36	8 123	1.7%
20	Industry	Petrochemicals	Improved heat exchanger efficiencies	60.35	341	0.1%

In order to achieve the desired emission reductions energy suppliers and energy users in each sector will need to undertake major improvements in the way they provide or use energy. For some measures this will lead to cost efficiencies while in others the cost to the user of energy will increase through the application of the measure. In many cases additional investment is required, with the energy user often having to raise the capital themselves. A summary of the implications for each sector is given below.

POWER GENERATION

The analysis shows the largest gains in terms of mitigation to be in the power generation sector, where the measures are associated with replacing coal fired power plants with renewable energy plants and natural gas fired plants. There are 8 measures identified of the total of 100 and the mitigation potential of these measures represents 31% of the total mitigation potential. The largest mitigation impact is anticipated to be from applying onshore wind for power generation, followed by natural gas with closed cycle gas turbines, solar photovoltaics and concentrated solar power.

The natural gas and photovoltaic options are ranked highest using the MCA with energy generation using biomass also ranking high. All of the measures are in the top two thirds of the ranking. However, the point made above about the provisional nature of the scoring for the MCA needs to raised here in interpreting the relative ranking of these power generation measures. This is a complex analysis undertaken in a limited budget and there is not a great deal of difference in the resulting scores. Therefore not too much store should be placed on the position of these measures in relation to each other.

It is notable that the results are based on a non-nuclear energy mix with the emphasis being on renewables and natural gas. However, nuclear power was considered in the analysis and has been scored under the MCA, with it coming out as one of the least favourable options, this is particularly due to the implementation requirements and costs associated with nuclear energy.

With regard to the implementation of these measures they are all aimed at generating power into the national grid and therefore are primarily under the influence of national government, the Department of Energy specifically. However, the province does have influence over the natural gas measure through promoting the import of natural gas in the province. This is not meant to imply that the Province should not continue to lobby for greater use of renewable energy as well.

INDUSTRY

This sector is the biggest user of energy and the biggest emitter of greenhouse gases in the Province. It also has the highest potential of the demand sectors to reduce emissions in terms of overall quantity of emissions (22% of total mitigation is associated with industrial energy measures). With the diversity of industries in the Province and the large numbers of industrial processes involved there are a wide variety of measures which can be implemented (56 of the 100 measures identified are in the industrial sector). Many of these are small, partly associated with the fact that some of the sector sub-divisions – such as lime and chemicals (excluding petrochemicals) – are small. On the other hand there is also a fairly large amount of mitigation associated with a grouping of 'All other remaining' industries which could not be analysed separately (45% of the industrial sector's mitigation potential comes from this grouping). The industrial sub-sector which was analysed separately with the biggest impact is pulp and paper (21% of the industrial sector's mitigation potential comes from this grouping) but it should be noted that this project did not provide for direct sector engagement with the pulp and paper industry and there are uncertainties associated with the applicability of the measures identified for this sector in a Western Cape context. The analysis shows the iron and steel industry to have the potential for 13% of industrial sector mitigation with this based on a brief assessment of the measures remaining to the one large plant in the province. Mitigation potential in the cement and brick and clay sectors are also significant.

With regard to the type of measures to be implemented the highest ranked measures which also have the potential for substantial mitigation gains are associated with energy efficiency measures associated with utilities as well as process improvements through improved process control, monitoring and energy management. Better motor control and variable speed drives also have the potential to bring significant gains. In the case of energy efficient boiler systems and kilns the analysis shows these to have the biggest impact in terms of total mitigation but they are expensive measures to implement. Also expensive to implement but with large potential for mitigation is fuel switching mainly from coal and heavy furnace oil to natural gas.

The implementation of these measures is clearly dependent on action being taken by individual businesses supported by sector organisations and overall industrial actions. The national Departments of Energy and Environment Affairs have a key role to play through the regulation and incentives. In this regard the Desired Emission Reduction Outcomes (DEROs) of DEA is an important driver of change in the industrial sector. DEROs are being determined for each significant sector and sub-sector of the South African economy and include short-, medium- and long-term Carbon Budgets (CBs) for those sectors where CBs are appropriate. There are already a number of national energy efficiency initiatives including those through the National Cleaner Production Centre's Industrial Energy Efficiency Improvement Programme, who provide industry advice on enhancing energy efficiency through the implementation of regular energy audits and other energy monitoring practices.

While the Province has limited influence over the industrial sector they can engage on the fuel switching option as this requires infrastructure to get gas to individual industries, something the Province and municipalities can promote.

PASSENGER TRANSPORT

Nine mitigation measures associated with passenger transport sector have been identified, with the potential for mitigating 15% of the total for the province. The measures are separated into two groups: improved or alternative vehicle engines (for both passenger rail and road-based vehicles) and a maximum possible modal shift from private to public transport (based on international leaders such as Bogata). Engine efficiency gains are driven by international initiatives in the motor industry and are generally outside the control of the Province.

The Province and the City of Cape Town have the potential to influence the modal shift in passenger transport which is highly ranked and needs to get concerted attention. It will, however, take time and considerable investment in infrastructure, urban-form, public attitudes and aspirations to bring about the required change.

FREIGHT TRANSPORT

The measures in this sector relate primarily to improved engine technology both for road and rail vehicles and modal shift from road to rail freight. Between the 3 measures identified they have the potential to mitigate 4% of the total for the province. The shift of freight from road to rail scores very highly, due in part to the relatively low level of investment required to upgrade the N1 Rail corridor between Cape Town and Gauteng, and the significant reduction in emissions which results from the reduced road-based freight emissions. This measure also has significant benefits in terms of social impact, and implementability.

However, the Province and municipalities have limited influence over this sector.

COMMERCIAL BUILDINGS

The 9 measures identified for this sector have the potential to mitigate 13% of the total for the province. Solar water heating and efficient lighting have high levels of potential mitigation and are highly ranked under the MCA. Improved heating, ventilation and air conditioning also have high mitigation potential but are not as easy to implement. There is long term potential for using embedded generation based on photovoltaic systems.

The Province and municipalities have a high degree of influence over these measures.

RESIDENTIAL BUILDINGS

The 11 measures identified for this sector which have the potential to mitigate 10% of the total for the Province. Solar water heating, energy efficient lighting and geyser efficiency (including geyser blankets) have high levels of potential mitigation and are highly ranked under the MCA. There is long term potential for using embedded generation based on photovoltaic systems.

The Province and municipalities have a high degree of influence over these measures.

AGRICULTURE

The 4 measures identified for this sector which have the potential to mitigate 6% of the total for the Province. Energy efficiency related to the introduction of variable speed drives (VSDs) used in pumped irrigation and on-farm cooling have high levels of potential mitigation but are not highly ranked under the MCA because the social impact of this measure is low, with most benefits accruing to farmers in the form of cost savings, with no direct job impacts. In contrast, while reduced tillage represents the smallest mitigation potential of all measures reviewed, it ranks fairly high in the MCA as it has significant other environmental benefits (e.g. reduced pesticide and fertiliser usage). It is also a significant source of abatement potential within the Agricultural sector, even if it scores low in absolute terms within the province. Agricultural energy consumption is related only to on-farm activities and does not include the transport of any goods to market or extensive processing.

The Province has a high degree of influence over these measures.

PROVINCIAL INTERVENTIONS - SUMMARY

This showed that the province can affect the implementation of 100% of mitigation measures in the commercial buildings, residential buildings and agricultural sectors (Figure 3: Provincial prioritisation of sector's to influence). The Province is also capable of affecting change in the passenger transport (44%), energy supply (37%), industrial (28%) and freight transport (17%) sectors.

The proposal made here is that, while effort should be made to pursue those measures which present the greatest abatement potential, there is equal motivation to pursue those which the province has the greatest power to influence or implement. As this study evidences, much of this influence rests in the buildings, passenger transport and agricultural sectors of the province.

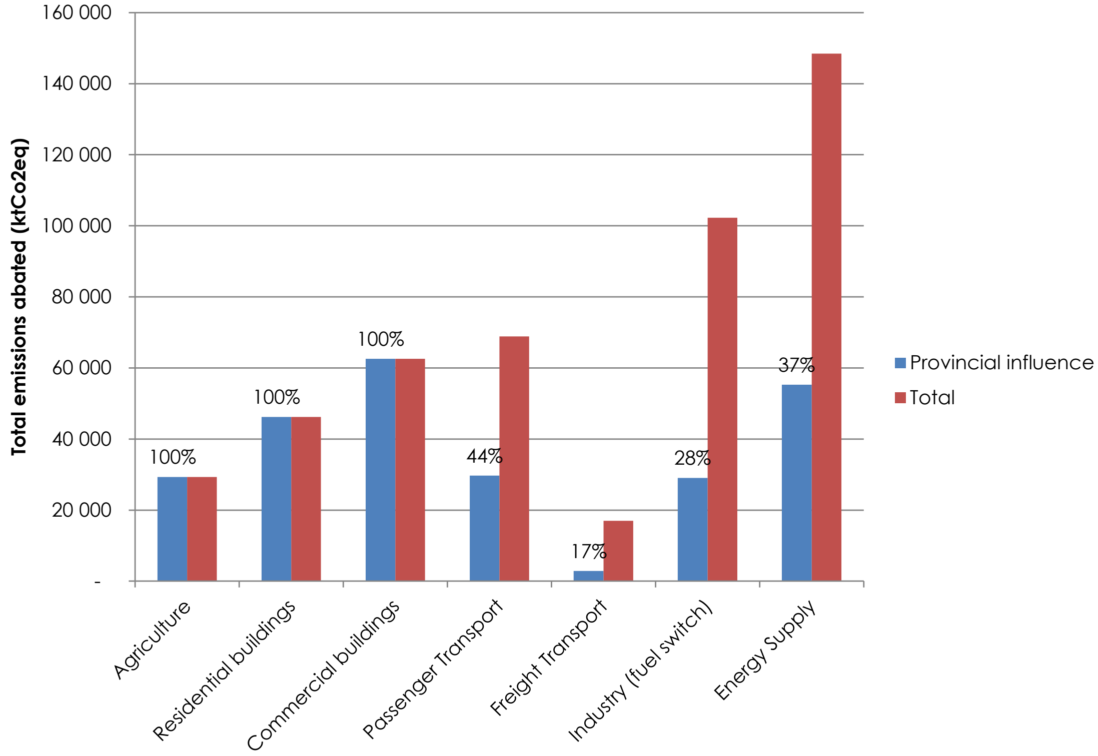

Figure 3: Provincial prioritisation of sector's to influence

CONTENTS

CLICK ON A SECTION TO BE TAKEN DIRECTLY TO THAT PAGE

TABLE OF TABLES

CLICK ON A TABLE TO BE TAKEN DIRECTLY TO THAT PAGE

TABLE OF FIGURES

CLICK ON A FIGURE TO BE TAKEN DIRECTLY TO THAT PAGE

1. INTRODUCTION

In February 2014, the Western Cape Government: Environmental Affairs and Development Planning (WCG: EADP) commissioned PDG to undertake a Climate Change Mitigation Scenario exercise for the Energy sector of the Western Cape.

This study builds on the Province's previous research in the realm of energy and climate change insofar as the development of the energy and emissions database for the Western Cape for 2009 (completed in 2012) and its update for 2012 (completed in 2015). This database was designed to deepen the Province's understanding of key energy and emission issues and management priorities in terms of their sector consumption and geographic distribution. Further, the database served to disaggregate energy and emissions profiles to district and sector levels in the Province.

This study also builds on the earlier national work undertaken by the National Department of Environmental Affairs' Mitigation Potential Analysis (DEA MPA) which Cabinet adopted in July 2014. At its core, the study aligns with the objectives of mitigation in the Province as outlined in the Western Cape Climate Change Response Strategy 2014 in terms of identifying desired sectoral mitigation contributions. This includes identifying those sectors to be targeted in the short term to achieve emission reduction outcomes.

The results of the modelling exercise in this project will be used to identify the interventions that need to be implemented in order to meet the WCG PSG4 Climate Change Work Group targets. These targets are aimed at contributing towards the national and international commitments to reducing greenhouse gas emissions and to direct both energy demand- and supply-side actions that are a priority for the Western Cape.

1.1 Policy context

1.1.1 National

The DEA MPA report adopted by Cabinet in July 2014 sets out potential low carbon pathways for the country between 2010 and 2050. The three core climate change mitigation scenarios modelled under the DEA MPA were:

1. Without Measures (WOM): The reference case projection which assumes no climate change mitigations actions took place between the years 2000 and 2010;
2. With Existing Measures (WEM): Considers the impacts of climate change mitigation actions to date including climate change policies and measures implemented by the year 2010;
3. With Additional Measures (WAM): Considers the impacts of impacts of climate change mitigation actions necessarily implemented in addition to any pre-existing mitigation actions.

The study identified mitigation options in key economic sectors, and included an updated projection of national greenhouse gas (GHG) emissions along with marginal abatement cost curves for key sectors. Using a Multi-Criteria Analysis (MCA) framework which accounts for more than just abatement potential and marginal abatement cost, the study found that the implementation of mitigation potential becomes more challenging as targeted levels of national emissions reduction increase. The implementation of mitigation potential becomes harder as emissions targets increase and measures become increasingly costly, have more negative social and environmental (water, land, air and non-greenhouse gas) impacts and technological limitations are reached.

The report's findings assist the South African government to identify actions, and to set sectoral GHG reduction limits. This process is currently underway with the determination of Desired Emission Reduction Outcomes (DEROs). DEROs are being determined for each significant sector and sub-sector of the economy and include short-, medium- and long-term Carbon Budgets (CBs) for those sectors where CBs are appropriate.

1.1.2 Western Cape

Under the Provincial Strategic Goal 4 (enable a resilient, sustainable, quality and inclusive living environment) the WCG has identified climate change and the need to reduce GHG emissions as a priority programme for the Western Cape. This requires firstly, an assessment of where emissions are occurring – typically referred to as an emissions 'inventory'; secondly, an assessment of what will happen to emissions without any intervention – a 'business as usual projection[1]' and; thirdly, an assessment of what interventions are possible and how much mitigation these measures will achieve. The Terms of Reference (ToR) for this project set out an approach for undertaking the work required for each of these three stages (see the full ToR in Appendix 1).

However, this project is not intended to deal with the full scope of emissions for which the province is responsible. It focuses only on energy related emissions. This was largely a function of the unavailability of data on non-energy related emissions. Therefore there can only be a limited alignment with the work done as part of the national Long Term Mitigation Scenarios (LTMS) and the DEA MPA (described in the previous section). There is a need in future to look at the mitigation measures available to other sources of emissions but this was beyond the scope of this study at the time.

There are a number of provincial studies, strategies and policies in the WCG which have informed the data collated for the modelling exercise and the scenario development in particular. Being the largest energy consuming and economic contributor to growth in the Province, a similar consideration was afforded to the City of Cape Town metropolitan municipality as they have recently identified distinct energy scenarios for the metropolitan area.[2] The main policies include:

- White Paper on a Sustainable Energy Strategy for the Western Cape (2010)
- Energy Scenarios for Cape Town (2011)
- OneCape 2040 (2012)
- Western Cape Green Economy Strategy Framework (2013)
- Western Cape Infrastructure Framework (2013)
- Western Cape Climate Change Response Strategy (2014) and Implementation Framework (2014)

1 Note that the term 'baseline' is typically used in the literature for such a projection. However, in the original ToR the baseline term is used for the current (actually 2012) emissions which is referred to as an 'inventory' in terms of national Department of Environmental Affairs (DEA) terminology.

2 The First Steering Committee meeting also revealed that the City of Cape Town: Environmental Resource Management Department (CoCT: ERMD) are currently updating the city's State of Energy report (and thereby the Cape Town Energy and Climate Action Plan (ECAP)). At the time of writing this report WCG: EADP was arranging for the team to engage with the city to ensure there is alignment between the WC LTMS and the updated CoCT ECAP.

1.2 National and provincial economic and energy profiles

Economic profile of key sectors

The Western Cape economy is dominated by the commerce and public services sector, followed closely by the industrial sectors (see Figure 4: Gross Domestic Product Regional (GDPR) versus GDP: WC versus SA (2011)). With the exception of the mining sector which comprised only 0.15% of the Province's economy in 2011, and commerce and public services (the Province has a larger commercial sector than the country as a whole), the composition of the provincial economy aligns closely to that of the national economy.

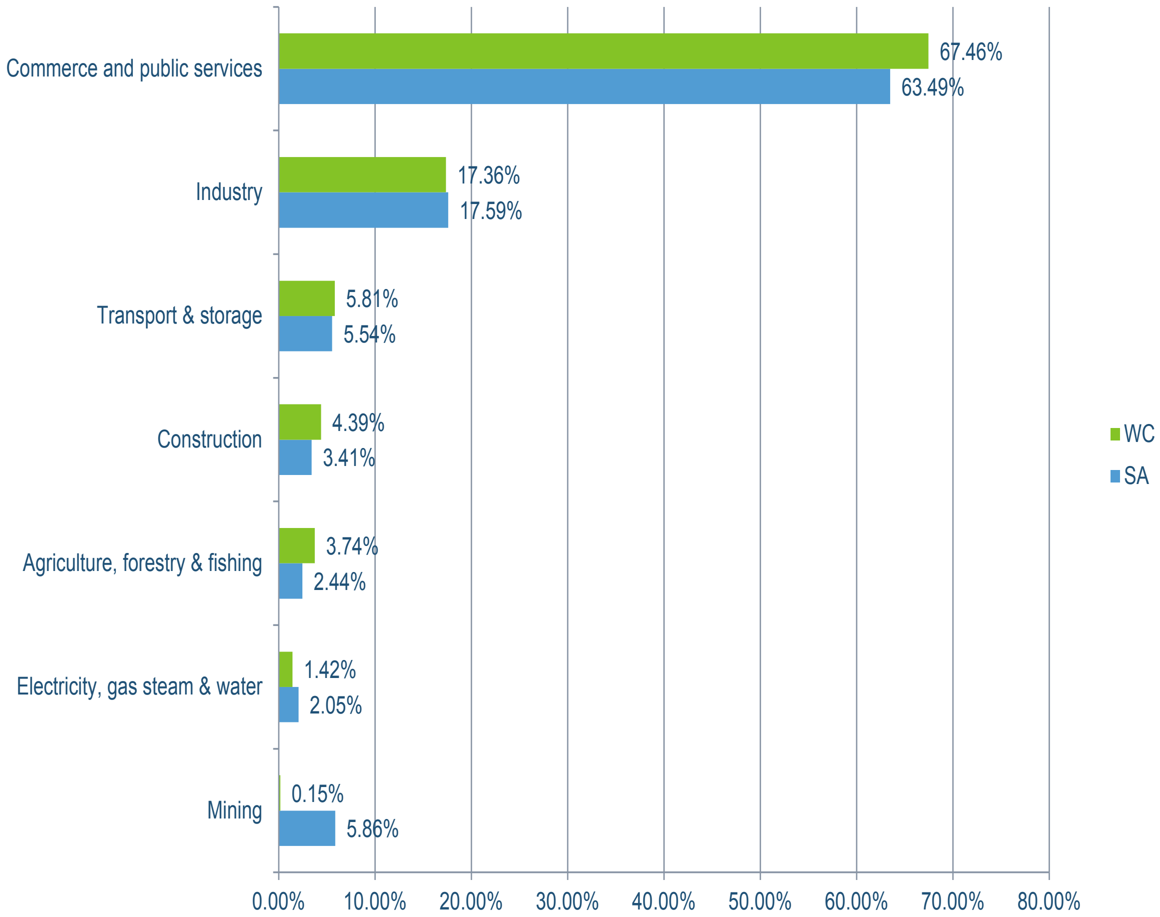

Figure 4: Gross Domestic Product Regional (GDPR) versus GDP: WC versus SA (2011)

Source: Western Cape Provincial Economic Review Outlook (PERO) 2013

The provincial industrial sub-sector contributions show a slightly different trend to the national contributions with a significantly larger proportion in the 'food & beverages' and 'textiles and clothing' sectors (Figure 5: Industrial sub-sector contributions to GDP (SA) and GDPR (WC): 2011). On the other hand the province has significantly smaller 'chemicals and petrochemicals', 'transport equipment' and 'basic iron and steel' sectors when compared to the national average.

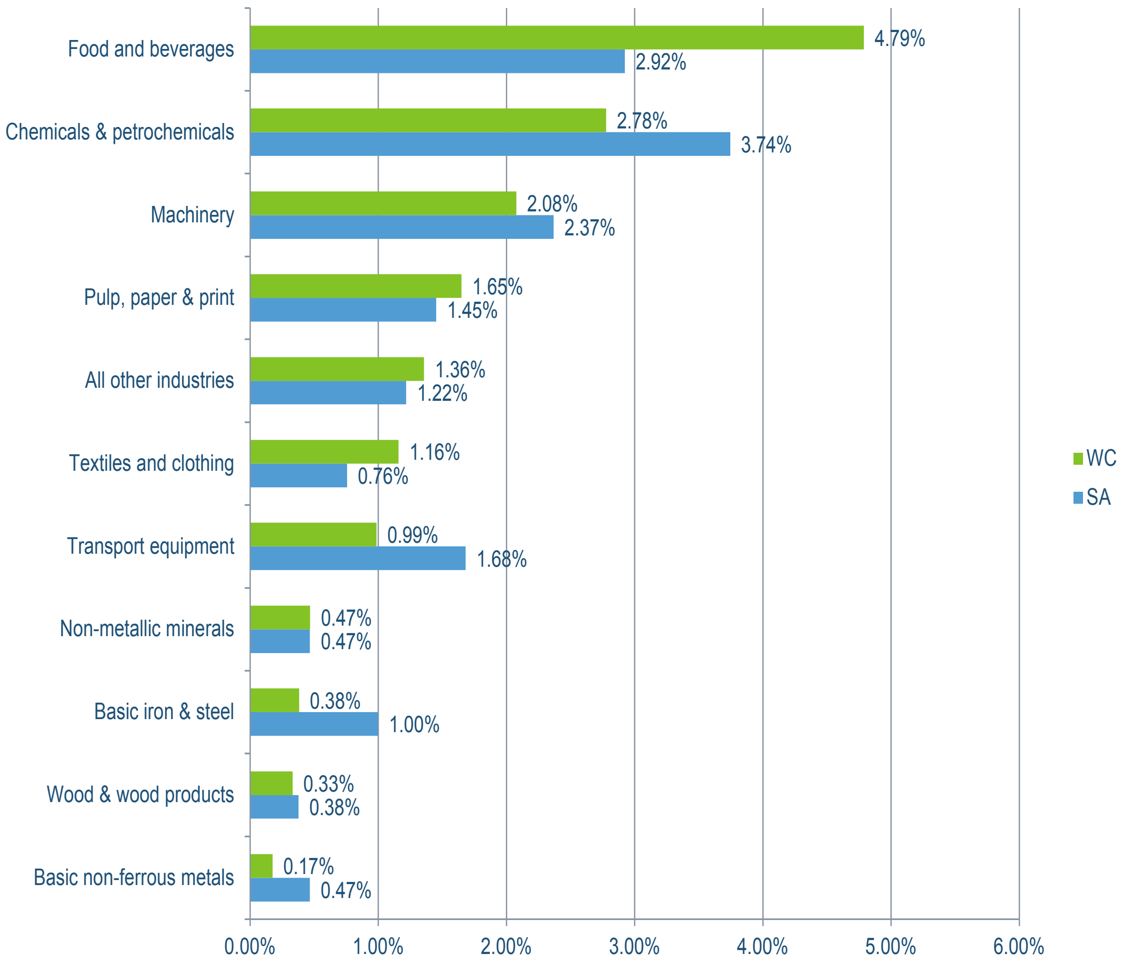

Figure 5: Industrial sub-sector contributions to GDP (SA) and GDPR (WC): 2011

Source: Western Cape Provincial Economic Review Outlook (PERO) 2013

2. METHODOLOGY

The timing of this work for Western Cape Government: Environmental Affairs and Development Planning (WCG: EADP) was fortuitous as there was an opportunity to use the results from the national DEA MPA study. The DEA MPA used the national 2010 emissions inventory as a starting point, made a baseline (or reference case) projection and dealt with emissions from all the major sectors of the economy. In addition, the DEA MPA took cognisance of key national policies including, but not limited to National Climate Change Response Policy (2011) and Integrated Resource Plan for Electricity (2010).

With regard to interventions – referred to in the DEA MPA as 'mitigation options' – the MPA study identified 172 measures of which approximately 75% are energy related. It included a projection in which with all identified mitigation measures were implemented[3].

The benefit of using the DEA MPA for this study is the ability to use assumptions made by, and agreed to, a wide stakeholder group to align with national climate change mitigation priorities. While the datasets of the DEA MPA could not be employed for this study due to concerns of the confidentiality of certain industries operational in the province, effort was made to align the selection of energy-related mitigation measures and the related emissions trajectory, to the DEA MPA.

3 For clarification, this is not directly comparable to the 2007 LTMS. The MPA was based on only on measures which use existing technology, and are currently considered to be feasible by the relevant sectors.

The methodology underpinning this study comprised five key phases:

1. Agreement on energy-related climate change mitigation measures;
2. Development of energy demand- and supply-side models for the Western Cape;
3. Selection of energy reduction scenarios for the emission trajectory of the Western Cape;
4. Projection of the energy consumption and emissions profile on implementation of the selected energy-related climate change mitigation measures across sectors in the Western Cape;
5. Comparison of the selected scenarios and the prioritisation of mitigation measures for implementation in the Western Cape.

Three stakeholder workshops were held throughout the study with key provincial and local government stakeholders as well as national government (where appropriate), parastatals and other key stakeholders. This was complemented with face-to-face, telephonic and/or electronic engagements with sector experts through the duration of the study. Each workshop had a different objective but was designed to gather expert input, gather key baseline data and to stimulate buy-in to the analysis. The first workshop focused on the selection of key sectors for analysis and the related mitigation measures. The second workshop provided a platform for the team to present the analysis outputs of the study. Based on feedback obtained through the second workshop, the team revised and updated the analysis and presented the revised analysis outputs at the final, third, workshop.

With regard to prioritisation of mitigation measures, this study mirrored the DEA MPA in its use of a Multi-Criteria Analysis (MCA) for all measures in all sectors (agriculture, residential and commercial buildings, energy supply, industry and transport) in the Western Cape. The MCA methodology is described in detail in Appendix 2 but involves the use of a relative weighting of quantitative and qualitative criteria including cost, economic, social, non-greenhouse gas environmental impacts and implementability. While it was not possible to undertake the full MCA for the Western Cape projects within the budget allocated for this project, the results of the national DEA MPA allowed for the prioritisation to be made based on the national analysis and for impacts such as employment to be assessed at a high level. These results can however be reviewed and adjusted to match the Western Cape circumstances more closely should the Province wish to do so.

2.1 Data sources

The data used to analyse and forecast the mitigation potential of the energy sectors in the Province was collected through a desktop literature review (of, in particular, government reports, infrastructure plans and strategies, parastatal plans and annual reports), interviews with key sectoral stakeholders as well as through garnering feedback from three stakeholder workshops during the study.

A number of key data sources were referred to in the development of the energy profiles of the selected demand and supply sectors. At a national level, the main points of reference were the Department of Energy (DoE) national energy balance (2006)[4] and the Energy Research Centre's South African TIMES Model (SATIM) energy balance (2006).

At a provincial scale, the main data source was the 2012 Western Cape Energy and Emissions Database (WCEED)[5]. Given that this data was consolidated while this study was underway, it was timely to use it as a benchmark against which the consumption as modelled through this study could be compared. However, at the time of its use as a benchmark, the database had yet to disaggregate

4 A decision was taken to use the 2006 DoE energy balance figures as there was a discernible trend between the 2006 to 2009 data. In contrast, from 2010 onwards, serious deviations across the years were observed and yet not understood as metadata on the balance is limited. **Note:** These errors appear to have been corrected in the latest updates of the 2010 SOE, but too late for use in this analysis.)

5 The Western Cape Energy and Emissions Database (WCEED) was completed in 2015, but is based on information for 2012 and is therefore referred to as the 2012 Western Cape Energy and Emissions Database

liquid fuels information across the range of sectoral energy consumers. Rather, it was fully allocated to the transport sector and thus it was not possible to compare the sectoral allocation of liquid fuels.

To complement the WCEED and understand the relative size of the sectors in the provincial economy, the Western Cape Government: Provincial Treasury's Provincial Economic Review & Outlook (PERO) 2013 was referred to. In particular, where information on energy demand by industrial sub-sectors in the province was absent, the team made an approximation of such sectors' energy demand in relation to its share of the province's economy. While perhaps a bold estimation, it was the closest approximation the team were able to make in the absence of province-specific energy consumption information on these sub-sectors.

2.2 Scenarios

At the second stakeholder workshop the scenarios selected were:

1. Reference case: Representing the continuation of status quo energy consumption and emissions;

2. All Possible Measures: Representing the application of the most feasible set of mitigation measures in the energy sector of the Western Cape6;

3. All Possible Measures with fuel switching: Representing the application of the most feasible set of mitigation measures in the energy sector of the Western Cape as well as the transition away from coal-generated electricity to natural gas.

Based on the All Possible Measures with fuel switching scenario results, a provincial prioritisation of mitigation measures was then done to highlight those which the provincial and local government of the Western Cape has the greatest potential to influence and/or implement.

2.3 Sector and mitigation measure identification

At the project's first stakeholder workshop, the team made a proposal as to the most significant energy consuming sectors in the Western Cape. The demand-side sectors were selected taking cognisance of the energy-related sectors assessed in the DEA MPA. Based on inputs garnered from stakeholders at the workshop including acknowledgement of the energy-related sectors making notable contributions to Gross Regional Product in the Province, the final selection of demand-side sectors included:

- Agriculture
- Buildings:
  - Residential
  - Commercial
- Industry:
  - Chemicals
  - Iron & Steel
  - Non-metallic minerals (Brick & Clay, Cement and Lime)
  - Petrochemicals
  - Pulp & Paper
  - Remaining / other industry
- Transport
  - Passenger
  - Freight

6 Note should be taken here that while the APM scenario includes all feasible mitigation measures in the energy sector of the Province, it does not comprise the full spectrum of mitigation measures which can be applied. The reason for this was that the focus was on identifying mitigation measures which the Province could implement in the short- to medium-term.

The supply-side model aligned closely to the WCIF and included:

- Electricity
- Refined liquid fuels & liquefied petroleum gas

This workshop was also the platform for discussion of the proposed mitigation measures for each of the selected sectors as discussed next.

2.3.1 Mitigation measures by sector

The list of mitigation options applied as part of the DEA MPA was revised through stakeholder inputs at the first stakeholder workshop to derive a final list of 100 energy related mitigation measures for the Province. The audience at the workshop included stakeholders from various provincial Western Cape departments, local municipality, parastatels, industrial associations as well as researchers in the energy and climate change sphere.

Having a mix of stakeholders present was valuable for reflection on both the relevance of the sectoral analysis to provincial priorities and allowed for coherence with research already underway in the province or nationally in South Africa.

In each case, a set of measures were modelled per sector to project energy demand, emissions abatement potential and cost projections.

The following section provides a brief overview of the key mitigation measures by sector. More details about the measures and the modelling methodology are available in Appendix 4.

2.3.2 Agriculture

The principal demand side measures identified through stakeholder engagement and literature review includes:

- Conservation agriculture practices, with the associated reduction in diesel costs through reduced tillage.
- Reduced electricity use through higher efficiency irrigation management, reduced water use, and reduced associated pumping costs.
- Improved energy efficiency with the installation of variable speed drives on irrigation pumps.
- Improved energy efficiency with the installation of variable speed motors, particularly with regard to post harvest processing and cooling.

Three of the measures result in reduced electricity demand, while the other results in substantial diesel reductions.

2.3.3 Buildings

The buildings sector was reviewed in terms of its two component sub-sectors, residential and commercial buildings.[7]

7 While public sector buildings are included under the commercial buildings sector, energy consumption in the provision of public utilities such as street lighting and waste water treatment has not been included. These activities were not identified in the initial DEA MPA set of mitigation measures, which formed the basis for this analysis.

2.3.3.1 Residential

In line with the DEA MPA and as adapted by stakeholders at the study's first workshop, mitigation measures for the residential buildings sub-sector consisted of:

- Energy efficient appliances;
- Geyser Efficiency;
- Improved Insulation - New Buildings;
- Improved Insulation - Existing Buildings;
- Efficient Lighting – Compact Fluorescent lamps (CFLs);
- Efficient Lighting – Light emitting diode (LEDs);
- Solar water heating;
- Liquefied Petroleum Gas (LPG) for cooking;
- Passive building/improved thermal design - New Buildings;
- Behavioural changes;
- Embedded generation: Photovoltaic (PV).

2.3.3.2 Commercial and public buildings

The Commercial buildings sector measures, which include public sector buildings, are driven by estimates of total building floor area in the Province. In line with the DEA MPA and as adapted by stakeholders at the study's first workshop, mitigation measures for this buildings sub-sector consisted of:

- Solar water heaters;
- Efficient Lighting;
- Heating, ventilation and air conditioning (HVAC) improvements (including heat pumps);
- Energy efficient appliances;
- Passive building/improved thermal design - New Buildings;
- Coal to gas (hospitals);
- Embedded generation: PV;
- Lift efficiency;
- Behavioural changes.

2.3.4 Industry

The industrial sector comprised 7 main sub-sectors. These 7 sub-sectors were:

1. Brick and Clay;
2. Cement;
3. Iron and Steel;
4. Lime;
5. Petrochemicals;
6. Pulp and Paper;
7. All remaining industrial sub-sector (which encompasses all other industrial sub-sectors not covered in the aforementioned sub-sectors).

A set of common electricity efficiency measures were assessed for each of these sub-sectors including:

- Energy efficient boiler systems and kilns;
- Energy monitoring and management system;
- Improved process control;
- Improved electric motor system controls and Variable Speed Drives (VSDs);
- Energy-efficient utility systems;
- Improved heat exchanger efficiencies;

In addition to these general energy efficiency measures, a number of sub-sector specific measures were assessed including those listed in Table 2: Industrial sub-sector mitigation measures.

Table 2: Industrial sub-sector mitigation measures

Industrial sub-sector	#	Mitigation measure
Brick & Clay	1	Replace kilns with Vertical Stacked Brick Kilns (VSBK)
Cement	1	Improved process control
Cement	2	Reduction of clinker content of cement products
Cement	3	Waste heat recovery from kilns and coolers/cogeneration
Cement	4	Utilise waste material as fuel
Cement	5	Geopolymer cement production
Chemicals	1	Revamp: increase capacity and energy efficiency
Iron & Steel	1	Furnace / Heating General efficiency measures
Lime	1	Installation of shaft preheaters
Lime	2	Replace rotary kilns with vertical kilns or Parallel Flow Regenerative Kilns (PFRK)
Lime	3	Use alternative fuels including waste and biomass
Petrochemicals	1	Improve steam generating boiler efficiency
Petrochemicals	2	Improve process heater efficiency
Petrochemicals	3	Waste heat recovery and utilization
Petrochemicals	4	Efficient energy production (Combined Cycle Gas Turbine (CCGT) and Combined Heat & Power (CHP))
Petrochemicals	5	Waste heat boiler and expander applied to flue gas from the FCC regenerator
Pulp & Paper	1	Convert fuel from coal to biomass/residual wood waste
Pulp & Paper	2	Application of Co-generation of Heat and Power (CHP)
Pulp & Paper	3	Energy recovery system

An obvious exclusion from the industrial list of mitigation measures is Carbon Capture and Storage (CCS), which expert industrial stakeholders engaged through this study's workshops felt, was irrelevant as its economic viability or feasibility in the province is yet to be determined, particularly considering the time-frames for this assessment.

An additional mitigation measure reviewed in each industrial sub-sector, excluding Petrochemicals[8] was fuel switching to capture the potential shift from coal-generated to natural gas generated electricity. This aligns with the province's 'Green Economy Strategy Framework' which aims to position the Western Cape as the leading green economic hub in Africa. In the strategy, the introduction of natural gas into the energy mix of the province is seen to be the 'game-changer' needed for the province to significantly lower its carbon footprint by shifting away from the dominant coal-based power generation.

8 The reason fuel switching was not assessed in the Petrochemicals sub-sector was because an alternative fuel switch measure was applied in the form of efficient energy production (CCGT and CHP).

2.3.5 Transport

The transport sector was dealt with as two separate demand drivers: freight energy demand based on ton kilometres, while passenger energy demand was based on vehicle kilometres, adjusted for passenger occupancy and modal share by mode.

2.3.5.1 Freight

The freight transport measures consisted of three broad types of measures:

- **Modal shift from road to rail freight**. This entails a shift from petroleum fuelled road transport, to more electricity-intensive rail freight. The potential of this measure depends greatly on the changing emissions factor for the national electricity supply;
- A **road based engine efficiency** measure consisting of a freight vehicle mix in 2040 of 80% more efficient diesel engines, 10% natural gas powered vehicles and 10% diesel hybrid electric vehicles, and;
- A **rail-based engine efficiency** measure whereby the freight engines will become 15% more efficient than they are now by 2040.

2.3.5.2 Passenger

The primary mitigation measures assessed in the passenger transport sector include:

- **Change of engine type** from conventional internal combustion engines (ICE) to a suite of more energy efficient vehicle types. The engine types considered include more efficient ICE, hybrid electric, plug-in electric hybrid, electric, fuel cell, and CNG powered vehicles. This base scenario assumes a constant modal share.
- **Change in all day modal split** from the current split to a much more aggressive shift from private to public transport modes. This scenario used the reduced demand after change of energy type, to ensure that reductions were not over-estimated or double-counted. It therefore keeps all other assumptions constant to the previous scenario, and the only factor changing is passenger modal share.
- **Use of most efficient Electric Multiple Unit (EMU) rail stock** (50% more efficient than current old stock), rather than replacement with the current new EMUs (which are 20% more efficient than current stock).
- **Upgrading the voltage of metrorail lines by 2030**, which is expected to result in a 10% reduction in electricity usage.

2.4 Modelling

The modelling framework applied for this study drew lessons from that used under the Western Cape Infrastructure Framework (WCIF) and the DEA MPA. The WCIF aimed to align all infrastructure to the province's strategic agenda and vision. A number of infrastructure transitions were proposed in the WCIF within development agendas including a 'business as usual' (BAU) agenda, which assumes that demand trends will remain constant and that infrastructure will continue to be provided as in the past; and an 'optimised' agenda that assumes all the required transitions will be implemented to achieve the 2040 vision (Western Cape Government: Department of Transport and Public Works, 2013b). These agendas and key transitions informed the selection of electricity supply side mitigation measures in this study.

The key transitions identified for the energy sector of the Province were:

1. Introduce natural gas processing and transport infrastructure to make gas available as a transition fuel;
2. Promote the development of renewable energy plants in the province and associated manufacturing capability;
3. Shift transport patterns to reduce reliance on liquid fuels.

There are a range of energy models available including the South African TIMES model and Sustainable National Accessible Power Planning (SNAPP) tool both developed by the Energy Research Centre at UCT and the LEAP (Long Range Energy Alternatives Planning) system. However, given the Province's request for a modelling framework that is user friendly, easy to update and does not require annual license fees, PDG developed the demand- and supply-side models in Microsoft Excel. The primary model is based on an energy projection model for the Western Cape and applied to the WCIF which was completed in early 2013. This model also aligns with the 2012 Western Cape Energy Consumption and Emissions Database (WCEED), being disaggregated by city and district, and including costing.

The base year of these models was 2012 (to align with the most recently available WCEED) with the end point of analysis being 2040 (to align with the OneCape2040 vision). A diagrammatic representation of the modelling exercise is provided in Figure 6: Structure of energy mitigation modelling.

The models formulated for the study included a set of demand-side models for each sector reflecting on the drivers of energy demand, emission abatement potential and associated costs and an overarching Main Overview Model (MOM). The MOM represents the core of the modelling framework as it includes a set of common input parameters, energy supply profile as well as an interrelationship with the demand models which collates all energy demand and emissions abatement. The MOM also provides the means for running various climate change mitigation scenarios for the energy sector as it comprises a scenario setting module, the full set of selected mitigation measures and the corresponding fuel mix which these would demand under the various scenarios. Using the scenario setting module and a Multi-Criteria Analysis the MOM provides a platform to trial run various scenarios and various magnitudes to the model's drivers (discussed next).

The value of these models is that they:

- Deal with fuel and electricity;
- Provide for alternative demand side projections by sector;
- Balance supply and demand;
- Have demand disaggregated into the City of Cape Town, and the remaining district municipalities.

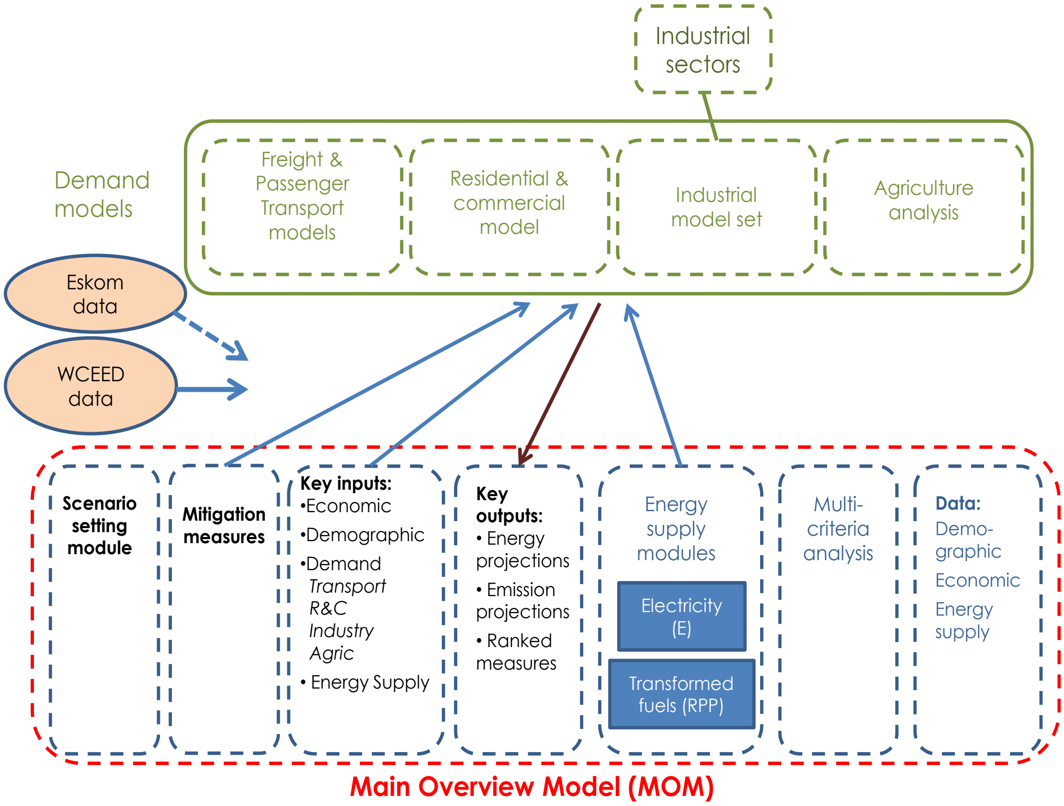

Figure 6: Structure of energy mitigation modelling

Source: Own model derivation

2.4.1 Key model assumptions and drivers

The energy model developed for this study includes a set of key model drivers, namely:

- Time-frame of analysis: 2012-2040;
- Discount rate: assumed to be 11%[9];
- Population and household growth;
- Number of households;
- Gross Domestic Product (Regional);
- Electricity and other fuel prices;
- Emissions conversion factors.

The key model drivers can be altered according to different scenarios to assess the impact on the sectoral energy demand and supply models.

2.4.2 Primary drivers of energy demand

Energy demand is driven by two key variables in the MOM: demographic growth and economic growth. These two variables were fed into all the demand-side models.

9 There is much debate about the correct discount rate, with (generally) a much lower discount rate of around 3% applicable if the analysis is focused on social benefit. However, for the current analysis the stakeholders concerned preferred to use a discount rate which reflected private sector needs.

Demographic trends

Using Census 2011 as a baseline, the WCIF found that although in-migration to the Western Cape is the second highest in the country, the average population growth declined marginally, from 2.7% between 1996 and 2001, to 2.6% between 2001 and 2011 as shown in Figure 7: Population and household projection envelopes (Western Cape Government: Department of Transport and Public Works, 2013: 36). While this declining growth is expected to continue, a simultaneous phenomenon is the reduction in household size, which declined from 3.7 to 3.4 people within a decade (2001–2011).

In terms of the impact on energy (and particularly electricity) demand which is often driven primarily by household creation rather than population size, WCIF predicts a significant increase in demand. The modelling framework of this study allows for a high or low growth option for population and households in the province to observe the potential differential impacts on energy demand from a change in population and household size.

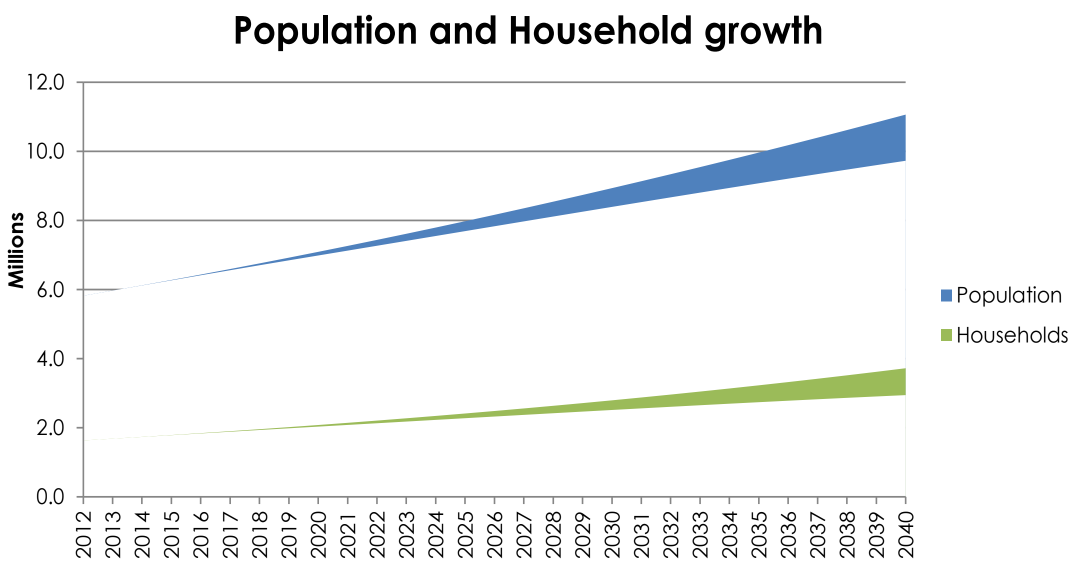

Figure 7: Population and household projection envelopes

Source: Western Cape Government: Department of Transport and Public Works, 2013

Economic growth

The economic growth used during the modelling process was informed by the WCIF, which observed that economic growth, affects almost all types of infrastructure demand (Western Cape Government: Department of Transport and Public Works, 2013: 37). In this context, the WCIF identifies two key dimensions for consideration. The first is that the global economy imposes exogenous impacts on South Africa and the Western Cape. The second is the impact of strategic policy and investment decisions to assist or impede certain economic sectors.

In line with WCIF, the economic growth projections for the models were built up using the current sectoral make-up and growth rates of the economies in each district. Then the growth in each sector was projected forward in three strategic scenarios for an economic baseline, which is based on Bureau of Economic Research projections up to 2017. On top of this baseline the impact of the global economy was assumed to be either stable (no external impact), positive (2% above baseline) or negative (2% below baseline). The net impact of these scenarios and assumption is an envelope of economic growth as shown in Figure 8: Envelope of low economic growth projections.

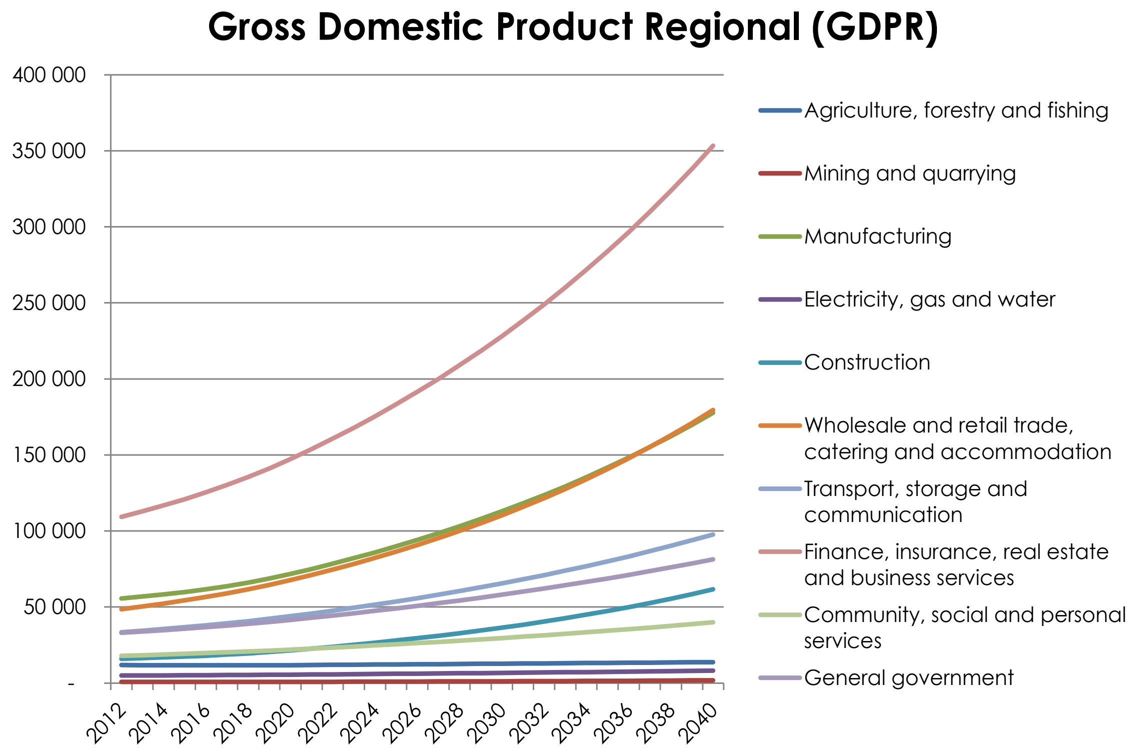

Figure 8: Envelope of low economic growth projections

Source: Based on Bureau of Economic Research projections

In the absence of better data, the baseline scenario has projected economic growth to be stable at around 4.2% from 2018 onwards which was the assumption made in WCIF informed by economic growth projections by the Bureau of Economic Research. In the modelling framework however, growth of up to 7.5% is possible (and necessary to meet the New Growth Path target of 7% average over 10 years) (Western Cape Government: Department of Transport and Public Works, 2013).

2.5 Sector energy models

In addition to the overall energy model, individual sector based models were also developed. Some were adapted from the DEA MPA, while others were completely new.

Individual models were developed for the buildings, industry, passenger transport, freight transport and agriculture. Each of the models were structured differently, with a number of key assumptions, main model drivers as well as core baseline energy balance information as derived from key information and other data resources.

The methodology behind each of the models is detailed in Appendix 4.

2.6 Multi Criteria Analysis Framework

The Multi Criteria Decision Analysis (MCA) approach used in the DEA MPA was mirrored for this study to assess the impact of all abatement opportunities identified, taking a range of criteria into consideration. Further, the results from the MCA model were used to derive the emission reduction scenarios.

MCA is a technique that explicitly considers multiple, often competing, criteria in a decision-making environment. The key benefits of MCA are that it provides a proper structure for a decision-making process, and that it makes the manner in which the multiple criteria are evaluated explicit. These criteria comprise quantitative and qualitative indicators.

The criterion included:

- Cost:
  - Net Present Value of life cycle cost per unit of CO_2eq mitigated.
- Economic impact:
  - Increase in Gross Value Added (GVA) per unit of CO_2eq mitigated.
- Social impact:
  - Job creation – total jobs created per unit of CO2eq mitigated.
  - Proportion of jobs to unskilled workers.
  - Non-monetary social impact.
- Non-greenhouse gas environmental impact:
  - Impact on water environment.
  - Impact on land.
  - Solid and hazardous waste impact.
- Implementability:
  - Technical and Institutional.

The quantitative criteria (cost, economic impact, job creation and proportion of unskilled worker jobs) were numerically calculated through the concomitant demand models. The qualitative, categorical criteria mirrored the values applied in the DEA MPA and where new mitigation measures were introduced for this study, an informed qualitative scoring of these criteria was made. Figure 9: Multi-Criteria Analysis criteria and sub-criteria displays the full set of criteria. The MCA methodology, as applied in the DEA MPA, is discussed in detail in Appendix 2.

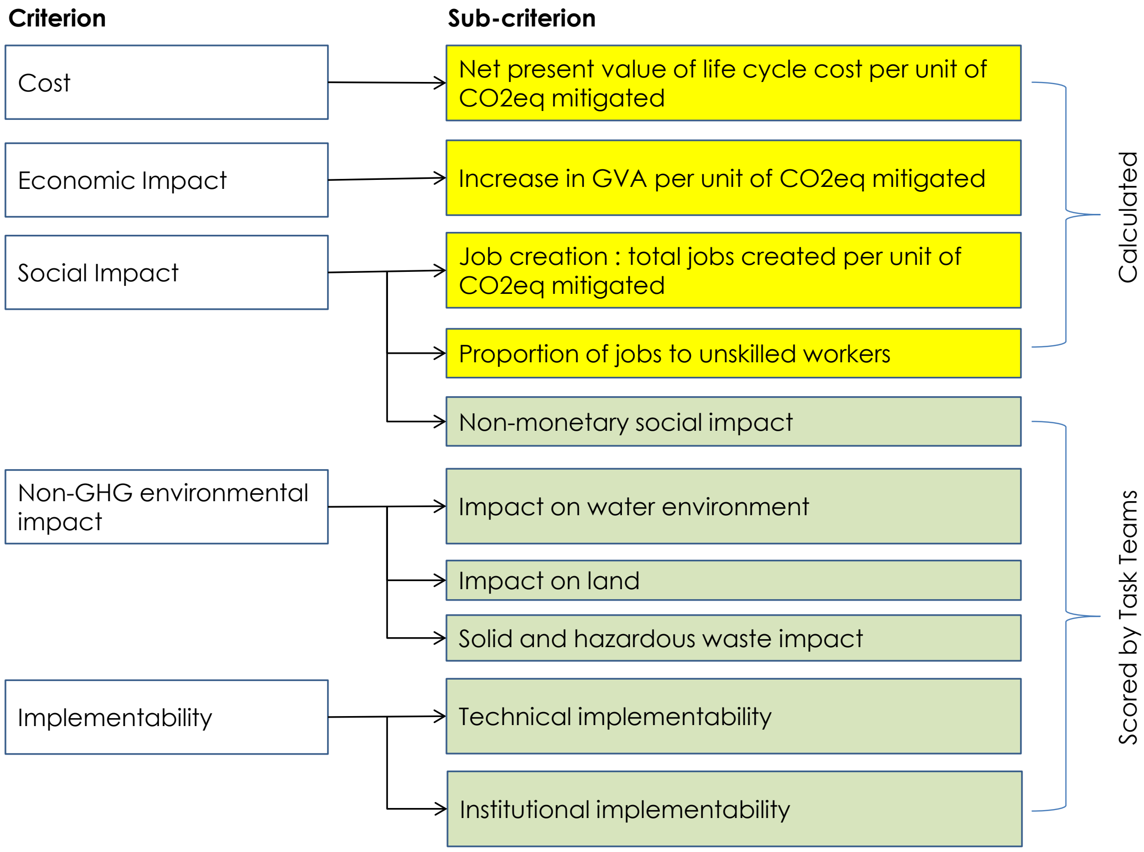

Figure 9: Multi-Criteria Analysis criteria and sub-criteria

Source: Department of Environmental Affairs Mitigation Potential Analysis (2014)

Based on these criteria, the MCA tool provides a scoring, weighting and ranking of the mitigation measures which identifies a classification of the measures to assist in their prioritisation. Measures which for example appear at the top end of the ranking reflect those which will necessarily happen, whereas the lowest lying measures may not be implemented. This ranking is also a function of the scenario under review.

3. ENERGY AND EMISSIONS PROJECTIONS BY SCENARIO

The scenarios modelled were:

1. Reference case: Representing the continuation of status quo energy consumption and emissions;
2. All Possible Measures: Representing the application of the most feasible set of mitigation measures in the energy sector of the Western Cape10;
3. All Possible Measures with fuel switching: Representing the application of the most feasible set of mitigation measures in the energy sector of the Western Cape as well as the transition away from coal-generated electricity to natural gas.

Based on the All Possible Measures with fuel switching scenario results, a provincial prioritisation of mitigation measures was then done to highlight those which the provincial and local government of the Western Cape has the greatest potential to influence and/or implement.

The high-level results for each scenario are described in the following sections.

3.1 Baseline energy balance

The baseline energy source mix used in this study is shown in Table 3: Baseline energy balance. This balance was developed based on the 2012 WCEED as well as data and information gathered through the desktop literature review and stakeholder engagements with sector experts. Natural gas in the primary energy source mix is subject to debate as there are currently no definite plans for its extended rollout in the short-term.[11] While the use of locally derived shale gas remains controversial, the import of liquefied natural gas (LNG) is increasingly seen as inevitable. As in the WCIF (2013), natural gas is included as a 'transitional' source pending the evolution of renewable energy generation technology.

10 Note should be taken here that while the APM scenario includes all feasible mitigation measures in the energy sector of the Province, it does not comprise the full spectrum of mitigation measures which can be applied. The reason for this was that the focus was on identifying mitigation measures which the Province could implement in the short- to medium-term.

11 WCG: Department of Economic Development and Tourism (WCG: DEDAT) is investing a lot of effort on this as there is potential for energy price stability through the rollout of natural gas. Investigations are underway on the various landing options in the province (onshore/offshore) for LNG imports and the province is trying to develop a business plan for the importation of LNG.

Table 3: Baseline energy balance[12]

Terajoules (TJ)	Electricity	Refined petroleum fuels liquid	Natural gas	Other fuels	Total
Construction & mining	700	4470	-	-	5170
Agriculture	7 053	15 919	-	256	23 228
Industry	25 658	10 809	2 098	70 446	109 012
Residential	25 022	3 688	312	5 005	34 026
Commercial	9 889	3 378	7	5 620	18 894
Transport	779	96 545	-	-	97 324
Passenger	-	58 939	-	610	59 550
Freight	-	23 501	-	168	23 670
Aviation	-	14 105	-	-	105
Total	**69 101**	**134 808**	**2 417**	**81 326**	**287 653**

Source: Own analysis (modelled energy balance, based on 2012 WCEED, SATIM and individual sector analysis)

3.2 Reference case

3.2.1 Energy and emissions projections by energy sector

Under the Reference case scenario the energy demand projection for the Western Cape assumes that there will be a continued increase in energy demand to an aggregate energy consumption level of 532,862 Terajoules, with an average growth rate of 2.5% per annum (Figure 10: Reference case: energy by sector (in TJ)). Much of this demand is expected to be dominated by the industrial sector (39%) with the passenger transport sector following it (23%) as well as the residential sector (13%). The freight (11%), agriculture and commercial sectors (6% and 7% respectively) comprise relatively smaller components of the energy demand balance.

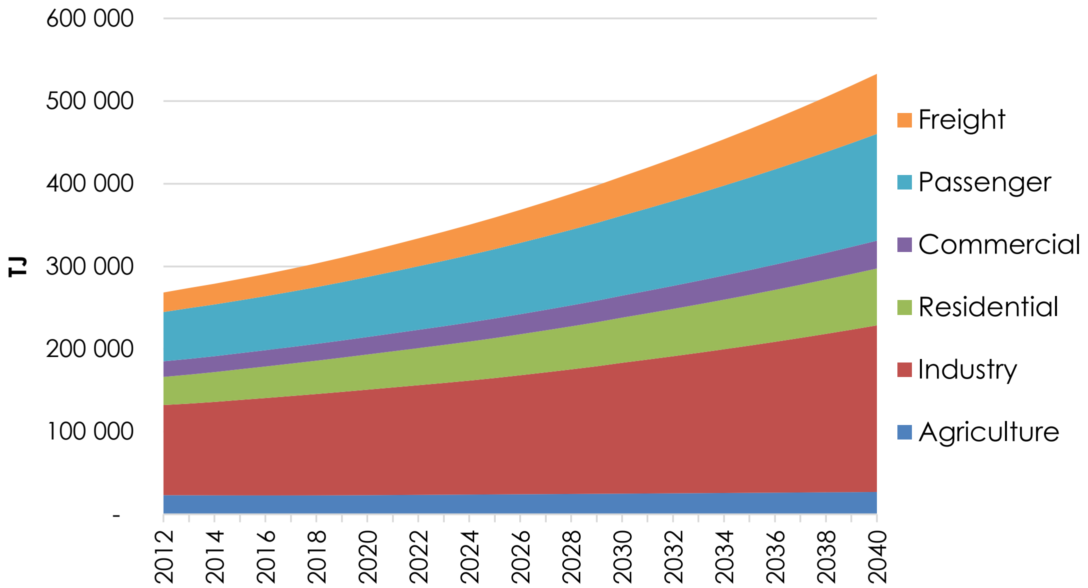

Figure 10: Reference case: energy by sector (in TJ)

12 Note that this energy balance excludes marine transport.

Under the reference case the projected greenhouse gas emissions[13] are dominated by the industrial sector (42%), followed by residential (22%) and passenger transport (14%) sector (Figure 11: Reference case: emissions by sector (in ktCO2eq)). The proportion of emissions from the freight sector (7%) is slightly smaller than that of its energy demand share (11%) and similarly for the agricultural (7%) and commercial (8%) sectors which show only a minor difference from their demand proportions of 6% and 7%, respectively. Overall, emissions under the reference case are predicted to reach up to 64 754 ktCO_2eq by 2040, increasing at an average of 2.3% per annum.

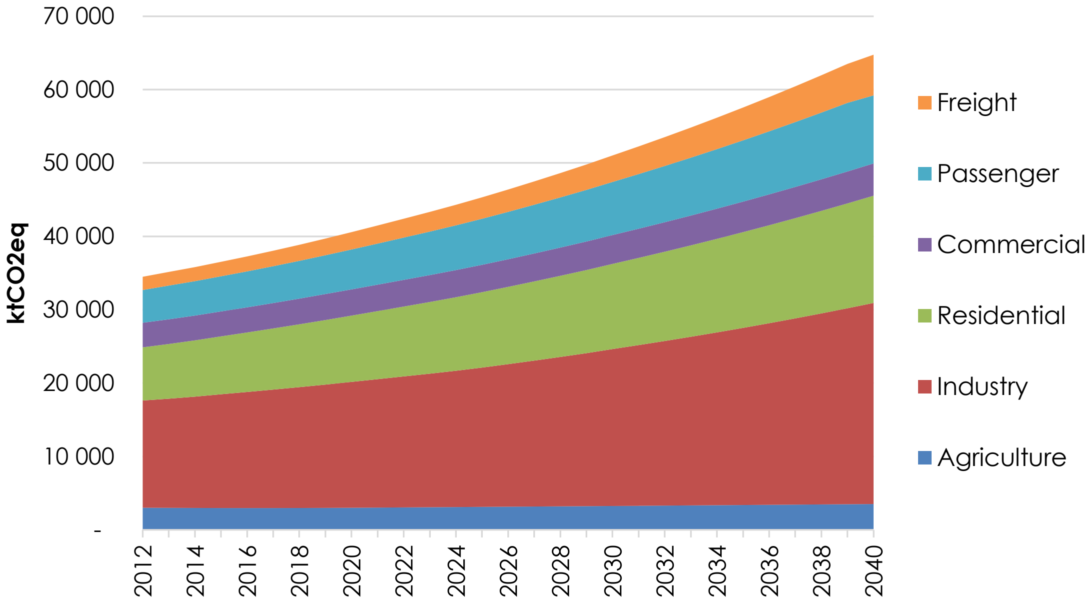

Figure 11: Reference case: emissions by sector (in ktCO_2eq)

3.2.2 Energy and emissions projections by energy source

Figure 12: Reference case: energy by source (in TJ) shows that the fuel mix under the reference case is anticipated to include a blend of electricity (26%), natural gas (1%), refined petroleum fuels (43%) and other fuels (31%) by 2040. Other fuels include coal, gas and residual fuels. In terms of related emissions, Figure 13: Reference case: emissions by source (in ktCO2eq) shows that emissions from such a fuel mix would be led by electricity emissions (48%), followed by those from refined petroleum fuels (26%) and other fuels (25%). Emissions from natural gas in contrast are expected to be negligible (1%).

13 The greenhouse gas emissions conversion factors used in this study were adapted from those used in the Western Cape Energy and Emissions Database (2009) and are provided in Appendix 3. Note that the electricity emissions conversion factor was assumed to remain constant throughout the time-frame of analysis in the Reference Case. In contrast, under the APM scenarios, the electricity emission conversion factor is expected to decline over the period of analysis as a shift is made to a green energy supply mix. (In the case of passenger vehicles, declining emissions due to technological improvements is captured through underlying vehicle efficiencies which change over time, while using a constant emission factor for the fuel itself.)

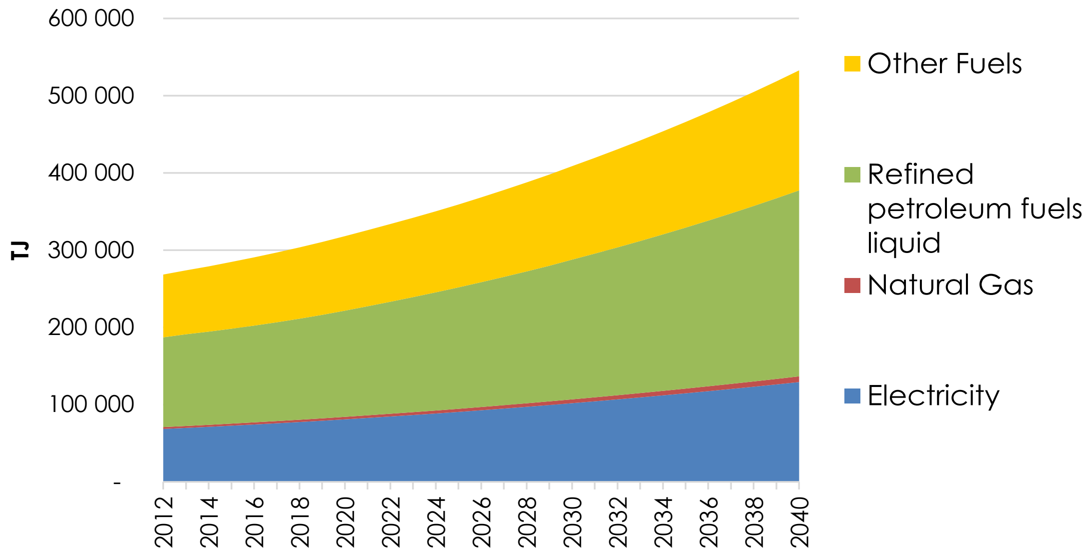

Figure 12: Reference case: energy by source (in TJ)

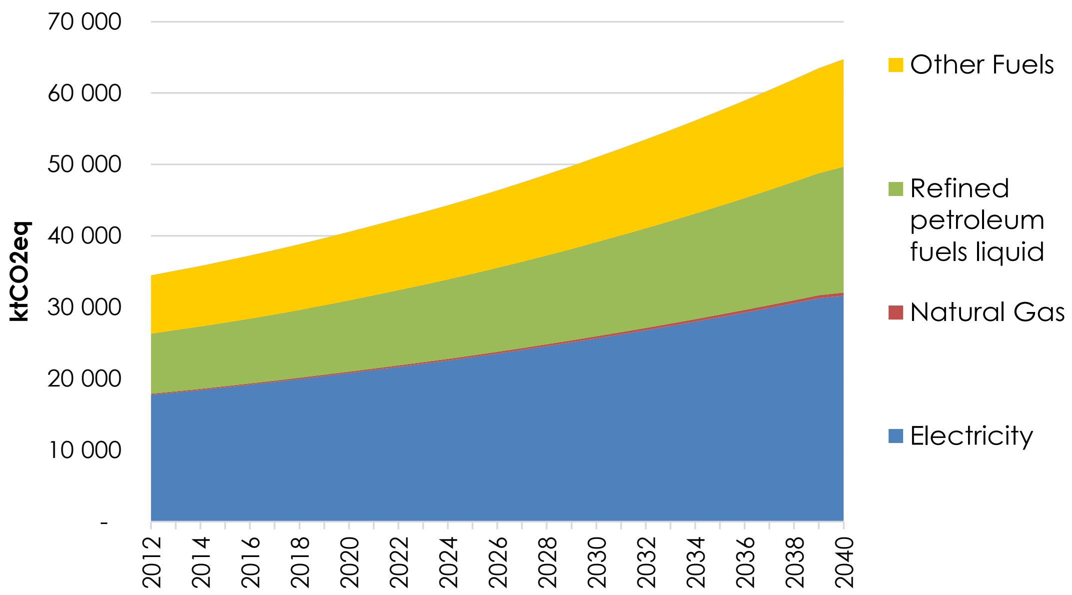

Figure 13: Reference case: emissions by source (in ktCO2eq)

3.3 All possible measures scenario

3.3.1 Energy and emissions projections by sector

The All Possible Measures (APM) scenario reflects a trajectory where climate mitigation is implemented through the application of the most feasible energy abatement measures. Within each sector then, the mitigation measures outlined in the previous section are implemented with the exception of fuel switching measures (which are captured under a separate mitigation scenario).

The implementation of APM results in a decline in energy demand by 29% from the reference case. Energy consumption under APM amounts to 380,648 Terajoules by 2040, an average growth rate of 1.3% per annum. The greatest share of this decline can be attributed to the passenger transport sector (31%) followed by the industrial sector (25%), freight transport sector (20%), residential sector (11%) and the agricultural and commercial sectors (6% and 7%, respectively) as illustrated by Figure 14: All possible measures: energy by sector (in TJ). The total energy consumption is based on demand projections per sector using the demographic and economic projections applicable to the Western Cape.

With regard to emissions, the APM scenario shows a substantial reduction in emissions to 45 400 $ktCO_2eq$ in 2040, with an average growth of 1.1% per annum: see Figure 15: All possible measures: emissions by sector (in ktCO2eq). The agriculture and commercial sectors show a reduction in emissions while the residential sector has little change. The major contributors to the additional emissions between 2012 and 2040 are shown in Table 4: Major contributors to additional emissions under the APM scenario.

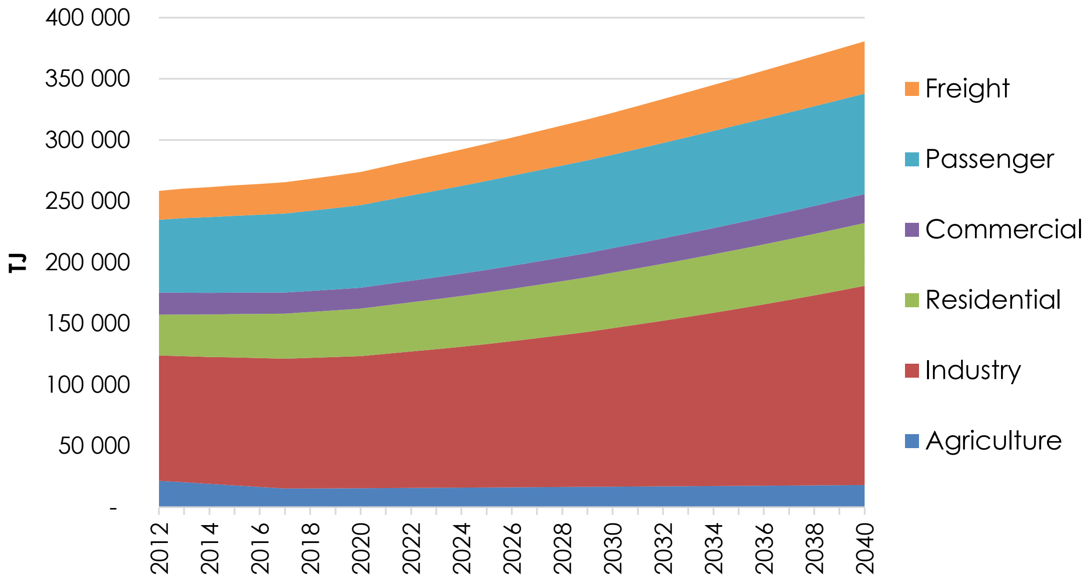

Figure 14: All possible measures: energy by sector (in TJ)

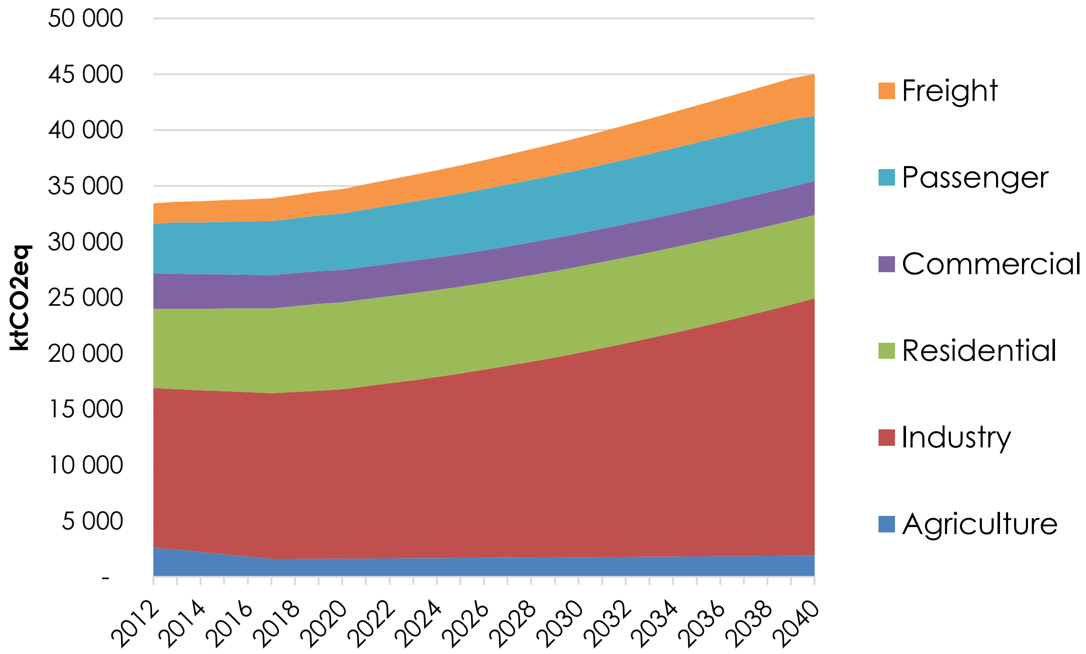

Figure 15: All possible measures: emissions by sector (in $ktCO_2eq$)

Table 4: Major contributors to additional emissions under the APM scenario

Demand sector	Addition from 2012-2040 (kt CO2eq)	% split of additional emissions
All	12 018	100%
Agriculture	-269	-2%
Industry	8 744	73%
Residential	376	3%
Commercial	-145	-1%
Passenger	1 364	11%
Freight	1 957	16%

Source: Own modelling analysis

3.3.2 Energy and emissions projections by energy source

The expected fuel mix under APM is anticipated to include a blend of refined petroleum fuels (38%), other fuels (32%), electricity (29%), and natural gas (1%) by 2040 (see Figure 16: All possible measures (no fuel switching): energy by source (in TJ)). Other fuels include coal, gas and residual fuels. Figure 17: All possible measures (no fuel switching): emissions by source (in ktCO2eq) shows that emissions from such a fuel mix would be led by electricity emissions (52%), followed by those from refined petroleum fuels (24%) and other fuels (23%). Emissions from natural gas in contrast are expected to be negligible (1%).

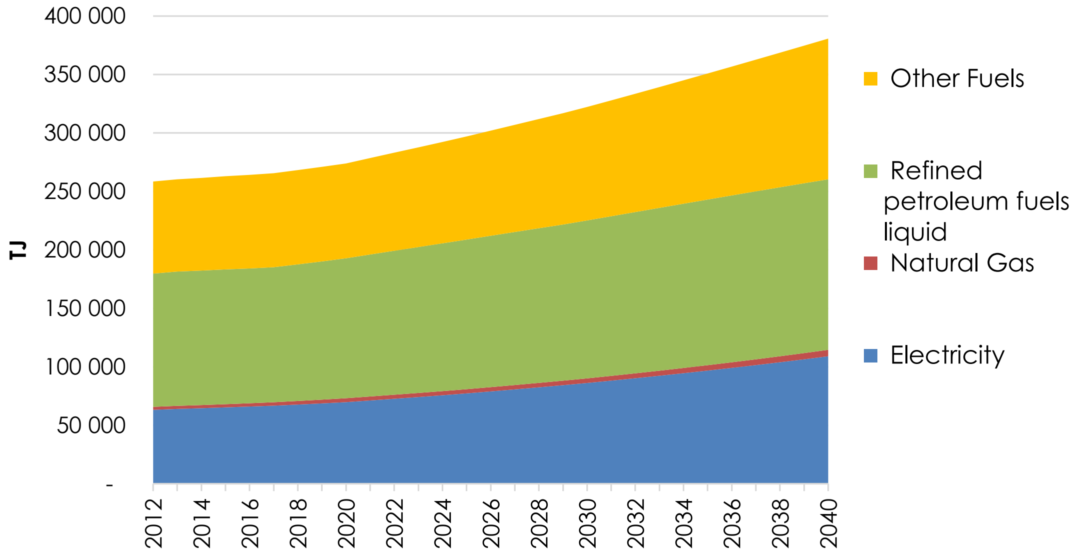

Figure 16: All possible measures (no fuel switching): energy by source (in TJ)

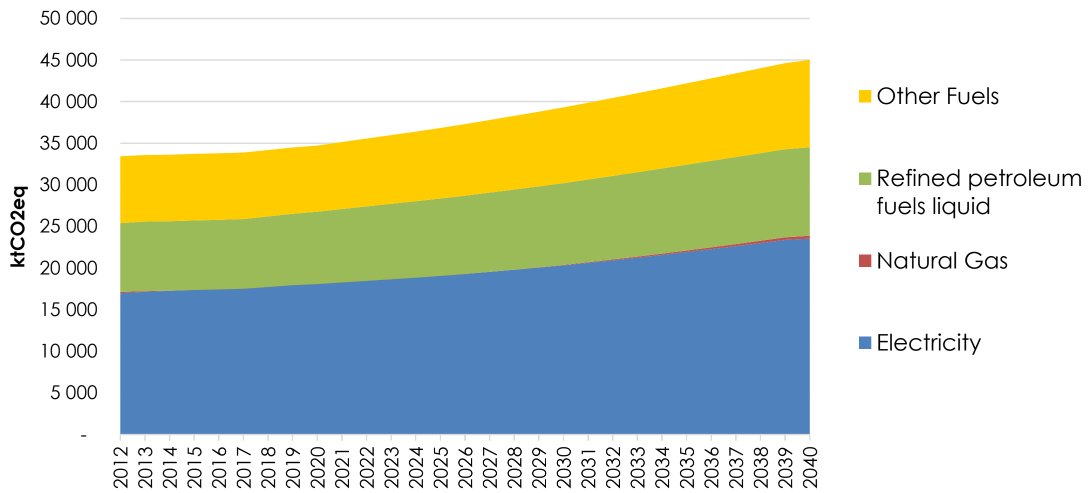

Figure 17: All possible measures (no fuel switching): emissions by source (in $ktCO_2eq$)

3.4 All possible measures combined with fuel switching scenario

3.4.1 Energy and emissions projections by energy source

Both the "APM" and "APM with fuel switching" scenario share the same energy demand forecast through to 2040. The key difference is that under the "APM with fuel switching" scenario selected industrial sub-sectors switch from coal to natural gas generated electricity. The only industrial sub-sector for which fuel switching was not applied was Petroleum Refining, as an alternative fuel switch measure was applied in the form of efficient energy production (CCGT and CHP).

The expected fuel mix under APM with fuel switching is anticipated to include a blend of refined petroleum fuels (38%), electricity (29%), other fuels (20%), and natural gas (13%) by 2040 (see Figure 18: APM with fuel switching: energy by source (in TJ)). By 2040, Figure 19: APM with fuel switching: emissions by source (in ktCO2eq) shows that emissions from such a fuel mix would be led by electricity emissions (55%), followed by those from refined petroleum fuels (25%) and other fuels (12%). The smallest share of emissions would come from natural gas amounting to 8%. Relative to the APM scenario which results in emissions of 45 400 $ktCO_2eq$ by 2040, the APM with fuel switching scenario results in emissions of 42 414 $ktCO_2eq$ by 2040 which is a decline in emissions of 7%.

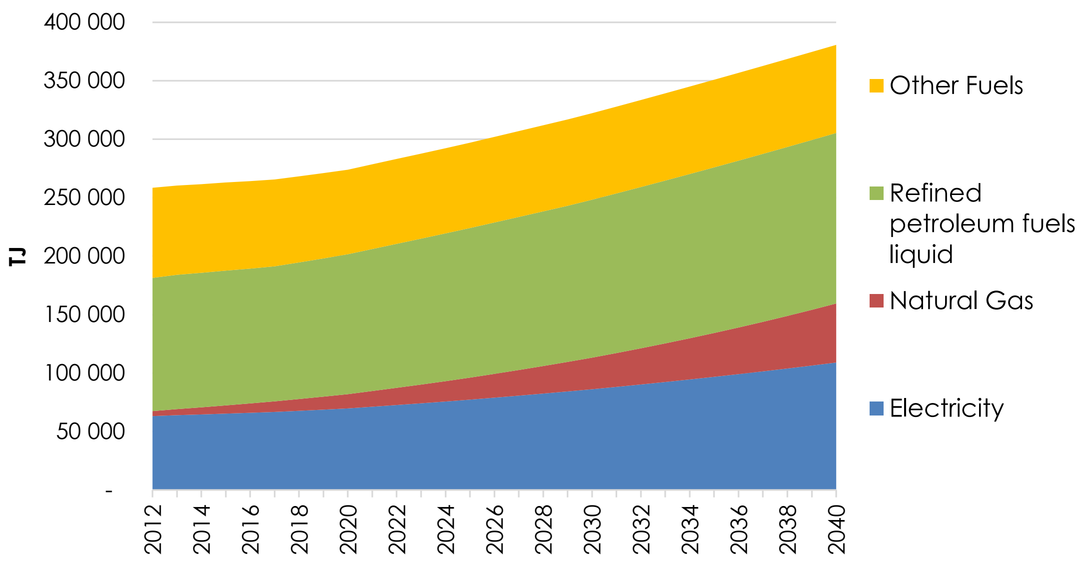

Figure 18: APM with fuel switching: energy by source (in TJ)

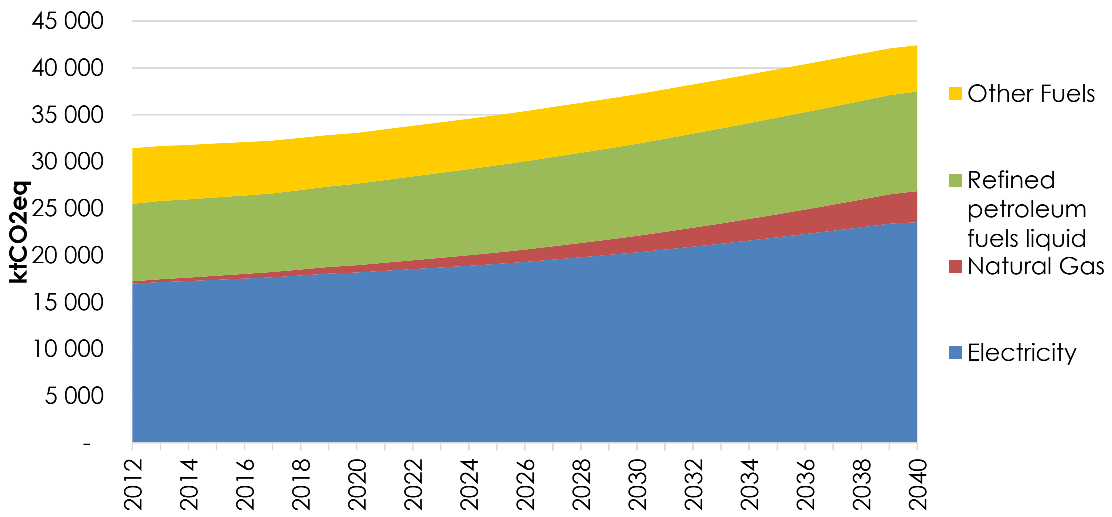

Figure 19: APM with fuel switching: emissions by source (in ktCO2eq)

3.5 Scenario comparison

On comparison of the various scenarios, it is evident that relative to the Reference case, the application of all possible mitigation measures (APM) can result in a notable (30%) decline in emissions over the 2012-2040 trajectory. Further to this, should the province simultaneously implement fuel switching (coal to natural gas power generation), there is an even greater (34%) opportunity to reduce emissions relative to the base case in the province as shown by Figure 20: Modelled scenario comparison – emissions (in ktCO2eq).

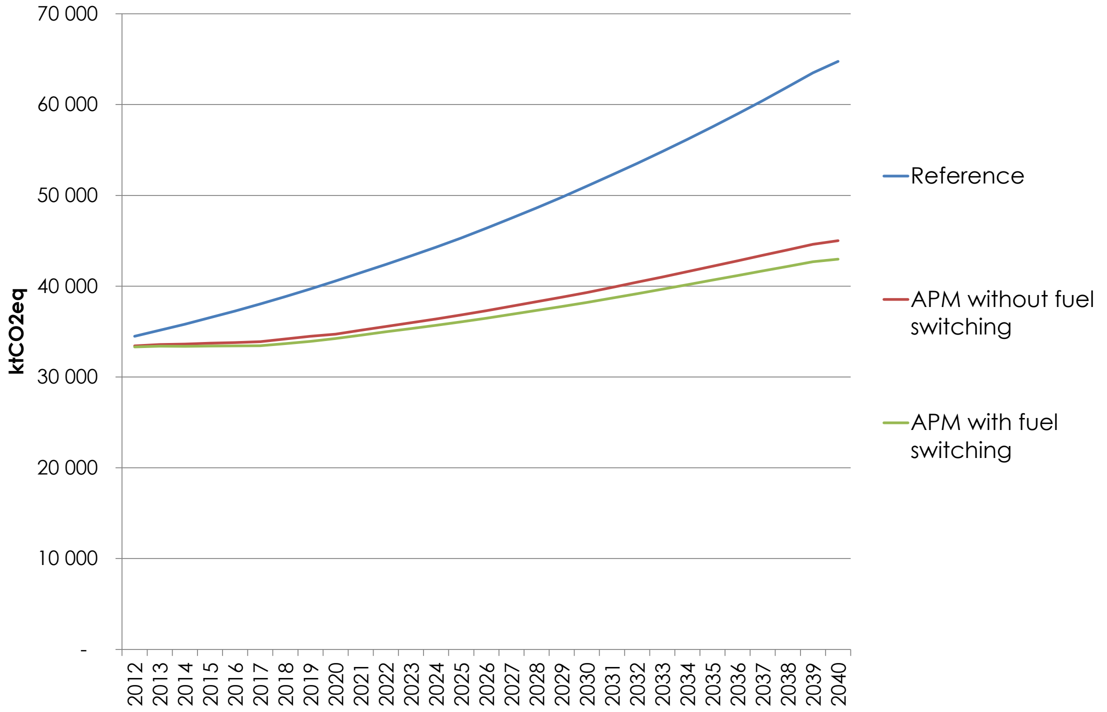

Figure 20: Modelled scenario comparison – emissions (in $ktCO_2eq$)

In contrasting the emissions derived from different fuel types as shown in Figure 21: Modelled scenario comparison – emissions by fuel type in 2040 (in ktCO2eq), it is evident that under the APM with fuel switching emissions are far less than those under the Reference case or APM scenarios because APM with fuel switching results in a decline in the energy demand for other fuels in favour of natural gas. The implication is that while overall energy demand under the APM and APM with fuel switching is the same, a less carbon-intensive fuel mix is possible through a switch from coal to natural gas.

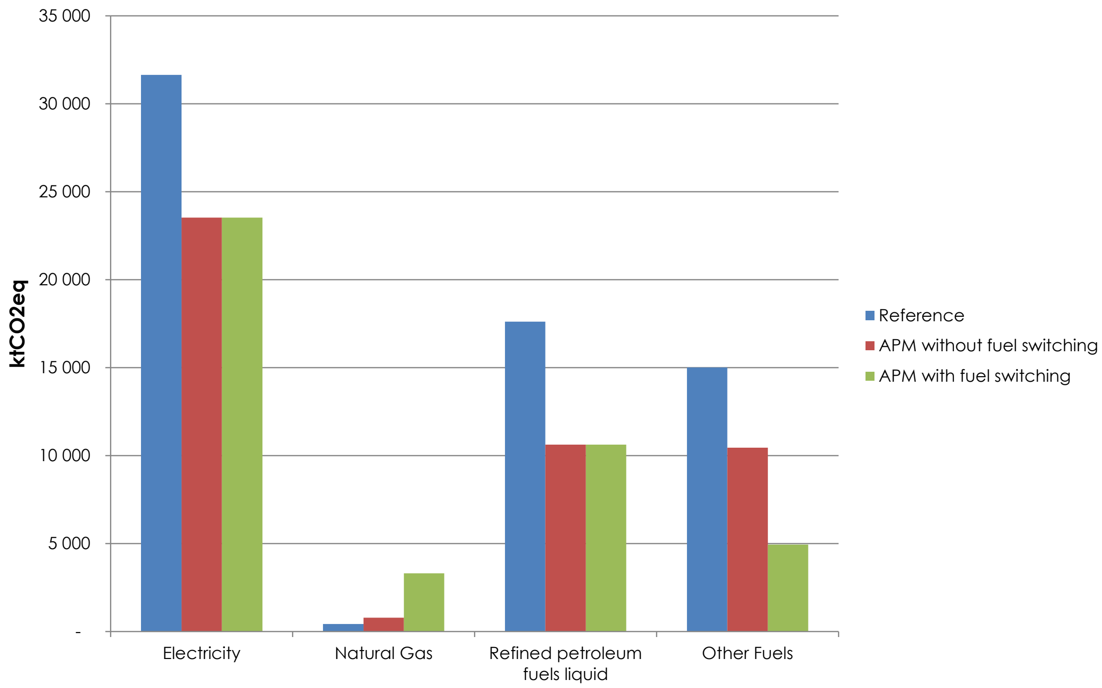

Figure 21: Modelled scenario comparison – emissions by fuel type in 2040 (in $ktCO_2eq$)

4. RESULTS SUMMARY

This section outlines the overall energy and emissions savings potential identified through the study.

4.1 Energy savings by sector

Figure 22: Energy savings potential in the Western Cape by sector shows how applying the APM with fuel switching scenario can lower the total provincial emissions, along with the contribution made by each sector. APM with fuel switching results in notable abatement by the various demand side sectors. In terms of the overall magnitude of potential energy savings, the industrial and transport sectors have the greatest potential in terms of the magnitude of savings possible. These are followed by the buildings sector, and the smallest contribution (in terms of energy savings) is from the agricultural sector.

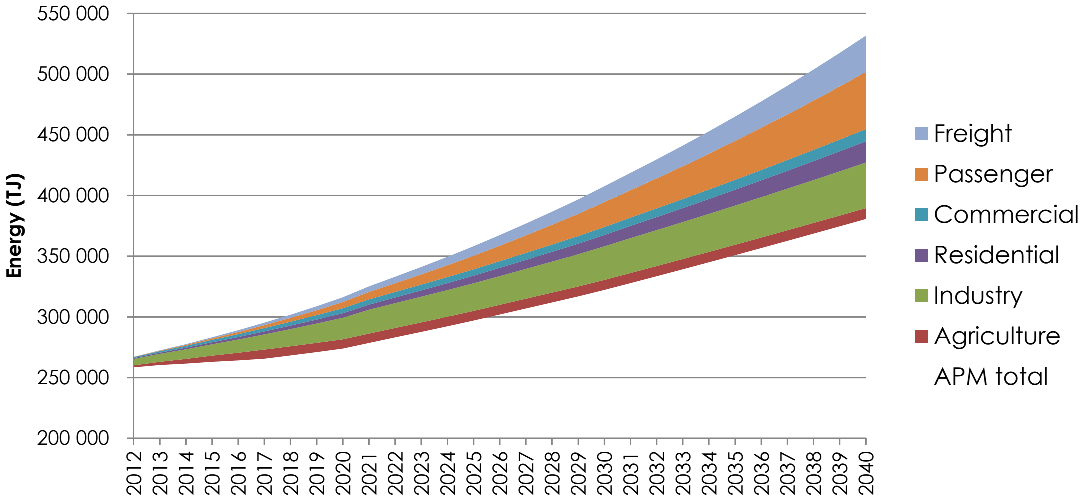

Figure 22: Energy savings potential in the Western Cape by sector

4.2 Emissions savings by sector

The overall picture in terms of the impact on overall provincial emissions if all measures are implemented (including fuel switching) is shown below. The top of the graph represents the volume of emissions under the Reference case scenario. If the wedges are subtracted from this, it results in the APM with fuel switching scenario.

The industrial and residential sectors have the greatest potential in terms of emissions reductions. These are followed by the transport sector. Although commercial buildings and agriculture is a small slice of the total provincial emissions, the electricity intensive nature of the sector means that significant reductions are possible relative to the Reference case scenario.

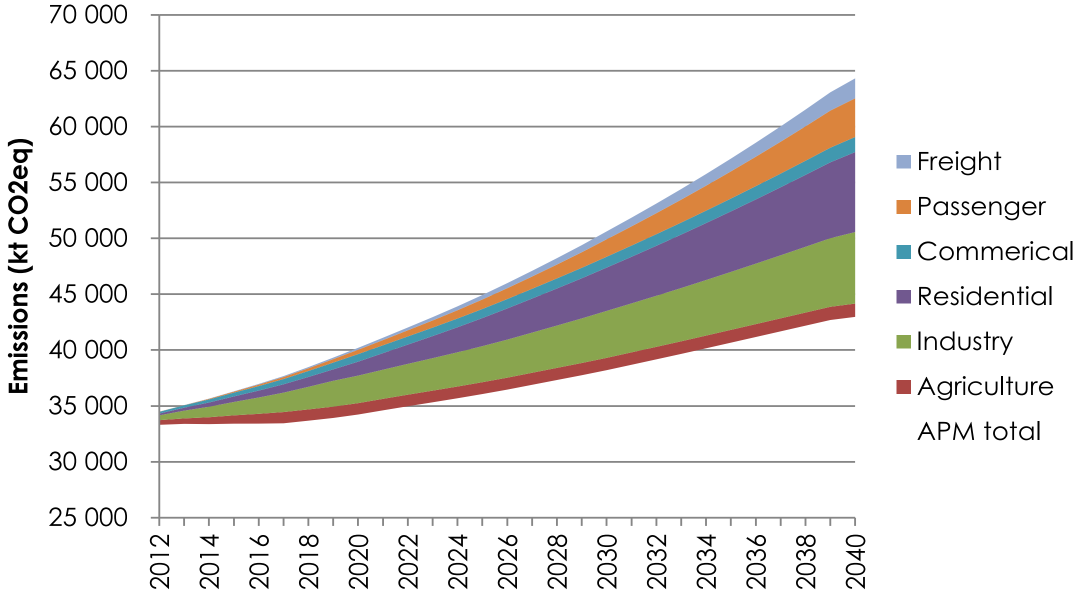

Figure 23: Emissions savings potential by sector in the Western Cape

4.3 Energy Supply Projections

In a sector as complex as the energy sector in South Africa, a wide range of supply options exist in the electricity and fuel sectors.

4.3.1 Electricity

The Reference case for the energy system is best defined by the Integrated Resource Plan (IRP) for electricity supply, which was completed by the Department of Energy in 2010. The IRP has a range of options – referred to as scenarios – and the one selected for comparison is referred to as the 'base scenario'. However, the base scenario assumes a high electricity growth rate in the country – 2.8% growth as far as can be ascertained. Therefore the approach taken here is to use the IRP 'base scenario' primary energy mix, which is nuclear intensive, but not the growth trends. This is shown in Figure 24: Energy source for electricity generation - IRP baseline.

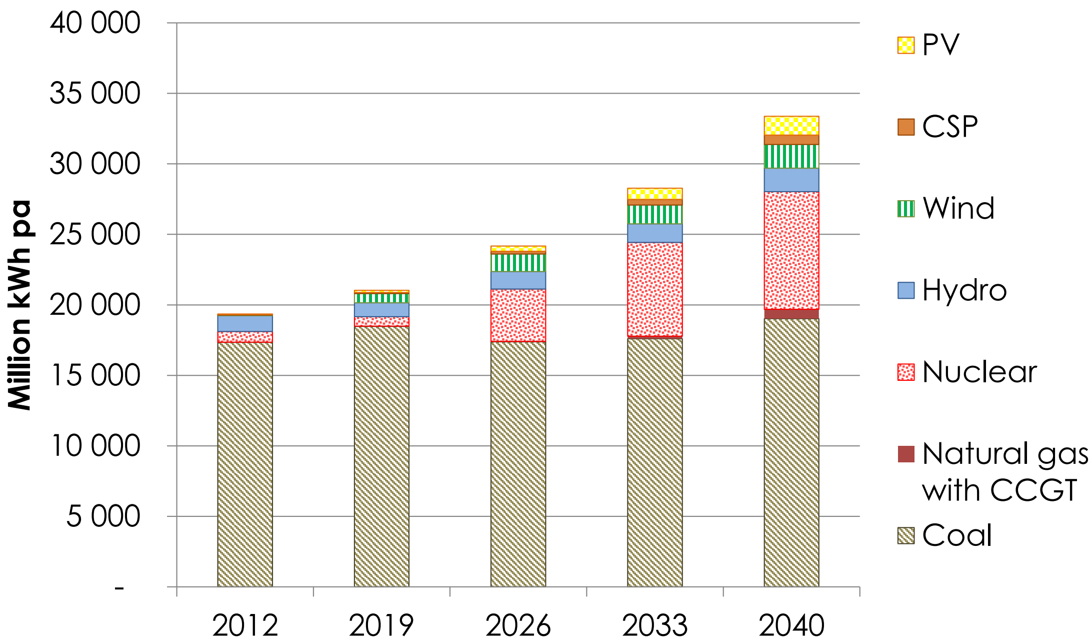

Figure 24: Energy source for electricity generation - IRP baseline

In contrast, in alignment with the Western Cape Infrastructure Framework (WCIF), an optimised development agenda[14] representing a "green economy" is also tailored to align with the Western Cape government's current thinking. This is based on a high proportion of renewable energy complemented by natural gas, which is assumed will become available at reasonable cost, primarily from the African east coast gas fields.

This optimised development agenda envisages using natural gas as a transition, while renewable energy generation capacity is built up and nuclear power is phased out. However, by 2040 there will not be enough time to 'wind down' the coal-based electricity generation component. The optimised development agenda also allows for individual users to feed distributed / embedded generation into the grid. The green energy mix is illustrated in Figure 25: Energy source for electricity generation - green energy option. These figures are based on a growth in electricity demand of 2.3% per annum.

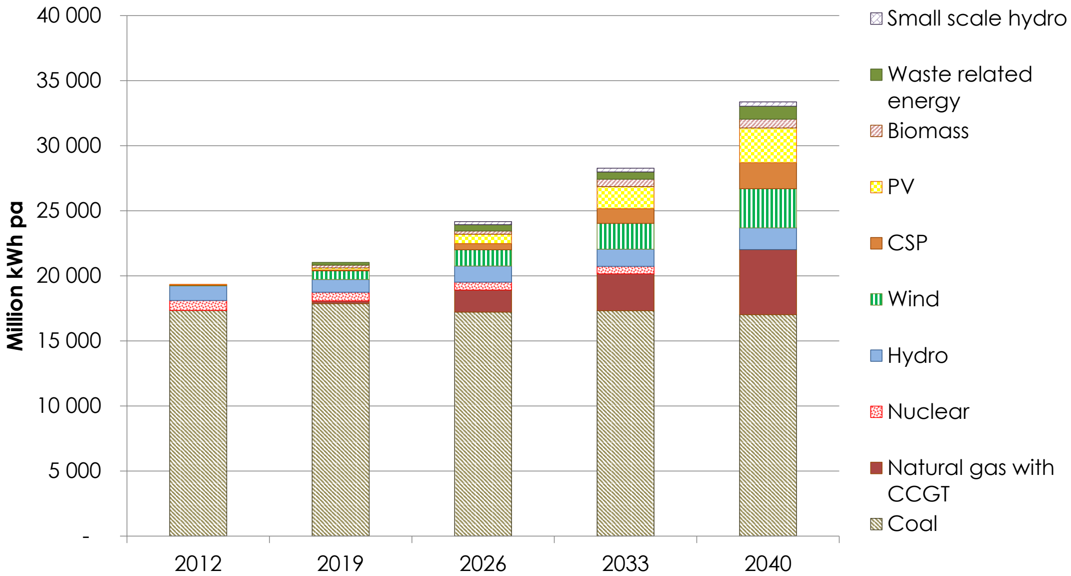

Figure 25: Energy source for electricity generation - green energy option

The proportional split of energy by source in the selected 'green energy option' is shown in Table 5: Split of energy by source under the 'green energy option'.

Table 5: Split of energy by source under the 'green energy option'

Energy source	2012	2019	2026	2033	2040
Coal	90%	85%	71%	61%	51%
Natural gas with Combined Cycle Gas Turbines (CCGT)	0%	1%	7%	10%	15%
Nuclear	4%	3%	3%	2%	0%
Hydropower	6%	5%	5%	5%	5%
Wind	0%	3%	5%	7%	9%
Concentrated Solar Power (CSP)	0%	0%	2%	4%	6%
Photovoltaics (PV)	0%	1%	3%	6%	8%
Biomass	0%	1%	1%	2%	2%
Waste related energy	0%	1%	2%	2%	3%
Small scale hydro	0%	0%	1%	1%	1%

14 Which assumes all the required transitions will be implemented to achieve the OneCape 2040 vision.

Source: Own analysis informed by Western Cape Infrastructure Framework (2013)

Electricity price trends

In this modelling framework a current (year 2012) average price of 67 cents per kilowatt hours (kWh) is used for the agriculture, industrial and commercial sectors, which is somewhat above Eskom's average price of 65 cents per kWh (Eskom, 2013). In the case of the price for residential users, an average mark-up on the Eskom bulk price of 40% is applied, giving an average electricity selling price in 2014 of 95 cents per kWh.

4.3.2 Fuel

The fuel sector is dominated by liquid fuels, with the addition of coal used for combustion primarily in industrial plants. The Reference case scenario is defined by the continued use of coal and natural gas use for liquid fuel production much at the current levels (sourced from the PetroSA plant in Mossel Bay for example). The 'All Possible Measures with fuel switching' scenario will have reduced use of coal and increased use of natural gas for liquid fuel production and direct combustion. Hereafter, only the mix of primary energy with fuel switching is reported: it has not been possible to do a price comparison of coal and gas based energy as the data to allow for such a comparison has not been sourced.

Liquid fuel price trends

Using approximate trends for cost elements of primary energy (including the prices of coal and natural gas and the costs of refining, distribution and tax), an average price increase of 2.8% (real) was projected for liquid fuels. This is based on the assumption that the price of fuel continues to account for 34% of the primary energy cost.[15]

4.4 Multi-criteria analysis

A Multi Criteria Analysis (MCA) approach (outlined in Section 2.6) was used to conduct an impact assessment on all identified energy-related mitigation opportunities, taking a range of criteria into consideration.

By introducing other criteria which focus on non-GHG related impacts and/or benefits, the MCA framework allows for a more holistic view to prioritising mitigation efforts than that which is feasible using the traditional Marginal Abatement Cost (MAC) analysis (which considers only the criterion of cost for a given amount of greenhouse gas mitigation).

Steps in the MCA process

In line with the approach undertaken through the DEA MPA, the development of the MCA model for this study involved:

1. Sector analysis of options (costs and emissions);
2. Multi-criteria analysis (of all criteria);
3. Development of sector energy, emissions and energy abatement projections;
4. Ranking of all mitigation measures.

The outputs of the MCA present a relative ranking of all mitigation measures by an overall weighted score (which encapsulates the quantitative and qualitative criteria presented in Section 2.6).

In addition, the MCA outputs also generate a ranking of all mitigation measures by their relative emissions abatement potential scores. This effectively places measures with the highest mitigation potential at the top of the ranks and those with the lowest, at the bottom. The results are also presented next.

15 20% distribution and retail, 26% tax and 20% refining cost; the latter figure is only a rough estimate.

4.4.1 Rank by overall weighted score

Based on the results of the MCA, the top 20 mitigation measures are derived from all the demand-side sub-sectors as shown in Table 6: Multi-criteria analysis rank by overall weighted score top 20 mitigation measures. These tentative results show that the top 20 measures have the potential to mitigate just over one-third (34%) of the energy emissions experienced by the province by 2040, as compared to the Reference scenario[16]

Table 6: Multi-criteria analysis rank by overall weighted score top 20 mitigation measures

Rank	Sector	Sub-sector	Mitigation measure	Overall weighted MCA score	Total Emissions Abated (ktCO2eq)	% of Total emissions abated
1	Transport	Freight	Road - Shifting freight from road to rail (modal shift)	86.55	2 867	0.6%
2	Transport	Road	Road - Shifting passengers from cars to public transport	68.44	29 701	6.3%
3	Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	66.33	26 450	5.6%
4	Electricity	Electricity	Solar Photovoltaics (Concentrated)	63.97	29 069	6.1%
5	Buildings	Residential	Solar water heating	63.50	9 004	1.9%
6	Buildings	Commercial	Solar water heaters	63.39	7 255	1.5%
7	Electricity	Electricity	Biomass	63.36	10 224	2.2%
8	Buildings	Commercial	Behavioural changes	62.52	6 324	1.3%
9	Buildings	Commercial	Efficient Lighting	62.01	14 932	3.1%
10	Industry	Pulp & Paper	Energy recovery system	61.93	2 360	0.5%
11	Buildings	Residential	LPG for cooking	61.30	438	0.1%
12	Industry	Petrochemicals	Energy monitoring and management system	61.30	838	0.2%
13	Agriculture	Agriculture	Reduced tillage	61.24	3 905	0.8%
14	Industry	Pulp & Paper	Convert fuel from coal to biomass/residual wood waste	61.23	10 111	2.1%
15	Industry	Petrochemicals	Improved electric motor system controls and Variable Speed Drives (VSDs)	61.22	225	0.0%
16	Industry	Petrochemicals	Improve steam generating boiler efficiency	60.81	320	0.1%
17	Industry	Petrochemicals	Improve process heater efficiency	60.79	149	0.0%
18	Industry	Chemicals	Improved electric motor system controls and VSDs	60.51	375	0.1%
19	Buildings	Residential	Efficient Lighting - CFLs	60.36	8 123	1.7%
20	Industry	Petrochemicals	Improved heat exchanger efficiencies	60.35	341	0.1%

16 The full list of mitigation measures ranked by score are displayed in Appendix 5.

Rank by overall weighted score – excluding outlier

An outlier in the MCA was identified on comparing the rank of mitigation measures by overall weighted score. The outlier was the freight modal shift mitigation measure ('Road - Shifting freight from road to rail (modal shift)') which, as Table 6: Multi-criteria analysis rank by overall weighted score top 20 mitigation measures shows obtains an overall weighted score of 86.55 which is nearly 20 points higher than the next highest ranked mitigation measure.

On investigation, it was found that the high score which this mitigation measure scores is largely due to a high score attained in terms of both the cost and social criteria. This drives its favourable placement in the ranking. The reason for the cost being so favourable is that the capital investment required to improve the railway system in the Western Cape is relatively small over the 28 year analysis time-frame of the study relative to the mitigation potential which this measure can achieve. Also, when considering the volumes of freight moved, the modelling framework in this study only considers improving one line, the Cape Town to Gauteng one which is relatively inexpensive to improve and has a large mitigation potential.

As the freight modal shift measure was a significant outlier, it has been removed from the graph below to ensure the comparative ranking of all other measures is more visible.

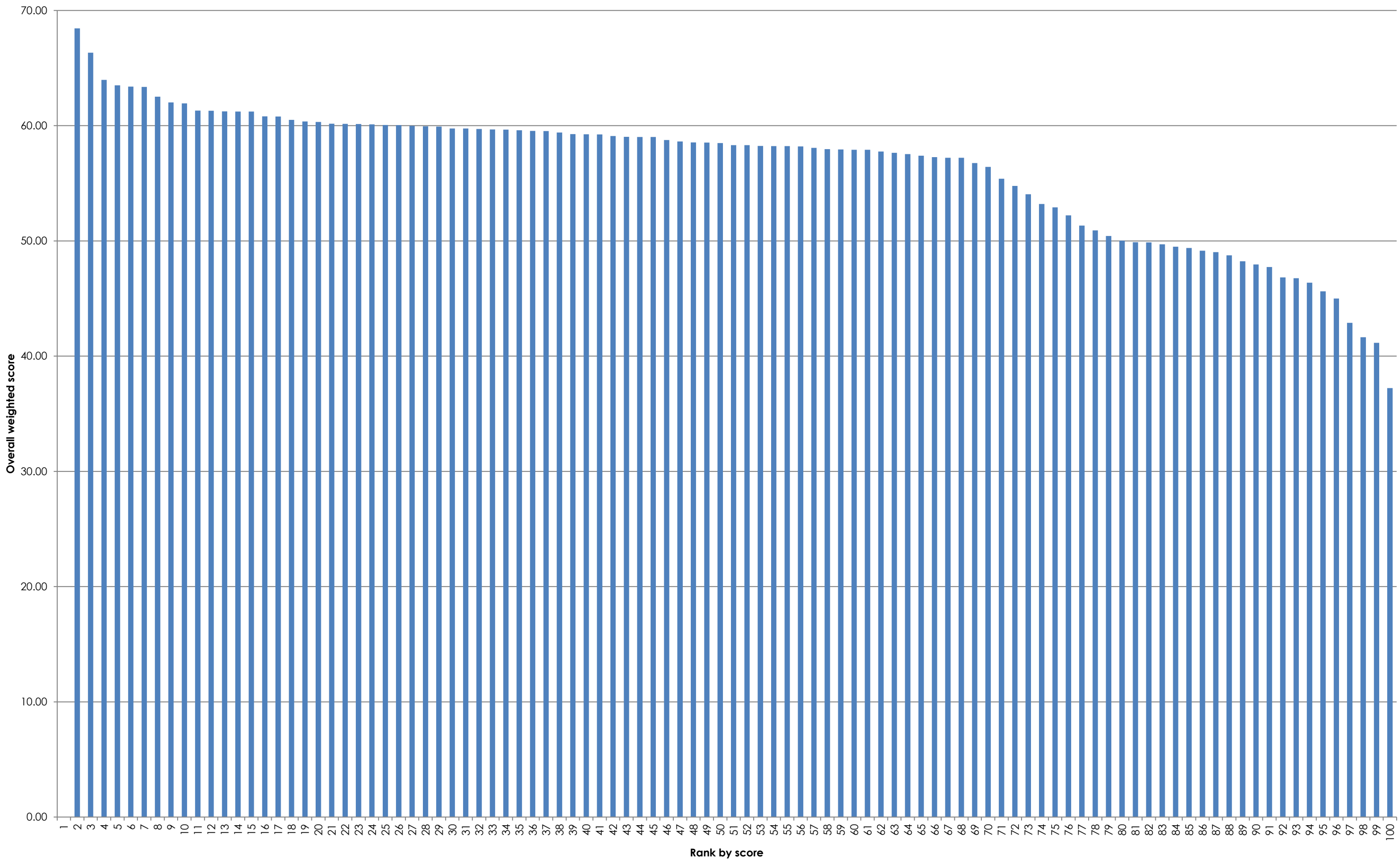

Figure 26: Rank of mitigation measures by overall weighted score excluding freight modal shift outlier.

4.4.2 Rank by emissions abatement potential

An alternative approach to selecting mitigation measures is to identify those with the greatest emissions abatement potential (Table 7: Multi-criteria analysis rank by emissions abatement top 20 mitigation measures). Under such a view, the mitigation measures which rank in the top 20 include energy supply-side, transport, buildings and selected industry measures.[17] The top 20 mitigation measures ranked by emissions abatement alone have the potential to result in a reduction of emissions by 68% relative to the Reference case.

Table 7: Multi-criteria analysis rank by emissions abatement top 20 mitigation measures

Rank	Sector	Sub-sector	Mitigation measure	Overall weighted MCA score	Total Emissions Abated (ktCO2eq)	% of Total emissions abated
1	Electricity	Electricity	Onshore wind	57.27	39 914	8%
2	Transport	Road	Road - Shifting passengers from cars to public transport	68.44	29 701	6%
3	Electricity	Electricity	Solar Photovoltaics (Concentrated)	63.97	29 069	6%
4	Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	66.33	26 450	6%
5	Transport	Road	Improved efficiency - Petrol and diesel Internal Combustion Engine (ICE)	58.22	21 054	4%
6	Electricity	Electricity	Concentrated Solar Power (Parabolic trough)	57.65	19 660	4%
7	Industry	All remaining industries	Energy efficient boiler systems and kilns	58.53	15 477	3%
8	Buildings	Commercial	Efficient Lighting	62.01	14 932	3%
9	Transport	Freight	More efficient engines	55.40	13 503	3%
10	Electricity	Electricity	Solid waste related energy	57.53	13 385	3%
11	Buildings	Commercial	HVAC improvements (incl. heat pumps)	56.76	11 085	2%
12	Industry	All remaining industries	Fuel Switch	49.15	10 357	2%
13	Agriculture	Agriculture	EE in pumped irrigations: Variable Speed Drives (VSDs)	50.42	10 356	2%
14	Electricity	Electricity	Biomass	63.36	10 224	2%
15	Industry	Pulp & Paper	Convert fuel from coal to biomass/ residual wood waste	61.23	10 111	2%
16	Transport	Road	Alternative fuels - Petrol and diesel hybrids	59.54	9 633	2%
17	Buildings	Commercial	Passive building/improved thermal design - New Buildings	50.02	9 377	2%
18	Buildings	Residential	Solar water heating	63.50	9 004	2%
19	Agriculture	Agriculture	EE in on-farm cooling	58.31	8 851	2%
20	Industry	Iron & Steel	Fuel Switch	59.41	8 267	2%

4.5 Prioritising measures

While the MCA framework allows for a clearer articulation of the full spectrum of criteria for consideration in selecting mitigation measures, the province (and the relevant local government partners) also requires insight to the measures over which it can exert influence. In particular, in implementing the mitigation measures proposed through this study, the province needs to understand which measures it can affect as well as those which are beyond its reach.

17 The full list of mitigation measures ranked by emissions abatement potential is displayed in Appendix 5.

To capture this provincial and local government control element, an additional assessment was conducted to identify the mitigation measures which the province is capable of influencing. At the final stakeholder workshop held for the study, it was agreed that this 'provincial prioritisation' scenario represents measures and sectors which the provincial government and local government in the province, can affect.

To understand the climate mitigation potential of the various mitigation measures, the team reviewed the full set of outputs from the demand and supply-side models in terms of the total emissions abated by the measures over the 2012-2040 trajectory. These are represented below for the APM with fuel switching scenario (Table 8: Total emissions abatement by mitigation measures).

Mitigation measures which can achieve mitigation above 3000 ktCO_2eq are identified in bold text in the 'Total Emissions Abated (ktCO2eq)' column. Through consultation with stakeholders at a workshop, the measures which were identified to be within the province's power of influence were selected and are shown by the shaded grey cells.

Table 8: Total emissions abatement by mitigation measures

Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)
Agriculture	Agriculture	EE in pumped irrigations: Variable Speed Drives (VSDs)	**10 356**
Agriculture	Agriculture	Reduced tillage	**3 905**
Agriculture	Agriculture	Irrigation management systems	**6 214**
Agriculture	Agriculture	EE in on-farm cooling	**8 851**
Industry	Iron & Steel	Furnace / Heating General efficiency measures	**3 259**
Industry	Iron & Steel	General electricity efficiency measures	2 235
Industry	Iron & Steel	Fuel Switch	**8 267**
Industry	Lime	Installation of shaft preheaters	535
Industry	Lime	Replace rotary kilns with vertical kilns or Parallel Flow Regenerative Kilns (PFRK)	388
Industry	Lime	Use alternative fuels including waste and biomass	513
Industry	Lime	Energy monitoring and management system	23
Industry	Lime	Improved process control	42
Industry	Lime	Improved electric motor system controls and Variable Speed Drives (VSDs)	13
Industry	Lime	Energy-efficient utility systems	10
Industry	Lime	Improved heat exchanger efficiencies	28
Industry	Lime	Fuel Switch	429
Industry	Cement	Improved process control	440
Industry	Cement	Reduction of clinker content of cement products	1 063
Industry	Cement	Waste heat recovery from kilns and coolers/cogeneration	183
Industry	Cement	Utilise waste material as fuel	1 442
Industry	Cement	Geopolymer cement production	74
Industry	Cement	Energy monitoring and management system	88
Industry	Cement	Improved electric motor system controls and variable speed drives	153
Industry	Cement	Energy-efficient utility systems	85
Industry	Cement	Fuel Switch	1 567
Industry	Brick & Clay	Replace kilns with Vertical Stacked Brick Kilns (VSBK)	**3 408**

Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)
Industry	Brick & Clay	Fuel Switch	**4 633**
Industry	Chemicals	Revamp: increase capacity and energy efficiency	841
Industry	Chemicals	Energy monitoring and management system	154
Industry	Chemicals	Advanced process control	72
Industry	Chemicals	Improved electric motor system controls and VSDs	375
Industry	Chemicals	Energy efficient utility systems	125
Industry	Chemicals	Increase process integration and improved heat systems	144
Industry	Chemicals	Fuel Switch	927
Industry	Pulp & Paper	Convert fuel from coal to biomass/residual wood waste	**10 111**
Industry	Pulp & Paper	Application of Co-generation of Heat and Power (CHP)	1 702
Industry	Pulp & Paper	Energy recovery system	2 360
Industry	Pulp & Paper	Energy monitoring and management system	279
Industry	Pulp & Paper	Energy efficient electric motors, improved controls and variable speed drives	602
Industry	Pulp & Paper	Energy-efficient utility systems (e.g. lighting, refrigeration, compressed air)	258
Industry	Pulp & Paper	Improved process control	964
Industry	Pulp & Paper	Energy efficient boiler systems and kilns and Improved heat systems	1 928
Industry	Pulp & Paper	Fuel Switch	2 853
Industry	All remaining industries	Energy efficient boiler systems and kilns	**15 477**
Industry	All remaining industries	Energy monitoring and management system	1 386
Industry	All remaining industries	Improved process control	1 238
Industry	All remaining industries	Improved electric motor system controls and Variable Speed Drives (VSDs)	**6 267**
Industry	All remaining industries	Energy-efficient utility systems	**4 341**
Industry	All remaining industries	Improved heat exchanger efficiencies	**6 604**
Industry	All remaining industries	Fuel Switch	**10 357**
Industry	Petrochemicals	Improve steam generating boiler efficiency	320
Industry	Petrochemicals	Improve process heater efficiency	149
Industry	Petrochemicals	Waste heat recovery and utilization	684
Industry	Petrochemicals	Efficient energy production (Combined Cycle Gas Turbine (CCGT) and Combined Heat & Power (CHP))	794
Industry	Petrochemicals	Waste heat boiler and expander applied to flue gas from the FCC regenerator	253
Industry	Petrochemicals	Energy monitoring and management system	438
Industry	Petrochemicals	Improved process control	438
Industry	Petrochemicals	Improved heat exchanger efficiencies	341
Industry	Petrochemicals	Improved electric motor system controls and Variable Speed Drives (VSDs)	225
Industry	Petrochemicals	Energy-efficient utility systems	150
Buildings	Residential	Energy efficient appliances	1 580
Buildings	Residential	Geyser Blankets	**3 333**

Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)
Buildings	Residential	Improved Insulation - New Buildings	2 160
Buildings	Residential	Improved Insulation - Existing Buildings	2 723
Buildings	Residential	Efficient Lighting - CFLs	**8 123**
Buildings	Residential	Efficient Lighting - LEDs	**6 339**
Buildings	Residential	Solar water heating	**9 004**
Buildings	Residential	LPG for cooking	838
Buildings	Residential	Passive building/improved thermal design - New Buildings	2 653
Buildings	Residential	Behavioural changes	2 323
Buildings	Residential	Embedded generation: PV	**7 108**
Buildings	Commercial	Solar water heaters	**7 255**
Buildings	Commercial	Efficient Lighting	**14 932**
Buildings	Commercial	HVAC improvements (incl. heat pumps)	**11 085**
Buildings	Commercial	Energy efficient appliances	**3 294**
Buildings	Commercial	Passive building/improved thermal design - New Buildings	**9 377**
Buildings	Commercial	Coal to gas (hospitals)	**3 269**
Buildings	Commercial	Embedded generation: PV	**6 918**
Buildings	Commercial	Lift efficiency	129
Buildings	Commercial	Behavioural changes	**6 324**
Transport	Road	Improved efficiency - Petrol and diesel Internal Combustion Engine (ICE)	**21 054**
Transport	Road	Alternative fuels - Petrol and diesel hybrids	**9 633**
Transport	Road	Alternative fuels - Petrol and diesel plug-in hybrids	2 918
Transport	Road	Alternative fuels – Electric drives	1 903
Transport	Road	Alternative fuels – Fuel cells	484
Transport	Road	Alternative fuels – Compressed Natural Gas ICE	1 162
Transport	Road	Road - Shifting passengers from cars to public transport	**29 701**
Transport	Freight	Road - Shifting freight from road to rail (modal shift)	2 867
Transport	Freight	More efficient engines	**13 503**
Transport	Freight	More efficient EMUs (freight)	638
Transport	Rail	Voltage upgrade	692
Transport	Rail	Improved efficiency - EMUs (Electric Multiple Units)	1 345
Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	**26 450**
Electricity	Electricity	Import (Hydro)	**4 500**
Electricity	Electricity	Onshore wind	**39 914**
Electricity	Electricity	Concentrated Solar Power (Parabolic trough)	**19 660**
Electricity	Electricity	Solar Photovoltaics (Concentrated)	**29 069**
Electricity	Electricity	Biomass	**10 224**
Electricity	Electricity	Solid waste related energy	**13 385**
Electricity	Electricity	Small-scale hydro power	**5 227**

At an aggregate sector level, the province has the ability to influence or affect the implementation of 100% of mitigation measures in the commercial buildings, residential buildings and agricultural sectors (Figure 27: Provincial prioritisation of sector's to influence). The province is also capable of affecting change towards a lower carbon trajectory in the passenger transport (44%), energy supply sector (37%), industrial (28%) and freight transport (17%). The proposal made here is that, while effort should be made to pursue those measures which present the greatest abatement potential, there is equal motivation to pursue those which the province has the greatest power to influence. As this study evidences, much of this influence rests in the buildings and agricultural sectors of the province.

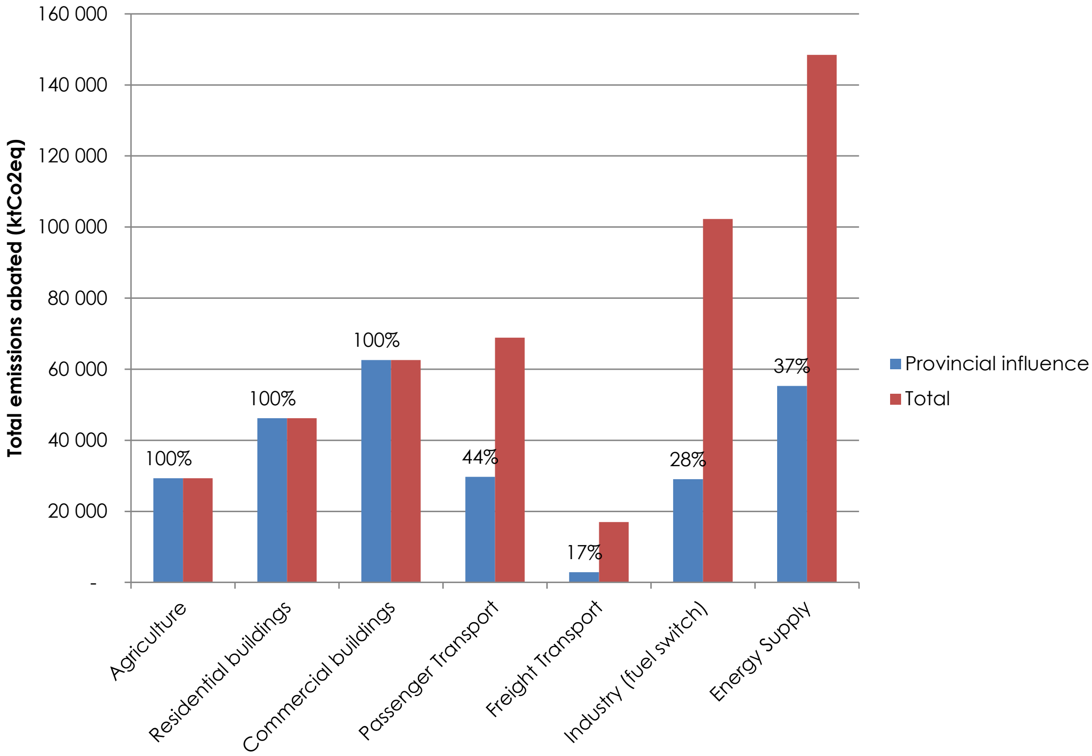

Figure 27: Provincial prioritisation of sector's to influence

5 CONCLUSIONS

This study is a first representation of the climate mitigation potential of the energy sector in the Western Cape. It is founded on an analysis of energy use in the Province using a set of models which allow for energy demand to be projected into the future, based on a set of variables which influence demand. On the energy supply side the analysis includes electricity and fuel supply options. The energy demand and supply analysis then leads to an assessment of energy-related greenhouse gas emissions. Starting from a base position (Reference) the study has then applied a set of mitigation measures aimed at reducing these emissions. A starting point for identifying these measures was the national Mitigation Potential Analysis (MPA) undertaken by the national department of Environment Affairs. The list of measures applied as part of the MPA was then amended through a stakeholder engagement process to get the final list of 100 measures to be applied for the Province. The models then allowed emission projections to be made for two core climate mitigation scenarios: 1) All Possible Measures (APM) and 2) APM with the addition of fuel switching from coal and liquid fuels to natural gas. The study also identified measures over which the Province and municipalities within the Province have influence, with the associated ability of these organisations to influence emissions.

The primary conclusion from this study is that, with all possible measures applied, other than fuel switching, there is the potential to reduce emissions substantially from a rate of increase of 2.3% per annum under the Reference case scenario to an average annual increase in emissions of 1.1% per annum over the period up to 2040. Further, should the province simultaneously implement all possible measure with fuel switching, there is an even greater opportunity to reduce emissions, with the average annual increase in emissions reduced to 0.9% per annum. While it is shown that it is not feasible to avoid an increase in emissions associated with energy use in the Province this is a substantial reduction. In this regard it needs to be kept in mind that the analysis excludes non-energy related emissions which, if included, will reduce emissions further.

However, the implementation of all measures will be an onerous task requiring a full commitment of energy providers and energy users in the agriculture, industrial, commercial, residential and transport sectors. The measures have various degrees of difficulty in being implemented in terms of cost and institutional obligations and they have various degrees of benefit other than through emissions reduction. In order to assess the relative costs, ease of implementation and benefits, a Multi-Criteria Analysis (MCA) was applied based on methodology used for the DEA MPA. This allowed for a ranking of measures to be provided with the implication that the highest ranked measures have the best balance between cost, implementability and benefits. It is important to note that, given the time and budget limitations for this study, this ranking needs to be seen as a provisional guide only and there is much room for refinement.

In order to achieve the desired emission reductions energy suppliers and energy users in each sector will need to undertake major improvements in the way they provide or use energy. For some measures this will lead to cost efficiencies while in others the cost to the user of energy will increase through the application of the measure. In many cases additional investment is required, with the energy user often having to raise the capital themselves. A summary of the implications for each sector is given below.

POWER GENERATION

The analysis shows the largest gains in terms of mitigation to be in the power generation sector, where the measures are associated with replacing coal fired power plants with renewable energy plants and natural gas fired plants. There are 8 measures identified of the total of 100 and the mitigation potential of these measures represents 31% of the total mitigation potential. The largest mitigation impact is anticipated to be from applying onshore wind for power generation, followed by natural gas with closed cycle gas turbines, solar photovoltaics and concentrated solar power.

The natural gas and photovoltaic options are ranked highest using the MCA with energy generation using biomass also ranking high. All of the measures are in the top two thirds of the ranking. However, the point made above about the provisional nature of the scoring for the MCA needs to raised here in interpreting the relative ranking of these power generation measures. This is a complex analysis undertaken in a limited budget and there is not a great deal of difference in the resulting scores. Therefore not too much store should be placed on the position of these measures in relation to each other.

It is notable that the results are based on a non-nuclear energy mix with the emphasis being on renewables and natural gas. However, nuclear power was considered in the analysis and has been scored under the MCA, with it coming out as one of the least favourable options.

With regard to the implementation of these measures they are all aimed at generating power into the national grid and therefore are primarily under the influence of national government, the Department of Energy specifically. However, the province does have influence over the natural gas measure through promoting the import of natural gas in the province. This is not meant to imply that the Province should not continue to lobby for greater use of renewable energy as well.

INDUSTRY

This sector is the biggest user of energy and the biggest emitter of greenhouse gases in the Province. It also has the highest potential of the demand sectors to reduce emissions in terms of overall quantity of emissions (22% of total mitigation is associated with industrial energy measures). With the diversity of industries in the Province and the large numbers of industrial processes involved there are a wide variety of measures which can be implemented (56 of the 100 measures identified are in the industrial sector). Many of these are small, partly associated with the fact that some of the sector sub-divisions – such as lime and chemicals (excluding petrochemicals) – are small. On the other hand there is also a fairly large amount of mitigation associated with a grouping of 'All other remaining' industries which could not be analysed separately (45% of the industrial sector's mitigation potential comes from this grouping). The industrial sub-sector which was analysed separately with the biggest impact is pulp and paper (21% of the industrial sector's mitigation potential comes from this grouping) but it should be noted that this project did not provide for direct sector engagement with the pulp and paper industry and there are uncertainties associated with the applicability of the measures identified for this sector in a Western Cape context. The analysis shows the iron and steel industry to have the potential for 13% of industrial sector mitigation with this based on a brief assessment of the measures remaining to the one large plant in the province. Mitigation potential in the cement and brick and clay sectors are also significant.

With regard to the type of measures to be implemented the highest ranked measures which also have the potential for substantial mitigation gains are associated with energy efficiency measures associated with utilities as well as process improvements through improved process control, monitoring and energy management. Better motor control and variable speed drives also have the potential to bring significant gains. In the case of energy efficient boiler systems and kilns the analysis shows these to have the biggest impact in terms of total mitigation but they are expensive measures to implement. Also expensive to implement but with large potential for mitigation is fuel switching mainly from coal and heavy furnace oil to natural gas.

The implementation of these measures is clearly dependent on action being taken by individual businesses supported by sector organisations and overall industrial actions. The national Departments of Energy and Environment Affairs have a key role to play through the regulation and incentives. In this regard the Desired Emission Reduction Outcomes (DEROs) of DEA is an important driver of change in the industrial sector. DEROs are being determined for each significant sector and sub-sector of the South African economy and include short-, medium- and long-term Carbon Budgets (CBs) for those sectors where CBs are appropriate. There are already a number of national energy efficiency initiatives including those through the National Cleaner Production Centre, who provide industry advice on enhancing energy efficiency through the implementation of regular energy audits and other energy monitoring practices.

While the Province has limited influence over the industrial sector they can engage on the fuel switching option as this requires infrastructure to get gas to individual industries, something the Province and municipalities can promote.

PASSENGER TRANSPORT

Nine mitigation measures associated with passenger transport sector have been identified, with the potential for mitigating 15% of the total for the province. The measures are separated into two groups: improved or alternative vehicle engines (for both passenger rail and road-based vehicles) and the maximum possible modal shift from private to public transport. Engine efficiency gains are driven by international initiatives in the motor industry and are generally outside the control of the Province.

The Province and the City of Cape Town have the potential to influence the modal shift in passenger transport which is highly ranked and needs to get concerted attention. It will, however, take time and considerable investment in infrastructure to bring about the required change.

FREIGHT TRANSPORT

The measures in this sector relate primarily to improved engine technology both for road and rail vehicles and modal shift from road to rail freight. Between the 3 measures identified they have the potential to mitigate 4% of the total for the province. The shift of freight from road to rail scores very highly, due in part to the relatively low level of investment required to upgrade the N1 Rail corridor between Cape Town and Gauteng, and the significant reduction in emissions which results from the reduced road-based freight emissions. This measure also has significant benefits in terms of social impact, and implementability.

However, the Province and municipalities have limited influence over this sector.

COMMERCIAL BUILDINGS

The 9 measures identified for this sector have the potential to mitigate 13% of the total for the province. Solar water heating and efficient lighting have high levels of potential mitigation and are highly ranked under the MCA. Improved heating, ventilation and air conditioning also have high mitigation potential but are not as easy to implement. There is long term potential for using embedded generation based on photovoltaic systems.

The Province and municipalities have a high degree of influence over these measures.

RESIDENTIAL BUILDINGS

The 11 measures identified for this sector which have the potential to mitigate 10% of the total for the Province. Solar water heating, energy efficient lighting and geyser efficiency (including geyser blankets) have high levels of potential mitigation and are highly ranked under the MCA. There is long term potential for using embedded generation based on photovoltaic systems.

The Province and municipalities have a high degree of influence over these measures.

AGRICULTURE

The 4 measures identified for this sector which have the potential to mitigate 6% of the total for the Province. Energy efficiency related to the introduction of variable speed drives (VSDs) used in pumped irrigation and on-farm cooling have high levels of potential mitigation but are not highly ranked under the MCA because the social impact of this measure is low, with most benefits accruing to farmers in the form of cost savings, with no direct job impacts. In contrast, while reduced tillage represents the smallest mitigation potential of all measures reviewed, it ranks fairly high in the MCA as it has significant other environmental benefits (e.g. reduced pesticide and fertiliser usage). It is also a significant source of abatement potential within the Agricultural sector, even if it scores much lower in absolute terms on a Provincial basis.

The Province has a high degree of influence over these measures.

PROVINCIAL INTERVENTIONS - SUMMARY

This showed that the province can affect the implementation of 100% of mitigation measures in the commercial buildings, residential buildings and agricultural sectors. The Province is also capable of affecting change in the passenger transport (44%), energy supply (37%), industrial (28%) and freight transport (17%) sectors.

The proposal made here is that, while effort should be made to pursue those measures which present the greatest abatement potential, there is equal motivation to pursue those which the province has the greatest power to influence or implement. As this study evidences, much of this influence rests in the buildings, passenger transport and agricultural sectors of the province.

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APPENDIX 1: TERMS OF REFERENCE

Terms of Reference for the Appointment of a Service Provider to undertake the completion of a climate change mitigation scenarios exercise in the energy sector for the Western Cape

1 INTRODUCTION

1.1 Service providers with relevant expertise and experience are herewith invited to submit bids to undertake a climate change mitigation scenarios exercise in the energy sector for the Western Cape.

2. BACKGROUND

2.1 In 2012, the Department of Environmental Affairs and Development Planning (DEA&DP) commissioned an energy consumption and CO_2 emissions database for the Western Cape. The database has been developed to support the strategic intentions to meet the following objectives:

- To provide an overarching energy consumption and CO2 database. It builds on data collated for 2004 and facilitates the tracking of energy and related emissions over time. It deepens the Western Cape Government's understanding of key energy and emission issues and management priorities both in terms of sector consumption and geographic distribution of that consumption;
- To provide a disaggregation of province energy and emissions profiles to district and sector levels.

The National Climate Change Response White Paper outlines the National Greenhouse Gas trajectory range, which

- Reflects South Africa's fair contribution to the global efforts to limit anthropogenic climate change
- Details the Peak, Plateau, Decline trajectory used as the initial benchmark against which efficacy of mitigation actions will be measured.

The Climate Change Response White Paper also states that each province will develop a climate change response strategy which evaluates provincial climate risks and impacts and seeks to give effect to the National Climate Change Response White Paper at a provincial level.

The results of this modeling exercise in this project will be used to identify the interventions that need to be implemented in order to meet the WCG PSO7 Energy Work Group energy efficiency and renewable energy targets. These targets are aimed at contributing towards the national and international commitments to reducing greenhouse gas emissions and to direct both energy demand- and supply-side actions that are a priority for the Western Cape.

3. SCOPE OF WORK

3.1 The scope of work undertaken by the service providers will include, but is not limited to:

- The conceptualization and development of energy reduction scenarios to model the emissions trajectory for the Western Cape in order to meet the Peak, Plateau and Decline Trajectory of the National Climate Change Response White Paper. The scenarios should include the impact of the different sectors as well as the impacts and requirements of the districts in the Western Cape;

- A model is to be developed for the Western Cape with the existing baseline information (2009 taken from the Western Cape Energy Consumption and CO_2 Emissions Database, 2013), a business as usual scenario and at least three future scenarios (the scope of the future scenarios is to be agreed on by the project team)
- The 2009 baseline for the Western Cape should be used, but where appropriate can be updated / expanded with appropriate data (this will be determined in discussion with project team);
- Both the demand (including energy efficiency, fuel-switching, etc.) and supply-side (the national electricity grid vs regional supply of energy/ the Integrated Resources Plan (IRP 2010) scenarios etc.) of the model should be populated and a transport component should be included (private, public and freight transport options);
- The scenarios should be based on reasonable population and GDP projections as well as other key socio-economic and demographic considerations;
- Sufficient costing information is to be included such that the overall costs of the different scenarios and the costs of different fuels types and interventions can be estimated, based on similar costing studies that are available in the public domain;
- All assumptions and data sources are to be included and referenced where appropriate;
- A report highlighting the proposed energy and emissions trajectory that the Western Cape needs to take in order to meet the Peak, Plateau and Decline trajectory of the National Climate Change Response White Paper. The report should include tables and graphs that highlight:
- The implications in terms of energy, emissions and costs of each scenario as well as comparisons between scenarios;
- The implication of each specific intervention in terms of energy, emissions and cost as it relates to the relevant sector or district;
- Sensitivity analyses for selected key variables, including the uptake and penetration of interventions in different sectors (to be discussed with project team);
- Where possible, the job creation potential from the interventions, based on studies and research that are available in the public domain; and
- A summary document on the key results of the study should also be developed.
- Stakeholder consultation around the scenario development should take place with key provincial and local government stakeholders as well as national government (where appropriate), parastatals and other key stakeholders in the form of both workshops and electronic engagements.
- The software used to complete the modelling should be user friendly, easy to update and not require annual license fees. The selected service provider would need to discuss the proposed software with the project team to ensure that it is compatible with the Western Cape Government IT requirements.

4. REPORTING AND MEETINGS

4.1 Consultants will be required to work closely with the project team and provide regular updates (minimum monthly) on project progress and challenges. These updates can be provided electronically.

4.2 The successful bidder and the project team will meet monthly for the duration of the project, where issues will be discussed and proposals debated. It is also at these meetings that the direction and progress of the project will be assessed.

4.3 The monthly meetings will be scheduled at the inception meeting.

4.4 The Department will provide the successful bidder with a venue in Cape Town for meetings.

5. PROJECT DELIVERABLES

5.1 The project deliverables are as follows:

5.1.1 Scenarios development : the generation of a baseline, business as usual and at least three future scenarios, including energy efficiency / demand side and energy supply interventions in order to identify the most appropriate GHG emissions trajectory for the Western Cape;

5.1.2 The scenarios model, modelling software and all data utilised in the model must be handed to the Department for future updating

5.1.3 Results must be presented in a graphical format

5.1.4 Workshops and Capacity Building

- Initial project meeting between appointed consultant and project team;
- Stakeholder engagement workshops (including all logistical requirements and costs for e.g. venue and catering) on the scenarios firstly with government officials (provincial and local) and then external stakeholders. The workshops should take place in at least Cape Town and one other venue in the Western Cape;
- At least two 1/2 day workshops for the presentation of results with provincial and local government officials; and
- Engagement with stakeholders via electronic means.

5.1.5 Final Report: method and analysis report detailing the interventions, scenarios and assumptions.

5.2 All deliverables and workshop materials must be provided in electronic form and should be made available to the Department once all reports have been approved and finalised.

6. ROLE OF THE DEPARTMENT

6.1 The responsibilities of the project team will be to:

- Interact with the successful consultant on behalf of the department;
- Assist consultants to access information held within the WCG, where problems are encountered;
- Consider and approve all the deliverables submitted by the consultants according to milestones and undertake regular review of the various steps of the project;
- Ensure that sufficient and effective measures are introduced to enable the recommendations of the consultants to be implemented effectively;
- A member of the project team will work closely with the consultant team in order to build capacity within the Department to undertake subsequent updating of the model. This representative should be included in all relevant meetings;
- The Department will also provide the energy consumption and CO2 emissions database for the Western Cape that was completed in 2013 using a 2009 base year.

7. COMPETENCIES, EXPERTISE AND QUALIFICATIONS OF SERVICE PROVIDER

7.1 The successful appointee must:

- Comprise members with appropriate qualifications for this assignment including an understanding of the energy sector, including energy efficiency interventions, costs and benefits, energy supply and energy and emissions modelling;
- Have knowledge and relevant experience in working with energy scenarios modelling;
- Have stakeholder facilitation experience;
- Have proven research, project management and analytical skills;
- Be knowledgeable about the environmental, social and economic development challenges facing the Western Cape;
- Be available to meet with individual interested sector and groups;
- Report to the project team on completion of each deliverable for discussion and validation;
- Be responsible for secretariat services of the project;
- Have the ability to produce thorough, readable and informative documents, reports and other communication materials.

8. BID EVALUATION CRITERIA

Submitted proposals will be evaluated in accordance with the 80/20 principle.

All applicants will be assessed according to the following criteria:

Bid criteria:	Weighting factors:
Price	80 points
B-BBEE Status	20 Points

Points must be awarded to a bidder for attaining the B-BBEE status level of Contribution in accordance with the table below in terms of preferential Procurement regulations, 2011:

B-BBEE Status Level of Contributor	Number of points (80/20 system)
1	20
2	18
3	16
4	12
5	8
6	6
7	4
8	2
Non-compliant contributor	0

A bid is not disqualified from the bidding process if the bidder does not submit a certificate substantiating the B-BBEE status level of contribution or is a non-compliant contributor. Such a bidder will score Zero (0) out of a maximum of 10 or 20 points respectively for B-BBEE.

9. RESPONSIVENESS CRITERIA

9.1 Indicate responsiveness criteria applicable for this bid

X	Bid form must be properly received on the bid closing date and time specified on the invitation, fully completed, dated and signed in ink.
X	Submission of the bid document as is without removing any pages
X	Invitation to Bid (WCBD 1), Submission of WCBD 4 (Declaration of Interest, Declaration of Bidders Past SCM Practice, Certificate of Independent Bid Determination), Preference Claim Certificate (WCBD 6.1a or WCBD 6.1b), Contract form for Goods/Works/Service (WCBD 7.1)
X	Submission of an Original Valid Tax Clearance Certificate, Business Registration Certificate e.g. CK1, certificate of incorporation and B-BBEE Status Level Verification Certificate

Responsiveness in terms of this document refers to the bidder's adherence and compliance to the requirements set out in section 9.1 and 9.2 in order for the department to evaluate their bid. Failure to comply with any of the responsive criteria will lead to disqualification of the bid.

The service provider must ensure that they are registered on the Western Cape Suppliers Database, failure to be registered will lead to disqualification of the bid. If registration has not been finalised, please provide proof of application.

9.2 Functionality responsiveness criteria applicable for this bid

Functionality Criteria:	Weighting Factors:
Service Providers, Skills and Competencies	30
Knowledge and experience of energy efficiency, energy supply and the energy sector in South Africa	20
Composition of the team and proof of relevant experience, including resumes of key professional staff [Schedule of personnel allocated to the project, their positions and designations and hours they will be involved in the project as well as hourly rates (inclusive of VAT)]	10
Interpretation of the terms of reference and quality of the methodology presented	40
Interpretation of the terms of reference & quality of the methodology presented. [Project Plan detailing roll out of the project including an organizational chart and work breakdown structure. The latter should include tasks, subtasks, calendar time allocation, major activities and milestones relative to cash flow expectations. Inclusion of administration and catering arrangements (including costing for venues) and costs].	40
Consultants' portfolio of evidence of similar projects	30
Proof of appropriate working experience in the field of energy efficiency, energy supply and the energy sector and appropriate experience in climate change scenarios modelling including references.	30

Note: Bidders will be required to score 70 points or more for functionality in order for their bid to be evaluated further.

9.3 Values

Weightings will be multiplied by the values below to arrive at the total Functionality score

Value	Description
0	Unacceptable
1	Poor
2	Acceptable
3	Good
4	Excellent

10. DURATION OF THE PROJECT

All deliverables to have been completed and the final document must be submitted to the Department by mid December 2014.

11. INTELLECTUAL PROPERTY

The appointee must note that all drafts, including the final draft of the document and any digital information derived in undertaking the project, including the model developed will be the sole property of the Western Cape Department of Environmental Affairs and Development Planning (DEADP). Any studies, reports or other material, graphic, software or otherwise prepared by the appointee for this project under this contract shall belong to and remain the property of DEADP. The service provider must relinquish any rights to use the model. No presentations of the reports may be made without prior written permission of DEADP and all information contained in these reports is considered confidential.

All materials emanating from services rendered with a branding implication must be consulted with the Department's Communication Services unit prior to the design or production thereof. Materials may include, but are not limited to, specialist reports; advertising; promotional materials and/or any other communication product produced for public or internal consumption.

12. DECLARATION OF CONFIDENTIALITY

The service provider/s shall regard all information in, or in support of the project, as confidential and may not use any information for personal or 3rd party gain. All communication with the media regarding this project (if any) will be conducted via the communication component of the Department (unless agreed upon otherwise).

The service provider will be required to sign a non-disclosure agreement with regards to the Eskom data that will be utilised in the model.

13. CONTACTABLE OFFICIALS FOR CLARIFICATION

FOR TECHNICAL QUERIES REGARDING THE SCOPE OF WORK, CONTACT
LIZE JENNINGS-BOOM
Directorate: Climate Change & Biodiversity
Tel: 021 483 0769
E-mail: lize.jennings@westerncape.gov.za

FOR ENQUIRIES RELATING TO THE BID DOCUMENTATION, CONTACT
SIYABULELA NCIPHA
Supply Chain Management
Tel: 021 483 2782
E-mail: Siyabulela.Ncipha@westerncape.gov.za

APPENDIX 2: MULTI CRITERIA ANALYSIS FRAMEWORK

INTRODUCTION

A Multi Criteria Analysis (MCA) approach was used to conduct an impact assessment on all identified energy-related mitigation opportunities, taking a range of criteria into consideration. MCA is a technique that explicitly considers multiple, often competing, criteria in a decision-making environment. The key benefits of MCA are that it provides a proper structure for a decision-making process, and that it makes the manner in which the multiple criteria are evaluated explicit.

By introducing other criteria which also focus on impacts and/or benefits, the MCA framework allows for a more holistic view to prioritising mitigation efforts than that feasible by use of the traditional Marginal Abatement Cost (MAC) analysis (which considers only the criterion of cost for a given amount of greenhouse gas mitigation). This section details the MCA process used in this study which mimicked that used in the DEA MPA. Readers are encouraged to refer to the detailed DEA MPA Technical Appendices A and B for further information.

STEPS IN THE MCA PROCESS

A MCA typically incorporates a number of steps. In line with the approach undertaken through the DEA MPA, the development of the MCA model for this study involved:

1 Sector analysis of options (costs and emissions);
2 Multi-criteria analysis (of all criteria);
3 Development of sector energy, emissions and energy abatement projections;
4 Ranking of all mitigation measures.

Step 1: *Decide on the decision context and stakeholders driving the MCA*

At the study's first stakeholder workshop the decision context was clarified and stakeholders were identified to participate in the development of customised MCA.

Step 2: *Identify mitigation measures*

In the second step, a list of mitigation measures was selected in alignment with the DEA MPA. Given that this study focused only on the energy-related emissions however, some mitigation measures assessed under the DEA MPA were omitted from analysis and yet other additional measures were introduced to represent a customised provincial energy-related mitigation potential analysis.

For this project, recommendations were made by the consulting team on the mitigation measures. These were then presented at the study's first stakeholder workshop in July 2014. Following discussions at these workshops a final list was prepared for further analysis and finalised to match the decision context in the province. The final list of mitigation measures comprised 100 options, a manageable number.

Step 3: *Identify criteria*

The criteria selected for this study match those in the DEA MPA and were specific, measurable objectives that can be used to assess the consequences of selecting a particular mitigation measure. In line with the DEA MPA, for this project a two-tier structure of criteria was set up with a set of main criterion and sub-criterion.

The criterion and related sub-criterion included:

Cost:

1 Net Present Value of life cycle cost per unit of CO_2eq mitigated.
2 Economic impact:
- Increase in Gross Value Added (GVA) per unit of CO_2eq mitigated.

3 Social impact:
- Job creation – total jobs created per unit of CO2eq mitigated;
- Proportion of jobs to unskilled workers;
- Non-monetary social impact.

4 Non-greenhouse gas environmental impact:
- Impact on water environment;
- Impact on land;
- Solid and hazardous waste impact.

5 Implementability:
- Technical implementability; and,
- Institutional implementability.

Step 4: *Set up scoring scales and undertake analysis*

There were quantitative and qualitative scoring scales. For criteria 1-3, the scoring scales were quantitative, with the exception for 'non-monetary social impact' which had a qualitative scoring scale. Criteria 4-5 were also scored on a qualitative scale.

For quantitative assessment, the scale emerges directly as it relates to the relative numbers and reflects the calculated impact of each mitigation measure in relation to the criterion. Qualitative criteria were assessed according to a constructed, categorical scale, where each level of performance is described and assigned a relative score. The scoring for qualitative criteria was based on judgement by stakeholders a party to the DEA MPA as well the informed expert opinion of this study's team. This MCA framework is represented in Figure 28: Multi-Criteria Analysis criteria and sub-criteria.

For criteria where quantitative analysis is possible, the following methodology was applied:

1 In the case of the cost criterion, the capital and net operating cost information applied to the demand and supply-side models was used to calculate a Net Present Value for each mitigation measure over the period 2012 to 2040.

2 For the economic impact criterion, the ratio of the relationship between NPV and GVA as found in the DEA MPA was used to impute the change in average annual GVA over the full period of analysis.

3 For the job creation sub-criterion, under the 'social' criterion, a quantitative value was imputed based on the ratio of the relationship between GVA and jobs as found in the DEA MPA. The output value represents the changes in the average number of jobs created per year.

4 For the criterion dealing with the proportion of unskilled jobs to total jobs, the ratio of the relationship between NPV and total jobs as found in the DEA MPA was used to impute the proportional split of jobs by skilled and unskilled labour.

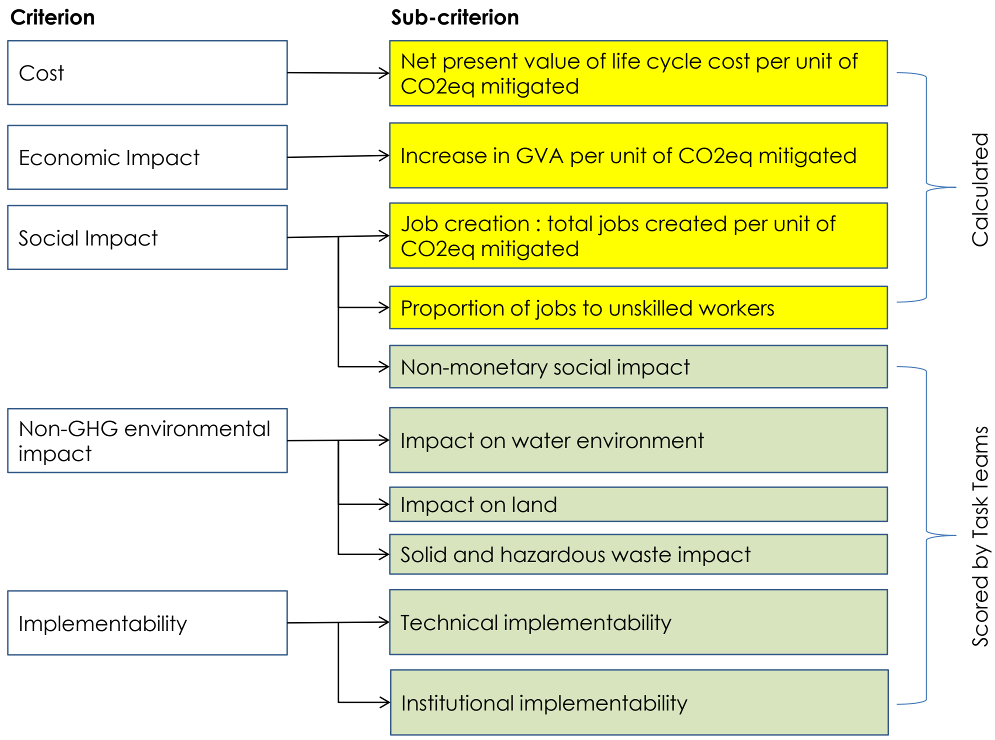

Figure 28: Multi-Criteria Analysis criteria and sub-criteria

Source: Department of Environmental Affairs Mitigation Potential Analysis

Step 5: *Score the mitigation measures*

Each mitigation measure was then scored against the established scale. For the quantitative criteria where data is readily available, scoring is based on the results of an analysis of numbers which, as noted above, result in a score based on the range of the numbers.

For qualitative criteria, the scoring selected by DEA MPA Task Teams who were engaged through workshops on each sector, were employed and complemented by the study team's informed opinion where additional mitigation measures were selected.

Step 6: *Use a value function to convert scores to points on a scale of 0 to 100*

A 'value function' was then used to translate scores on differing scales into points on a scale of 0 to 100, which allowed for comparability between criteria. In the case of this project a linear value function was used for all criteria, whereby scores are related to points along a straight line.

Step 7: *Assign weights*

While weights can be used to understand the relative importance of one measure relative to another, they are best understood as scaling constants, allowing a unit of preference on one criterion to be compared to a unit of preference on another. For this project the various sub-criteria were weighted in order to come up with a score for each criterion. In addition, the various criteria were then weighted in order to come up with an overall weighted score for each opportunity. This was then used to generate a ranked list of opportunities based on their overall impact.

While the ranked list was a significant output from the MCA, the primary objective was to provide information on where opportunities perform strongly and where perform poorly. One weighting criteria, 'balanced weighting', was applied in this study to represent the best compromise between various stakeholder interests.

Step 8: *Calculate overall weighted scores at each level in the decision tree hierarchy*

This is a mathematical process. In an additive aggregation function process (such as that outlined here), an option's score on a criterion is multiplied by the weight of the criterion. This is done for all criteria, and the products are summed to give an overall preference score. The process is repeated for all criteria.

Mathematically:

$$S_i = \sum_{j=1}^{n} w_j s_{ij}$$

where S_i is the overall preference score for option i, n is the total number of criteria, s_{ij} is the preference score for option i on criterion j, and the weight for criterion j is W_j.

For this project, the scoring and weighting is undertaken in an MCA Excel workbook for each sector within the 'MOM' workbook which integrates all the measures considered into a single analysis.

Step 9: *Examine the results and make recommendations*

The final step in the MCA is to establish a ranking of the options and make recommendations. For this project this was done in the 'MOM' workbook. This allows the relative prioritisation of the large numbers of measures to be undertaken.

IDENTIFICATION OF MITIGATION MEASURES

The identification of mitigation measures to be evaluated for the purposes of this project is covered in the main body of the report and in other Appendices.

The list of 100 mitigation measures distributed across sectors as shown in the table below.

Table 9: Number of mitigation opportunities per sector.

Sector	Number of opportunities
Agriculture	4
Buildings (Commercial and Residential)	20
Energy supply	8
Industry	56
Transport (passenger & freight)	12
Total	100

'Normalising' the criteria against mitigation potential

The approach taken when defining the criteria has been to normalise the quantitatively calculated results against tonnes of CO_2eq avoided. In this case, the cost criteria were R million costs per tonne of CO_2eq avoided, rather than the total magnitude of the cost in R million. As a consequence, mitigation potential has been omitted as a criterion as this was the basis for comparing relative impact for all other criteria.

The following criteria were 'normalised' in this way:

- Economic impact measures as R million GVA per unit of CO_2eq mitigated.
- Jobs impact measured as number of jobs created per unit of CO_2eq mitigated.

Qualitative criteria were not normalised. The implication of this has been that the scoring is for an equivalent amount of mitigation.

Discounting future costs and benefits

Discounting future costs and benefits that can be expressed in monetary terms is common practice and, while there remains significant debate about what discount rate is to be used, there is also considerable precedent with sound underlying rationale on which to rely when choosing a discount rate. Therefore this approach is taken for the cost criterion, with a discount rate of 11%[18] applied as in the DEA MPA. The modelling framework of the MOM does however allow for the discount rate to be varied. The choice of discount rate has a direct impact on the discounted Net Present Value modelled for each of the demand and supply-side models.

INDIVIDUAL CRITERIA: DATA AND SCORING

Cost

Cost was included as a criterion based on the argument that lower costs are advantageous and would be a major factor in causing a mitigation measure being implemented. The cost scores for the MCA were calculated on a continuous basis with a linear value function with the highest score being the lowest cost per unit of CO_2eq mitigated, and the lowest score being the highest cost.

Economic impact: Gross Value Added (GVA)

GVA is a commonly applied measure for the scale of economic activity, measuring the value which the activity adds to the economy in millions of Rands. The impact on GVA is a key component of an assessment of economic impact.

The indicator was defined as additional Gross Value Added (GVA) created (or lost) up until 2040 in millions of Rands, per unit of CO_2eq mitigated, in relation to the counterfactual. GVA was calculated as described under step 4 above.

The scores for the MCA were calculated on a continuous basis with a linear value function with the highest score being the highest value of GVA per unit of CO2eq mitigated.

Social impact: Job creation – total jobs

In the context of a country with an unemployment profile such as that seen in South Africa, the creation of unskilled or semi-skilled jobs is critical for social development.

The indicator was defined as the number of additional jobs (unskilled, semi-skilled and skilled) created or lost over the period up to 2040, in relation to the counterfactual. Job numbers were calculated as described under step 4 above.

The scores for the MCA were calculated on a continuous basis with a linear value function with the highest score being the highest number of jobs created per unit of CO_2eq mitigated.

18 There is much debate about the correct discount rate, with (generally) a much lower discount rate of around 3% applicable if the analysis is focused on social benefit. However, for the current analysis the stakeholders concerned preferred to use a discount rate which reflected private sector needs.

Social impact: Nature of jobs created

This criterion is introduced to provide for the fact that unskilled and semi-skilled jobs are more important from the point of view of social development than skilled jobs. The indicator is the ratio of unskilled jobs and semi-skilled jobs to skilled jobs. The numbers of jobs in each of these three categories was calculated as described under step 4 above. Therefore the required ratio can be calculated from these outputs.

The scores for the MCA were calculated on a continuous basis with a linear value function with the highest score being the highest ratio: most unskilled and semi-skilled jobs created in relation to skilled jobs.

Social impact: Non-monetary social impact

This criterion was introduced to measure non-monetary social impacts: those which do not relate to income (jobs) or expenditure (prices). The indicator is described as: 'The extent to which the measure improves 'livability' or 'happiness' for people, with the primary emphasis on poor people'.

The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 10: Scores and interpretation for non-monetary social impact criteria.):

Table 10: Scores and interpretation for non-monetary social impact criteria.

Score	Interpretation
-1	Has a negative impact (e.g. unsightly or noisy facilities likely to be built close to settlements)
0	No impact
1	Small positive impact (e.g. improved experience of nature outside settlements)
2	Moderate positive impact
3	High positive impact (e.g. tree planting in urban areas; new public transport facilities reducing travel time; improved homes)

These scores were converted to points on a 0 to 100 scale using a linear value function with a score of -1 being zero and +3 being 100.

Environmental impact: Water

Under circumstances of water scarcity, such as those in South Africa, any intervention which requires additional water represents a negative impact on the environment. This takes place both through quantity impacts – using more water – and through quality impacts: lowering the quality of wastewater returned to the environment or increasing the level of pollutants in runoff.

The indicator was stated simply as: 'The impact of the measure on the water environment in terms of quantity and quality'. The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 11):

Table 11: Scores and interpretation for environmental impact (water) criterion.

Score	Interpretation
-3	Very negative impact in terms of increase in quantity of water abstracted and/or reduced quality of water in receiving water bodies (e.g. forestry with no trading of water with other users)
-2	Moderate negative impact
-1	Small negative impact
0	No significant impact
1	Has a positive impact in terms of improving water quality or reducing the amount of water abstracted thereby increasing the amount of water available for other uses (e.g. grassland and thicket rehabilitation)

The importance of the counterfactual with regard to electricity generation measures was notable. Each measure was compared against the impact of coal fired power stations with the associated mining of coal included.

The scores for each measure were converted to points on a 0 to 100 scale using a linear value function with a score of -3 being zero and 1 being 100.

Environmental impact: Land

Land impact is taken to have two components:

- Impact on reducing biodiversity.
- Reducing the land use options in the future.

While it is, in theory, possible to calculate the impact quantitatively, this is not practical and therefore a qualitative assessment is required taking both these components into consideration.

The indicator was stated as: 'The extent to which the measure impacts on land either in terms of reducing biodiversity or limiting the uses of land of a variety of other purposes in the future.'

The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 12):

Table 12: Scores and interpretation for environmental impact (land) criterion.

Score	Interpretation
-2	Substantially negative impact (e.g. new commercial forestry)
-1	Moderate negative impact.
0	No significant impact
1	Moderate positive impact.
2	Substantially positive impact (e.g. restoration of grasslands or other improving other natural biomes)

These scores were converted to points on a 0 to 100 scale using a linear value function with a score of -2 being zero and 2 being 100.

Environmental impact: Waste

Waste management is a significant concern for some mitigation measures. This criterion is intended to assess the extent of difficulty in disposing of waste (both solid and other hazardous wastes) relative to the counterfactual. Increased difficulty in disposing of waste will relate both to a change in the magnitude of the waste stream produced and to a change in its nature (general, or hazardous).

The indicator was stated as: 'The extent to which solid waste and other hazardous wastes impact on the environment'.

The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 13).

Table 13: Scores and interpretation for environmental impact (waste) criterion.

Score	Interpretation
-3	Extremely high negative impact typically associated with hazardous waste or large quantities of industrial waste.
-2	Moderate to high negative impact
-1	Small negative impact
0	No significant impact
1	Moderately positive impact, relating to a reduction in the quantity of waste produced or quantity disposed of to land (e.g. waste recycling measures).
2	Highly positive impact in relation to existing situation. For example avoiding a large proportion of coal based energy generation and associated coal mining

It was notable again that the counterfactual in the case of electricity generation measures (existing coal based power generation) was particularly important due to the high impact which these existing generation measures (including coal mining) have relating to waste. This meant that other electricity generation options which have a high waste impact may have resulted in 'no significant impact' as they were more-or-less equal in impact to the counterfactual.

The scores for all measures were converted to points on a 0 to 100 scale using a linear value function with a score of -3 being zero and 2 being 100.

Implementability: Technical factors

Ready access to technology and the ability to implement this technology easily in South Africa are key factors which need to be taken into consideration when comparing mitigation measures. This criterion in intended to deal with both factors: the extent to which the technology is available internationally and the extent to which it has been implemented in South Africa.

The indicator was described as: 'The extent of difficulty in implementing the measure, taking the availability of technology and the extent of development of the field in SA into consideration'.

The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 14).

Table 14: Scores and interpretation for implementability (technical factors) criterion.

Score	Interpretation
1	No implementation difficulties from a technical point of view: widely applied in SA; well-developed industry.
2	Technology previously applied in SA but industry in early stages of development.
3	Technology applied relatively widely internationally but not in SA; industry not developed in SA.
4	Technology applied to a limited degree internationally; no experience in SA over past two decades.
5	High degree of difficulty expected both because of nascent stage of development of technology and lack of industry experience with this measure.

The scores for all measures were converted to points on a 0 to 100 scale using a linear value function with a score of 5 being zero and 1 being 100.

Implementability: Institutional factors

The extent to which a measure can be easily implemented also relates to the difficulty in the process of getting approvals for a project. This covers both the need to meet regulatory requirements imposed by government and the need to gain support by other key stakeholders.

The indicator was described as: 'The extent to which implementing the measure requires engagement and approval of multiple public bodies and involves multiple regulations'.

The mitigation measures were scored against this criterion based on the informed opinion of DEA MPA Task Team members and the informed expert opinion of this study's team, applying the following scale (Table 15).

Table 15: Scores and interpretation for implementability (institutional factors) criterion.

Score	Interpretation
-1	Public bodies activate measures and actively support measures, effectively building the 'industry', with no regulatory requirements (e.g. urban tree planting).
0	No significant difficulties with institutional aspects, no regulatory requirements.
1	Small degree of difficulty: some straight-forward approvals needed (e.g. grassland rehabilitation).
2	Moderate degree of difficulty: Engagement with several public bodies and other stakeholders required to get approvals but approvals relatively standard (e.g. establishment of a new waste composting facility).
3	High degree of difficulty expected both because complexity of approvals and stakeholder engagement process. e.g. Nuclear power station.

The scores for all measures were converted to points on a 0 to 100 scale using a linear value function with a score of 3 being zero and -1 being 100.

WEIGHTING OF CRITERIA

Once scores have been allocated, a large amount of information about the relative performance of the mitigation measures becomes available. The various sub-criteria were then weighted to come up with a score for each criterion. In addition, the various criteria can be weighted in order to come up with an overall weighted score for each opportunity. This was then used to generate a ranked list of opportunities based on their overall impact.

APPENDIX 3: GREENHOUSE GAS EMISSION CONVERSION FACTORS

Energy Source	kt CO2eq/TJ
Anthracite	0.090
Bituminous Coal	0.097
Coking Coal	0.095
Diesel	0.073
Electricity	0.260
Gas Diesel	0.070
Gasworks Gas	0.044
Heavy Furnace Oil	0.075
Liquified Petroleum Gas	0.061
Natural Gas	0.056
Paraffin	0.072
Petrol	0.067
Solar	0.001
Wood/ Biomass	0.092

Source: Adapted factors as used in the Western Cape Energy and Emissions Database 2009.

While the reference case for electricity assumes a constant emissions factor, the APM scenarios provide for a declining electricity emissions factor over time as renewable energy and natural gas become more prominent in the fuel mix. The declining electricity emissions factor is shown below.

APM electricity emissions factor	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**	**2020**	**2021**
	0.26	0.26	0.26	0.25	0.25	0.25	0.25	0.25	0.24	0.24
	2022	**2023**	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**	**2031**
	0.23	0.23	0.23	0.22	0.22	0.21	0.21	0.21	0.20	0.20
	2032	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	
	0.20	0.19	0.19	0.19	0.18	0.18	0.18	0.17	0.17	

APPENDIX 4: KEY MODELLING ASSUMPTIONS AND METHODOLOGY BY SECTOR

A. AGRICULTURE

Cautionary note

The following measures provide an envelope for provincial level planning, for the level of emissions reductions which are possible from the agricultural sector. This envelope has been developed using a top-down, rather than farm-level bottom up approach, and can be substantially improved on. However, the analysis is suitable for the purposes of a provincial exercise aimed at assessing the relative magnitude of emissions reduction measures possible in the sector.

Sector overview

The Agricultural category includes Standard Industrial Classification codes 11, 12 and 13: Agriculture and hunting (11), forestry (12), & fishing (13). However fishing accounts for only approximately 1% of the energy consumed in the sector, so it hasn't been separated out as a sub-sector (WC PERO, 2013).

As a province the Western Cape contributed some 14% to the country's GDP. However it generates about 23% of the total value added of the agricultural sector in South Africa (Wyngaard, 2006 and Western Cape Provincial Treasury, 2013: 56).

While the Western Cape is therefore significant in terms of share of agricultural activities and energy consumption in South Africa, as an economic sector Agriculture accounts for 4% of the Western Cape's economy, but only 2% in the rest of South Africa. (Western Cape Provincial Treasury, 2013).

Calculating an initial energy balance for agriculture

Unfortunately the latest provincial energy balance for agriculture only provides information on the proportion of electricity used in the sector: there is no data on the use of any other fuel for the agricultural sector, due to the difficulties in getting disaggregated data for the fuels used by this sector.

Table 16: Western Cape Agricultural sector energy balance: 2009 versus 2012/13

	Electricity		Total	
Single Energy Unit (PJ)	2009	2012/13	2009	2012/13
Total final consumption	81,023	76,726	292,342	276,005
Agriculture	4,698	6,968	4,698	6,968
% of total WC	5.8%	9.1%	1.6%	2.5%

Source: WCEED 2009 and 2012

Earlier national energy balances produced by Statistics South Africa (1995 to 2009) were used to generate a split for the agriculture sector between electricity, diesel and coal.

Table 17: Comparison of State of Energy results for 2006, 2009 and 2010

Single Energy Unit (TJ)	Coal	Petroleum	Electricity	Total
Agriculture: 2006 database	763	48,498	21,029	70,291
% share	1%	69%	30%	100%
Agriculture: 2009	679	47,418	21,029	69,126
% share	1%	69%	30%	100%
Agriculture: 2010 database	1,799	228,592	21,029	251,420
% share	1%	91%	8%	100%

Source: Department of Energy (DOE) (energy balance database), http://www.energy.gov.za/files/energyStats_frame.html

As the 2009 data has a total provincial total of 107 PJ (excluding aviation and international marine fuel – not shown above), the 2010 DOE figure of 228 PJ for the Agricultural sector is highly suspect, and should not be used for modelling purposes. The 2009 State of Energy data-set was therefore the most recent data-set used from the DOE. (Subsequent to this analysis, the DOE has updated the 2010 State of Energy data to correct these errors.)

Both the provincial and national data sets have substantial limitations for the Agricultural sector. The Western Cape Energy and Emissions Database has no information for any other energy source other than electricity for the Agricultural sector, while the national balances appear to be based on ratios since 2006, and can only be apportioned to provinces using measures such as share of GDP. This data was therefore supplemented by the 2006 South African Times (SATIM) work undertaken by Harald Winkler et al (2006).

Using the 2006 split of fuel usage for the Agricultural sector from the DOE Energy Balance calculations, there was a split of 1% coal, 69% petroleum products, and 30% electricity. This split applied for the following years up to 2009.

The following table explains the process used for deriving a sector total for the agricultural sector in the Western Cape.

Table 18: Derivation of energy balance for the Western Cape Agricultural sector, by fuel type

National	Coal	Petroleum products	-	Electricity	Total	Notes
	PJ	PJ		PJ	PJ	
1995	8.0	58.3		19.1	85.4	StatsSA, 2005,Energy accounts for south africa, 1995-2001 http://www.statssa.gov.za/publications/discussenergyacc/discussenergyacc.pdf Annual data is available for the period 1995 to 2009, but only a representative sample has been shown here, for the years 1995, 2001, 2006 and 2009
1995 (%)	9%	68%		22%	100%	
2001	2.7	52.2		15.0	70.0	StatsSA, 2005,Energy accounts for south africa, 1995-2001 http://www.statssa.gov.za/publications/discussenergyacc/discussenergyacc.pdf
2001 (%)	4%	75%		21%	100%	
2006	0.74	48.6		21.03	70.4	Statistics South Africa, 2009, Energy Accounts for SA, http://beta2.statssa.gov.za/publications/D040511/D0405112006.pdf
2006 (%)	1%	69%		30%	100%	

National	Coal	Petroleum products	-	Electricity	Total	Notes
2009	0.68	47.4		21.03	69.2	http://beta2.statssa.gov.za/publications/D040511/D0405112009.pdf
2009 (%)	1%	68%		30%	100%	
SATIM splits	1%	62%	6%	30%		Winkler et al, 2006. Note the consistency between the 2006 SATIM work, and subsequent Energy Balances between 2006 and 2009.
Western Cape	**Coal**	**Diesel & Petrol**	**Other petroleum products**	**Electricity**	**Total**	**Notes**
2009	unavailable			4.698	unavailable	Western Cape Energy and Emissions Database, 2009
2012	unavailable			6.968	unavailable	Western Cape Energy and Emissions Database, 2012
2009	0.18	9.93	0.98	4.84	15.93	Derived data. Other than electricity, volumes are derived using the SATIM percentages shown above.
2012	0.26	14.48	1.43	6.968	23.23	Derived data, with the exception of electricity. This assumes that the ratio of electricity has remained at 30%. As the overall trend for energy consumption in the sector has been decreasing since 1995, it seems unlikely that the trend will have completely reversed since 2006. However, 23 PJ can probably safely be seen as a maximum estimate for energy consumption in the agricultural sector in the Western Cape.

Deriving an activity based split for agricultural energy consumption

Once a total for the Western Cape agricultural sector was derived, the next step was to understand how to allocate it to different parts of the sector. It would have been preferable to allocate it based on energy intensity data for different agricultural products, by value or land area, but this data couldn't be found.

The following energy disaggregation is based on the 2006 SATIM assumptions, based on the major activities, and ignores fishing as an energy sector. The following set of end-use demands were used:

- Traction (tractors, harvesters and on-site transport)
- Irrigation (electricity, diesel and petrol driven pumps)
- Primary processing (electric equipment)
- Heat (hot water for dairies, incubators, drying of crops)
- Other (electricity demands such as lighting and cooling etc.)

The assumptions regarding energy use by fuel type and activity are taken from the SATIM study). A set of end-use energy intensities were then derived for the agricultural sector. These were used as the basis for allocating fuel to different activities. "The allocation is therefore a "best guess" although there is a high confidence in attributing the majority of this to traction." (Winkler, 2006).

The following tables are taken directly from the SATIM work, and are based on national analysis:

Table 19: Agriculture Sector Energy Service Share of Final Energy Consumption by Primary Fuel / Energy Service

End-use Fractional Shares by Sub-sector	Coal	Oil Diesel	Electricity	Oil Gasoline	Oil Heavy Furnace Oil (HFO)	Oil Paraffin	Oil LPG
Agriculture - Heating	100%	0%	0%	0%	100%	100%	100%
Agriculture - Processing	0%	0%	26%	0%	0%	0%	0%
Agriculture - Traction	0%	99%	0%	98%	0%	0%	0%
Agriculture - Irrigation	0%	1%	36%	2%	0%	0%	0%
Agriculture - Other	0%	0%	38%	0%	0%	0%	0%
Total	100%	100%	100%	100%	100%	100%	100%

Source: Winkler, 2006 (SATIM)

Table 20: Activity based energy allocation for the Western Cape for 2012

End-use Final Energy Consumption by Fuel (Petajoules)	Coal	Oil Diesel	Electricity	Oil Gasoline	Oil HFO	Oil Paraffin	Oil LPG	Total
Agriculture - Heating	0.76				1.76	2.51	0	5.04
Agriculture - Processing			5.49					5.49
Agriculture - Traction		37.91		4.88				42.79
Agriculture - Irrigation		0.32	7.6	0.08				8
Agriculture - Other			7.95					7.95
Total	0.76	38.23	21.03	4.96	1.76	2.51	0	69.26
Reference case Agricultural fuel split	1%	55%	30%	7%	3%	4%	0%	100%

Source: Own analysis, using SATIM fuel splits (Winkler, 2006)

These percentage splits between activities and fuel types were applied to the total agricultural demand which had been derived (detailed in the previous section.)

Table 21: Activity based energy allocation for the Western Cape for 2012

Terajoules	Agri - Traction	Agri - Irrigation	Agri - Processing	Agri - Other
Oil Diesel	12,713	107	-	-
Electricity	-	2,518	1,818	2,633
Oil Gasoline	1,638	27	-	-

Source: Own analysis

Identified energy-related mitigation measures in the Agriculture sector

Agricultural energy consumption is assumed to be related only to on-farm activities, and does not include the transport of any goods to market, or extensive processing.

Note: The use of agricultural biomass as a source of electricity is not dealt with here, as these measures are focussed on demand side measures, while biomass is a potential source of supply. However, it has been noted that many farm wastes are best used in-situ, due to a combination of factors such as seasonality of waste (post-harvest), higher value usage elsewhere in the agricultural cycle, transport costs, low volumes. Piggery and chicken farm waste remain a notable exception, which requires additional investigation depending on waste location and volumes.

The principal demand side measures identified through stakeholder engagement and literature review includes:

- Conservation agriculture practices, with the associated reduction in fuel costs through reduced tillage;
- Reduced electricity costs through higher efficiency irrigation & reduced water use;
- Reduced electricity costs through on farm behavioural improvements with regards to efficiency;
- Reduced electricity costs through the use of variable speed motors.

These activities are centred on the use of diesel and electricity. In each case, the 2006 SATIM agricultural energy splits by activity were used to further sub-divide the estimated energy demand, and to provide a range of energy consumption for each activity.

Additional supply side energy options in the Agricultural sector included:

- Anaerobic digestion and biogas for piggeries and chicken farms, due to the year round supply.
- Production of bioethanol, particularly from marginal rain-fed land in the Western Cape.

Reduced tillage and conservation agriculture

The only proposed measure which results in a reduction of on-farm diesel consumption, this measure does not include any transport of goods from the farm to market. It is focussed on energy savings from reduced tillage practices which are possible when conservation agriculture methods are adopted.

Energy use related to tillage in the agricultural sector is significant with regard to:

- Preparing the land;
- Applying nutrients, pesticides and herbicides;
- Harvesting.

Conservation agriculture, including reduced tillage, crop rotation and use of crop residues has been shown to reduce the energy demand for tractors and harvesters.

Tillage is not a major farming practice within perennial orchards and vineyards, and is more relevant for annual crops (Confronting Climate Change, Carbon Calculator Protocol)

The total amount of energy consumption related to traction (derived above) was applied to obtain an estimate of the total petrol and diesel demand for this activity. This was then adjusted further based on the proportion of annual crops versus horticulture on a land area basis. Although this is flawed because it assumes the same energy consumption per cultivated hectare, no other basis was available at the time.

Based on SATIM splits, energy consumption related to traction is assumed to amount to 14,351 TJ in 2012. Of this, only the 71% of the land cultivated for annuals has been considered for fuel reductions from reduced tillage practices. As no other basis for refining the data was available, this proportion was used as a proxy for calculating the amount of fuel used for traction on farms which produce annual crops. This results in a base consumption of 10,272 TJ for both petrol and diesel consumption in the Western Cape.

Table 22: Agricultural land usage in the Western Cape (Thousand ha)

Western Cape land usage	Unit: 1000ha
WC crop lands	1,117
Irrigated agriculture	406
Field crops	89
Horticulture	317
Dryland agriculture	711

Source: Table 3 base scenario in Hassan et al, 2008. South Africa 2002 Water-SAM

A recent analysis by the Agricultural Research Council (ARC) has found that reduced tillage practices reduce diesel consumption by at least 60% compared to conventional practices.

Key assumptions:

- Only annual crops were assumed to benefit from the measure.
- As the current extent of penetration wasn't known, a conservative saving of 50% has been assumed, phased in over 5 years from 2012 to 2017. This is partly to account for farms where this practice has already been implemented.
- The area of land under cultivation is assumed to remain constant. It appears to have declined over the past 20 years, so this is not an unrealistic assumption.

Reduced irrigation energy demand from the use of variable speed drives

The electricity usage from irrigation pumps is a major component of many growers' energy consumption and carbon footprint (South African Fruit and Wine Initiative, 2011). Case studies have shown that by installing variable speed drives on to irrigation pumps, an energy saving of between 35-75% can be achieved, depending on the original usage requirements and pumping head. The smooth stopping and starting of the irrigation system will help ensure reduced mechanical and operational costs, in addition to energy savings.

Key assumptions:

- As no farm level data was available on energy usage by crop type, rather than attempting to model the demand bottom up, we used SATIM activity based usage estimates to derive the total amount of electrical energy used for irrigation.
- The model assumes that a total of 35% savings are possible off the current total irrigation related cost. This is partly to compensate for the uptake which has already occurred.
- Assumed current penetration of Variable Speed Drives of 10%.
- All irrigation has been assumed to be pumped, rather than gravity fed.

Energy savings from irrigation management systems

Regular monitoring of water usage and soil moisture content, using soil moisture probes that work with a computerised irrigation system, improves the effectiveness of the irrigation, reducing water wastage and thus energy-related requirements. A 2013 study concluded that the implementation of a management system is a more viable method of reducing the water footprint than purchasing a new irrigation system.(Dryden & Campbell , 2013)

Note: While the Fruitlook satellite data system was also considered, the possible savings are lower than that of an irrigation management system. As the degree of overlap of these savings is not known, the savings from using the Fruitlook system is assumed to be captured under this measure. While the current cost of using the Fruitlook satellite data is currently low, the future cost is unknown.

According to research done by Dryden & Campbell (2013) water tension meters range between R350 and R800. They require minimal maintenance, are low cost and function in dry regions. Use of the sensors effectively reducing the water consumption by 26% (Holler, 2008).

Key assumptions:

- Energy savings from improved water management were linked to lower VSD energy usage, providing a lower base-line to avoid over-estimation of savings;
- The total area under irrigation in the Western Cape is estimated at 406,000ha
- 25% of irrigated land by area was assumed to already have irrigation management systems;
- A 26% reduction in water usage is assumed to result in an equivalent energy savings.
- A monitoring location is needed every 15-20 acres, or every 6-8ha (http://www.irrometer.com/pdf/supportmaterial/ADG2006.pdf);
- Cost per sensor of R500. Range of costs from R350 to R800 in 2010;
- Estimated cost based on capex and fuel savings, no operational cost was included.

Post harvest electricity reductions

Bouwer (2013) has identified high levels of energy inefficiency currently in the sector, which can be reduced using a variety of measures. Electricity usage in post-harvest chain has been highlighted as contributing significantly to producers' carbon footprints, particularly those with large-scale operations. Very often the improvements in energy efficiency need not involve high capital outlay, and can be a simple upgrade of the insulation in the heating/cooling exchanges, switching to CFL or LED lighting, or changing the time of day the energy is used (peak versus off-peak) which will result in a significant decrease in energy requirements, energy costs and carbon emissions.

This mitigation measure assumes the use of higher efficiency equipment, specifically the introduction of variable speed motors, although other measures are possible. There are also cost-free behavioural changes which can result in significant savings in post-harvest energy consumption, related to cooling and refrigeration in particular. Some examples include harvesting at night-time to reduce cooling costs, or installing screens on cool rooms to reduce the loss of cool air.

Key assumptions

- Using the SATIM activity based information, the total electricity baseline this activity is estimated at 4,451 TJ in 2012, for both packing/processing and cooling activities.
- A conservative savings of 25% over baseline has been assumed
- While there are operational maintenance savings costs, these have not been included.

B. BUILDINGS

B1. Residential

Sector overview

The Growth Potential of Towns study completed by the University of Stellenbosch in 2013 evidenced that in general, the Western Cape is well served with infrastructure, having the highest national percentages of households with access to services on their property: water supply, flushing toilets, electricity for lighting and refuse removal according to Census 2011. However, large numbers of people still live in poorly serviced areas with low or very low levels of infrastructure as shown in Figure 29: Infrastructure index of the Western Cape.

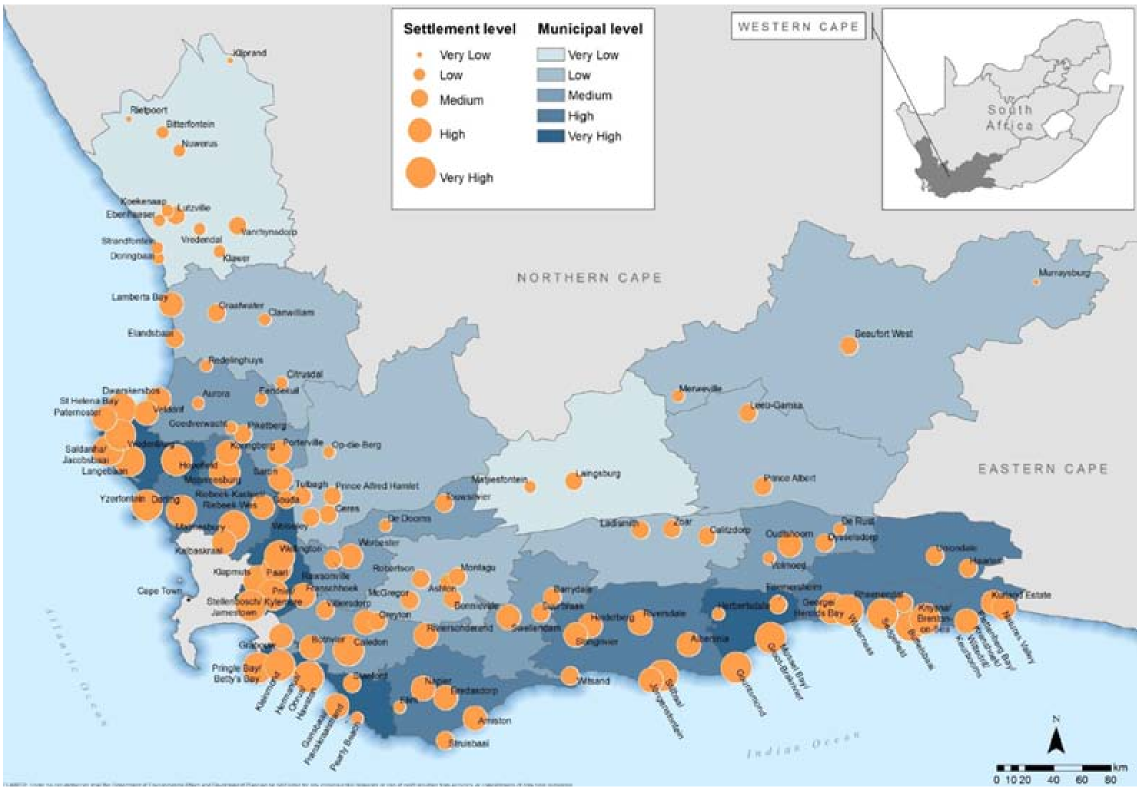

Figure 29: Infrastructure index of the Western Cape

Source: Growth Potential of Towns study (University of Stellenbosch & CSIR), 2013:32

Key assumptions & main model drivers

In this study, low income households were designated as those earning below R3 200/month by the census 2011 household income categories. Middle income households correlate to those earning between R3 200 and R12 800/month and high income households those earning above R12 800/month. According to Census 2011 figures (Table 23), the Western Cape is dominated by households in the low income group (47%) relative to the middle (30%) and high (24%) income households. While most middle and high income households reside in formal dwelling structures, less than 75% of low income households do. Similarly, while most middle and high income households are electrified, less than 90% of low income households are.

Table 23: Distribution of households by income group, dwelling & electrification status

	Low income	Middle income	High income
Overall split of households (%)	47%	30%	24%
Households in formal dwellings (%)	74%	90%	98%
Households electrified (%)	89%	97%	100%

Source: Statistics South Africa, Census 2011.

In this study, energy consumption by households was modelled based on the split of household income groups by electrification status (Table 24).[19] In terms of energy consumption high income households were found to be the largest energy consuming group in the province. Following close behind were middle and low income electrified households comprising 27% and 26% respectively of energy consumption across all households. While non-electrified households comprised less than 15% of the share of energy consumption, their energy use was key to unpacking the split of energy use in the province.

Table 24: Household income group split modelled by electrification status

Income and electrification status	% of households per group	Terajoules energy consumption	% of energy consumption
Low income electrified (LIE)	44%	11 936	35%
Middle income electrified (MIE)	28%	9 216	27%
High income electrified (HIE)	22%	8 780	26%
Low income non-electrified (LINE)	5%	3 419	10%
Middle income non-electrified (MINE)	0.9%	631	2%
TOTAL	100%	33 983	100%

Source: Statistics South Africa, Census 2011.

Energy consumption of the residential sector in the Western Cape was calculated based on energy consumption estimates from SATIM and the size of the residential dwelling sector in the Western Cape. The SATIM energy consumption estimates used are those shown in Table 25.

Table 25: Final energy consumption (2006)

Final energy consumption by sub-sector (PJ)	Electricity	Oil Paraffin	Coal	Biomass / Wood	Oil LPG	Total
Low Income Electrified (LIE)						
Lighting	4.75	-	-	-	-	4.75
Cooking	6.92	1.49	-	19.60	0.16	28.17
Space Heating	4.29	1.12	5.96	3.67	0.01	15.04
Water Heating	8.07	1.22	-	5.60	0.16	15.06
Refrigeration	2.72	-	-	-	-	2.72
Other	1.02	-	-	-	-	1.02
Non Energy	-	0.36	-	-	-	0.36
Total	**27.76**	**4.18**	**5.96**	**28.87**	**0.34**	**67.12**

19 Note that no high-income households are considered to be non-electrified.

Final energy consumption by sub-sector (PJ)	Electricity	Oil Paraffin	Coal	Biomass / Wood	Oil LPG	Total
Middle Income Electrified (MIE)						
Lighting	11.93	-	-	-	-	11.93
Cooking	10.56	1.04	-	12.07	0.26	23.93
Space Heating	6.38	1.17	7.46	2.30	0.03	17.33
Water Heating	16.19	0.63	-	3.45	0.13	20.40
Refrigeration	5.98	-	-	-	-	5.98
Other	4.76	-	-	-	-	4.76
Non Energy	-	0.31	-	-	-	0.31
Total	**55.80**	**3.15**	**7.46**	**17.81**	**0.42**	**84.64**
High Income Electrified (HIE)						
Lighting	10.62	-	-	-	-	10.62
Cooking	9.37	0.09	-	0.17	0.28	9.91
Space Heating	7.61	0.37	0.80	0.32	0.08	9.18
Water Heating	29.92	0.05	-	0.40	0.12	30.49
Refrigeration	8.40	-	-	-	-	8.40
Other	9.43	-	-	-	-	9.43
Non Energy	-	0.21	-	-	-	0.21
Total	**75.36**	**0.71**	**0.80**	**0.89**	**0.48**	**78.24**
Low Income Non-Electrified (LINE)						
Lighting	-	1.04	-	-	-	1.04
Cooking	-	3.79	3.14	37.69	0.21	44.82
Space Heating	-	1.67	4.59	7.06	0.02	13.35
Water Heating	-	3.11	-	10.77	0.14	14.01
Refrigeration	-	-	-	-	-	-
Other	-	-	-	-	-	-
Non Energy	-	0.14	-	-	-	0.14
Total	**-**	**9.76**	**7.73**	**55.52**	**0.37**	**73.37**
Middle Income Non-Electrified (MINE)						
Lighting	-	0.10	-	-	-	0.10
Cooking	-	2.18	2.36	15.35	0.15	20.04
Space Heating	-	1.00	2.52	2.92	0.02	6.46
Water Heating	-	1.42	-	4.39	0.08	5.88
Refrigeration	-	-	-	-	-	-
Other	-	-	-	-	-	-
Non Energy	-	0.07	-	-	-	0.07

Final energy consumption by sub-sector (PJ)	Electricity	Oil Paraffin	Coal	Biomass / Wood	Oil LPG	Total
Total	**-**	**4.76**	**4.88**	**22.66**	**0.25**	**32.55**
Grand Total	**158.92**	**22.56**	**26.82**	**125.76**	**1.85**	**335.92**

Source: SATIM Version 3.2 (Energy Research Centre, University of Cape Town)

By applying the SATIM and census 2011 assumptions, a representation of the energy use split across the various income groups was established as presented in Table 26.

Table 26: Energy consumption split by fuel (all income groups) – Terajoules

	Electricity	Other fuels	Paraffin	Wood	LPG	Coal	Solar	Biomass	Total
LIE	25%	-	30%	49%	7%	-	25%	-	8 791
MIE	28%	-	15%	51%	24%	80%	32%	-	9 228
HIE	47%	-	4%	-	28%	-	44%	-	11 951
LINE	-	-	45%	-	19%	-	-	84%	3 423
MINE	-	-	6%	-	21%	20%	-	16%	632
Total	**25 022**	**-**	**3 688**	**2 810**	**312**	**109**	**48**	**2 037**	**34 026**

Source: Own calculations using South African Times model and census 2011.

Overview of mitigation measures

The selection of mitigation measures for analysis under this study aligned with that reviewed under the DEA MPA:

- Energy efficient appliances;
- Geyser Blankets;
- Improved Insulation - New Buildings;
- Improved Insulation - Existing Buildings;
- Efficient Lighting – CFLs;
- Efficient Lighting – LEDs;
- Solar water heating;
- LPG for cooking; and,
- Passive building/improved thermal design - New Buildings.

At the study's first stakeholder workshop, two additional mitigation measures were proposed for analysis, namely: 1. behavioural changes and, 2. embedded generation (photovoltaic) as these were viewed to be of equal importance in the Western Cape. In a context where the residential buildings sector comprises 13% of energy demand in the province, there is notable opportunity for energy emissions abatement in this sector alone.

B2. Commercial

Sector overview

The commercial buildings sector comprised 7% of the Western Cape's energy demand in 2012. Establishing the size of the commercial sector in any province in South Africa is a notoriously challenging task as, while Statistics South Africa keep records of all buildings built since 1993, records of historical building records are not published through any free publication platforms and even when sourced from private records, tend to over- or under-estimate the true sector size.

Key assumptions & main model drivers

In order to get an approximate size of the commercial buildings sector in the province as well as to estimate the projected growth of the sector between 2012 and 2040, the model relied on a number of key data sources:

1. 2013 Provincial Economic Review Outlook (Western Cape Provincial Treasury) estimate of economic growth for the wholesale and retail trade, catering and accommodation; finance, insurance, real estate and business services and general government sub-sectors (to estimate a weighted average growth of the commercial sector);
2. 1993-2013 Statistics South Africa Building Survey records of buildings completed in the Western Cape over this time frame;
3. 2011 Statistics South Africa Census records of household sector size (against which an estimated relative commercial building size estimate was made).

The key model driver of the commercial model is a stock trend (million square metres) which is derived from the 3 aforementioned sources. Further to this, the SATIM estimates of commercial building energy use by end use were employed to project average commercial building energy use in the Western Cape. These SATIM assumptions are represented in Table 27.

Table 27: Final energy consumption by the commercial sector

MJ/m2	Lighting	Space heating	Water heating	Cooling & ventilation	Refrigeration	Cooking	Other	Total MJ/m2	kWh/m2
Electricity	469	57	38	350	83	4	166	1 167	324
Paraffin	0	0	0	0	0	0	0	0.13	0
Wood	0	0	0	0	0	4	0	3.62	1
Coal	0	466	391	0	0	1	0	858	238
Diesel	0	0	0	0	0	0	200	199	55
HFO	0	0	0	0	0	0	10	9.72	2.7
LPG	0	0	2	0	0	0	0	2.67	0.7
Total MJ/m^2	469	523	432	350	83	9	376	2 241	622
kWh/m^2	130	145	120	9	23	2.4	104	622	

Source: SATIM Version 3.2 (Energy Research Centre, University of Cape Town)

The Reference case energy balance of the commercial sector was thus found to be as illustrated in Table 28, with a dominance of electricity, coal and Heavy Furnace Oil in the fuel mix of the sector.

Table 28: Energy consumption split by fuel in 2012 - Terajoules

Energy source	Terajoules	%
Electricity	32 591	52.1%
Coal	17 747	28.4%
Liquefied petroleum gas	980	1.6%
Liquefied natural gas	24	0.0%
Heavy Furnace Oil	9 832	15.7%
Diesel	591	0.9%
Paraffin	355	0.6%
Petrol	118	0.2%
Gas	236	0.4%
Solar	103	0.2%
TOTAL	62 576	100%

Source: Own calculations informed by SATIM (2006)

Overview of mitigation measures

The selection of mitigation measures for analysis under this study aligned with that reviewed under the DEA MPA:

- Efficient Lighting;
- HVAC improvements (incl. heat pumps);
- Energy efficient appliances;
- Passive building/improved thermal design - New Buildings.

At the study's first stakeholder workshop, five additional mitigation measures were proposed for analysis, namely: 1. Solar water heaters, 2. Coal to gas (hospitals), 3. Embedded generation (photovoltaic), 4. Lift efficiency, 5. Behavioural changes as these were viewed to be of equal importance in the Western Cape.

C. INDUSTRY

The main components of the national DEA MPA industrial sector assumptions were adapted according to the Western Cape.

Sector overview

The Reference case 2012 energy balance of the industrial sector was formulated based on a proportioning of the DEA MPA 2010 energy balance and the DoE 2006 energy balance down to the Western Cape. This proportioning exercise was done in line with the proportion that each sub-sector contributes to the Gross Regional Domestic Product of the province as evidenced in the 2013 Provincial Economic Review Outlook. This was done for all industrial sub-sectors with the exception of the Iron and Steel (including Ferroalloys) and Brick and Clay sub-sectors as these particular sub-sectors were consulted directly and calculations were based on information obtained from them. While the Iron & Steel industry was assessed under the DEA MPA, the Brick & Clay industry was not. For this reason, details are only available for the Brick and Clay sub-sectors.

In terms of the overarching modelled energy balance of the industrial sector in the base year of

2012, it comprised a mix of electricity (24%), refined petroleum fuels (10%), natural gas (2%) and other fuels (65%) as shown in Table 29.[20]

Table 29: Industrial sector energy balance (2012)

Energy demand in Terajoules	Electricity	Refined petroleum fuels liquid	Natural gas	Other fuels	All energy
Industry	25 658	10 809	2 098	70 446	109 012

Source: Modelled energy balance

Key assumptions, main model drivers and measures

One of the primary model drivers in the projections of energy demand and emissions was economic growth of the manufacturing and construction sectors. With the exception of the 'Brick & Clay' sub-sector and 'All remaining other industry' which were constructed through a bottom-up modelling approach, all other industrial sub-sectors were developed based on the DEA MPA analysis, and for this reason are not explored in detail here. Readers wishing to know more of these sub-sectors are encouraged to consult the 2014 DEA MPA.

Fuel Switching

Fuel switching is an additional mitigation measure and is presented through the APM with fuel switching scenario (i.e. reference projection less mitigation savings) and applies only to the fuel consumption. It is therefore assumed that the savings from the mitigation measures apply to the bituminous coal consumption only. The implications modelled through this mitigation measure are:

- All industrial sub-sector models (excluding Petrochemicals which has alternative fuel switch measures) change with the implementation of fuel switching in terms of the reduction in emissions, a change in fuel costs and a change in energy consumption;
- No capital costs associated with fuel switching towards natural gas are captured;
- Only the change in fuel costs and the additional costs/savings are taken into account;
- Costs were taken from a study completed by the Western Cape Government: Department of Economic Development and Tourism (DEDAT) on the potential for Liquefied Natural Gas (LNG) in the Province and were assumed to be US$10.00 per Million British Thermal Units (MMBtu) and US$15.00/MMBtu;
- Capital Cost was assumed to be R157.69/GJ; and,
- Operating Cost R7.88/GJ.

Brick and Clay

Note: The Brick and Clay sector measures are the only measures for which new research was conducted, as the available analysis in the DEA MPA was not sufficient for this sector. Readers interested in knowing more about the other industrial sub-sectors should refer to Appendix D of the DEA MPA report.

The Brick and Clay energy demand model was constructed using a bottom-up approach whereby stakeholders in the industry were engaged. Production estimates were based on a downscaling of Statistics South Africa (2013) estimates of brick sales as shown in Table 30, to the Western Cape.

20 Note that due to the commercial privacy concerns of industry in the Province, a more detailed industrial sub-sector energy balance is not provided here. As the national DEA is leading the implementation of industrial mitigation measures, there is limited policy relevance at the industrial sub-sector level for the Province. This study suggests that the Province can however exercise influence over industry is in terms of a fuel switch from coal to natural gas.

Table 30: Brick sales in South Africa

Year	Tons of Brick (Sales)
2009	7 841 222
2010	6 982 151
2011	7 645 694
2012	7 187 684

Source: Statistics South Africa (2013)

The Department of Mineral Resources (2008) reported a national capacity of 3.5 billion clay bricks. This is in line with the Clay Brick Association's (CBA) report by EcoMetrix Africa which stated that there were 129 brick suppliers across the country, producing 3.5 billion clay bricks. Based on the above data, it is assumed that there are 2.08 tons per brick equivalent (assuming 1000 bricks per brick equivalent or BEQ).

The Department of Mineral Resources reported that an average increase of 3% per annum is expected. The Western Cape demand in this modelling framework was assumed to be 24% and this is based on the ratio of buildings in the Western Cape.

Energy

Dlamini (2014) discovered that the embodied energy of clay bricks fired with fossil fuels was 0.01 TJ/ton.

Table 31: Embodied energy of clay bricks

	Bulk density kg/m3	Energy content MJ/m3	GJ/m3[1]	TJ/ton
Brick fired with fossil fuels	700.00	2 524.20	2.52	0.01

Source: Dlamini (2014)

However in a presentation showing the benefits of Vertical Stacked Brick Kilns (VSBK) technology, showing the average energy consumption is 0.002 TJ/ton. However this related only to the energy required for firing.

Table 32: Average energy consumption of VSBK

Technology	Energy (GJ/ton)
Tunnel kiln	1.875
Transverse Arch kiln	3
Clamp kiln	2.95
VSBK Worldwide	0.97
SA-VSBK (Langkloof Bricks)	0.85
average	1.93

Source: Keller (2014)

Since the model uses emissions as a basis for energy consumption, it means that the model assumes 0.01 TJ/BEQ or 0.004 TJ/ton bricks.

Emissions

The CBA report on the Carbon Tax reported the average carbon intensity per brick equivalent according to firing technology.

Table 33: Average carbon intensity per brick

Firing technology	Average Carbon Intensity/Brick Equivalent
Clamp	0.935
Tunnel	0.759
VSBK	0.529
Weighted average	0.82

Source: EcoMetrix Africa (2014)

However, the VSBK is not widespread in South Africa and so an average of 0.85 tCO_2/BEQ should be used for the reference projection. The report also outlined the breakdown of energy source consumption (based in tCO_2).

Table 34: Energy source consumption of bricks

Energy source	% emissions
Electricity	11.50%
Natural Gas	12.20%
Fuel	76.30%

Source: EcoMetrix Africa (2014)

The process emissions are assumed to be zero for the clay brick industry.

Selected mitigation measures

The ultimate mitigation measures then selected for analysis in the Brick & Clay sector were:

- Replace kilns with VSBK
- Fuel switching (away from coal towards natural gas)

Replace kilns with VSBK

In terms of VSBK, the thermal energy saving potential is currently assumed to be 50%. The fuel savings are based on this potential of 50% multiplied by annual fuel consumption and then by the uptake of kilns in the country. Currently the upper limit sits at 80% and there is a consistent annual uptake is projected.

The costs are based on engagement with the Energy Efficient Clay Brick (EECB) Project and this means that a capital cost of R3000/BEQ is assumed. Across all the industry sectors, operating costs are assumed to be 5% of the capital cost and therefore this is assumed in this case.

Common mitigation measures – All other remaining industries

Energy consumption for the 'All other remaining industries' are based on the annual DoE's energy balance 2006 figures, broken down to the individual industries and into the fuel types. The percentage share is based on GDPR and is used to calculate the associated Western Cape energy demand. The fuel mix is assumed to be consumed in the same proportion as the national balance.

A factor to change energy demand (TJ) to emissions (kt CO_2eq) was taken from the WCEED 2009 and applied to calculate the reference projections for fuel emissions. The final selection of 'common' mitigation measures were:

- Energy efficient boiler systems and kilns
- Energy monitoring and management system
- Improved process control
- Improved electric motor system controls and VSDs
- Energy-efficient utility systems
- Improved heat exchanger efficiencies
- On-site power generation
- Use of excess heat energy for electricity (Waste energy use for water recycling)

D. TRANSPORT

Energy demand and mitigation measures in the Western Cape for the transport sector were divided into freight and passenger transport. Stand-alone models were developed for each of these sectors, which fed into the main scenario model.

The primary energy sources for the sector are:

- Electricity for Rail (Freight and Passenger)
- Diesel for Road and Rail Transport
- Petrol for Road Transport
- Jet Fuel and Aviation Gas for the Aviation Sector. Mitigation measures have not been developed for this segment of the transport sector.

Table 35: Comparison of Transport Energy Demand in 2009 and 2012 in the Western Cape

Single Energy Unit (Gigajoules)	Electricity		Petrol		Diesel		Jet Fuel		Aviation Gas		Total	
	2009	2012	2009	2012	2009	2012	2009	2012	2009	2012	2009	2012
Total final consumption	81 023	76 726	58 589	61 326	49 017	69 228	18 942	14 027	94	77	207 665	221 385
Transport Sector	1 421	1 638	58 589	61 326	49 017	69 228	18 942	14 027	94	77	128 064	146 293
% of total WC	180%	2.10%	100%	100%	100%	100%	100%	100%	100%	100%	62%	66%

Source: WCEED 2009 and 2012

D1. Passenger Transport

The passenger transport model is driven by estimates of passenger demand, converted into passenger vehicle kilometres (and not passenger kilometres). Both road and rail passenger transport was modelled.

The passenger demand was calculated separately for Cape Town, while the population in the Districts were modelled together. The demand for Cape Town and the Districts were then combined to obtain results on each of the measures.

Change of engine types

The engine type measures are modelled in the absence of any modal shift. The following engine types were modelled, along with a projected share of the passenger vehicle fleet in 2040.

Table 36: Change in composition of vehicle fleet by engine type (2012 to 2014)

Passenger engines: Road				
2012	Car	MBT	Bus	
Internal combustion engine (ICE) – both petrol and diesel	100%	100%	100%	Completely phased out by 2040
Passenger vehicle fleet by 2040	Car	MBT	Bus	Engine type phased in from:
ICE - more efficient	68%	76%	78%	2012
Hybrid electric	22%	24%	18%	2012
Plug-in hybrid electric	5%			2015
Battery Electric	2%			2015
Fuel Cell	1%		1%	2030
CNG ICE	3%		4%	2020
Total	100%	100%	100%	

Source: DEA MPA assumptions regarding penetration of new vehicle-engine types by 2040

Passenger demand was initially calculated assuming a constant modal share, with trip demand growing based on both economic and population growth projections.

Based on vehicle capacity assumptions and modal split assumptions, passenger trips were allocated to vehicles, to obtain the projected number of vehicle trips each year.

These were multiplied by the average vehicle trip distance per day, to arrive at a total number of vehicle kilometres per annum for each mode (private car, bus, MBT and Metrorail).

Annual Vehicle kilometres were then further allocated to each engine type over the modelling period, to obtain fuel costs and emission projections to 2040.

The target 2040 vehicle fleet is used to allocate the vehicle kilometres appropriately within each mode.

Data on the capital and operating cost and fuel efficiency were obtained from the earlier work done by Ricardo AEA. The fuel efficiency information for each data type is measured in MJ/km, rather than in fuel units. Declining emissions due to technological improvements is captured through underlying vehicle efficiencies which change over time, while using a constant emission factor for the fuel itself.

Metrorail: Introduction of more efficient EMU's

Due to the current state of the Metrorail rolling stock, it was assumed for modelling purposes that under the reference case scenario the entire current fleet will be replaced by new EMU's which are 20% more energy efficient than the older models.

The mitigation measure assumed the purchase of new EMU's which are 10% more expensive, but achieve 50% greater energy efficiency in terms of electricity consumption over the older models.

Capital costs were taken from the earlier national analysis, while no change is expected in operational costs for this measure.

Metrorail: Voltage upgrade by 2030

Voltage upgrade is assumed to result in a 10% energy saving. The capital cost was based on the available national figure, apportioned to the Western Cape based on the provincial share of the Metrorail network, which was estimated at 22% based on track kilometres.

Passenger Modal shift

The modal shift measure uses the change in engine type as a starting point, rather than a reference case of no engine change. This was done to minimise any double counting or over-estimation of possible emissions reductions. Cape Town and the 5 Districts were modelled separately, before the results were combined.

The daily modal split for Cape Town was derived based on current data contained within the Cape Town 2013 Integrated Transport Plan. (It should be noted that this modal split excludes non-motorised transport):

		Daily passenger trips (excl NMT)
Car	52.3%	1,310,833
Rail	24.8%	621,833
Buses	9.6%	240,000
My Citi	0.4%	10,754
MBT	12.9%	323,263
		2,506,683

Source: CT ITP 2013.

However, while the actual numbers for public transport ridership were taken directly from the 2013 ITP, the numbers for private motorised trips were felt to be significantly under-estimated, based on international comparisons. Using population figures; international data on typical trip numbers per person, and the data contained within the 2006 Public Transport Plan, the number of trips by vehicle were increased to obtain a better match with fuel sale information.

Page 32 of the 2006 PTP states:
"From modal split trends determined using the Cape Town CBD screenline counts, it may be deduced that some 3,5 million motorised trips are made per day in the City. For the current population of 3,1 million, this equates to 1,13 motorised trips per person for all modes, of which 0,76 trips are made by private car and 0,37 are made by public transport. This can be compared with other cities in the world which typically produce between 1 – 2 motorised trips per population per day (Santiago 1,4; *Stockholm 1,9)." (emphasis added)*

The final and projected motorised all-day modal shares for the City of Cape Town in 2040 are contained in the model are shown below. While the modal shift proposed is substantial and ambitious, the current figures for Bogata have been provided as comparison, to show that the target represents a possible maximum shift. This will of course require significant investment, and a reconfiguration of the urban landscape to achieve. (Based on a 2008 survey, documented in a London Transport Authority report. http://www.lta.gov.sg/ltaacademy/doc/J11Nov-p60PassengerTransportModeShares.pdf). Note that the percentages have been recalculated to exclude non-motorised transport in our model.

CAPE TOWN	2012	2040	Bogata comparison
Private Car: motorized	73%	30%	23%
Public Rail	14%	20%	
Public Mini-bus Taxi	7%	25%	
Public Bus	6%	25%	
Total public: motorized	27%	70%	77%

The current all day modal split in the Western Cape Districts is estimated as follows, and is kept constant through-out the period.

Modal split including NMT	Private	Rail	Bus	Taxi	NMT & other	Population	Source
Winelands	27.9%	4.6%	0.1%	10.5%	56.9%	787,490	from 2012/13 IDP
West Coast	38.0%	0.0%	1.0%	6.0%	55.0%	391,767	WC PTLF. PT has7% share, but breakdown estimated
Overberg	28.0%	0.0%	3.0%	12.0%	57.0%	258,176	WC PTLF. PT has 15% share, but breakdown estimated
Eden	46.0%	0.0%	3.0%	17.0%	34.0%	574,265	New data from 2013/14 IDP. All bus is school traffic according to PLTF
Karoo	16.0%	0.2%	2.2%	4.6%	77.0%	71,011	C Karoo ITP, revised based on WC PLTF
Weighted average	34.4%	1.7%	1.5%	11.4%	50.9%		
Motorised modal split	Private	Rail	Bus	Taxi	Total		
District average	70%	4%	3%	23%	100%		

The final fuel consumption across all modes and vehicles was then compared to that of the model where no modal change was assumed.

However, the infrastructure investments required to enable such a shift are very difficult to estimate, but will be large. The current capital costs were based on the recent national mitigation potential analysis, where the costs had been based on Western Cape information, and apportioned to the rest of the country.

D2. FREIGHT TRANSPORT

Sector overview

There are two main categories which freight can be classified as, either bulk freight or general freight. Bulk freight is generally the produce of mines or primary economic activities, and is easily transported in large quantities. Examples of bulk freight are export coal and iron ore. Products moved by pipelines are also considered to be bulk products. General freight is the remainder of the freight, and consist of a variety of products.

There are three main methods of moving freight, via pipeline, rail and road. For the purposes of this study, pipelines were not considered. Bulk movements in the Western Cape (mainly iron ore exported at Saldanha) are also not considered as there is little influence that the province has over this. The current modal split for the remaining general freight (by ton kilometre21) is that only 4% travels on rail. This heavy reliance on road means that the predominant energy used is petroleum based products, mainly diesel. The use of electricity for rail based freight movements has the potential to be a good mitigation measure, although the use of 'cleaner' generation technology would be required.

In order for there to be a modal shift from road to rail, there would have to be significant investment in rail infrastructure and intermodal facilities, as currently they are not able to handle any increased volumes.

Key assumptions

There is a large drive towards the use of rail as the main method of transporting freight (Department of Transport, 2011), due to the inherent efficiencies in this mode of transport (greater quantities moved at lower energy expense).

The Department of Public Enterprises has proposed an expansion plan for the rail network, which has been approved by parliament.

The key assumption in this case is that the freight, which is based on a corridor22, will shift from road to rail. Transnet aims to achieve a 70% modal share on these corridors by 2043. Freight movements which are not based on corridors are assumed to have the same modal shift into the future, and freight movements which remain on the road will remain in trucks. Trucks on the roads are assumed to be making a transition towards more efficient engines, with the current fleet being replace by more efficient diesel internal combustion engines, diesel hybrid electric vehicles and natural gas vehicles in varying proportions. These engine types were found to be the most feasible for freight transport during the DEA MPA study. It is also assumed that with the construction and acquisition of new rail fleet, the rail engines will become more efficient.

Main model drivers

The main model drivers are the rate of increase of freight growth, which is currently the average economic growth rate, as well as the ratio of freight which moves to rail.

The other, more specific drivers of the model are the road vehicle capacity and the train capacity and efficiency.

21 A ton kilometre is the unit used to measure the movement of one ton, one kilometre. It is known as the 'transport effort'

22 A railway has a defined geographical area of influence, so the freight moving from one point to another must be of a sufficient quantity to justify the creation of a railway otherwise road based transport is sufficient.

Overview of mitigation measures

Currently the electricity generation is largely by coal fired power stations which are considered major emitters of carbon dioxide, and freight moved via rail uses electricity for energy. If the current dirty electricity is used into the future, there is a negative effect on the climate, although if new, clean electricity is used, then the modal shift is a very effective greenhouse gas mitigation measure. There are two engine based measure, one for road and one for rail based movements. The road based measure are encompassed into one measure, which comprises of a vehicle mix in 2040 of 80% more efficient diesel engines, 10% natural gas powered vehicles and 10% diesel hybrid electric vehicles. The other engine efficiency measure is rail based whereby the engines will become 15% more efficient than they are now by 2040.

APPENDIX 5: MCA RANK OF MEASURES BY SCORE AND EMISSIONS ABATEMENT POTENTIAL

MCA rank by overall weighted score results

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
1	Transport	Freight	Road - Shifting freight from road to rail (modal shift)	2 867	86.55
2	Transport	Road	Road - Shifting passengers from cars to public transport	29 701	68.44
3	Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	26 450	66.33
4	Electricity	Electricity	Solar Photovoltaics (Concentrated)	29 069	63.97
5	Buildings	Residential	Solar water heating	9 004	63.50
6	Buildings	Commercial	Solar water heaters	7 255	63.39
7	Electricity	Electricity	Biomass	10 224	63.36
8	Buildings	Commercial	Behavioural changes	6 324	62.52
9	Buildings	Commercial	Efficient Lighting	14 932	62.01
10	Industry	Pulp & Paper	Energy recovery system	2 360	61.93
11	Industry	Petrochemicals	Energy monitoring and management system	438	61.52
12	Buildings	Residential	LPG for cooking	838	61.30
13	Agriculture	Agriculture	Reduced tillage	3 905	61.24
14	Industry	Pulp & Paper	Convert fuel from coal to biomass/residual wood waste	10 111	61.23
15	Industry	Petrochemicals	Improved electric motor system controls and Variable Speed Drives (VSDs)	225	61.22
16	Industry	Petrochemicals	Improve steam generating boiler efficiency	320	61.05
17	Industry	Petrochemicals	Improve process heater efficiency	149	61.03
18	Industry	Chemicals	Improved electric motor system controls and VSDs	375	60.51
19	Buildings	Residential	Efficient Lighting - CFLs	8 123	60.36
20	Industry	Petrochemicals	Improved heat exchanger efficiencies	341	60.35
21	Industry	All remaining industries	Improved electric motor system controls and Variable Speed Drives (VSDs)	6 267	60.32
22	Industry	Petrochemicals	Improved process control	438	60.18

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
23	Industry	All remaining industries	Energy monitoring and management system	1 386	60.15
24	Industry	Lime	Improved electric motor system controls and Variable Speed Drives (VSDs)	13	60.14
25	Buildings	Residential	Efficient Lighting - LEDs	6 339	60.11
26	Industry	All remaining industries	Energy-efficient utility systems	4 341	60.05
27	Industry	Pulp & Paper	Energy monitoring and management system	279	59.99
28	Buildings	Residential	Geyser Blankets	3 333	59.95
29	Industry	Lime	Energy-efficient utility systems	10	59.92
30	Buildings	Residential	Behavioural changes	2 323	59.76
31	Industry	Pulp & Paper	Energy efficient electric motors, improved controls and variable speed drives	602	59.75
32	Buildings	Commercial	Energy efficient appliances	3 294	59.71
33	Industry	Chemicals	Advanced process control	72	59.68
34	Industry	Chemicals	Energy efficient utility systems	125	59.65
35	Buildings	Commercial	Embedded generation: PV	6 918	59.60
36	Transport	Road	Alternative fuels - Petrol and diesel hybrids	9 633	59.54
37	Industry	Lime	Energy monitoring and management system	23	59.53
38	Industry	Iron & Steel	Fuel Switch	8 267	59.41
39	Industry	Cement	Energy monitoring and management system	88	59.27
40	Industry	Pulp & Paper	Energy efficient boiler systems and kilns and Improved heat systems	1 928	59.25
41	Industry	Lime	Improved heat exchanger efficiencies	28	59.24
42	Industry	Cement	Fuel Switch	1 567	59.10
43	Buildings	Commercial	Coal to gas (hospitals)	3 269	59.02
44	Industry	Lime	Improved process control	42	59.02
45	Industry	Cement	Improved electric motor system controls and variable speed drives	153	59.02
46	Industry	Pulp & Paper	Improved process control	964	58.75
47	Industry	Chemicals	Increase process integration and improved heat systems	144	58.63
48	Industry	Cement	Reduction of clinker content of cement products	1 063	58.55
49	Industry	All remaining industries	Energy efficient boiler systems and kilns	15 477	58.53
50	Industry	Pulp & Paper	Energy-efficient utility systems (e.g. lighting, refrigeration, compressed air)	258	58.48
51	Agriculture	Agriculture	EE in on-farm cooling	8 851	58.31
52	Agriculture	Agriculture	Irrigation management systems	6 214	58.31
53	Industry	Petrochemicals	Energy-efficient utility systems	150	58.23
54	Transport	Rail	Improved efficiency - EMUs (Electric Multiple Units)	1 345	58.23
55	Transport	Road	Improved efficiency - Petrol and diesel Internal Combustion Engine (ICE)	21 054	58.22

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
56	Transport	Freight	More efficient EMUs (freight)	638	58.19
57	Industry	All remaining industries	Improved process control	1 238	58.08
58	Industry	Cement	Improved process control	440	57.96
59	Industry	Iron & Steel	Furnace / Heating General efficiency measures	3 259	57.94
60	Buildings	Residential	Energy efficient appliances	1 580	57.91
61	Industry	All remaining industries	Improved heat exchanger efficiencies	6 604	57.90
62	Industry	Cement	Energy-efficient utility systems	85	57.76
63	Electricity	Electricity	Concentrated Solar Power (Parabolic trough)	19 660	57.65
64	Electricity	Electricity	Solid waste related energy	13 385	57.53
65	Transport	Road	Alternative fuels – Compressed Natural Gas ICE	1 162	57.40
66	Electricity	Electricity	Onshore wind	39 914	57.27
67	Industry	Iron & Steel	General electricity efficiency measures	2 235	57.22
68	Electricity	Electricity	Import (Hydro)	4 500	57.22
69	Buildings	Commercial	HVAC improvements (incl. heat pumps)	11 085	56.76
70	Buildings	Residential	Embedded generation: PV	7 108	56.42
71	Transport	Freight	More efficient engines	13 503	55.40
72	Transport	Road	Alternative fuels – Electric drives	1 903	54.77
73	Industry	Lime	Fuel Switch	429	54.05
74	Industry	Lime	Replace rotary kilns with vertical kilns or Paralle Flow Regenerative Kilns (PFRK)	388	53.20
75	Industry	Chemicals	Energy monitoring and management system	154	52.91
76	Buildings	Commercial	Lift efficiency	129	52.21
77	Industry	Chemicals	Fuel Switch	927	51.33
78	Industry	Lime	Installation of shaft preheaters	535	50.91
79	Agriculture	Agriculture	EE in pumped irrigations: Variable Speed Drives (VSDs)	10 356	50.42
80	Buildings	Commercial	Passive building/improved thermal design - New Buildings	9 377	50.02
81	Industry	Pulp & Paper	Application of Co-generation of Heat and Power (CHP)	1 702	49.88
82	Buildings	Residential	Improved Insulation - New Buildings	2 160	49.87
83	Industry	Petrochemicals	Waste heat recovery and utilization	684	49.84
84	Industry	Brick & Clay	Fuel Switch	4 633	49.38
85	Industry	All remaining industries	Fuel Switch	10 357	49.15
86	Industry	Cement	Utilise waste material as fuel	1 442	49.02
87	Industry	Brick & Clay	Replace kilns with Vertical Stacked Brick Kilns (VSBK)	3 408	48.75
88	Industry	Lime	Use alternative fuels including waste and biomass	513	48.23

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
89	Transport	Road	Alternative fuels - Petrol and diesel plug-in hybrids	2 918	47.95
90	Industry	Pulp & Paper	Fuel Switch	2 853	47.73
91	Industry	Petrochemicals	Waste heat boiler and expander applied to flue gas from the FCC regenerator	253	46.97
92	Industry	Cement	Waste heat recovery from kilns and coolers/ cogeneration	183	46.76
93	Industry	Petrochemicals	Efficient energy production (Combined Cycle Gas Turbine (CCGT) and Combined Heat & Power (CHP))	794	46.37
94	Buildings	Residential	Passive building/improved thermal design - New Buildings	2 653	45.63
95	Buildings	Residential	Improved Insulation - Existing Buildings	2 723	45.00
96	Transport	Rail	Voltage upgrade	692	42.89
97	Transport	Road	Alternative fuels – Fuel cells	484	41.63
98	Industry	Chemicals	Revamp: increase capacity and energy efficiency	841	41.15
99	Industry	Cement	Geopolymer cement production	74	37.22
100	Electricity	Electricity	Small-scale hydro	5 227	33.23

MCA rank by emissions abatement results

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
1	Electricity	Electricity	Onshore wind	39 914	57.27
2	Transport	Road	Road - Shifting passengers from cars to public transport	29 701	68.44
3	Electricity	Electricity	Solar Photovoltaics (Concentrated)	29 069	63.97
4	Electricity	Electricity	Natural Gas Combined Cycle Gas Turbine (CCGT)	26 450	66.33
5	Transport	Road	Improved efficiency - Petrol and diesel Internal Combustion Engine (ICE)	21 054	58.22
6	Electricity	Electricity	Concentrated Solar Power (Parabolic trough)	19 660	57.65
7	Industry	All remaining industries	Energy efficient boiler systems and kilns	15 477	58.53
8	Buildings	Commercial	Efficient Lighting	14 932	62.01
9	Transport	Freight	More efficient engines	13 503	55.40
10	Electricity	Electricity	Solid waste related energy	13 385	57.53
11	Buildings	Commercial	HVAC improvements (incl. heat pumps)	11 085	56.76
12	Industry	All remaining industries	Fuel Switch	10 357	49.15
13	Agriculture	Agriculture	EE in pumped irrigations: Variable Speed Drives (VSDs)	10 356	50.42
14	Electricity	Electricity	Biomass	10 224	63.36
15	Industry	Pulp & Paper	Convert fuel from coal to biomass/residual wood waste	10 111	61.23
16	Transport	Road	Alternative fuels - Petrol and diesel hybrids	9 633	59.54
17	Buildings	Commercial	Passive building/improved thermal design - New Buildings	9 377	50.02

Rank	Sector	Sub-sector	Mitigation measure	Total Emissions Abated (ktCO2eq)	Overall weighted score
18	Buildings	Residential	Solar water heating	9 004	63.50
19	Agriculture	Agriculture	EE in on-farm cooling	8 851	58.31
20	Industry	Iron & Steel	Fuel Switch	8 267	59.41
21	Buildings	Residential	Efficient Lighting - CFLs	8 123	60.36
22	Buildings	Commercial	Solar water heaters	7 255	63.39
23	Buildings	Residential	Embedded generation: PV	7 108	56.42
24	Buildings	Commercial	Embedded generation: PV	6 918	59.60
25	Industry	All remaining industries	Improved heat exchanger efficiencies	6 604	57.90
26	Buildings	Residential	Efficient Lighting - LEDs	6 339	60.11
27	Buildings	Commercial	Behavioural changes	6 324	62.52
28	Industry	All remaining industries	Improved electric motor system controls and Variable Speed Drives (VSDs)	6 267	60.32
29	Agriculture	Agriculture	Irrigation management systems	6 214	58.31
30	Electricity	Electricity	Small-scale hydro	5 227	33.23
31	Industry	Brick & Clay	Fuel Switch	4 633	49.38
32	Electricity	Electricity	Import (Hydro)	4 500	57.22
33	Industry	All remaining industries	Energy-efficient utility systems	4 341	60.05
34	Agriculture	Agriculture	Reduced tillage	3 905	61.24
35	Industry	Brick & Clay	Replace kilns with Vertical Stacked Brick Kilns (VSBK)	3 408	48.75
36	Buildings	Residential	Geyser Blankets	3 333	59.95
37	Buildings	Commercial	Energy efficient appliances	3 294	59.71
38	Buildings	Commercial	Coal to gas (hospitals)	3 269	59.02
39	Industry	Iron & Steel	Furnace / Heating General efficiency measures	3 259	57.94
40	Transport	Road	Alternative fuels - Petrol and diesel plug-in hybrids	2 918	47.95
41	Transport	Freight	Road - Shifting freight from road to rail (modal shift)	2 867	86.55
42	Industry	Pulp & Paper	Fuel Switch	2 853	47.73
43	Buildings	Residential	Improved Insulation - Existing Buildings	2 723	45.00
44	Buildings	Residential	Passive building/improved thermal design - New Buildings	2 653	45.63
45	Industry	Pulp & Paper	Energy recovery system	2 360	61.93
46	Buildings	Residential	Behavioural changes	2 323	59.76
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49	Industry	Pulp & Paper	Energy efficient boiler systems and kilns and Improved heat systems	1 928	59.25
50	Transport	Road	Alternative fuels – Electric drives	1 903	54.77
51	Industry	Pulp & Paper	Application of Co-generation of Heat and Power (CHP)	1 702	49.88

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52	Buildings	Residential	Energy efficient appliances	1 580	57.91
53	Industry	Cement	Fuel Switch	1 567	59.10
54	Industry	Cement	Utilise waste material as fuel	1 442	49.02
55	Industry	All remaining industries	Energy monitoring and management system	1 386	60.15
56	Transport	Rail	Improved efficiency - EMUs (Electric Multiple Units)	1 345	58.23
57	Industry	All remaining industries	Improved process control	1 238	58.08
58	Transport	Road	Alternative fuels – Compressed Natural Gas ICE	1 162	57.40
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60	Industry	Pulp & Paper	Improved process control	964	58.75
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69	Industry	Lime	Installation of shaft preheaters	535	50.91
70	Industry	Lime	Use alternative fuels including waste and biomass	513	48.23
71	Transport	Road	Alternative fuels – Fuel cells	484	41.63
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84	Industry	Cement	Waste heat recovery from kilns and coolers/cogeneration	183	46.76
85	Industry	Chemicals	Energy monitoring and management system	154	52.91
86	Industry	Cement	Improved electric motor system controls and variable speed drives	153	59.02
87	Industry	Petrochemicals	Energy-efficient utility systems	150	58.23
88	Industry	Petrochemicals	Improve process heater efficiency	149	61.03
89	Industry	Chemicals	Increase process integration and improved heat systems	144	58.63
90	Buildings	Commercial	Lift efficiency	129	52.21
91	Industry	Chemicals	Energy efficient utility systems	125	59.65
92	Industry	Cement	Energy monitoring and management system	88	59.27
93	Industry	Cement	Energy-efficient utility systems	85	57.76
94	Industry	Cement	Geopolymer cement production	74	37.22
95	Industry	Chemicals	Advanced process control	72	59.68
96	Industry	Lime	Improved process control	42	59.02
97	Industry	Lime	Improved heat exchanger efficiencies	28	59.24
98	Industry	Lime	Energy monitoring and management system	23	59.53
99	Industry	Lime	Improved electric motor system controls and Variable Speed Drives (VSDs)	13	60.14
100	Industry	Lime	Energy-efficient utility systems	10	59.92

(Footnotes)

1 Assuming 2.4m3 per ton of clay brick, the energy demand per ton of brick is 0.01TJ.

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