Government Gazette
Staatskoerant

REPUBLIC OF SOUTH AFRICA
REPUBLIEK VAN SUID-AFRIKA

Vol. 577 Pretoria, 24 July / Julie 2013 No. 36690

36690
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GOVERNMENT NOTICES

DEPARTMENT OF ENERGY

No. 512 **24 July 2013**

DEPARTMENT OF ENERGY

DRAFT 2012 INTEGRATED ENERGY PLANNING REPORT

EXECUTIVE SUMMARY

(For Public Consultation)

June 2013

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EXECUTIVE SUMMARY

1 Background

The purpose and objectives of the Integrated Energy Plan (IEP) are anchored in the National Energy Act, 2008 (Act No. 34 of 2008). Integrated energy planning is undertaken to determine the best way to meet current and future energy service needs in the most efficient and socially beneficial manner, while:

- Maintaining control over economic costs;
- Serving national imperatives such as job creation and poverty alleviation; and
- Minimising the adverse impacts of the energy sector on the environment.

Government strives to improve the lives of the people of South Africa through various programmes. This improvement is effected through policy development and the implementation of appropriate policy choices.

The IEP takes into consideration the crucial role that energy plays in the entire economy and is informed by the output of analyses founded on a solid fact base. It is a multi-faceted, long-term energy framework which has multiple objectives, some of which include:

- To guide the development of energy policies and, where relevant, set the framework for regulations in the energy sector;
- To guide the selection of appropriate technologies to meet energy demand (i.e. the types and sizes of new power plants and refineries to be built and the prices that should be charged for fuels);
- To guide investment in and the development of energy infrastructure in South Africa; and
- To propose alternative energy strategies which are informed by testing the potential impacts of various factors such as proposed policies, introduction of new technologies, and effects of exogenous macro-economic factors.

Energy is an integral part of the economy and the energy sector is a key enabler for the attainment of national policy imperatives such as those expressed in the National Development Plan and its supporting pillars which include the New Growth Path and the Industrial Policy Action Plan, amongst others. It is therefore important that a mechanism is developed to enable energy policymakers to quantify and provide feedback on the extent to which the energy sector can contribute to the attainment of these and other national policy imperatives. It is equally important to quantify and provide feedback on the extent to which policy objectives outside the energy sector may impact on the attainment of energy sector imperatives. Examples of these include objectives, targets and/or constraints set in the following policy documents:

- The Beneficiation Strategy;
- The National Climate Change Response Policy;

- The National Transport Master Plan (NATMAP 2050); and
- The proposed Carbon Tax policy

While sectoral plans look at how to ensure that energy needs are met, the IEP endeavours to provide a long-term vision of how energy can be optimally used as a mechanism for South Africa to remain competitive. Optimal use of energy may at times require a shift in the use of a particular energy resource. For example, with the challenge of carbon emissions related to the use of coal in the generation of electricity, alternative supply options such as renewable and nuclear energy should be considered, as they provide a cleaner source of energy. That said, the cost associated with these alternatives needs to be considered and investment needs to be made to promote the development of new technologies to improve the use of coal.

Today's choices about how energy is produced and used will determine the sustainability of the future energy system and consequently of socio-economic progress. Integrated energy planning involves thorough analysis of the benefits and shortcomings of integrated relationships and seeks to optimise the energy system as a whole. The benefits and advantages associated with the pursuit of a particular strategic pathway are thoroughly explored and assessed against the trade-offs of not considering other alternative pathways. Integrated energy planning is therefore not only about ensuring that South Africa's energy needs are met, but also about finding alignment and ensuring that cross-sectoral impacts are analysed in a systematic way.

As a fast emerging economy, South Africa needs to balance the competing need for continued economic growth with its social needs and the protection of the natural environment. South Africa needs to grow its energy supply to support economic expansion and in so doing, alleviate supply bottlenecks and supply-demand deficits. In addition, it is essential that all citizens are provided with clean and modern forms of energy at an affordable price. The IEP will take these and other constraints into consideration. From the myriad of factors which need to be considered and addressed during the Integrated Energy Planning process, eight key objectives were identified.

- Objective 1: Ensure the security of supply;
- Objective 2: Minimise the cost of energy;
- Objective 3: Increase access to energy;
- Objective 4: Diversify supply sources and primary sources of energy;
- Objective 5: Minimise emissions from the energy sector;
- Objective 6: Promote energy efficiency in the economy;
- Objective 7: Promote localisation and technology transfer and the creation of jobs; and
- Objective 8: Promote the conservation of water.

2 Energy Demand

Energy is a basic human need and is also a key enabler for the attainment of economic growth and other broader national imperatives. The desired structure of the economy as well as the level of activity within each of the sectors of the economy provide the starting point on which future energy requirements to support the desired economic growth can be determined. Access to modern forms of energy improves the livelihood of individuals and the growth of the population is therefore a key factor in determining future energy requirements for domestic use.

The energy planning process therefore starts with an understanding of the drivers for energy demand (with economic growth, population growth and energy prices being the three key drivers).

2.1 Macroeconomic Drivers

The National Treasury provided 20-year projections of domestic average potential economic growth for three scenarios (low growth, moderate growth and high growth) which were based on various sets of assumptions. The moderate growth assumptions assume the steady growth of the economy, with continued skills constraints and infrastructure bottlenecks in the short- to medium-term. These projections have been used in the Integrated Energy Planning process and are taken as the baseline. The GDP growth assumptions based on the National Development Plan (NDP) have been used for the high-growth scenario, but the relevant outputs have not yet been analysed.

The population growth combined with the average household size provides a good basis for determining the number of households in the future. Energy demand in the residential sector is determined by estimating the average energy consumption by different household types.

In the transport sector, GDP per capita is used to estimate future demand for passenger transportation.

Using the above-mentioned key drivers as a basis, demand projections were conducted for each of the energy demand sectors (agriculture, commerce, industry, mining, residential and transport).

- For the agricultural, commercial, industrial , mining and residential sectors, energy demand was estimated and projected for individual energy carriers (i.e. electricity, natural gas, LPG, coal, diesel, etc.); and
- For the transport sector, energy demand was projected for energy end-use (i.e. mobility measured by passenger kilometres or freight tonne kilometers) as opposed to individual fuels (i.e. petrol, diesel, jet fuel, etc).This second approach makes it possible to quantify the extent to which different fuels can be used to meet the same energy end-use/need.

The demand projections and inferred energy intensity are provided in the sections that follow.

2.2 Total Energy Demand

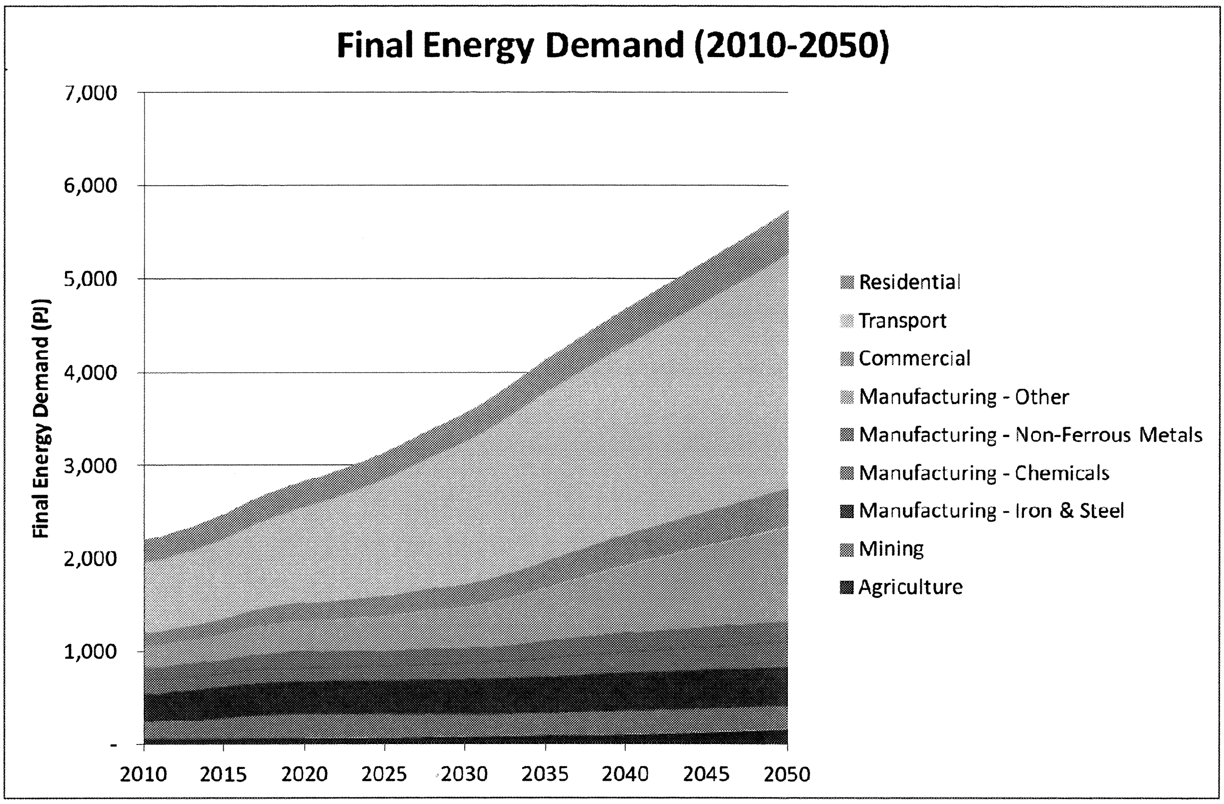


Figure 2-1: Projected energy demand for the entire economy by sector

The demand projections indicate a substantial increase in total energy demand by 2050, increasing at an average annual rate of 2% to more than double the 2010 levels.

The transport sector, comprising 34% of total energy demand in 2010, will continue to impose the most significant demand on total energy.

In line with global growth patterns, the key driver for continued passenger transport demand is linked to increased mobility which results from economic development. Disposable income levels influence the preferred mode of passenger transport with the tendency for individuals to use private passenger vehicles rather than mass public transport as income levels increase. However other factors which influence this preference include quality of roads as well as safety, efficiency and reliability of public transport systems. More recent factors that could possibly slow down the trend for people to move from public transport to private passenger vehicles include government policy interventions, which aim to accelerate the improvement of public transport by establishing integrated rapid public transport networks. These will introduce priority rail corridors and Bus Rapid Transit (BRT) systems in cities. Taxes on passenger vehicles to discourage their use, particularly in city centres, have also been introduced in efforts to reduce Greenhouse Gas (GHG) emissions. Transportation demand is largely met through liquid fuel, however the penetration of electric and hybrid vehicles could see demand shift from petroleum products to electricity for small private passenger vehicles in the future. This will see significant reduction in energy demanded relative to economic growth and an overall reduction in energy intensity for passenger transportation in the long-term.

Freight haulage, predominantly by road, has contributed the most substantially to increases in transport demand and related fuel consumption. In recent years the rail freight market lost its market share to road haulage, and presently it is estimated that 85% of total freight is hauled by road, with the remainder being transported by rail. Road freight transport, which is more reliable, flexible, accessible, and secure and provides shorter transit times by comparison with rail freight transport, is preferred by the industrial sector. However this carries with it negative externalities such as increased and rapid damage to roads, road congestion, air pollution and higher fuel/energy requirements.

Demand for freight haulage is strongly linked to the value-add of the transport sector and overall economic growth. However government has now reviewed its rail investment programme to accelerate the shift from road to rail. This will see an investment of about R63billion by Transnet in the freight rail system over the next five years. The move should result in a reduction in projected road freight haulage and resultant energy demanded and will therefore require further analysis.

Outside of the transport sector, the most significant energy demand increase is expected to be in industry (the manufacturing sector), followed by the commercial sector. The energy demand in the 'Manufacturing - Other' is largely associated with projected economic growth, while the increase in energy demand within the commercial sector is associated with the continued expansion of the tertiary sector as South Africa moves to become more of a knowledge-based economy.

Demand in the residential sector is largely driven by population growth coupled with increased urbanisation. As living standards improve, people tend to consume more energy; however, energy efficiency interventions could see this trend start to slow down in the future.

The graph below shows projected energy demand for individual energy carriers.

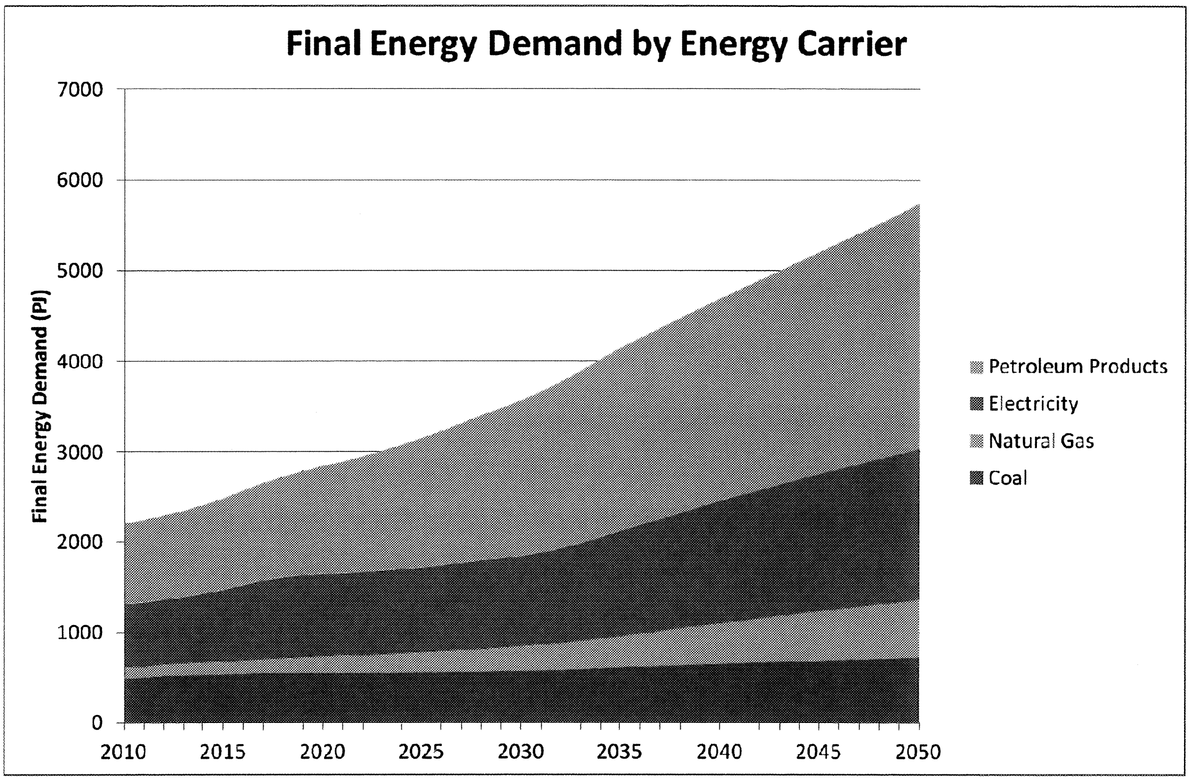


Figure 2-2: Total energy demand for different energy carriers

Demand for petroleum products increases the most significantly between 2010 and 2050 in comparison to that for other energy carriers. This is mostly attributed to the continued use of petrol and diesel vehicles to meet transportation needs into the foreseeable future with electric vehicles only beginning to make a significant contribution for passenger transport after 2030. Demand for LPG is expected to increase steadily in the residential sector and although fairly minor, ranks as the third largest increase between 2010 and 2050. Diesel consumption continues to increase in the mining sub-sector but only marginally when compared to electricity and natural gas. The use of illuminating paraffin is expected to decrease in future.

Demand for natural gas shows the next most significant increase after that of petroleum products. Natural gas is primarily used in the industrial sector and the projected growth of the sector is a factor in this increase.

Demand for electricity continues to rise as more houses become electrified and as the tertiary sector, largely comprised of commercial and public buildings continues to expand. In the industrial sector, the increase in electricity demand is largely attributed to the manufacturing sector with the exception of the iron & steel sub-sector. The iron & steel and mining sub-sectors show very little energy demand increase from current levels.

Demand for coal will continue to grow in the industrial sector, while in the residential sector it is expected to start declining due to ongoing electrification of previously non-electrified households and improvement in household incomes.

2.3 Proportion of Final Energy Demand within Different Sectors

The share of total energy demanded across different sectors in 2010, 2030 and 2050 is provided in the table below.

Table 2-1: Proportion of current and projected final energy demand within different sectors

SECTOR	2010	2030	2050	Change
Industry (Excluding Mining)	37%	33%	34%	⬇
Mining	8%	7%	4%	⬇
Agriculture	3%	2%	3%	▬
Commerce	7%	7%	7%	▬
Residential	11%	9%	8%	⬇
Transport	34%	43%	44%	⬆
TOTAL	**100%**	**100%**	**100%**	

2.4 Energy Intensity

Figure 2-3 and Figure 2-4 below reflect the changes in energy intensity for the different energy demand sectors relative to 2010 levels. Using 2010 as the base year (with an energy intensity index = 1), an energy intensity index below 1 indicates an improvement or reduction in energy intensity relative to that of 2010, while an energy intensity index above 1 indicates an increase in energy intensity relative to that of 2010.

Figure 2-3 indicates an improvement in the energy intensity of the industrial, mining, commercial and transport sectors. Although energy demand increases in the tertiary sector (commerce and transport) the rate of increase is slower than projected economic growth and continues to decline throughout the planning period. The energy intensity in the mining sector increases initially (between 2010 and 2017) and starts to decline thereafter.

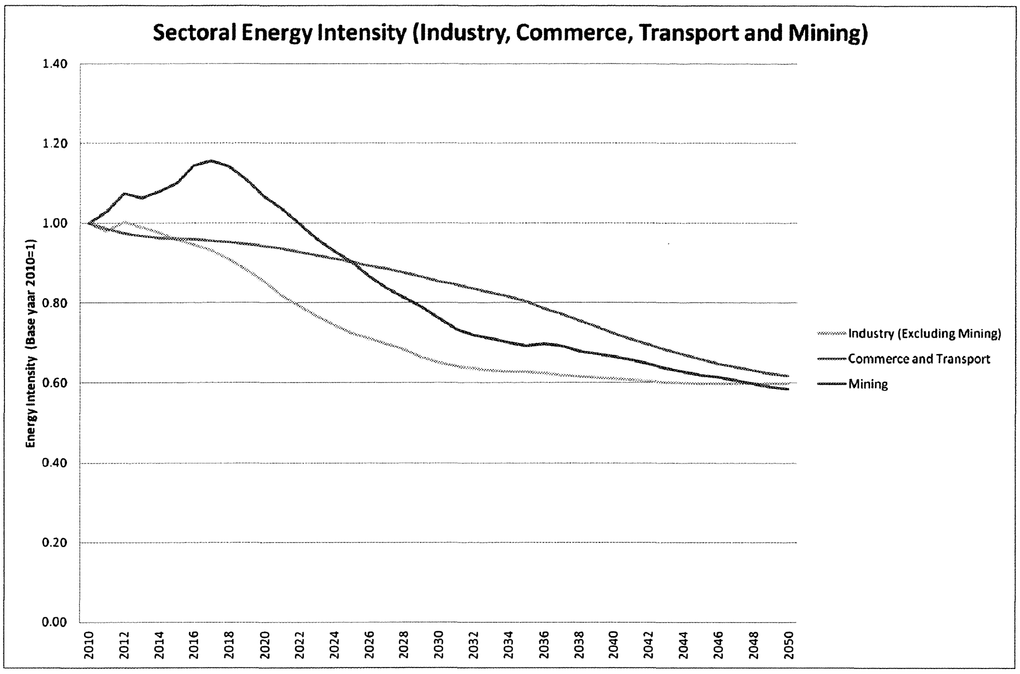


Figure 2-3: Energy Intensity Indices for the Industrial, Mining, Commercial and Transport Sectors

Unlike the sectors discussed above, energy intensity in the agricultural and residential sectors is likely to increase (See Figure 2-4). In the agricultural sector, the significant increase in energy consumption has historically been driven by the adoption of large-scale, intensive farming practices, which are assumed to continue into the foreseeable future. In the residential sector this increase will be driven by an assumed increase in the population.

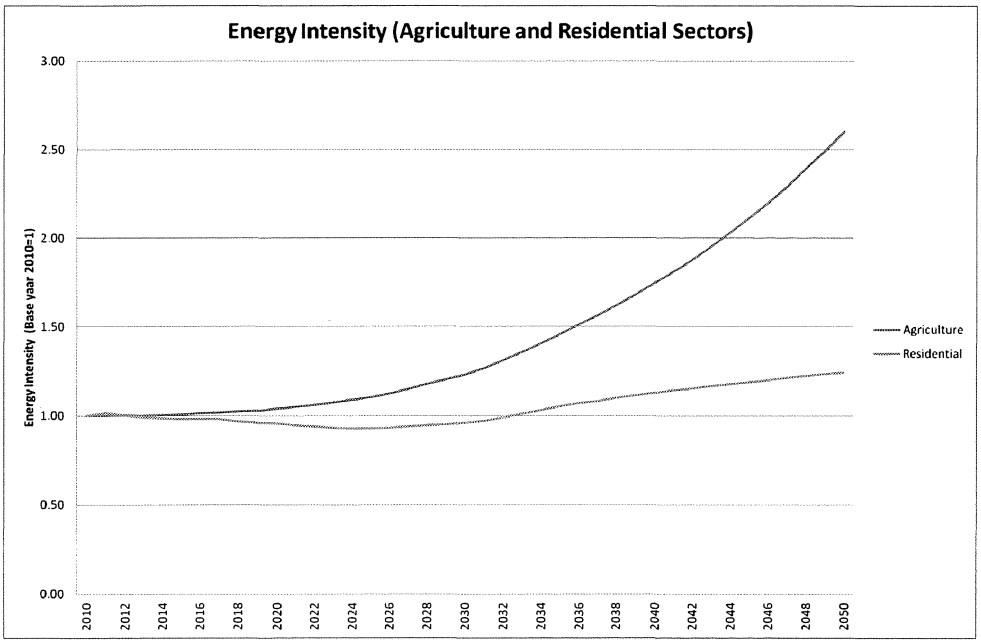


Figure 2-4: Energy intensity indices for the agriculture and residential sectors

Figure 2-5 indicates an overall reduction in the intensity of the economy. Structural changes; significant changes in the level of activity; and technological and process improvements which have taken place within each of the sectors inform the projected demand and hence the reduction in energy intensity, Further analysis is required to quantify and separate the historical impact of structural changes, activity level changes and technological changes on energy intensity. Improvements in technologies, industrial processes and practices alone can play a significant role in future efficiency improvements and government policies, such as the recently published Draft National Energy Efficiency Strategy and interventions such the financial and tax incentives for energy efficiency could materialise in further reductions of energy intensity within these sectors.

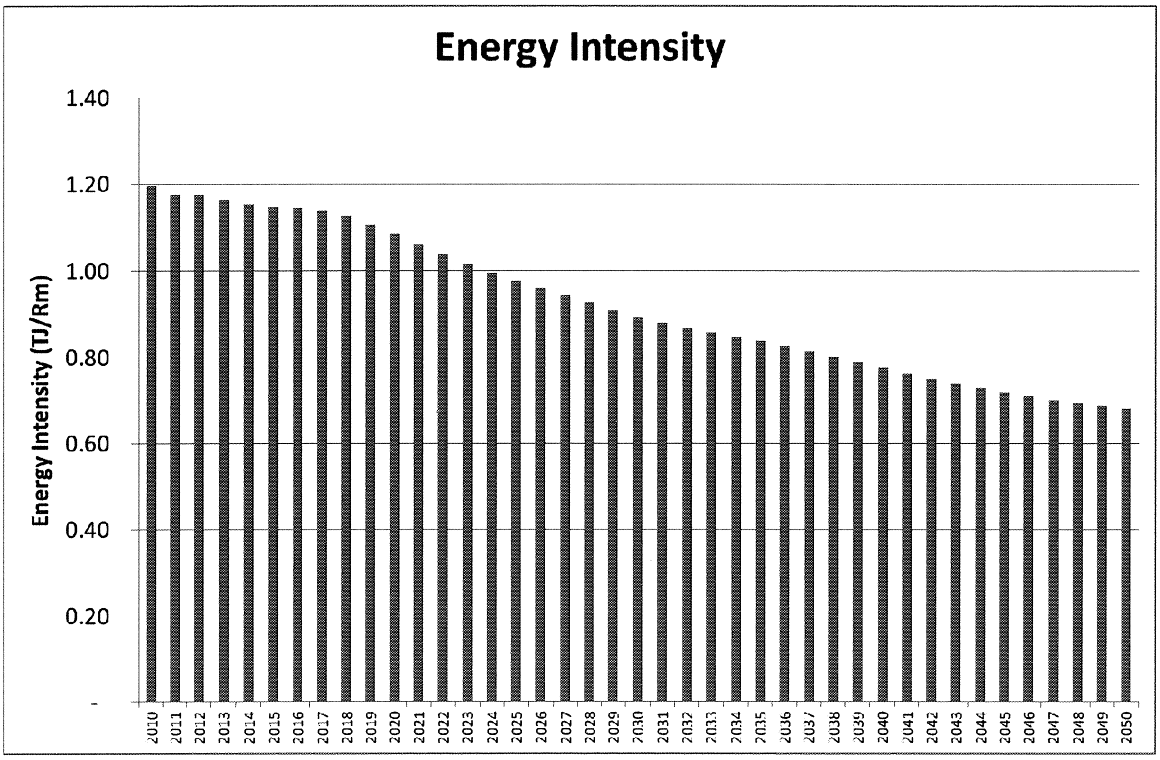


Figure 2-5: Energy intensity of the economy

3 The Base Case and Alternative Cases

The demand projections are a key input into the energy model and have a significant influence on the outcome of the Base Case and the various Test Cases. The underpinning objective is to ensure that future energy supply options meet future energy demand.

To ensure that the most appropriate supply-side options are selected, it is important to define a starting point or base against which all options are compared and analysed. This base has been defined as the 'Base Case' whilst alternative options that can be considered have been defined as 'Test Cases'.

BASE CASE

- The Base Case encapsulates the state of energy demand and supply over the planning horizon, which is most closely informed by current energy market trends; the national macroeconomic outlook; assumed energy prices; existing energy infrastructure and the existing suite of policies and government programmes. Thus, while the IEP seeks to recommend an energy roadmap or policy pathway for the energy sector, this process is not conducted in isolation and should build on energy policies, strategies and plans which have already been adopted.
- **The Base Case, is therefore not a representation of the most likely future or most likely scenario, but is rather a simplistic representation of a future outcome that could materialise in light of current policies and macroeconomic trends. It represents a Business-As-Usual or Status Quo scenario where current trends continue into the future.**

Alternative policy options or 'policy alternatives' look at different pathways that can be pursued by policymakers to achieve energy sustainability and in some instances this requires testing the impacts of competing factors. These policy alternatives are defined as 'Test Cases'.

TEST CASE

- A Test Case has been defined as a **deviation from the status quo** where current trends do not continue into the future and **deviations are as a result of specific policy interventions**. A Test Case therefore defines a set of circumstances and resultant outcomes or impacts which is informed by the possible impacts of policies and policy interventions. A Test Case does not indicate what will happen but rather tests what could happen if a particular course of action is pursued.
- While Test Cases are sometimes also referred to as scenarios, within the context of the IEP and for the purposes of common interpretation, a Test Case is specifically differentiated from a Scenario in that a **Scenario is largely influenced by exogenous forces** which the policy maker has no control over, while **a Test Case seeks to test the possible implications of active policy interventions**.

The Base Case assumes that only prevailing policies are pursued to shape the future energy pathway. The Test Cases which were also considered and modelled are described briefly below. Each Test Case has been informed by the policy imperatives of high-impact policies within the energy sector which include the Integrated Resource Plan, the National Development Plan and the National Climate Change Response White Paper.

1. **"Peak-Plateau-Decline" Emission Limit Test Case:** This Test Case assumes that the country's target (i.e. a reduction on the 'business as usual' emission level of 34% by 2020 and

of 42% by 2025) for electricity generation and liquid fuel production is met at all costs. This is achieved by setting emission limits ***on electricity generation and liquid fuel supply only*** in line with the upper bound of the "Peak-Plateau-Decline" emission trajectory, as defined in the National Climate Change Response Policy. No carbon tax is assumed. This Test Case seeks to analyse the effect of the emission limit constraints on energy supply options and costs.

2. **Emission Limit - No Nuclear Build Programme Case**: This Test Case assumes that the emission limit of the "Peak Plateau Decline" must be met as described above but that the 9,600MW Nuclear Build Programme is explicitly excluded as a supply option. This Test Case seeks to analyse the effect of embarking upon, or not embarking upon, the Nuclear Build Programme in terms of future energy security, as well as meeting the emission limit targets defined in the National Climate Change Response Policy.
3. **Renewable Energy Target Case:** No emission limit constraints are set but renewable energy options are gradually introduced into the energy mix from 2010 to 2030 such that by 2030, 10% of total energy output (electricity generation and liquid fuel production) is from renewable energy sources. From 2031 onwards, the target of 10% is maintained as a minimum. (It should be noted that given the low load factors for most renewable energy technologies, the installed capacity would effectively be much higher than 10%). This Test Case analyses the efficacy of setting renewable energy targets for reducing emissions within the energy sector.
4. **Emission Limit - Natural Gas Case:** This assumes that the emission limit of the "Peak Plateau Decline" trajectory must be met and that the Nuclear Build Programme is excluded as a supply option, as in the Test Case above. However the nuclear option is replaced by natural gas options as a policy intervention. This Test Case seeks to analyse the efficacy of including natural gas in the energy supply mix as a transitional fuel towards a low carbon economy and the implications of choosing this as a supply option over nuclear. In this context natural gas includes conventional gas, coal bed methane and shale gas.
5. **Carbon Tax Cases:** In these two Test Cases no emission limit constraints are set but the carbon tax is implemented as a test case with an upper bound of R120 per ton of CO_2-eq and a second case is implemented with a R48 per ton to simulate the 60% tax-free threshold. These test cases analyse the cost implications of a possible carbon tax on the energy sector as defined in the impending Carbon Tax Policy.

In addition, the following sensitivity analyses were conducted for the Base Case in order to test the impact of different crude oil price growth assumptions on decisions for new refining capacity:

1. **Low Crude Oil Price Case:** Assumes a low growth in the future crude oil price.
2. **High Crude Oil Price Case:** Assumes a high growth in the future crude oil price.

The model output from the Base Case and "Peak-Plateau-Decline" Emission Limit Test Case are described briefly in the two sections that follow.

4 Summary of Model Output

Based on the key macroeconomic, policy and technology assumptions made for the Base Case, the following section provides a summary of the total capacity for electricity generation, liquid fuel production and primary energy mix as well as estimated annual emissions and water use throughout the planning horizon.

4.1 Electricity Generation

The technology options for electricity generation for the High Oil Price and the Low Oil Price Test Cases remains the same as the Base Case as changes in crude oil price have little impact on electricity generation options.

- Coal technologies continue to play a role in the Base Case and all Test Cases however this is reduced significantly by 2030 as the existing fleet of coal technologies starts to be retired. The role of coal technologies continues to decline in the three Test Cases within emissions limits as no new coal power plants (besides Medupi and Kusile) are brought onstream. However in the Base Case and the Renewable Energy Target Cases new coal technologies continue to contribute to electricity supply (approximately an additional 50GW by 2050 in the Base Case and 30GW in the Renewable Energy Target Case).

- Solar plays a significant role in the Base Case and all Test Cases as the cost of solar technologies is projected to continue declining in the foreseeable future. Solar shows the biggest increase in contribution to the total energy mix in the Base Case and all Test Cases.

- The contribution of wind technologies is reduced in the Base Case as other options are more cost effective than wind technologies in the absence of emissions limits or renewable energy targets. However wind does play a significant role in the Emissions Limit and Renewable Energy Target Test Cases. Wind shows the second biggest increase in contribution in all Test Cases with emissions limits.

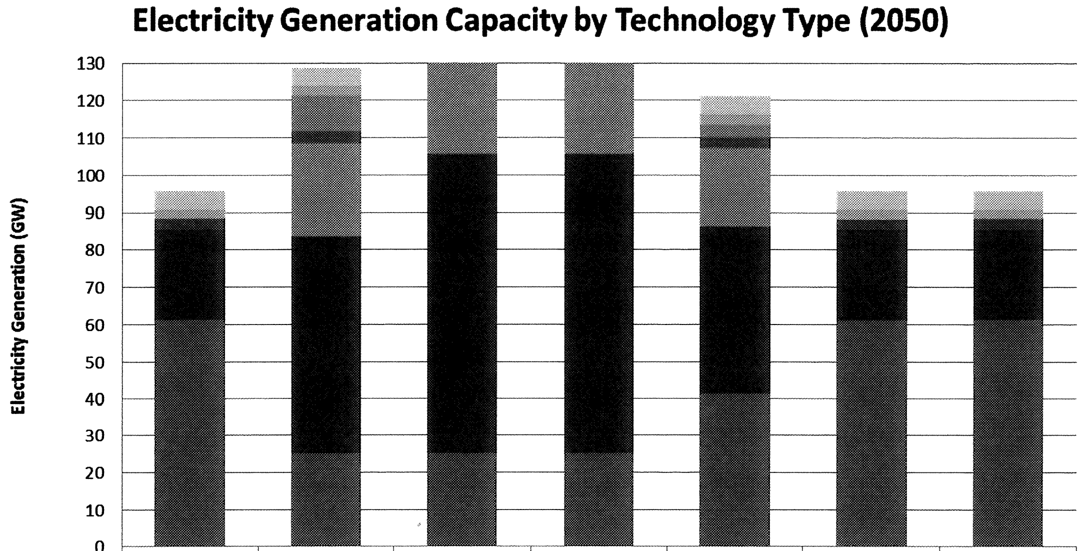
- A new nuclear plant is selected by the model in the Emissions Limit Case with no explicit exclusion of nuclear. Nuclear, together with Renewable Energy technologies are therefore viable options in reducing emissions in the Emissions Limit Test Cases. Nuclear does not feature in the Renewable Energy Target Case as preference is given to renewable energy technologies in this Test Case.

- Biomass only features in the Renewable Energy Target Test Case in order to ensure that the renewable energy targets are met.

- Besides the natural gas options included as part of the ministerial determinations, new natural gas options do not feature prominently in the Base Case or any of the Test Cases. New natural gas only features in the Test Case where Natural Gas options are explicitly enforced.

- While coal-fired power plants with Carbon Capture and Storage (CCS) technologies were considered as an option, due to their relatively high cost the model does not select any CCS technologies in the Test Cases with emissions limits as other cheaper alternatives (i.e. Wind and Solar technologies) are available.

Figure 4-1 presents the electricity generation capacity for different technologies by 2050.



	Base Case	Emissions Limit Case	Emissions Limit - No Nuclear Case	Emissions Limit - Natural Gas Case	Renewable Energy Target Case	High Oil Price Case	Low Oil Price Case
Other *	4.9	4.9	4.9	4.9	4.91	4.9	4.9
Gas	0.2	0.2		4	0.237	0.2	0.2
Petroleum	2.4	2.4	2.4	2.4	2.415	2.4	2.4
Nuclear		9.6					
Biomass					3.417120576		
Hydro	3.1	3.1	3.1	3.1	3.109	3.1	3.1
Wind		25	25	25	20.90722329		
Solar	24	58.1	80.1	80.1	44.99309098	24	24
Coal	61.2	25.4	25.4	25.4	41.20415853	61.1	61.2

Figure 4-1: Electricity generation capacity by technology type (2050)

4.2 Liquid Fuel Production

The exclusion of nuclear energy (i.e. Emissions Limit – No Nuclear Case) has no significant impact on the liquid fuels sector in comparison to the Emissions limit case. Likewise the enforcement of natural gas as a supply option (i.e. Emissions Limit – Natural Gas Case) also has no significant impact on the liquid fuel sector. The output from these two test cases therefore requires no further analysis in this section as the output is the same as that for the Emissions Limit Test Case.

- In the Base Case and all Test Cases, the model selects new refining capacity to meet future liquid fuel demand from as early as 2020. Total liquid fuel production slows down by 2034 and plateaus to 2040 after which it declines as a result of electric vehicle penetration in all Test Cases.

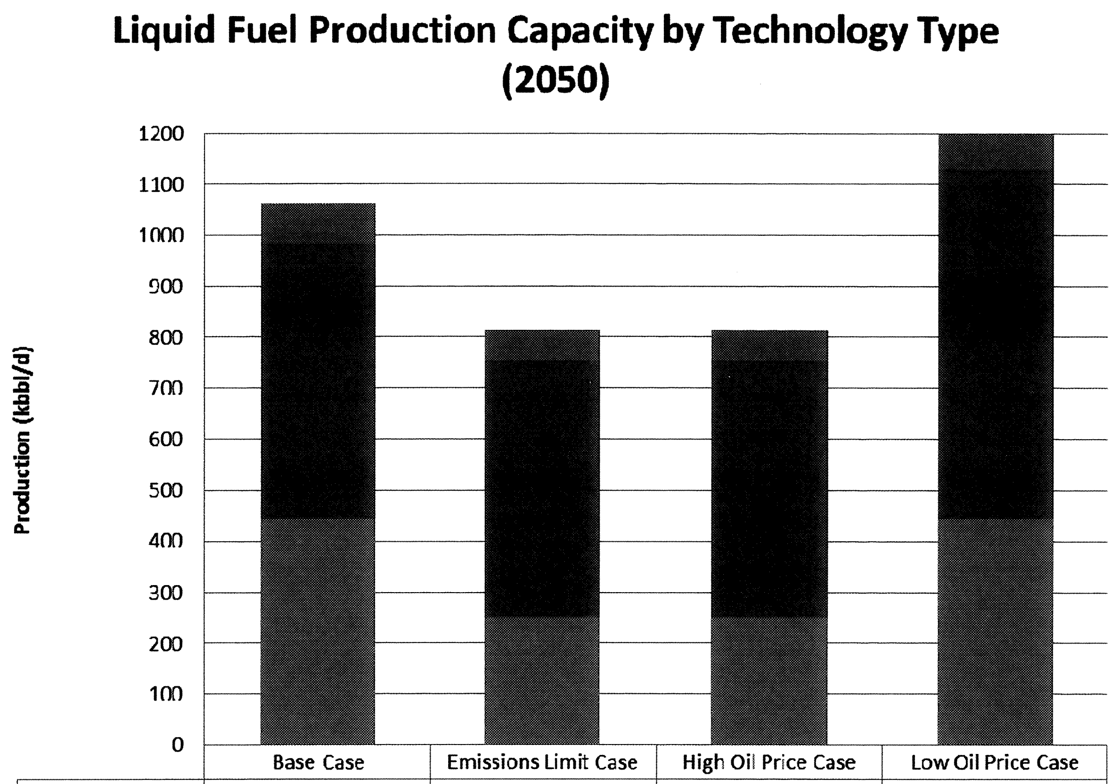
- New conventional crude oil refineries are a viable option in the Base Case and all Test Cases however additional capacity in the outer years is reduced for the Emission Limit Test Cases. It is assumed that existing conventional refineries are not retired within the modelling period and that their operational life is extended through continued maintenance, occasional upgrades (usually related to fuel specifications) and the low cost of maintaining the existing refineries relative to the cost of crude oil processed.

- In the Base Case and test cases without emissions limits, the cost of producing liquid fuels from coal is lower than that for both conventional refineries and gas to liquid plants as presented in the assumptions. In these test cases a coal-to-liquid plant is built to the maximum constraint set in the input parameters of 80 000 barrels per day, after which conventional refineries are selected to provide for the increasing liquid fuels demand. In the Emissions Limit Test Case, the selection of a new coal-to-liquid plant is restricted as a consequence of the high associated carbon emissions. A new plant does however feature only after 2040 when the existing coal to liquids plant is decommissioned and the use of electric vehicles reduces overall emissions below the emissions limits therefore providing scope for the more cost-effective coal to liquid plant. In the absence of a carbon tax, the total discounted cost of producing liquid fuels from coal-to-liquid plants is lower than that for both conventional refineries and gas to liquids.

- No new Gas-to-Liquid (GTL) plants are selected by the model. This is partially informed by the relative costs of new GTL plants as compared to conventional crude oil refineries as well as projected natural gas prices.

- In the absence of emissions limit constraints, the model output shows sensitivity to new capacity for different crude oil price assumptions. The capacity of new conventional refineries is highest in the Low Oil Price Case as compared to the Base Case and all the other Test Cases. On the contrary, the capacity of new conventional refineries in the High Oil Price Case is lower than that of the Base Case but is comparable to that of new capacity in the Emissions Limit Case.

- All supply shortfalls are met via imports in all Test Cases. Imports are especially high in the High Oil Price Case and the test cases which set limits on carbon emissions.



	Base Case	Emissions Limit Case	High Oil Price Case	Low Oil Price Case
New GTL				
Existing GTL				
New CTL	79	61	61	79
Existing CTL				
New refinery	538	503	503	683
Existing refinery	444	251	251	444

Figure 4-2: Liquid fuel production by technology type (2050)

4.3 Primary Energy Supply

- Coal loses its share in the primary energy mix in the Base Case and all three Test Cases however this is pronounced in the Emissions Limit Cases.
- New nuclear only features in the Emission Limit Test Case without technology constraints.
- Solar technologies are viable and play a prominent role in all Test Cases however the share contribution is reduced in the Renewable Energy Target Case as Wind – which is included earlier in this Test Case reduces the requirements for new renewable energy technologies in the outer years.
- New biomass only features when a renewable energy target is set.
- Transport demand continues to increase which results in an increase in the demand for liquid fuel. In the Base Case and the Test Cases without emissions limits, this demand is met

through local production (primarily crude oil refining and limited production of synfuels from coal and gas). The share of crude oil in the primary energy mix therefore increases in these Test Cases.

- In the Emissions Limit Test Cases, local production of liquid fuel is displaced with imports and this sees an increase in the share of petroleum products in the primary energy mix. In the High Crude Oil Price Case, the import of final product surpasses crude oil imports and the inverse is the case in the Low Crude Oil Price Case.
- Imported natural gas plays an increasing role in all Test Cases throughout the planning period; however this is not prominent in comparison to other primary energy sources.

4.4 Discounted Cost

The total discounted cost represents all the costs of the energy system discounted to a single number for comparison purposes. It is the main variable used to compare the policy interventions which inform the various test cases which have been defined.

A large dependence on imported energy (crude oil and liquid fuels) in all test cases can be observed from an analysis of costs related to the energy system as presented in Figure 4-3. Imports increase from about 70% to 80% of the total energy supply costs for the Base Case between 2010 and 2050; from 80% to 90% in the Emissions Limit Case and the No Nuclear Case; from 70% to 80% in the Renewable Energy Target Case.

The total discounted costs for the Emissions Limit Case and the No Nuclear Case are both 4.8% more than that for the Base Case; and that for the Renewable Energy Target Case is 1% more than that for the Base Case. The higher costs are due to an increase in the share of imported energy and the use of technologies which are less carbon intensive in the test cases with emissions limits.

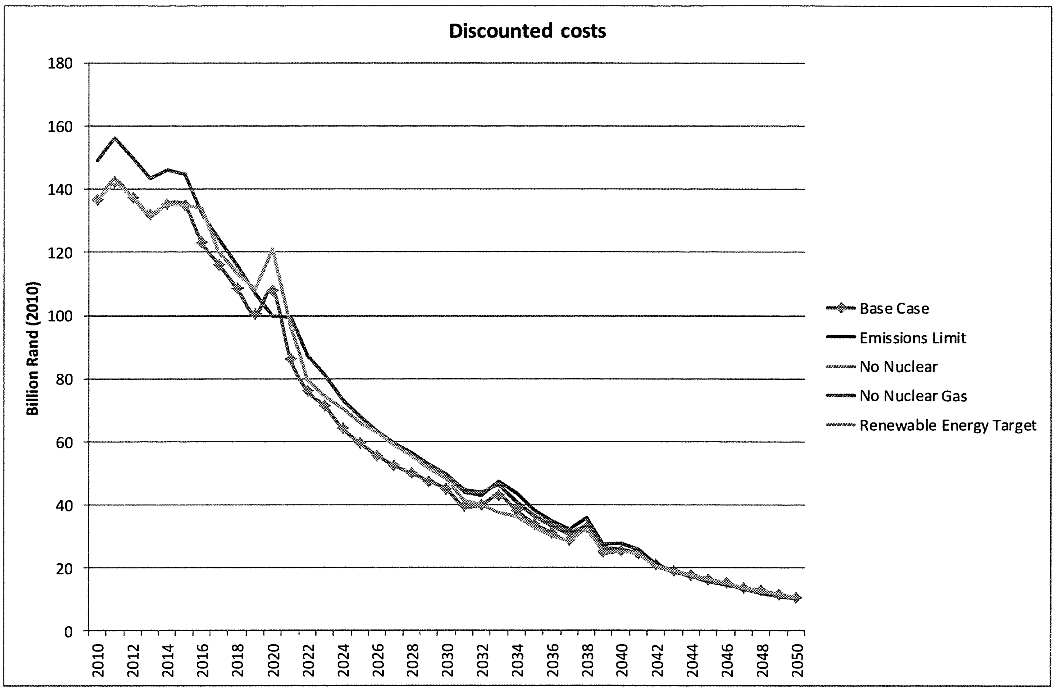


Figure 4-3: Discounted costs for all Test Cases

4.5 Emissions

Carbon dioxide emissions for the Base Case and test cases are presented in Figure 4-4. These emissions are primarily driven by the use of coal for electricity generation and liquid fuel production; however a considerable amount of coal is also used in other parts of the economy and is not included here. The abatement cost for meeting the emissions limit for the Emissions Limit Test Case and the No Nuclear Test Case is calculated at R41/t (in 2010 Rand). Setting emissions limits on energy production (i.e. refineries and electricity generation) without setting emissions constraints or emissions penalties on energy end-use (i.e. demand-side emissions controls) results in greater use of imported energy. Emissions resulting from energy end-use therefore continue growing unconstrained. Therefore national emissions limits cannot be met without addressing final demand for energy carriers.

Fuel switching between final energy carriers was only modelled for the transport sector and this allows for the switching from fuel-powered vehicles to hybrid and electric vehicles which results in reduced emissions in the transport sector when constraints are set.

In summary:

- Emissions in the Base Case continue to increase.
- Emissions are reduced for the Renewable Energy Target Test Case however the reduction is not significant enough for them to be below the levels required by the "Peak Plateau Decline" Emissions Trajectory.

- The carbon emissions associated with energy supply (electricity generation and liquid fuel production) for all the test cases with emissions limits are within the “Peak Plateau Decline” Emissions Trajectory as this is set as a constraint. The reduction in the use of coal has the most significant impact on this reduction and the emissions constraints resulted in a 7.5 billion tonnes (or 31%) reduction in carbon dioxide emissions over the 40 year period as compared to the Base Case.

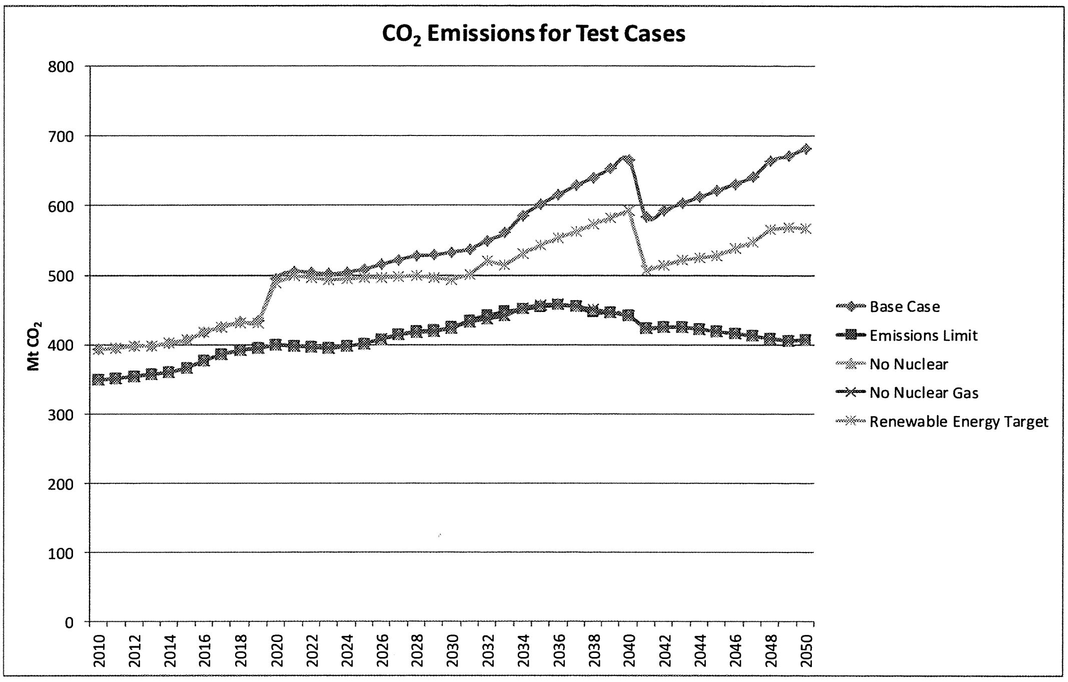


Figure 4-4: CO_2 emissions for all Test Cases

4.6 Water Use

Water use in the various test cases is shown in Figure 4-5. Coal-to-liquid plants use large quantities of water - this is evident by comparing the water consumption of the Base Case (which includes a new coal-to-liquid plant) with that of the Emissions Limit case (all of which exclude a new coal-to-liquid plant). There is very little difference in water consumption for the Emissions Limit case and the No Nuclear case. The small difference is because nuclear (which is selected by the model in the Emissions Limit Test Case) is assumed to use sea water whereas the CSP technologies (which are selected by the model partially in place of nuclear in the Emissions Limit – No Nuclear Test Case) use fresh water. In general the test cases which have limited or no production from coal-to-liquid plants have a reduced demand for water in comparison to those that have significant production. In the latter years, water demand is also reduced as dry-cooled plants replace wet-cooled plants for electricity generation and renewable energy technologies which use less water start to play a more prominent role in the energy mix.

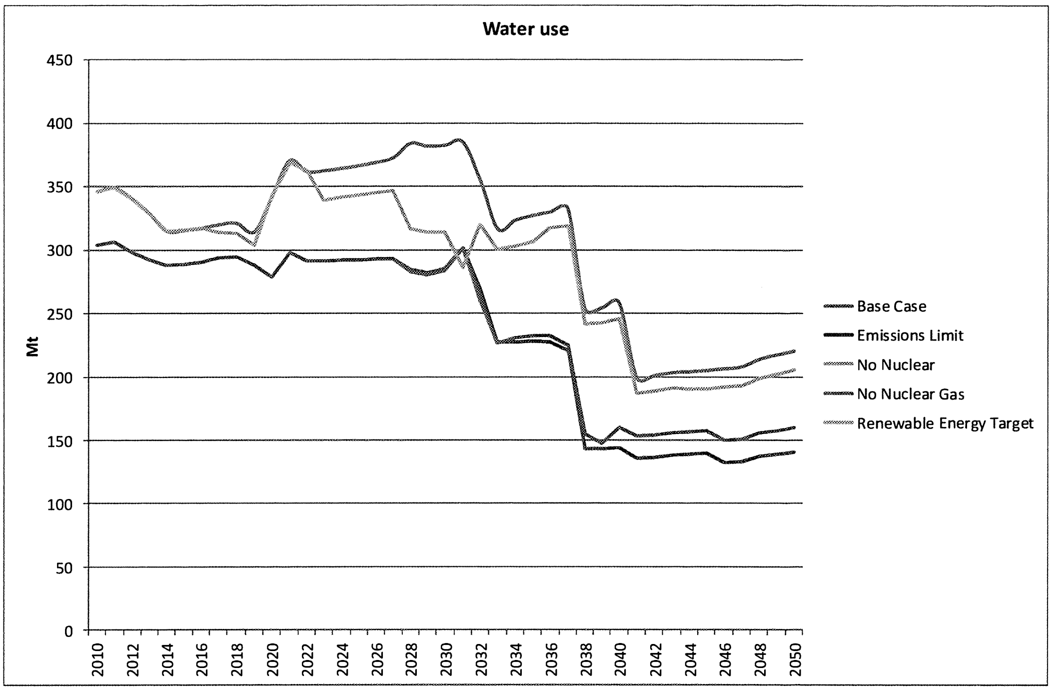


Figure 4-5: Water use for the test case

5 Way Forward

The energy planning process entails quantitative analysis as well as qualitative analysis or value judgement. The key inputs into the energy models and the underpinning assumptions which inform that input are therefore critical and need to be well communicated. The demand projections are largely informed by the macroeconomic and demographic assumptions which have been made, and in the case of the transport sector assumptions about energy end-use technologies (or vehicles). The final output from the energy models is greatly influenced by the projected demand, together with assumptions made about the impact of policies, energy supply technologies as well technological developments.

The Draft Integrated Energy Planning Report presents the energy planning approach followed, including the methodologies used to estimate energy demand projections in light of the data scarcity issues encountered. It also presents the model output and analysis for the Base Case and the test cases which were modelled.

This document therefore does not seek to make recommendations but provides the preliminary model output and a basis from which stakeholder input can be obtained. Once published various stakeholder consultations will take place over a period of approximately four (4) months. During the stakeholder consultation process, it is anticipated that various inputs will be received which will provide information to guide further analysis. Some of the assumptions, (for example GDP growth rates) may need to be revised based on the latest national forecasts. Areas which require further analysis include the following:

- Assess the impact of Transnet Freight Rail's expansion plan on displacement of freight haulage from road to rail and the impact that this may have on projected demand;
- Conduct further analysis of the constraints that natural gas infrastructure may have in meeting projected demand for natural gas, particularly in the industrial and commercial sectors;
- Explore options for natural gas imports and analyse the potential impact on projected natural gas import prices including imports from Mozambique and other countries within the region;
- Obtain more data and information to explore regional options such as the Northern Mozambique Power Development Programme and the Grand Inga Hydropower Scheme;
- Gain a better understanding of the land limitations which may constrain growth in the agricultural sector and in particular the projected demand for diesel, which is primarily used by tractors for ploughing; and
- Assess in more detail and better quantify the impact of technological advancements and process improvements which could result in further energy efficiency gains in the industrial and commercial sectors.

The input obtained from the stakeholder engagement process may result in the revision of some of the key planning assumptions. Such revisions may also result in changes to the demand projections and subsequently outputs from the Base Case and test cases.

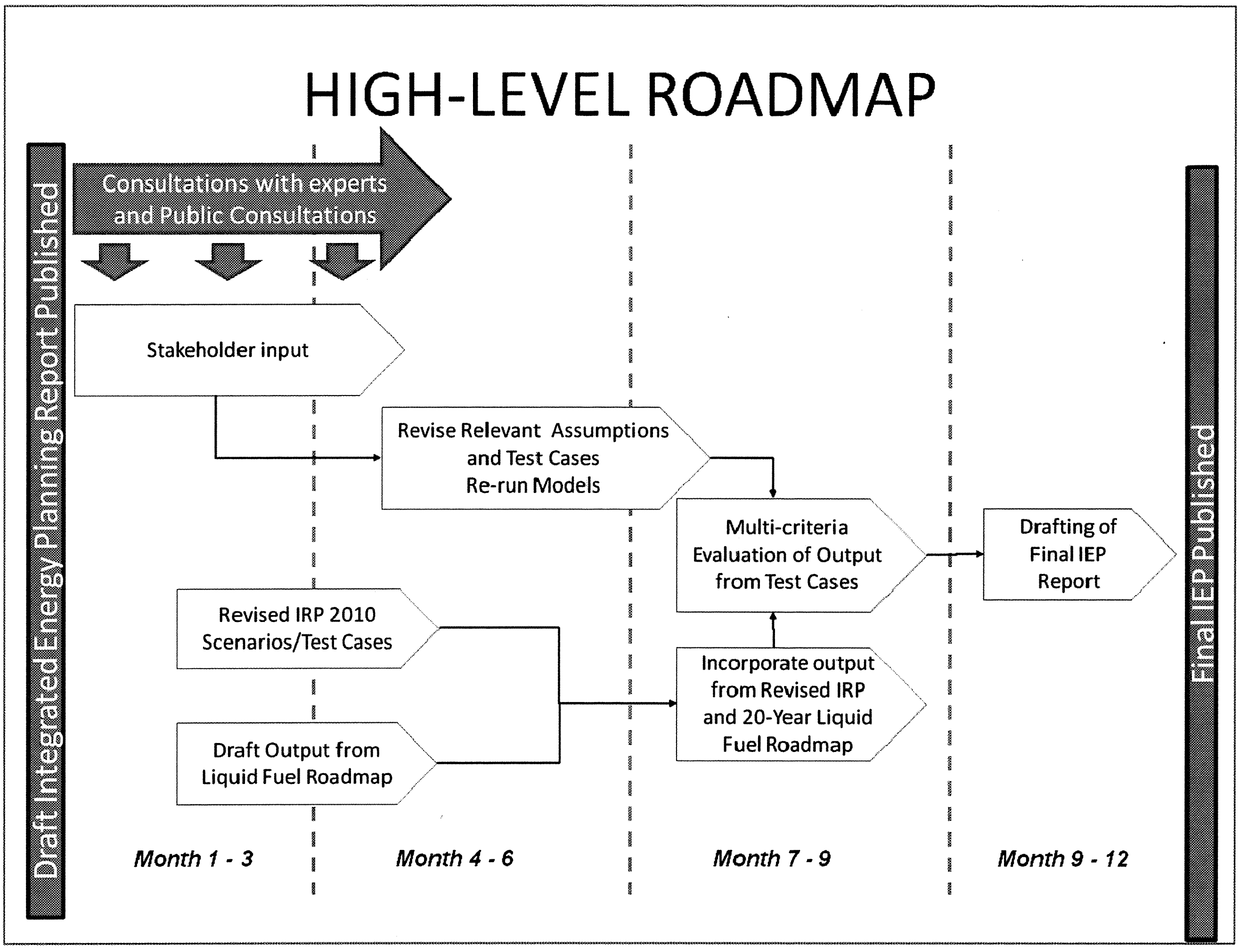


Figure 5-1: High-level roadmap

After the stakeholder engagement process, the final set of outputs will be evaluated using a Multi-Criteria Decision Analysis (MCDA) technique. The outcome from this process will inform the final IEP.

6 Document Structure

- Section 1 presents the main introduction of the report and defines the scope of the IEP. It also covers the high-level integrated energy planning approach and sets the scene for the remainder of the document.
- Section 2 provides a discussion on the key policies which have informed the Integrated Energy Planning process, including those policies outside of the energy sector which are considered to have a high impact on the energy sector. The eight (8) competing objectives that the Integrated Energy Planning process seeks to balance are discussed.
- Section 3 provides an overview of the South African energy sector, including an overview of primary energy sources and their potential future role in the energy mix.
- Section 4 provides the key macroeconomic assumptions including the detailed write-up and values with supporting calculations and tables where relevant.

- Section 5 provides an analysis of the projected energy demand by sectors. In each instance the key assumed drivers for demand are discussed.
- Section 6 provides the detailed write-up of the Base Case policy assumptions and Test Cases which were modelled.
- Section 7 provides analyses of the model output for the Base Case and all the Test Cases.
- Lastly, Section 8 presents the way forward, including the stakeholder consultation process and timelines and how input will be incorporated into the final IEP Report. This section also outlines how the Multi-Criteria-Decision-Making (MCDA) technique will be used to evaluate all model outputs and make final recommendations based on the key objectives of the IEP. The MCDA technique is also described in detail in Appendix 1.

No. 513 **24 July 2013**

DEPARTMENT OF ENERGY

DRAFT 2012 INTEGRATED ENERGY PLANNING REPORT

(For Public Consultation)

June 2013

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ABBREVIATIONS AND ACRONYMS

bpsd	Barrels per Stream Day
CBM	Coal Bed Methane
CCGT	Combined-Cycle Gas Turbine
CCS	Carbon Capture and Storage
CDM	Clean Development Mechanism
CFC	Chlorofluorocarbon
CH_4	Methane
CMM	Coal Mine Methane
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2e	Carbon Dioxide Equivalent
CSP	Concentrated Solar Power
CTL	Coal to Liquids
CUE	Cost of Unserved Energy
DC	Direct Current
DME	Department of Minerals and Energy
DoE	Department of Energy
DRC	Democratic Republic of the Congo
EIA	Energy Information Administration
ESMP	Energy Security Master Plan
EU	European Union
GDP	Gross Domestic Product
GEF	Global Environment Facility
GHG	Greenhouse Gas
GTL	Gas-to-Liquid
GW	Gigawatt
GWh	Giga Watt Hours
IEA	International Energy Agency
IEP	Integrated Energy Plan
IPP	Independent Power Producer
IRP	Integrated Resource Plan
km	Kilometre
kt	Kiloton
kWh	kilowatt hour
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas

mb/d	Million Barrels per Day
MCDA	Multi-Criteria Decision Analysis
MJ	Megajoule
MMbbl	Million Barrels
MMBtu	Million British Thermal Units
m/s	meters per second
Mt	Million Tons
Mtoe	Million Tons of Oil Equivalent
MTSF	Medium Term Strategic Framework
MW	Megawatt
MWe	Megawatt Electric
NATMAP	National Transport Master Plan
NCCRP	National Climate Change Response Policy
NDP	National Development Plan
Necsa	South African Nuclear Energy Corporation
NO_X	Nitrogen Oxide
NPT	Non-Proliferation Treaty
OCGT	Open-Cycle Gas Turbine
OECD	Organisation of Economic Cooperation and Development
OPEC	Organisation of Petroleum Exporting Countries
PASA	Petroleum Agency of South Africa
PGM	Platinum Group Metals
PJ	Petajoule
PPP	Purchasing Power Parity
PV	Photovoltaic
PWR	Pressurised Water Reactor
R&D	Research and Development
SANEDI	South African National Energy Development Institute
SAWEP	South African Wind Energy Programme
Tcf	Trillion Cubic Feet
TJ	Terajoule
V	Volt
W/m^2	Watt per square meter
UCG	Underground Coal Gasification
USA	United States of America

SECTION 1: INTRODUCTION

Energy is essential to many human activities and is critical to the social and economic development of an economy. One of the key objectives of the Department of Energy (DoE) is to ensure energy security, which in essence is about ensuring the availability of energy resources, and access to energy services in an affordable and sustainable manner, while minimising the associated adverse environmental impacts. Many factors pose potential threats to energy security including scarce and depleting energy resources, geopolitical instability, inadequate energy infrastructure, and more recently natural disasters. To ensure continued security of energy supply, it is essential that a co-ordinated and integrated approach to energy planning, which takes into account these complex issues, is undertaken.

The development of a National Integrated Energy Plan (IEP) was envisaged in the White Paper on the Energy Policy of the Republic of South Africa of 1998 and, in terms of the National Energy Act, 2008 (Act No. 34 of 2008), the Minister of Energy is mandated to develop and, on an annual basis, review and publish the IEP in the *Government Gazette*. The purpose of the IEP is to provide a roadmap of the future energy landscape for South Africa which guides future energy infrastructure investments and policy development. The National Energy Act requires the IEP to have a planning horizon of no less than 20 years. The development of the IEP is therefore a continuous process as it needs to be reviewed periodically to take into account changes in the macro-economic environment, developments in new technologies and changes in national priorities and imperatives, amongst other factors. While change is on-going, the plan must remain relevant.

Integrated Energy Planning entails understanding the current and future energy requirements of different types of consumers (e.g. industry, commerce, mining, agriculture, households, etc.) and then determining the most optimal mix of energy sources and technologies to meet those energy needs in the most cost-effective, efficient, socially beneficial and environmentally responsible manner. Delivering energy to end users requires multiple processes (production, conversion, transmission and distribution) and involves many participants, from both the public and private sectors. Today's choices about how energy is extracted, harnessed and used will determine the sustainability of the energy system in the future and thereby influence the extent of socio-economic development.

Integrated energy planning at a national level is therefore focused on the entire energy value chain and requires a comprehensive representation and understanding of the entire energy system. The energy planning process starts with an understanding of the different forms of energy which are consumed by different end users and the applications in which those forms of energy are used. The alternative technologies for producing and distributing those different forms of energy are evaluated according to a number of factors such as cost, efficiency, lifecycle and associated emissions. The different primary energy sources which are available are considered, since these inform the types of production and the distribution technologies that will be required and contribute to the final energy end use cost as well as emissions.

These multiple aspects must be considered in a balanced manner to ensure that the objective of achieving sustainable socio-economic development is realised. *"Integrated energy planning is the systematic analysis of all the factors that influence the evolution of energy systems. It facilitates problem solving and makes it possible to explore linkages, evaluate trade-offs and compare consequences, thereby helping countries to develop an effective energy strategy that supports national sustainable development goals.*[1]

The integrated energy planning process analyses the benefits and shortcomings of relationships between components of the energy sector and seeks to optimise the energy system as a whole. For example, the increase in car ownership, coupled with tight oil refining capacity and inadequate logistics infrastructure continues to threaten the security of liquid fuel supplies in South Africa. Similarly, the upsurge in property development, especially in the residential and commercial sectors, coupled with the successful rollout of the electrification programme, has resulted in increased demand for electricity. Against this background, environmental pressures, increases in the global crude oil prices, potential increases in coal prices together with new potential discoveries of shale gas in the Karoo and natural gas in Mozambique are all potential game-changers which require a sharpened focus on the use of alternative energy sources as well as the efficient use of traditional energy sources. Thus, in energy planning, it is essential to take the broader aspirations and goals of the country into consideration as well as external factors which characterise the sector.

Key government and political commitments such as the Millennium Development Goals, the National Development Plan, the Climate Change Response Policy, and the shift to the Green Economy need to be considered as part of energy planning. Integrated energy planning is therefore not only about ensuring that South Africa's energy needs are met, but rather takes a broader approach in ensuring alignment between cross-sectoral impacts and the National Objectives - where applicable, Regional developments are also considered. While sectoral plans look at how to ensure that energy needs are met, the IEP seeks to provide a long-term vision of how South Africa can remain competitive and how it can use energy as a mechanism to remain competitive.

1.1 Scope of the IEP

The IEP considers the national supply and demand balance and proposes alternative capacity expansion plans based on varying sets of assumptions and constraints. While infrastructural issues are briefly discussed, the IEP does not explicitly consider supply and demand at specific geographical locations within the country nor does it take into account infrastructure bottlenecks at specific locations.

[1] International Atomic Energy Agency, Integrated Energy Planning for Sustainable Development

- With regard to electricity infrastructure issues (transmission and distribution) these are dealt with in other plans and going forward the Integrated Resource Plan (IRP) should assess these in detail, taking into consideration grid planning currently conducted by Eskom.
- With regard to liquid fuels, the 20-Year Liquid Fuel Infrastructure Roadmap will deal with logistical issues relating to pipelines and storage facilities for petroleum products.
- The gas infrastructure framework which is currently in the early stages of development will take into consideration bottleneck and capacity constraints of the current natural gas infrastructure.
- All the above will provide feedback into the integrated energy planning process and will enable overall enhancement through ongoing periodic iterations.

1.2 High-Level Integrated Energy Planning Approach

The high-level energy planning approach, depicted in Figure 1-1, is used to ensure that the process of developing the IEP is continuous and takes into account stakeholder engagement. The scope of this process is encompassed in Steps I, II and III.

Steps IV, V, and VI are within the broader scope of the IEP process, but fall outside the sphere of its development. Once the IEP recommendations have been made and promulgated, implementation, monitoring and review of those recommendations need to take place. The outcomes from these steps must inform future iterations of the IEP.

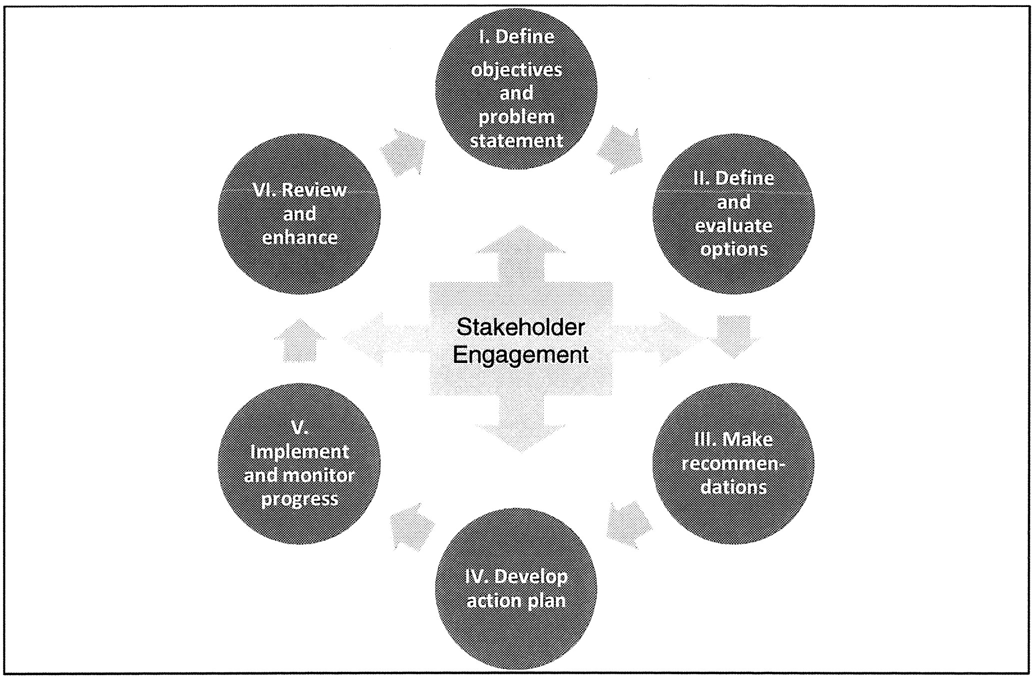


Figure 1-1: High-Level Planning Approach

The high-level approach is described in the following six key steps:

I. **Define objectives and problem statement:** The National Objectives of the South African Government are set to ensure that government departments work in a co-ordinated way to fulfil their respective public mandates. The National Objectives set the priorities of the country and are articulated on an annual basis as part of the President's State of the Nation Address as well as government's Programme of Action. The first step is to understand those key objectives so that, through the IEP, the DoE can achieve those objectives that are within its mandate. The objectives of the IEP must be placed first and foremost in the planning process.

II. **Define and evaluate policy options or pathways:** This step requires an understanding of the policy objectives that should be considered in the planning process. Once these are identified and understood, their impact is assessed. This process involves defining the main questions to be tackled by the IEP, examining the different policy pathways or options that can be pursued and testing the relative impacts of these possible pathways/options. To ensure that different alternatives are considered in a congruent manner, a policy analysis framework has been developed. The framework describes how different high-impact policies – or those with a potential impact – should be considered within government. During the planning process it is acknowledged that, while data provides a fact base which enables analytical tools and models to inform the final plan, the most significant outcomes of this process are based on human input and judgment. The policy analysis framework provides transparency on how various policies were included, and how the key criteria for evaluating the alternative policy pathways were chosen and eventually applied in reaching the final recommendations. In this step it is therefore important that a detailed methodology, which shows the linkages and feedback loops between the technical and the non-technical elements, is developed. Although the planning process is non-linear, the methodology provides a high-level overview of the key steps and decision points in a linear fashion. The technical elements include activities such as identifying the data requirements and collection of data, developing energy models, conducting demand forecasts and running various Test Cases through the energy optimisation models. The non-technical elements include defining the key objectives and the problem statement of the IEP, defining the key policy questions to be addressed and alternative policy options or pathways to be considered, and based on the objectives defining the key criteria for assessing alternative policy options or pathways. Other critical elements of the non-technical aspects of energy planning include defining the macro-economic and policy assumptions which inform the input into the energy models.

III. **Make recommendations:** Once the future energy demand path has been projected and various policy options have been analysed and evaluated, recommendations on how best to meet the country's energy needs are made. As described in the previous steps, recommendations are informed by a combination of output from the analytical tools and human judgment and therefore the assumptions which inform the analytical tools are critical.

IV. Develop action plan: Once the recommendations have been made and approved, they must be supported by a clear action plan for implementation. Anticipated challenges and shortcomings must be highlighted and mechanisms to address those challenges should be proposed.

V. Implementation and monitoring: Implementation of the recommendations lies in different areas, and could entail policy interventions that need to be put in place by various policy units within the Department of Energy. Action could be required from regulators, State-Owned Entities or the private sector and civil society. In all cases, mechanisms to raise awareness to ensure action by the relevant stakeholders should be introduced. An integral part of any policymaking and implementation process entails monitoring the progress and effectiveness of policy recommendations which have been implemented, as well as assessing key constraints to those which have not been implemented. The monitoring process should also include assessing the effectiveness of the integrated energy planning methodology and approach as well as the governance structures to ensure ongoing enhancement.

VI. Review and enhance: The energy planning process must be dynamic as the energy system must meet consumer needs that are constantly changing. Prices of commodities and materials continually fluctuate, new technologies are continually being developed and improved, and geo-political issues and uprisings may sporadically occur. The IEP must be reviewed periodically in order it to be up to date and remain relevant in line with the realities of the day.

The outcomes of the monitoring process need to be factored in to subsequent IEP development in a process of continual learning. Once the effectiveness of the process followed has been assessed, and the progress of the implementation programme together with challenges and successes has been measured, recommendations for possible enhancement should be made.

1.2.1 Stakeholder Engagement

Stakeholder engagement underpins the entire IEP development process and is critical in ensuring that the IEP is understood, its development process is transparent, and that ultimately the necessary stakeholder buy-in is obtained. Stakeholder engagement at inter-governmental level is anchored by the IEP Steering Committee, which is an inter-departmental government committee led by the Department of Energy and consisting of the departments of Science and Technology; Environmental Affairs; Water Affairs; National Treasury; Economic Development; Trade and Industry; Human Settlements; Transport; Rural Development and Land Reform; Mineral Resources and National Planning Commission. The IEP Steering Committee oversees the IEP development process and ensures that legislation, strategies and policies that have an impact upon the energy sector are taken into account. The IEP Steering Committee is supported by various working groups whose focus is on more specific policy issues and, where relevant, the provision of technical input. Industry and community stakeholders are consulted at different stages and through various forums throughout the planning process including public stakeholder workshops, bilateral engagements, and presentations at parliamentary and other energy forums. The high-level energy planning approach and stakeholder engagement framework were presented to Cabinet for noting in February 2011.

1.3 Energy Planning Methodology

Integrated energy planning is about taking into account multiple factors and assessing 'what-if' scenarios for their impact on the energy sector so as to inform choices amongst the many alternative courses of action that could possibly be taken. While the previous section outlined the high-level planning approach, this section deals with the detailed methodology involved in Steps I, II and III in Figure 1-1.

There is no single, prescribed or best suited method or process for developing long-term plans. In the OECD countries, energy planning has often considered the '3E' elements – **'Energy access and security; Economic growth and development; and Environmental sustainability'** – to ensure that the effects of achieving one objective are weighed up against the other two. South Africa is faced with additional challenges such as high levels of unemployment and poverty and lack of access to modern and clean forms of energy. The IEP Methodology seeks to ensure that the process of designing the future energy roadmap keeps a balanced view of the '3E' imperatives.

While the National Energy Act provides details as to which elements should be considered in the development of the national IEP, it does not provide details on the mechanisms or processes which must be followed in order to achieve this. The purpose of defining a methodology is therefore to provide a framework which will ensure that a systematic and transparent approach is followed, thereby making the overall process consistent and repeatable and strengthening the Department's ability to improve the integrated energy planning process in future.

Figure 1-2 below depicts in more detail the phases entailed in Steps I, II and III as represented in Figure 1-1. Although the methodology is depicted and described in sequential steps or phases, the energy planning process is an iterative one where several phases take place in parallel and output from some of the phases is informed through feedback loops from subsequent phases. The process also entails a series of discussions and debates which feed into or inform the technical process. The individual steps in the methodology also provide a logical breakdown of the sets of activities or process steps within which interaction and input from stakeholders is required. These are described briefly below and also inform subsequent sections in this document.

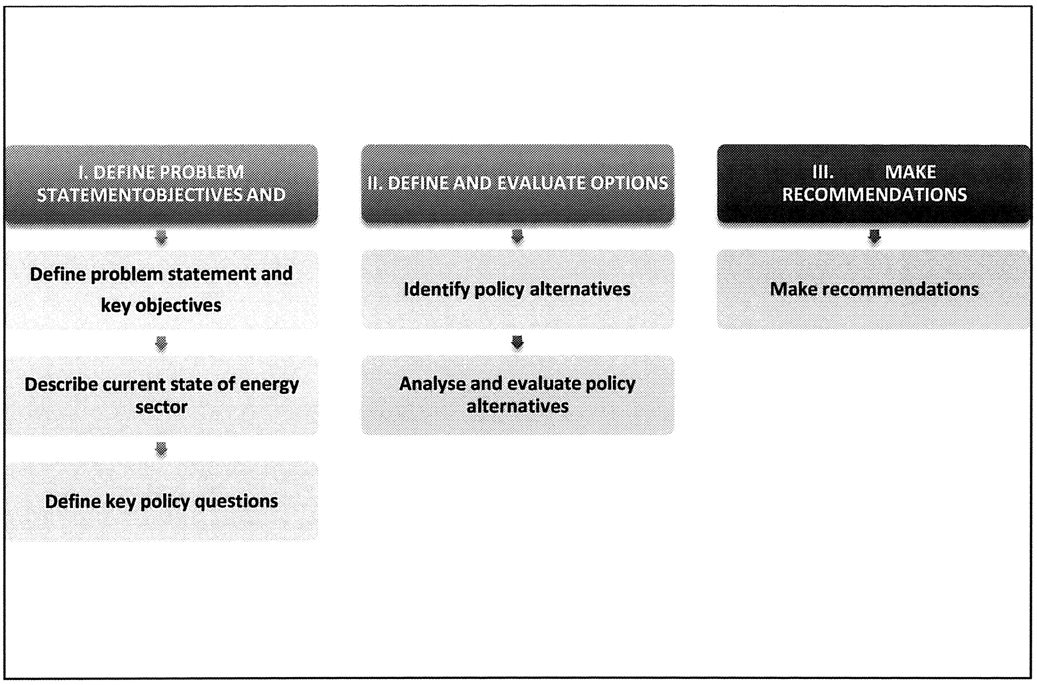


Figure 1-2: Schematic diagram of the IEP methodology

Figure 1-3: Outline of the key steps of the IEP methodology

1.4 Purpose of this Report

The Draft Integrated Energy Planning Report ***does not provide recommendations but presents model output from the Base Case and various Test Cases. This output gives insight on the possible implications of pursuing alternative energy policy options***. Once the implications of all the alternative options have been explored and evaluated against each of the eight (8) key objectives, final recommendations will be made in the form of the Final IEP Report.

SECTION 2: KEY OBJECTIVES OF THE INTEGRATED ENERGY PLAN

The IEP takes into consideration the central role that energy plays in the entire economy and is guided by a sound fact base in determining viable options. The IEP development process should provide for a co-ordinated view of the energy sector which considers the impacts of different plans within the energy sector, as well as those from other government departments – the focus being their impact on the energy sector and vice versa.

The decisions made in energy planning are highly integrated and their effects on one another should always be considered. If for example, a choice is made to implement wind technology for electricity generation, the optimal area and location of land required for these wind farms may be valuable agricultural land which provides food to the population. While South Africa is endowed with abundant coal resources which provide an affordable supply of energy, continued use of coal for power generation and synfuel production results in high levels of GHG emissions which are harmful to the environment.

The increase in car ownership, coupled with tight oil refining capacity and an inadequate logistics infrastructural base continue to threaten the security of liquid fuel supplies. Similarly, the production and operation of electric and hybrid cars may require more electricity and result in significant changes to the current electricity demand profile. Moreover the upsurge in property development, especially in the residential and commercial sectors, has resulted in increased demand for electricity supplies. Amidst all this, increases in the global oil and local electricity prices, as well as environmental pressures, have sharpened the focus on the increased generation and use of alternative energy sources as well as the efficient use of traditional energy sources.

Choices made in respect of energy, impact not only on the demand for energy, but also on the supply of feedstock and other resources such as water. Therefore not only do these choices have an impact on the economy but on the environment as well. The above-mentioned choices have to be made within the context of overall planning of the energy sector and how this will impact on other sectors.

At government level, the introduction and execution of policies requires proper contextualisation and detailed analysis. As cabinet considers other energy-related policies brought to it, such as climate change mitigation strategies, questions should be raised on the likely impact of such strategies on the overall economy of the country.

The IEP seeks to provide a future energy roadmap premised on a balanced view of the '3E' imperatives – Energy access and security; Economic growth and development; and Environmental sustainability, while taking into account key challenges facing South Africa such as poverty, inequality and unemployment, and the boundaries and constraints posed by overarching government policies and high-impact policies from other sectors.

The White Paper on the Energy Policy of the Republic of South Africa (Energy White Paper), which was adopted and published in 1998, is the premier policy document which guides all subsequent policies, strategies and legislation within the energy sector. The Energy White Paper provides specific policy statements on what government intends for the energy system as a whole and sets out five (5) key objectives (see Table 2-1). These objectives have subsequently formed the foundation and informed the development of energy policy in South Africa and still remain relevant. Various other energy policies have been developed and are in different stages of implementation. Some of the key policies include:

- The White Paper on Renewable Energy, 2003 (Renewable Energy White Paper);
- The National Energy Efficiency Strategy of the Republic of South Africa, 2008 (Energy Efficiency Strategy);
- The Nuclear Energy Policy for the Republic of South Africa, 2008 (Nuclear Energy Policy);
- The Biofuels Industrial Strategy of the Republic of South Africa, 2007 (Biofuels Strategy); and
- The Electricity Basic Services Support Tariff (Free Basic Electricity) Policy, 2003 (Free Basic Electricity Policy).

Table 2-1: The Five Energy Policy Objectives Defined in the Energy White Paper

OBJECTIVE	*DESCRIPTION*
Increasing access to affordable energy services	• *Government will promote access to affordable energy services for disadvantaged households, small businesses, small farms and community services.*
Improving energy governance	• *Governance of the energy sector will be improved. The relative roles and functions of the various energy governance institutions will be clarified, the operation of these institutions will become more accountable and transparent, and their membership will become more representative, particularly in terms of participation by blacks and women.* • *Stakeholders will be consulted in the formulation and implementation of new energy policies, in order to ensure that policies are sympathetic to the needs of a wider range of stakeholder communities.* • *Co-ordination between government departments, government policies, and the various spheres of government will be improved in order to achieve greater integration in energy policy formulation and implementation.* • *Government capacity will be strengthened in order to better formulate and implement energy policies.*
Stimulating	• *Government will encourage competition within energy markets.*

economic development	• *Where market failures are identified government will intervene through transparent, regulatory and other carefully defined and time delineated mechanisms, to ensure effective delivery of energy services to consumers.* • *Government policy is to remove distortions and encourage energy prices to be as cost-reflective as possible. To this end prices will increasingly include quantifiable externalities.* • *If subsidies are required, these should be implemented transparently based on agreed criteria.* • *Energy taxation will continue to remain an option within government's fiscal policy, but will be exercised with more consideration for the economic and behavioural impacts of such policies.* • *Government will work towards an investor-friendly climate in the energy sector through good governance, stable, transparent, regulatory regimes and other appropriate policy instruments.*
Managing energy-related environmental impacts	• *Government will promote access to basic energy services for poor households, in order to ameliorate the negative health impacts arising from the use of certain fuels.* • *Government will work towards the establishment and acceptance of broad national targets for the reduction of energy-related emissions that are harmful to the environment and to human health.* • *Government will ensure a balance between exploiting fossil fuels and maintenance of acceptable environmental requirements.*
Securing supply through diversity	• *Given increased opportunities for energy trade, particularly within the Southern African region, government will pursue energy security by encouraging a diversity of both supply sources and primary energy carriers.*

The National Energy Act, 2008 (Act No. 34 of 2008) was developed to introduce measures to ensure energy security as well as to address those objectives of the Energy White Paper which had not been effected due to legislative and regulatory shortfalls. The National Energy Act thus encapsulates the key objectives espoused in the Energy White Paper and more specifically translates them into concrete objectives that must be addressed by the Integrated Energy Plan (IEP). Chapter 3 of the National Energy Act specifies that the IEP must assist government in its efforts to:

- Ensure security of energy supply;
- Ensure optimal usage of economically available energy resources;

- Ensure affordability of energy services;
- Promote universal accessibility of modern forms of energy;
- Promote social equity through the energy sector;
- Contribute towards employment creation;
- Protect the environment;
- Fulfil its international commitments;
- Ensure consumer protection from dangers of energy; and
- Ensure the contribution of energy supply to socio-economic development.

2.1 High-Impact Policies

While many government policies have an impact on the energy sector in one way or another, several policies have a more significant impact and therefore have a substantial influence on energy policies that should be developed. The nature of the impact can be broadly categorised as follows:

- **Overarching national policies:** These policies set high-level aspirations or goals for the country and influence energy policy in such a way that the energy sector needs to respond to or contribute to some of these aspirations and goals.
- **Policies with a unidirectional impact:** These policies, by their nature and definition, have a unidirectional impact on energy policy in that they set certain constraints or boundaries within which the energy sector must comply. Energy policy must therefore be developed in such a manner that the policy constraints or targets set by these policies are adhered to as closely as possible (taking into consideration other conflicting factors). The manner in which the energy sector responds to these constraints does not have a reciprocal impact on the relevant policies.
- **Policies with a bi-directional impact:** These are policies which are reliant on the response of the energy sector for their targets and constraints to be met.

One of the key elements during the energy planning process is to ensure alignment and identify synergies amongst various government policies.

Table 2-2 lists the high-impact policies which have been identified within the different categories as described above.

Table 2-2: High Impact Policies Considered in the IEP

OVERARCHING NATIONAL POLICIES	POLICIES WITH UNIDIRECTIONAL IMPACT	POLICIES WITH BIDIRECTIONAL IMPACT
• National Development Plan (NDP) • New Growth Path	• Proposed Carbon Tax Policy	• National Climate Change Response Policy (NCCRP) • Beneficiation Strategy • National Transport Master Plan (NATMAP)

2.1.1 National Development Plan, 2012

The NDP outlines the 2030 vision for South Africa's energy sector. It states that the energy sector will promote:

- Economic growth and development through adequate investment in energy infrastructure and the provision of quality energy services that are competitively priced, reliable and efficient. Local production of energy technology will support job creation;
- Social equity through expanded access to energy services, with affordable tariffs and well targeted and sustainable subsidies for needy households; and
- Environmental sustainability through efforts to reduce pollution and mitigate the effects of climate change.

Furthermore, the NDP envisages a South Africa which by 2030 will have adequate supplies of electricity and liquid fuels to avoid disruptions to economic activity, transport and welfare. It acknowledges that energy prices are likely to be higher in future, but will still be competitive when compared with South Africa's major trading partners. In addition, the NDP affirms that more than 90 percent of the population should enjoy access to electricity by 2030.

The NDP proposes diversity and alternative energy resources and energy supply options, both in terms of power generation and the supply of liquid fuels. The purpose of the IEP is to test the various options presented in the NDP and make firm recommendations in the form of an energy sector roadmap.

2.1.2 New Growth Path, 2011

The New Growth Path (NGP) reflects Government's commitment to prioritising employment creation in all economic policies. The NGP outlines five key physical and social infrastructure areas – energy, transport, communication, water and housing – as being critical in growing the economy of South Africa. It lays out the strategies to collectively achieve a more developed, democratic, cohesive and equitable economy and society over the medium term, in the context of sustained growth.

The New Growth Path targets 300 000 additional direct jobs by 2020 to green the economy, with 80 000 in manufacturing and the rest in construction, operations and maintenance of new environmentally friendly infrastructure. The potential for job creation envisaged rises to well over 400 000 by 2030.

2.1.3 Proposed Carbon Tax Policy (Discussion Paper, 2010)

In December 2010, the National Treasury published a carbon tax discussion paper. The discussion paper outlines the primary objective of the proposed carbon tax, which is to reduce GHG emissions and facilitate the transition to a Green Economy. In the discussion paper, **carbon taxation and emission trading schemes** were identified as the two main economic policy instruments available for putting a price on carbon and curbing GHG emissions.

The discussion paper acknowledges that although carbon tax does not set a fixed quantitative limit to GHG emissions over the short term, such a tax at an appropriate level and phased in over time to the 'correct' level will provide a strong price signal to both producers and consumers to change their behaviour over the medium to long term. The introduction of a carbon price is expected to change the relative prices of goods and services, over time making emission-intensive goods more expensive relative to those that are less emission intensive. Assuming that South Africa's trading partners follow suit, this will provide a powerful incentive for consumers and businesses to adjust their behaviour, resulting in a reduction of emissions.

The discussion paper deems a carbon tax to be the most appropriate mechanism on which to base the pricing of carbon and begin to internalise the externalities associated with GHG emissions within the South African context. Some of the key reasons presented in this regard include:

- The design of a carbon tax can be relatively easy;
- Measuring and monitoring of direct GHG emissions might be a challenge;
- A proxy tax base can be considered, i.e. a fuel input tax;
- The level of the tax can be phased in over time. Such a price trajectory will provide certainty; and
- Distribution and competitiveness concerns can be dealt with in a transparent manner.

The development of carbon taxation policies for South Africa should be informed by the following key considerations:

- The tax rate should, over time, be equivalent to the marginal external damage costs of GHGs to affect appropriate incentives;
- Comprehensive coverage should be targeted, and the tax should, as far as possible, cover all sectors;

- Should a proxy tax base be used, the tax should be levied according to the carbon content of fossil fuels;
- Relief measures, if any, should be minimal and temporary; and
- The design of the tax needs to minimise the potential regressive impacts on low-income households and protect the competitiveness of key industries.

The discussion paper therefore proposes the phasing in of the carbon tax, which approach is envisaged to send the necessary policy signals to investors and consumers of the need to ensure investment in low-carbon options, which in turn will minimise the need for retrofit and the risk of redundant, large-scale, major capital projects and related investments in the future.

As an initial proposition, the discussion paper highlights the preference of a carbon tax based on measured and verified emissions, although a proxy tax base, based on the carbon content of fuel inputs, could be considered in future. An initial tax of R75 per ton of CO_2, with an increase to about R200 per ton CO_2 (at 2005 prices) was identified as both feasible and appropriate to achieve the desired behavioural changes and emission-reduction targets.

The IEP needs to consider the implications of the possible introduction of the proposed carbon tax on future energy options and the associated costs.

2.1.4 National Climate Change Response White Paper, 2011

The National Climate Change Response White Paper was published by the Department of Environmental Affairs in 2011. This White Paper presents the South African Government's vision for an effective climate change response and the long-term transition to a climate-resilient and lower-carbon economy and society.

South Africa's response to climate change, as defined within the policy document, has two objectives:

- Effectively manage inevitable climate change impacts through interventions that build and sustain South Africa's social, economic and environmental resilience and emergency response capacity; and
- Make a fair contribution to the global effort to stabilise greenhouse gas (GHG) concentrations in the atmosphere at a level that avoids dangerous anthropogenic interference with the climate system within a timeframe that enables economic, social and environmental development to proceed in a sustainable manner.

The policy document identifies several key elements in the overall approach to mitigation, which include:

- Using a National GHG Emission Trajectory Range, against which the collective outcome of all mitigation actions will be measured;

- Defining desired emission reduction outcomes for each significant sector and sub-sector of the economy based on an in-depth assessment of the mitigation potential, best available mitigation options, science, evidence and a full assessment of the costs and benefits;
- The deployment of a range of economic instruments to support the system of desired emission reduction outcomes, including the appropriate pricing of carbon and economic incentives, as well as the possible use of emission offsets or emission reduction trading mechanisms for those relevant sectors, sub-sectors, companies or entities where a carbon budget approach has been selected.

According to the policy document, in 2000, emissions as a result of average energy use for developing countries constituted 49 percent of total emissions, whereas South Africa's energy use emissions constituted just less than 80 percent of total emissions. In terms of South Africa's latest Greenhouse Gas Inventory (base year 2000), the majority of South Africa's energy emissions arose from electricity generation, which constituted around half of South Africa's energy emissions and just under 40 percent of total emissions in 2000. Transportation and energy used in industry contributed just less than 10 percent each of total emissions and industrial process emissions constituted around 14 percent of total emissions. Clearly the bulk of South Africa's emissions arises from energy supply (electricity and liquid fuels) and use (mining, industry and transport), and mitigation actions with the largest emission reduction potential focus on these areas.

While the policy document acknowledges that opportunities for mitigation of emissions from non-energy sources do exist, it highlights that the most substantial mitigation contributions will have to come from reduced emissions from energy generation and use. The main opportunities for mitigation consist of energy efficiency, demand management and moving to a less emission-intensive energy mix, with consequent economic benefits of improved efficiency and competitiveness as well as incentivising economic growth in sectors with lower energy intensities. In this regard the policy document also identifies several 'near-term' flagship programmes, some of which apply to the energy sector and were already under way at the time that the Climate Change White Paper was published. These include:

- The Renewable Energy Flagship Programme;
- The Energy Efficiency and Energy Demand Management Flagship Programme; and
- The Carbon Capture and Sequestration Flagship Programme.

In response to a less emission-intensive energy mix, the IEP considers the emission limits which have been set for the energy sector up to 2050 and identifies the most appropriate energy mix as well as the associated costs. The output from the analysis in turn enables feedback on the extent to which such emission limits can be met, taking into consideration other socio-economic factors, including job creation, cost to the economy and the effect that the cost of energy will have on final energy prices.

2.1.5 Beneficiation Strategy, 2011

The Beneficiation Strategy provides a framework within which to translate the country's comparative advantage, inherited from its mineral resources endowment, into a national competitive advantage and presents opportunities for South Africa to continue sustainable growth of its economy beyond mining.

The strategy identifies several instruments that constitute an enabling environment for beneficiation and highlights prevailing constraints to the effective implementation of beneficiation that require an integrated mitigation approach. Amongst the key enablers, it recognises that infrastructure, including amongst other factors the adequate supply of energy, has a material impact on sustaining current beneficiation and that the bulk of early-stage beneficiation programmes require large and uninterrupted energy supply. The lack of adequate and reliable energy supply therefore poses a major threat to future prospects of growth in mineral value addition. The country's limited exposure to breakthrough research and development is also identified as a significant barrier to prospects of innovation in creating new products for beneficiation.

While the concept of beneficiation is not new to South Africa or to the energy sector (since the bulk of the country's electricity is generated from coal power stations, where more than 50 percent of the country's annual production of coal is beneficiated), new beneficiation opportunities are sought to complement conventional electricity generation in the country, which will underpin the much needed economic growth. Other critical infrastructure such as rail, water and ports have a material impact on sustaining current beneficiation initiatives and pose a major threat to future prospects of growth in mineral value addition. Therefore successful implementation of the strategy depends on intensive co-ordination across a range of departments, including the Department of Energy.

The strategy outlines five value chains, of which energy is one, which were identified as a result of the advancement of selected mineral commodities through various stages of beneficiation. The beneficiation of energy commodities is seen as critical, especially in light of the projected increase in future energy demand world-wide and in South Africa. Three commodities (or classes of commodities) were identified for potential beneficiation in order to meet future energy needs:

Platinum Group Metals (PGM): PGM fuel cell technology presents an opportunity for new energy generation sources, since the extent and scope for further growth in traditional sources of energy generation are limited. Ongoing research by the Department of Science and Technology with respect to fuel cell technology needs to continue.

Synergies with and the role of energy-focused research institutes, such as the South African National Energy Development Institute (SANEDI), need to be pursued once this technology becomes more proven and enters into the demonstration phase.

Coal: Given that coal is currently the most abundant and affordable of all fossil fuels, the strategy sees this as continuing to play a vital role in meeting energy demand world-wide and also in South Africa. The strategy also recommends coal conversion technologies to produce synthetic gas and liquid transportation fuels derived from coal. However, given the high levels of harmful emissions associated with coal-generated electricity and other fuels produced from coal, it has become increasingly important for cleaner alternatives to be considered. In addition to diversifying to renewable and other clean sources of energy, South Africa is to actively pursue alternative options for reducing carbon emitted from coal, which include:

- The capturing of harmful gases at source, processing them and then storing them in underground geological formations to mitigate their contribution to global warming.
- The implementation of carbon emission reduction measures (either carbon tax or market mechanisms) to curb the use of such technologies. These options may, however, contribute to an increase in the cost of energy produced from coal such as electricity and synthetic fuel from coal; and
- Research and development (R&D) to be directed at finding an alternative approach, such as the potential for recycling captured gases in the process of energy generation for re-generation of electricity as well as other uses.

The strategy document also identifies several interventions for the optimal value creation (beneficiation) of coal, including:

- Policy support for clean and efficient use of coal in power generation to encourage the take-up of existing advances in technologies for low emission coal-fired electricity production – providing secure and clean energy;
- Policy support for technology transfer, through mechanisms such as the Clean Development Mechanism (CDM). Bilateral and multilateral funds such as the Global Environment Facility and the Prototype Carbon Fund must be explored;
- Investment in research, development and the demonstration of new technologies such as clean coal technologies and carbon capture and storage (CCS). These could provide a very significant opportunity for the major reduction in emissions;
- Investment in R&D to find innovative means for the beneficiation (recycling) of gases emitted in the generation of electricity;
- Investment in technology to optimise the use of coal bed methane (CBM);
- Investment in metallurgical research to disentangle uranium and coal in the Springbok flats coalfield, which will increase the country's reserve base of coal and uranium; and
- Exploration of options for further final-stage beneficiation of coal through production of chemicals as feedstock for plastics and fertilisers.

Uranium and Thorium: Uranium is used to fuel commercial nuclear power plants. South Africa is currently exporting uranium in its oxide form – the first stage of beneficiation – and importing the enriched uranium from the northern hemisphere for its own power generation purposes. This is due to the closure of South Africa's uranium beneficiation operations due to its obligations under the Nuclear Non-Proliferation Treaty (NPT), which was signed by South Africa in 1991. South Africa has gained expertise over many years in the beneficiation of uranium, from the mining of the ore through to producing uranium for power generation and beyond.

Researchers have subsequently been exploring the possibility of using thorium as an alternative fuel for nuclear reactors and preliminary research indicates that the prospect is positive. Thorium is estimated to be three times more abundant than uranium. However, present knowledge of the distribution of thorium resources is poor due to low key exploration efforts as a result of insignificant demand. With the commitment of government to build nuclear power stations to complement fossil fuel based electricity, preparatory work for the beneficiation of uranium/thorium and other minerals, such as fluorspar, is critical. The following interventions for the successful implementation of nuclear power generation have been identified:

- Quantify the uranium and/or thorium reserves and resources in the country;
- Ascertain the economic feasibility of re-establishing uranium enrichment;
- Plan for comprehensive waste treatment and mine rehabilitation; and
- Finalise the uranium policy with all relevant stakeholders.

The strategy document highlights critical areas of intervention to ensure the co-ordinated, seamless and effective implementation of the beneficiation of South Africa's mineral commodities. These include, amongst others, ***ensuring security of energy supply through investment in new generation capacity, implementing energy efficiency measures and pursuing co-generation potential, where possible.***

2.1.6 National Transport Master Plan

The National Transport Master Plan (NATMAP 2050), which was published by the Department of Transport (DoT) in 2010, is a long-term strategy for the transportation sector which in part addresses the impact of the transport sector on various issues. The goal thereof is to develop a dynamic, long-term, sustainable land use/multi-modal transportation systems framework for the development of network infrastructure facilities, interchange terminus facilities and service delivery.

South Africa faces many challenges in instituting a practical National Transportation Plan in an environment of increasing energy demand, sustained high oil prices, regular disruptions in the energy value chain, increasing requirements for diminished GHG emissions and other environmental and social considerations. Transportation requires access to energy sources and it is therefore imperative that synergies be established between transportation planning and national energy planning. Transportation objectives must be aligned with the country's energy supply-demand conditions and *vice versa*. At the same time transportation has an environmental footprint that stretches from the global level (via international travel – trains, ships, planes), through to the national, regional and local levels (the effects of construction and operation).

Transportation in South Africa is almost totally dependent on petroleum liquids, with less than 5 percent of the energy used in transport is in the form of electricity. This makes the transport sector extremely vulnerable to the availability of oil, as well as the cost of oil and therefore the cost of fuel. Almost 69 percent of the energy that is used in transportation is derived from oil that is imported. The balance is from fuel derived from coal (the SASOL coal to liquid process), and natural gas (the Mossgas project).

Some of the goals of NATMAP 2050 that require a corresponding response from the energy sector are as follows:

- To minimise the impact on the environment and reduce the carbon footprint of transport (through less carbon-intensive transport fuels);
- To provide energy-efficient transport, using energy sources that are sustainable in the long term;
- To provide affordable transport to end users, operators and government; and
- To develop transport infrastructure that meets international standards and is technologically sustainable.

The IEP takes into consideration the implications of some of the goals of the NATMAP and the resultant actions or responses that are required from the energy sector. In particular, the effects that such objectives will have on the future demand for energy were assessed. Some key considerations are outlined below:

- In the short term, measures to improve fuel efficiency need to be continually explored and enhanced;
- The effect that various interventions will have on liquid fuel consumption needs to be evaluated and monitored so as to improve the understanding of their implications on future demand. These include interventions by the DoT to emphasise modes of transport where mechanical energy is used most efficiently and to advocate non-motorised transport within urban areas (short distances); and
- The effects that various interventions may have on shifting demand from liquid fuels to electricity need to be analysed. These include long-term strategies to encourage modal shifts from private passenger transportation to mass transit (most probably to rail and buses) as well as those that encourage the shift of long-distance freight off roads and on to rail.

The effects of these policy imperatives should be factored into long-term IEP policy assumptions. The processes of monitoring, reviewing and evaluating some of these interventions will require ongoing alignment between the two respective departments.

2.2 The Objectives of the IEP

The IEP takes a balanced view of the objectives of various policies. Those policies which are overarching set aspirational targets and provide the context within which the IEP was developed. The impact of policies which will influence energy markets cannot be ignored, and their possible implications were taken into consideration in order to develop long-term energy sector response strategies which are sustainable.

Keeping the '3E's imperatives in mind, and taking the Energy White Paper, the National Energy Act and the above-mentioned high-impact policies, amongst others into consideration, eight key (competing and, at times seemingly, conflicting) objectives were identified for the IEP and are represented in Figure 2-1 below.

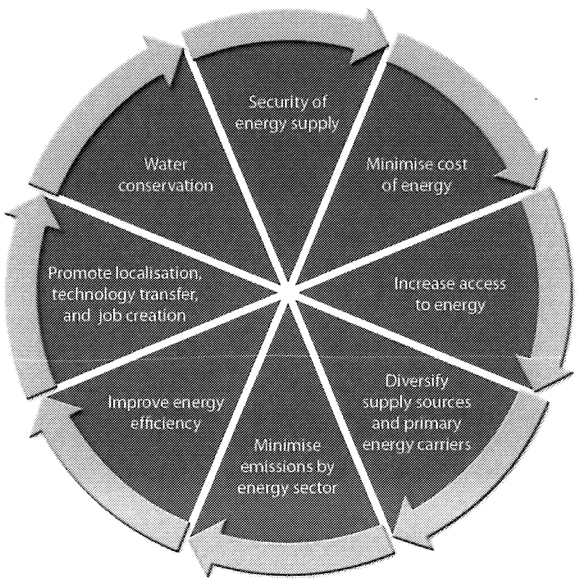


Figure 2-1: Key IEP Objectives

Each of the objectives depicted in Figure 2-1 is described in Table 2-3 below and also form the basis of the key criteria against which different policy alternatives and proposals made in the IEP were evaluated.

Table 2-3: Key Objectives of the IEP

OBJECTIVE	DESCRIPTION
Security of energy supply	A fundamental objective of the IEP is to ensure that all projected future energy demand is met. In determining the point at which the cost of guaranteeing the supply of energy (i.e. reliability cost) is at a minimum and does not exceed the benefit of providing that energy, the Cost of Unserved Energy (CUE) is calculated. The Energy Security Master Plan (ESMP) – Electricity of 2007 recommended a reserve margin of 19% for electricity generation capacity in South Africa. The reserve margin of 19% therefore indicates the point where the trade-off between cost and reliability is at a minimum (based on costs as calculated during the drafting of the ESMP).
	Ensuring adequate and reliable forms of energy for end-consumers is the underpinning objective of the IEP. An adequate reserve margin of 19% for electricity generation has been determined for South Africa.
Minimise cost of energy	Other than labour, energy is a major input into the production of goods and services. The lower the cost of energy, the lower the production cost of tangible and non-tangible items. Lower energy costs are directly related to higher profit margins.
	The objective of the IEP is to identify and highlight the mix of technology options and energy resources and sources that minimise the total cost of energy, while meeting the projected energy demand.
Increase access to energy	Access to sustainable, modern, affordable, and reliable energy services is central to addressing many of today's global development challenges, including poverty, gender inequality, climate change, food security, health and education. Energy access is now widely recognised as a prerequisite for human development. Energy is needed for survival (for example to power hospital emergency equipment). It is important for the provision of social services such as education, and it is critical to all economic sectors from households and farming, to business and industry. The wealth and development status of a nation and its inhabitants closely correlates with the type and extent of its access to energy. The more that usable energy is available, the better are the conditions for development of individuals,

households, communities, the society and its economy. Thus, improving access to energy is a continuous challenge for governments and development organisations. Access to energy is a function of availability and affordability and implies access to clean and reliable energy. According to the White Paper on the Energy Policy of the Republic of South Africa of 1998, the South African Government will promote access to affordable energy services for disadvantaged households, small businesses, small farms and community services.

While several policies and programmes aimed at increasing access to modern forms of energy have already been developed and are currently being implemented, the IEP seeks to explore further options that can be pursued in order to address some of the challenges identified.

Diversify supply sources and primary energy carriers

If South Africa is to make the transition to a low carbon economy, it will become increasingly important to reduce dependence on fossil fuels and diversify energy resources to include other energy forms such as natural gas, nuclear and renewable energies. These are necessary to improve security of supply while at the same time minimising environmental impact and facilitating regional development. The dominance of a single-energy system, which is highly reliant on fossil fuels, inevitably places an excessive burden on a particular aspect of the environment. This eventually weakens it through environmental fatigue, failure (permanent damage) or even catastrophe if the situation continues for too long. This inevitably poses a health and environmental risk.

The IEP takes into consideration all energy resources and weighs up the costs and benefits associated with each against the ultimate objective of proposing a balanced energy mix, comprising traditional and alternative energy resources and sources.

Minimise emissions from the energy sector

Energy planning needs to be done in such a manner that it does not impair government's goals of reducing CO_2 emissions. Because of South Africa's extensive use of coal and petroleum fuels, the adverse impact on both the local and global environment is significant. In 2004, the world produced about 49,000 million metric tonnes carbon dioxide equivalent (Mt CO_2e), mainly from energy generation and deforestation. In comparison, South Africa produced about 440 Mt CO_2e, or about 1 percent of the global figure.

	South Africa's emissions are large relative to its population and economy. The IEP identifies and highlights those technology options with emissions that are within the constraints identified in the National Climate Change Response White Paper. It is important that the associated economic and socio-economic implications of such options are also identified.
Improve energy efficiency (reduce energy intensity of the economy)	Energy efficiency relates to the economical and efficient production and utilisation of an energy carrier or resource. It results in achieving the same quality and level of some 'end use' of energy (heating, cooling, lighting, etc.) with a lower level of energy input. Increased energy efficiency reduces overall energy demand, with a substantial decrease in cost to the energy system. The benefits of energy efficiency to the environment are self-evident. These benefits are of particular relevance to South Africa, which remains one of the highest emitters of the greenhouse gas CO_2 per capita in the world. This can largely be attributed to South Africa's coal-based energy economy which has enabled it to enjoy relatively low energy prices historically and in turn also favoured energy-intensive industries. At a local level the problems of CO_2 and smoke emissions have been the focus of concern for many communities living adjacent to heavily industrialised areas. Energy efficiency can address both the macroscopic and microscopic aspects of atmospheric pollution while contributing overall benefits and cost containment to the economy. While the Draft Second National Energy Efficiency Strategy Review of 2012 sets targets for energy efficiency improvements within the economy, the IEP explores further technology options that can be pursued. Of particular importance is the proposed mix of those options (supply- and demand-side) making them more efficient and therefore contributing overall efficiency improvements.
Promote localisation, technology transfer, and job creation	Localisation will ensure knowledge transfer of both technical know-how and management processes from international suppliers to local industries. The objective is to build 'initial' or 'enhanced' innovative capacity in South Africa's energy sector. The New Growth Path targets 300,000 additional direct jobs by 2020 to green the economy, with 80,000 in manufacturing and the rest in construction, operations and maintenance of new environmentally friendly

infrastructure. The potential for job creation rises to well over 400,000 by 2030.

As part of the development of the IEP it is acknowledged that an indirect consequence of the implementation process is the creation of jobs. These can be partly achieved by encouraging energy technologies that are labour intensive.

Water conservation	One of government's vision statements is "*A South Africa where environmental assets and natural resources are valued, protected and continually enhanced*". South Africa is a water scarce country and minimising the consumption of water is critical to contributing to this vision. . The energy sector is highly-reliant on water, and in particular in the generation of electricity and the production of synfuels through the coal liquefaction process. According to the second National Water Resources Strategy, the energy sector contributes about 2% of total national water consumption, however that being said, it is still important that the energy sector look at ways in which to minimise water consumption especially in the generation of electricity and refining of liquid fuels. Overall conservation of water in turn also reduces the demand for energy as energy is required to move water. The Department of Water Affairs advocates the introduction of dry-cooled power plants in the inland region which will ensure the reduction of the burden on power plants.
	The IEP highlights the estimated water usage associated with the various technology options.

SECTION 3: OVERVIEW OF THE ENERGY SECTOR

According to the 2012 Energy Sustainability Index developed by the World Energy Council, out of 94 countries, South Africa ranked 57th on the Energy Sustainability Index, this was partly informed by a ranking of 78th on energy security and 53rd on environment impact mitigation, the latter being an improvement from previous years ratings. According to the report, the drop by two places to 57th place was mostly driven by a drop in energy security due to a decrease in the wholesale margin on gasoline, and a particular weak performance in diversification of electricity production. The report does however also acknowledge that positive developments such as the introduction of Independent Power Producers (IPPs) and renewable energy technologies into the electricity sector are not reflected in the rating. The report further highlights the provision of energy to rural communities and ensuring affordability of energy as some of the critical challenges that South Africa should focus on.

3.1 Primary Energy Supply

Primary Energy supply in South Africa is dominated by coal (~67%), followed by crude oil (~20%). Nuclear, natural gas and renewable energy (including hydro and biomass) have historically played a less significant role in the total energy mix, collectively contributing the remaining ~13%.

A closer examination of the electricity generation industry (Department of Energy, 2010) reveals that 90 percent of electricity was generated from coal, followed by nuclear and hydro at 5 percent and 4.5 percent respectively. Petroleum products (diesel), natural gas and other renewable energy sources (i.e. solar, wind, biomass, bagasse, and landfill gas) collectively contributed less than 0.5 percent towards the total installed capacity for electricity generation. Imported crude oil dominated the primary supply of liquid fuels at approximately 70 percent, followed by coal at approximately 20 percent and natural gas at an estimated 10 percent. Production of fuel from renewable energy sources and waste remained in its infancy and had not really taken off.

Over the last few years, various policies have been developed by the Department of Energy (DoE) in an effort to increase diversification of primary energy sources as well as to reduce over-reliance on fossil fuels for the supply of energy. The threat of climate change and global developments in renewable energy technologies could see South Africa's future energy mix being quite different from that of the past.

3.1.1 Coal

South Africa ranks amongst the top 10 countries in terms of coal reserves (SA Coal Roadmap, 2010) and is currently the sixth largest coal producer in the world with total production being equivalent to approximately 4 percent of world production (SA Coal Roadmap, 2010). While South Africa dominates Africa's coal industry, this picture could change in the medium term as other Southern African nations, including Mozambique, Zimbabwe, Botswana, Tanzania, Zambia, Swaziland and Malawi, are also endowed with significant coal reserves (IEA, 2012).

While approximately 26.2 percent of South African produced coal is exported, the remainder contributes to approximately 80 percent of the country's total primary energy requirements. 92.8 percent of South Africa's electricity is generated by Eskom, with only the remaining 7.2% being generated by IPPs. Approximately 30 percent of South Africa's total liquid fuel requirements are produced from coal through Sasol (SA Coal Roadmap, 2010).

As a result, South Africa emits more than its share of carbon dioxide and contributes disproportionately to climate change. According to the 2012 Energy Sustainability Index, developed by the World Energy Council, the emission intensity of the South African economy (measured in kg of CO_2 per USD) is 3.97.

The advantages of coal-generated power for South Africa are that the country has abundant coal reserves, the infrastructure to generate electricity from coal is well established, and coal-fired power stations reliable. However, coal is the most polluting source of energy for electricity generation and produces the greatest amount of waste, which is a significant cause of air pollution, and greenhouse gas (GHG) emissions. In addition to these threats, a major challenge in continuing to use coal is the threat of penalties imposed for emitting GHGs, and hence the environmental aspects of coal-fired stations will become pressing.

Another disadvantage of coal is that the building of new coal-fired power stations is a long and expensive process. Furthermore, South Africa's coal fields are concentrated in Mpumalanga, which limits the location options for power stations and therefore increases transmission costs. However coal deposits in the Waterberg present a possible alternative for new coal-fired power plants, but the scarcity of water in the area presents a new challenge.

Globally, coal is the second most important primary energy source after oil with power generation being responsible for the largest absolute use of coal. The use of coal in the production of energy has however come under the global spotlight in view of the associated high levels of greenhouse gas (GHG) emissions. The IEA's World Energy Outlook 2012 scenarios for the coal market suggest that coal demand will continue to grow at an estimated average rate of 1.9 percent per year if there are no further changes to current government policies on climate change globally. However, this trend in demand is projected to be on the lower end should government's world-wide embark on aggressive policies to curb climate change. Unless new technologies, aimed at reducing the carbon intensity of coal are discovered and put into use, the international competitiveness of South African exports could potentially be negatively affected. In the medium term, however, coal will continue to play an important role in the country's energy mix.

Research and development in clean coal technologies has been slowly taking off in South Africa. In 2007 Eskom began a pilot project on Underground Coal Gasification (UCG) at the Majuba plant. UCG is a method of converting unworked coal (coal still in the ground) into a combustible gas which can be used for industrial heating and power generation, or the manufacture of hydrogen, synthetic natural gas or diesel fuel. UCG technology allows countries that are endowed with coal to continue to utilise their resource in an economically viable and environmentally safer way by converting coal into high value products such as electricity, liquid fuels, syngas, fertilisers and chemical feedstocks. While the process had previously been criticised for generating large quantities of hydrogen as a useless by-product, hydrogen is now in demand as a feedstock for the chemical industry and shows potential as an alternative fuel for vehicles.

Other advantages of the use of this technology include low plant costs (as no surface gasifiers are required) and the absence of coal transport costs. UCG presents the opportunity to reduce emissions as there are fewer surface emissions and could also have synergies with Carbon Capture and Storage (CCS) because the CO_2 could be stored in the coal cavity after gasification (World Coal Association).

According to Eskom, in terms of coal extraction, UCG is the most efficient underground mining technology known. In the Majuba coalfield, the pilot plant has achieved up to 83% extraction, whereas conventional mining could not achieve more than 25% extraction due to geological disruptions.

In 2010 Eskom's UCG demonstration plant commenced delivery of gas to one of the units at Majuba Power Station. The gas is co-fired with coal, and contributes 3 MW to the unit's current electricity production of approximately 650 MW. This demonstration plant is the first production of commercial electricity from UCG gas outside of the former Soviet Union.

3.1.2 Crude Oil

South Africa's crude oil requirements are met by imports, mainly from the Middle East and Africa. Almost all crude oil is used toward the production of liquid fuels, with a small percentage used towards lubricants, bitumen, solvents and other petrochemicals. Like elsewhere in the world, liquid fuels are primarily used to meet the country's mobility needs. As a net importer of crude oil South Africa is not sufficiently influential to affect the price of crude oil and the economy is therefore highly susceptible to the volatility of the global oil market. The South African liquid fuels industry and its economy at large are therefore highly impacted by global developments and fluctuations in the crude oil price.

Projections for global oil demand show a continued increase in the medium to long term if current policies, politics and levels of access continue (EIA, 2012). The continued growth in demand is spurred by robust economic growth in the non-OECD nations, including China and India, which will offset the slower growth projected for many OECD nations. Lower growth in crude oil demand is expected only if economic growth in non-OECD countries is slower than projected. It is envisaged that passenger transportation will continue to create the highest demand for crude oil, followed by freight, power-generation and non-energy uses.

While government policy is an important factor influencing long-term trends in global oil demand, other factors such as economic activity, population, prices and technology play a key role. Developments in vehicle technologies have the greatest potential to impact future global oil demand and improvements in efficiency can help to decouple the increasing demand for mobility from fuel consumption.

3.1.3 Nuclear

Nuclear power accounts for roughly 5 percent of South Africa's primary energy supply (Department of Energy, 2010). South Africa has one nuclear power station, Koeberg, situated about 30 km north-west of Cape Town. Koeberg has a capacity of 1 800 MW and consists of two 900 MW Pressurised Water Reactors (PWRs). Built in the early 1980s, with the first unit commissioned in 1984, the two units at the plant were designed with a 40-year lifespan; with retrofitting this could be increased to 50 or even 60 years. Koeberg' s electricity costs are now comparable with those of the coal-fired power stations, although the capital outlay of building the power plant was higher, as is expected for nuclear power plants.

South Africa has significant uranium resources and nuclear power generation has the potential to play a very significant role in efforts to reduce South Africa's carbon footprint from power generation because nuclear reactors generate very large amounts of electricity from very small amounts of fuel and release no greenhouse gases in their operation. While nuclear plants require larger capital outlays than other technologies, such as wind power or coal-fired plants incorporating carbon capture and storage (CCS), the lifecycle cost of nuclear power per megawatt of electricity remains competitive. Unlike CCS, nuclear power has the additional advantage that it is fully proven and provides base-load electricity generation capacity, which has yet to become a reality for either wind or solar power generation. Controlling the capital costs of nuclear projects is the critical factor if nuclear is to remain a competitive and viable supply option.

Despite the advantages of no emissions and the low lifecycle costs associated with nuclear plants, opinion is fragmented internationally as to whether nuclear power should form part of future plans for low-emission power. Concerns were raised after the 2011 crisis at the nuclear facility in Fukushima, Japan, and the safe storage of nuclear fuel waste continues to be of concern because the radioactive waste produced by nuclear power stations degrades very slowly and there are currently no long-term storage solutions for this waste anywhere in the world. While some countries, such as Germany are reducing the role of nuclear in their energy mix by decommissioning all nuclear plants, others, such as China, Russia, India, South Korea, the USA and Canada have commenced with the construction of new nuclear plants.

3.1.4 Natural Gas

Natural gas plays a relatively small part (roughly 3 percent) in South Africa's total energy mix. South Africa has substantial local expertise in field development work as well as drilling and exploration activities in pursuit of energy security. Production has historically taken place in the offshore Bredasdorp Basin to supply PetroSA's Mossel Bay Gas-to-Liquid (GTL) facility, however the available resources at this Basin are near depletion and have affected operations of PetroSA's GTL facility.

At a national level, natural gas consumption currently exceeds production, with the majority of demand being met through imports from Mozambique. The gas infrastructure between Mozambique and South Africa consists of a high-pressure pipeline from Mozambique's Temane Pande gas fields to Sasol's Secunda site, where it links to the Sasol Gas network. This network provides gas to industrial and commercial customers, primarily within the Gauteng region. Recent exploration suggests that Mozambique's Rovuma basin may yield further recoverable natural gas in excess of 100 trillion cubic feet (Tcf). The Government of Mozambique has thus developed a Natural Gas Masterplan for Mozambique to ensure exploitation of the natural gas discoveries in a manner that will bring about the greatest socio-economic benefit for its citizens (IFC International, 2012). Due to South Africa's limited LNG import infrastructure; there are no other sources of gas imports. However South Africa has the opportunity to explore options for exploiting the Mozambican new gas discoveries.

Furthermore, despite extensive drilling along South Africa's coastline, only marginal conventional gas discoveries have been made, with limited historical prospects. This, together with the vastness of the country, has made it difficult to justify expansion of the gas transmission pipeline or gas grid infrastructure to link pockets of gas to each other and to the markets in the regions where there have been discoveries.

Despite the limited proven reserves of conventional natural gas, a recent report by the Energy Information Administration (EIA) has estimated unconventional gas resources (shale gas and coal bed methane) in the Southern Karoo basin of 485 Tcf. Further exploration is however still required in order to determine the extent of the recoverable resource. The perceived environmental risks of extracting 'tight' gas such as shale gas are considered to be significant, since the process (called hydraulic fracturing) requires substantial amounts of water, which presents a challenge in water-scarce areas. There are also environmental concerns over the possible contamination of ground water, which may result as a consequence of improper disposal of fluids during the hydraulic fracturing process.

Due to these concerns, the Department of Mineral Resources (DMR) placed a moratorium on the granting of licensing for the exploration of shale gas and commissioned a study to evaluate the potential environmental risks posed by the process of hydraulic fracturing in South Africa, as well as the positive and negative social and economic impacts of shale gas exploration (DMR, 2012).

The study concluded that, due to the limited amount of data currently available, was not possible to quantify the extent of the shale gas resource accurately, however acknowledged that the existence of a significant shale gas resource in the Karoo would have positive implications for South Africa's energy security by reducing national dependence on other fossil fuels. This concession is based on the fact that the construction of the PetroSA Mossel Bay plant was based on 1Tcf of natural gas, therefore if even a fraction of the estimated 485 Tcf is found to be proven, this could have a significant impact on the South African economy. The DMR is currently in the process of reviewing the regulatory framework with the objective of ensuring that any resultant negative impacts associated with hydraulic fracturing for shale gas exploration and exploitation are adequately mitigated.

One of the challenges of introducing gas into new markets is that large, capital-intensive investment in infrastructure along the supply chain is required. Transporting gas by pipeline is relatively expensive, more so than oil, because of the additional capital-intensive equipment needed to overcome the lower energy density of gas.

Natural gas also has a significant potential both for power generation as well as direct thermal uses. Power generation remains the main driver behind gas demand growth globally and remains a key potential for South Africa. South Africa has a limited gas network but with a well-developed electricity transmission grid, the construction of an LNG facility would need to be underpinned by a gas-fired power plant as a key off-taker as the most feasible solution in the short- to medium-term. This option could enable South Africa to move towards a low carbon future as natural gas has lower carbon content than coal.

In the longer term, thermal applications of natural gas, requiring a well-developed gas network could find application. Developments in Natural Gas Vehicles (which use CNG and LNG) could see natural gas providing a cleaner alternative to petroleum products in the longer term.

3.1.5 Renewable Energy

South Africa is well endowed with renewable energy resources, which have in the past remained largely untapped. South Africa generally receives sufficient sunlight to support a sustainable solar power industry. The Northern Cape has some of the world's best conditions for solar power, and much of South Africa's coastal region is suitable for wind power. While a wind power generation industry could thrive, it is acknowledged that erratic wind flow, resulting in inconsistent supply of electricity, could dilute the potential of this energy source, causing intermittency.

The South African government is currently developing the renewable energy industry in order to meet the long-term goal of a sustainable energy sector. In 2003, a 10-year target of 10 000 Gigawatt hour (GWh) (the equivalent of 0.8 Megaton oil equivalent (Mtoe)) was set for renewable energy, which was the envisaged industry contribution to final energy consumption by 2013. By 2008, the nascent renewable energy industry contributed less than 8 percent of South Africa's primary energy supply. The IRP2010 envisaged electricity generated from hydropower maintaining its share of 5% and from other renewable energy technologies forms to 9% (from almost negligible) by 2030. Total installed capacity of renewable energy technologies would be in the magnitude of 26.3% of total installed capacity by 2030.

The DoE embarked on an aggressive programme which will see an increase in the share of renewable energy technologies in the energy mix. The table below shows the total allocation for each type of technology from the bids awarded in rounds 1 and 2 of the Renewable Energy Independent Power Producers (RE IPPs) procurement process. During 2012, government signed contracts to the value of R47 billion for 28 projects, which include wind, solar and small hydro technologies to be developed in the Eastern Cape, Western Cape, Northern Cape and Free State provinces. The third round of the RE IPP procurement process is due to close in August 2013.

Table 3-1: Total allocation for renewable energy technologies through the RE IPP Programme

	Allocation to preferred bidders: Window 1		**Allocation to preferred bidders: Window 2**		**Allocation per determination still available**		**MW allocation per determination**
	MW	*%*	**MW**	*%*	**MW**	*%*	
Solar PV	632	*44%*	417	*29%*	401	*28%*	**1,450**
Solar CSP	150	*75%*	50	*25%*	-	-	**200**
Wind	634	*34%*	562	*30%*	654	*35%*	**1,850**
Biomass	-	-	-	-	13	*100%*	**13**
Biogas	-	-	-	-	13	*100%*	**13**
Landfill Gas	-	-	-	-	26	*100%*	**25**
Small Hydro	-	-	14	*19%*	60.7	*81%*	**75**
Total MW	1,416	*39%*	1,044	*28%*	2,210	*32%*	**3,625**

(Source: http://www.ipprenewables.co.za)

3.1.5.1 Solar Energy

South Africa experiences some of the highest levels of solar radiation in the world and this renewable resource holds great potential for the country.

The daily solar radiation in South Africa varies between 4.5 and 6.5 kWh/m^2 (16 and 23 MJ/m^2) (Stassen, 1996), compared to about 3.6 kWh/m^2 in parts of the United States and about 2.5 kWh/m^2 in Europe and the United Kingdom. The total area of high radiation in South Africa amounts to approximately 194 000 km^2, including the Northern Cape, which is one of the best solar resource areas in the world. With electricity production per square kilometre of mirror surface in a solar thermal power station being 30.2 MW, and just 1 percent of the high radiation area in the country being made available for solar power generation, the generation potential is approximately 64 GW. Solar energy has the potential to contribute quite substantial to South Africa's future energy needs. This would, however, require large investments in transmission lines from the areas of high radiation to the main electricity consumer centres.

There are two main technologies for producing electricity from solar radiation: concentrated solar power (CSP), also known as solar thermal energy, and solar photovoltaic (PV). CSP technology uses mirrors to concentrate the thermal energy of the sun and heat a transfer fluid. The heat energy is then used to produce steam, with which electricity is generated in conventional turbines. PV technology on the other hand uses silicon-based PV to convert the solar radiation directly into electricity. PV technologies which have become commercialised are PV thinfilm and PV crystalline.

A 2011 report from the US puts the levelised electricity generation cost for new CSP plants at approximately 19.5 to 22.6 US cents per kWh (Pew Center on Global Climate Change, 2011). This comparatively high cost is due to the high initial investment in solar thermal power stations. CSP is suitable for large-scale plants and provides base load, as the heat produced can be stored more easily and cheaply than, for example, electricity from solar photovoltaic systems. However, CSP technology is still at an early stage of commercialisation. The cost reduction potential has not yet been fully explored. The German Aerospace Centre estimates that a cost reduction down to €0.05 per kWh at a global total installed capacity of 40 GW could be achieved between 2020 and 2025.

The best applications of solar power have primarily been the heating of water for households and the provision of photovoltaic electricity for remote rural communities in houses, schools and clinics. However, solar energy technologies are also starting to see growth in large-scale commercial applications.

Government is considering the best way to mobilise industrial development around an ambitious solar park concept, which is planned for deployment in the Northern Cape Province over the coming years, primarily because of the intense solar radiation in this province. The pre-feasibility study indicates that the project could theoretically generate 5 000 MW from solar energy. Once completed, the solar park is expected to provide as much power as one large coal-fired power station.

In 2009, the Minister of Energy also embarked on an aggressive solar water heating programme with the target being to install 1 million solar water heater geysers in households and commercial buildings by 2014. As at January 2013, 315 000 solar water geysers had been rolled out, mostly to poor households.

3.1.5.2 Wind

An estimate of wind power potential for South Africa was undertaken by Prof. Roseanne Diab (Diab, 1995) wherein it was observed that wind power potential is generally good along the entire coast with localised areas, such as the coastal promontories, showing very good potential, i.e. mean annual speeds above 6 m/s and power exceeding 200 Watt per square metre (W/m^2). Moderate wind power potential areas include the Eastern Highveld Plateau and the Drakensberg foothills in the Eastern Cape and KwaZulu-Natal. The remainder of the country has low wind power potential.

About 500 wind turbines have been installed on a number of wind farms and are used to generate Direct Current (DC) electricity, usually at 36 V.

The Klipheuwel Wind Farm near Cape Town is an Eskom demonstration plant which is being used to explore the use of wind energy for bulk electricity generation. The wind farm consists of three units, the first of which was commissioned in 2002 and the last in 2003. Total capacity is 3.2 MW and, at a load factor of between 20 and 30 percent, average annual production is just over 4 GWh.

The Darling Wind Farm, 70 km north of Cape Town, consists of four wind turbines with a capacity of 1.3 MW each, bringing the total installed capacity to 5.2 MW. At an average load factor of 28%, the facility has an annual average output of 13.2 GWh. As the first Independent Power Producer, the Darling Wind Farm Company uses the national grid (through a Power Wheeling Agreement with Eskom) and supplies electricity to the city of Cape Town through a 20-year Power Purchase Agreement (PPA). The site is used as an example for future public-private partnerships in the establishment of electricity generation and was declared a National Demonstration Project by the Minister of Minerals and Energy in June 2000.

The Department of Energy has established the South African Wind Energy Programme (SAWEP). Funded by the Global Environment Facility, this programme aims to provide dedicated support for wind energy development in the country and to update South Africa's wind atlas, which is publicly available to prospective wind energy developers. A strong focus on capacity building is targeted at research and development institutions.

3.1.5.3 Hydro

South Africa is a water-scarce country and is a net importer of hydro-electricity. The country has a mix of small hydro-electricity stations (688 MW) and pumped water storage schemes (1 580 MW) (Banks and Schäffler, 2006) and imports 1 300 MW of hydropower from Mozambique's Cahora Bassa Dam. However, due to a major reactor failure in 2012, combined with various other failures on power lines and recent disruptions due to floods in Mozambique, the capacity has been reduced to 650 MW.

In 2002, the then Department of Minerals and Energy (DME) conducted a Baseline Study on Hydropower in South Africa (Barta, 2002) which found that in specific areas of the country significant potential exists for the development of all categories of hydropower in the short and medium term. The Eastern Cape and KwaZulu-Natal provinces are endowed with the best potential for the development of small (i.e. less than 10 MW) plants. The advantages and attractiveness of these plants are that they can either be standalone or in a hybrid combination with other renewable energy sources. Further advantage can be derived from association with other water uses (for example water supply, irrigation, flood control, etc.), which are critical to the future economic and socio-economic development of South Africa.

Despite the advantages of hydropower, global pressures regarding the environmental impact and displacement of settlements by huge storage dams will likely limit the exploitation of hydropower on a large scale. In addition, as a water-stressed country, South Africa would not be able to rely on smaller-scale hydropower resources during dry periods. Irrespective of the size of any prospective installation, local hydropower development will require authorisation in terms of the National Water Act, 1998 (Act No. 36 of 1998).

The Southern African Power Pool (SAPP) allows the free trade of electricity between Southern African Development Community (SADC) member countries. Therefore, despite the recent disruptions in hydropower supply from Cahora Bassa, government remains committed to its vision of importing clean hydropower that is developed in the region. South Africa and the Democratic Republic of Congo signed a memorandum of understanding in 2011 and a draft treaty in 2012 for the development of the Grand Inga Hydro-electric project (Grand Inga 4). With an estimated capacity of 39 000 MW comprised of 52 turbines of 750 MW capacity each, Grand Inga is the world's largest proposed hydropower scheme and is the centrepiece of a continent-wide power system which is being developed in multiple phases.

Although South Africa is not particularly well endowed with hydropower potential, there is therefore some potential to develop micro-hydro locally and significant potential to co-develop and import hydropower from the region.

Biomass

The main sources of biomass are wood waste (generated in the commercial forestry industry) and bagasse (generated in the cane sugar industry). Biomass is used commercially in the pulp and paper mills, and in sugar refineries where bulk from logs, black liquor and bagasse are burned to produce process heat and generate electricity (a process commonly referred to as own-generation or co-generation). Some of this energy could be sold into the national grid (depending on electricity prices and environmental regulations).

In the forestry sector, the volume of waste remaining in the forests is substantial. This waste is about three times the total waste used or discarded in all the mills and, as such, is a potentially large renewable energy resource that might have use for charcoal, gasification or direct generation of power.

Wood

Wood, as a source of energy in South Africa, has two quite different uses, namely industrial and domestic. Industrial use of wood is primarily by South Africa's modern pulp and paper industry, which produces about approximately 2.4 million tons of pulp and 2.7 million tons of paper per year. In the chemical pulp mills, the fibre is separated out in chemical digesters and the residue, known as 'black liquor' and containing useful energy, is burned in recovery boilers to raise steam for process heat and electricity generation. Bark and sawdust from the wood are also burned in boilers.

The domestic use of wood is primarily by poor households, mainly in the remote rural areas, making wood a very important residential fuel in South Africa, as is the case throughout the continent. The exact quantity of residential fuel-wood used in South Africa is unknown, but is estimated at about 86 Petajoules

(PJ), which is equivalent to 7 million tons of wood per year. These estimates suggest that present wood consumption is unsustainable because it is being consumed faster than it is replenished.

Bagasse

Bagasse from sugarcane production and waste from the pulp and paper industry are used to provide energy within these industries but can be used to a greater extent to provide energy for nearby consumers. Bagasse (waste fibre from sugar cane) is the most important energy source for South Africa's sugar refining industry. The total sugar cane crop is over 20 million tons per year, which yields about 7 million tons of bagasse with a heating value of 6.7 MJ/kg, most of which is used as energy in raising steam for process heat and electricity generation. The installed generation capacity of the industry is about 245 MWe. Some bagasse is used for making paper.

Biofuels

There is high potential for the production of biofuels from energy crops such as sugarcane, sugar beet, sunflowers and canola. However, the low energy density of these makes it uneconomical to transport them over long distances and hence they need to be used either close to where they are produced, or they need to be condensed for more economical transport. The production of biofuels from food crops is a contentious issue which presents itself globally. In December 2007, cabinet approved the Biofuels Industrial Strategy which outlines government's approach to the development of policy, regulations and incentives to develop and stimulate the biofuels industry in South Africa. The strategy seeks to achieve a 2% penetration rate of biofuels in the national liquid fuel supply and specifically excludes food crops, such as maize, based on food security concerns. Since the publishing of the strategy, an initial study was conducted on the feasibility of a biofuel manufacturing plant using grain sorghum and soya beans as feedstock. Based on 2010 data, the study found that ethanol production from sugar cane would be much more expensive than that from grain sorghum in South Africa. The Department of Energy has also published regulations which require a minimum of 5% biodiesel blending with Diesel and between 2% and 10% bioethanol blending with Petrol. Consultations are currently taking place regarding the development of a biofuels industry as well as the implications of the infrastructure requirements and costs associated with the manufacturing and blending of biofuels with petrol and diesel.

Municipal Waste

South Africa disposes of almost all of its refuse in landfill sites. It has been estimated that the total domestic and industrial refuse has an energy content of about 11 000 GWh per annum. This could be directly incinerated or converted into biogas and methane to produce electricity. There have been proposals for such schemes, and some landfill sites already produce electricity, such as the Durban Landfill-Gas-to-Electricity Project, Mariannhill and La Mercy Landfills, Ekurhuleni Landfill Gas Recovery

Project, New England Landfill Gas to Energy Project, Alton Landfill Gas to Electricity Project, Nelson Mandela Bay Metropolitan's Landfill, and the EnviroServ Chloorkop Landfill Gas Recovery Project.

3.1.5.4 Barriers to Renewable Energy Development and Global Trends

There are some natural barriers to the use of renewables such as the inherent limitations of biomass and the need for waterless cooling systems because of the scarcity of water. However, the main barriers are to be found in the South African energy innovation system and in the economics of renewable energy technologies. In addition to the higher risk they entail, the cost of renewable energy technologies is a very significant barrier in South Africa. While rising electricity prices will improve the competitive position of renewable energy technologies in the future, these technologies will still need considerable support if they are to be deployed on a commercial, large-scale basis. The Department of Energy's renewable energies procurement process has seen significant competition in the renewable energy market, as well as significant drops in average prices of renewable energy technologies, with the most notable differences being between PV and CSP technologies.

Storage remains one of the most important challenges to the widespread use (small- and large-scale) of renewable energy. Due to the intermittent nature of renewable energy systems and the variability in electricity load requirements, storage of the electricity generated when demand is low is especially critical.

The demand for biofuels internationally is being driven by higher oil prices and government targets and incentives. The leading ethanol producers are Brazil and the USA, both of which receive large government subsidies and use non-staple food crops as feedstock. To put South African ethanol producers on the same footing would require an oil price which is US$20/bbl higher than that of Brazil, or about US$65/bbl.

Comparative analysis of international experience shows that the biofuels industry, particularly in its infant stages, is at the mercy of volatile oil prices, crop prices and exchange rates. It therefore needs government support in the initial stages.

The market expansion of renewable energy technologies globally has been accompanied by cost reductions in critical technologies such as wind and solar PV, and such trends are set to continue. The portfolio of renewable technologies, which includes established hydropower, geothermal and bio-energy technologies is now, therefore, cost-competitive in an increasingly broad range of circumstances, providing investment opportunities without the need for specific economic support.

At a global level, each of the renewable sectors has grown strongly, as reflected below:

- The renewable electricity sector grew by 17.8 percent between 2005 and 2009, providing 19.3 percent of total power generation in the world;

- Hydropower is still the major source of renewable electricity (83.8 percent of renewable generation, corresponding to about 16 percent of total generation in 2009), and the absolute growth in hydropower generation over the previous five years was equivalent to that of all the other renewable electricity technologies, mainly because of developments in China. Hydropower will continue to be an important technology for years to come;
- Renewable heat grew by 5.9 percent between 2005 and 2009. Although the use of biomass is still the dominant technology (and includes the use of 'traditional' biomass with low efficiency for heating and cooking), growth in solar heating and, to a lesser extent, geothermal heating technologies was strong, with an overall growth rate of nearly 12 percent between 2005 and 2009. Growth here was particularly driven by rapid increases in solar heating in China;
- The production and use of biofuels grew by 26 percent between 2005 and 2009, and in 2009 biofuels provided 53.7 Mt, equivalent to some 3 percent of road transport fuels (or 2 percent of all transport fuels). Biofuel production and consumption are concentrated in Brazil, the USA and in the European Union. The main centres for ethanol production and consumption are the USA and Brazil, while Europe produces and consumes mainly biodiesel. The remaining markets in other regions and the rest of the world account for only 6 percent of total production and for 3.3 percent of consumption. Trade in biofuels plays a limited, yet increasingly important role.

Overall, at a global level, renewable energy deployment has expanded rapidly, providing evidence that this group of low-carbon energy technologies can deliver the intended policy benefits of improved energy security, GHG reductions and other environmental benefits, as well as economic development opportunities.

3.1.6 Alternative Energy Sources

The hydrogen economy is undergoing serious consideration in South Africa, in an effort to develop safe, clean and reliable alternative energy sources to fossil fuels. Hydrogen, as an energy carrier, is used to store and distribute energy and can be combined with the use of fuel cell technologies to produce electricity. Another driving force behind this technology is the prevalence of platinum reserves found in South Africa. Platinum group metals (PGMs) are the key catalytic materials used in most fuel cells, and more than 75% of the world's known platinum reserves are found within the South African borders. Hence there is great potential for socio-economic benefits to be obtained from these natural resources. Fuel cells directly convert chemical energy into electrical energy in a clean, environmentally friendly way with no harmful CO_2 emissions at the point of use. Converting hydrogen gas into electricity does not destroy the hydrogen, but rather transforms it into water. Hydrogen can be produced from carbon compounds, including fossil fuels, but the emphasis in South Africa is upon developing hydrogen from renewable energy sources in the long-term. In combination with renewable energy sources, hydrogen has the potential to become a crucial energy carrier in a future sustainable energy system.

3.2 Transformation and related infrastructure

3.2.1 Electricity

South Africa has a total installed capacity of 43 895 MW of which more than 90% is owned by Eskom (IRP 2010). Eskom generates, transmits and distributes electricity to industrial, mining, commercial, agricultural and residential customers and redistributors. Table 3-2 shows existing Eskom-owned and operated power plants together with the capacities.

Table 3-2: Existing Eskom Power Plants

Eskom Existing	Capacity (GW)	Plant Type	Remaining Life	Year of Decommissioning
Arnot	2.28	Coal	13	2023
Camden	1.52	Coal	15	2025
Duvha	3.45	Coal	22	2032
Grootvlei	0.752	Coal	19	2029
Hendrina	1.87	Coal	12	2022
Kendal	3.84	Coal	30	2040
Komati	0.202	Coal	14	2024
Kriel	2.85	Coal	18	2028
Lethabo	3.558	Coal	27	2037
Majuba	3.843	Coal	41	2051
Matimba	3.69	Coal	29	2039
Matla	3.45	Coal	21	2031
Tutuka	3.51	Coal	27	2037
Gariep	0.36	Hydro	15	2025
Van der Kloof	0.24	Hydro	17	2027
Acacia	0.342	Diesel	21	2031
Ankerlig	1.323	Diesel	22	2032
Gourikwa	0.735	Diesel	22	2032
Koeberg	1.8	Nuclear	37	2047
Drakensberg	1	Pumped Storage	21	2031
Palmiet	0.4	Pumped Storage	28	2038
Total	**41.015**			

Source: Eskom

Eskom is currently embarking on a build programme to expand electricity supply capacity. Three major projects are underway and are indicated in the table below.

Table 3-3: Eskom Greenfields Projects

Eskom Committed Plant (GW)	Type	Projected Life	Year of Decommissioning
Medupi (4.332)	Coal	40	2052
Kusile (4.338)	Coal	40	2054
Ingula (1.332)	Pumped Storage	60	2073
Sere (0.1)	Wind	20	2032

Source: Eskom

Table 3-4: Non-Eskom Plants

non-Eskom Existing Plant	Capacity (GW)	Plant Type	Remaining Life	Year of Decommissioning
Coal	1.08	Coal	30	2040
Cahora Bassa	1.5	Hydro (Imported)	23	2033
Other	0.5	Co-generation	30	2040
Steenbras	0.18	Pumped Storage	-	-
Total	**3.26**			

3.2.2 Distributed Generation and Off-Grid Solutions

While South Africa is striving to increase the rate of electrification, and more specifically connectivity to the grid, it is acknowledged that 100 percent electrification is a target that will be difficult, if not impossible, to meet. The statement in the National Development Plan that "*more than 90 percent of the population should enjoy access to grid-connected and off-grid electricity within 20 years*" firstly acknowledges that challenges exist which may not allow for full electrification to be realised, and secondly that both off-grid and on-grid solutions need to be considered. Whereas electricity is currently generated and distributed (on-grid) from centralised power plants, government recognises the potential for renewable energy and distributed generation technologies to improve connectivity.

Distributed generation is essentially an off-grid solution that includes the use of small generators, typically ranging in capacity from 5 kW to 10 MW, at or near to the end-user to provide the electric power needed. Many of the renewable energy technologies lend themselves particularly well to distributed generation applications. Government has already implemented small-scale generation options in various provinces and to date photovoltaic (PV) solar systems have been used for the electrification of over 2 000 clinics and 16 800 schools. PV or solar home systems are eventually expected to electrify an estimated 200 000 homes and 100 000 small businesses in a comprehensive off-grid electrification programme.

One of the main advantages of distributed generation is that it reduces reliance on large-scale transmission lines and, if properly applied, can reduce substation loading and the need for substation/transmission line upgrades. Smaller scale generation options typically require shorter lead times for construction, and construction programmes can be adapted more easily to changes in total demand. Large-scale centralised plant construction programmes, on the other hand, carry significant economic risk, in that a slower than anticipated growth in electricity demand can result in expensive excess capacity (as happened in the period from the late 1970s to the early 1980s in South Africa) (Banks and Schaffler, 2006).

At the next level, distributed generation can include generation, energy storage, on-site management (i.e., dispatch, control, communications), and all ancillary devices and services (Petrie *et al.,* 2009). This means that distributed generation technologies could be operated at a localised level, with excess capacity being fed back into the local or national power grid.

However distributed generation faces numerous technological challenges in this regard, mainly because such systems are essentially designed to operate independently. Most wind turbine operation systems, for example, are automated to immediately stop power production when the frequency or voltage of the grid is below or above certain thresholds, so that no excess is available.

The nature of an efficient distributed generation management system will depend largely on whether the generators are dispatchable or non-dispatchable. While dispatchable units can be controlled by a central system and relied upon to generate according to the needs of the power system, non-dispatchable technologies generate power according to the intermittent availability of their energy source. Most renewable energy systems (e.g., wind and solar) are non-dispatchable and the fact that these technologies cannot be controlled or dispatched by central control has made them historically less popular and less understood than other technologies. However, with the advent of hybrid systems which consist of multiple technologies and whose design exploits the strong points of the technologies to optimise performance and cost, dispatchable generation can be used at times when renewable power generation is unavailable. This seems to offer the most promise when considering the multiple needs of environment, system performance, and overall cost.

Distributed generation tends to have greater economic advantage where customer locations are very remote or expensive to reach; the number of customers is quite small and they are far apart; or the per capita usage is low (Petrie *et al.*, 2009). However while distributed generation represents an opportunity to increase the quality of life for individuals in remote rural areas, several other barriers exist that could make even technologically viable solutions unsuccessful. Such barriers include the sociological dimension of introducing new technologies to communities that are not aware of the benefits that such technology can provide (Szewczuk, 2009). This sociological dimension is understood to be an extremely complex issue. Some recommendations which have been made with regard to how this can be addressed include linking economic development with energy by integrating renewable energy into local planning activities and integrating renewable energy programmes with training and development programmes.

As the electricity supply sector evolves, there is likely to be greater use of distributed generation.

3.2.3 Liquid Fuels

South Africa has a total of six refineries with a combined nameplate capacity of 692 000 barrels per stream day (bpsd). Four of the refineries are located on the coast and the remaining two inland. Available capacity is lower than design capacity, with some of the contributing factors being planned and unplanned shutdowns, ageing of refineries and, in the case of PetroSA, the depletion of natural gas feedstock.

The supply of liquid fuels to the coastal market is either directly from a local refinery by road and rail, or by coastal transfer using ships. Generally the local refineries in a coastal region can provide sufficient supply to the particular region. The largest demand for liquid fuels in South Africa is, however, the inland market which is supplied by the coastal refineries via pipeline, rail or road.

The inland market is linked to the coastal region by the 12-inch Durban-to-Johannesburg Pipeline (DJP) which currently operates at full capacity and has reached the end of its design life. In January 2012, the first phase (construction of the main trunkline) of the New Multi-Product Pipeline (NMPP) was commissioned, which has alleviated some of the capacity constraints of the DJP. The NMPP will be completed in further construction phases and comprises a 24-inch main trunkline (currently completed and operational) and 16-inch pipelines (which are still under construction), with a design lifespan of 70 years.

The major players in the South African oil industry are BP Southern Africa, Chevron South Africa, Engen Petroleum, PetroSA, Sasol Oil, Shell South Africa and Total South Africa. These players own refineries as well some of the storage terminals and distribution facilities throughout the country (www.sapia.co.za).

Table 3-5: Existing Refinery Capacity

Refinery	Refinery Type	Nameplate Capacity (bpsd[2])	Ownership	Location
Chevref	Conventional (Crude Oil)	100 000	Chevron South Africa	Cape Town
Enref	Conventional	125 000	Engen Petroleum	Durban
Natref	Conventional	92 000	Sasol/Total South Africa (64/36%)	Gauteng
Sapref	Conventional	180 000	Shell South Africa/BP Southern Africa (50/50%)	Durban
Sasol (Secunda)	Coal-to-Liquid	150 000 (crude equivalent @ average yield)	Sasol	Gauteng
PetroSA	Gas-to-Liquid	45 000 (crude equivalent @ average yield)	PetroSA	Western Cape

Source: www.sapia.co.za

3.3 Technology, Research and Development

South Africa is a very small player in energy-related research and development (R&D) when compared to the bigger economies. China, the USA and the European Union (EU), with their larger financial and human capital are currently leaders in developing new technologies in the energy sector, with Brazil and India not far behind. Generally, R&D requires partnerships between government, the private sector and academia and in most cases (particularly in the initial stage of an innovation process that is set to benefit the entire economy) governments take the lead by injecting financial capital. Compared to the countries

[2] bpsd – barrels per stream day

mentioned above, and as mentioned previously, South Africa's resource capability – both financial and human – is insignificant in comparison with the rest of the world. This is a major constraint to the country's ability to develop the new technologies required to pioneer innovation in the sector. To mitigate this risk co-operation at all levels – public, private and academic – is required if South Africa is not to fall far behind the innovation curve.

In 2010, government established the South African National Energy Development Institute (SANEDI) to undertake nationally focused energy research, development and innovation as well as undertake energy efficiency measures with a strong relevance for South Africa. While SANEDI was established as an organ of state, various other government and academic institutions undertake energy-related research in specialised areas. SANEDI needs to leverage the strengths, knowledge and expertise of existing institutions involved in energy research by establishing synergies which will enable it to lead the transformation of the energy sector through technology. This should be supported by a strong focus on Human Capital Development.

3.3.1 Technology Learning Rates

Technology learning refers to the reduction in the cost to construct and operate new technologies. Costs of commercialised technologies have generally shown the propensity to decline with cumulative manufacturing and project construction experience. Cost reduction and performance improvements can occur for a wide variety of reasons, including research and development, economies of scale, technology spill-over, economy-wide advances in science and technology, and process improvement resulting from manufacturing learning. Most of these factors are virtually impossible to separate from each other because of high correlations among many of the factors and the lack of sufficient data.

As future costs of technologies are uncertain, technological learning is incorporated into models to cater for the potential reduction in the capital costs of various technologies. For mature technologies, learning rates are assumed to be slower or negligible, while for newer technologies these may increase initially and plateau as the technologies become more mature and mainstream. Figure 3-1 illustrates the assumed learning rates for different types of electricity-generation technologies.

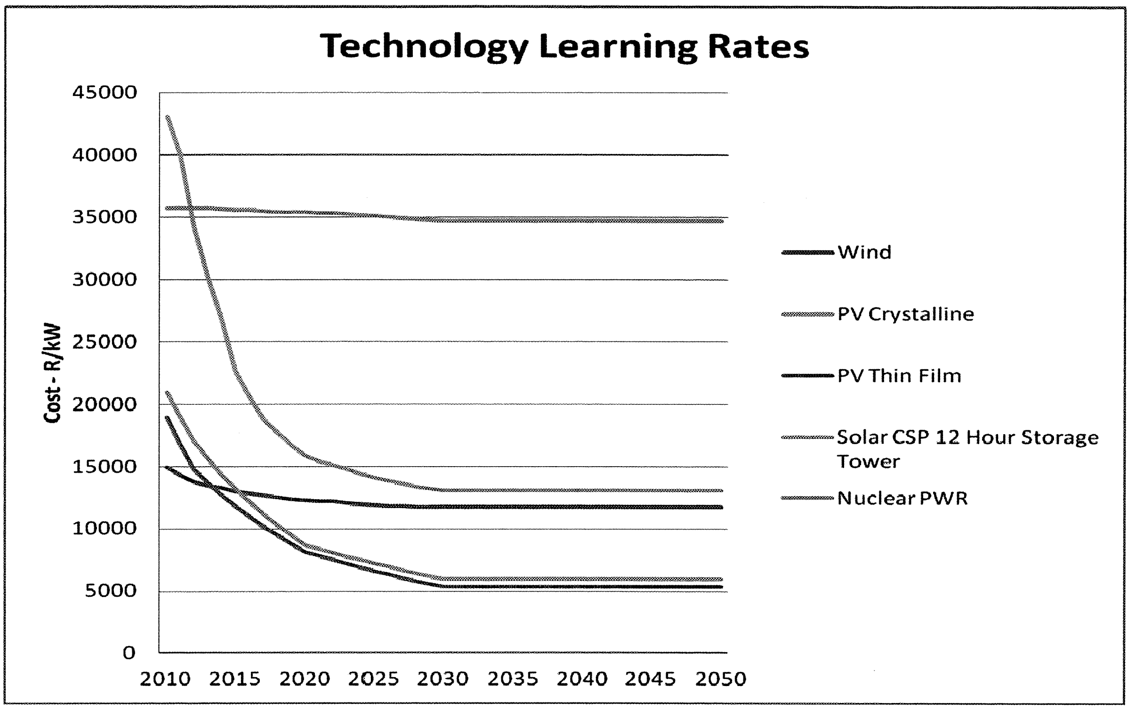


Figure 3-1: Assumed technology learning rates for electricity generation

SECTION 4: KEY MACROECONOMIC ASSUMPTIONS

This section presents the key macroeconomic parameters and assumptions for the IEP, namely: Inflation Rate, Exchange Rates, Discount Rate; Economic Growth (GDP), Global Oil Prices and Natural Gas Import Prices.

Table 4-1: Summary of Key IEP Macroeconomic Parameters for Base Case

PARAMETER	DESCRIPTION	SOURCE OF INFORMATION	UNIT	ASSUMPTION
Discount Rate	The rate at which future benefits and costs decline in importance because they occur in the future. Used to express a time preference for money – money right now is preferred to money in the future.	National Treasury	Percentage per year	11.3%
Average Potential Economic Growth over planning period (GDP)	An increase in the capacity of goods and services produced by an economy from one period of time to another.	• **2012-2031:** National Treasury (July 2012) • **2032-2050:** Projected assuming slowing down of growth as economy reaches maturity	Percentage per Year	Base case assumes on Moderate GDP growth scenario • 2012: 2.7% • 2013: 3.6% • 2014: 4.2% • 2015-2020: 4% • 2021-2042: 4% 2043-2045: 3.5% 2045-2050: 3%
Global Oil Prices (Assumed to inform the variable cost of oil imports)	The annual average global spot price of crude oil	• **Projections for 2012 to 2035:** U.S. Energy Information Administration, Annual Energy Outlook 2012 (AEO2012) • **Projections for 2036 until 2050:** Assumed continued trends from AEO2012	Real 2010 US dollars per barrel (US$/bbl)	• **2012-2035:** Base Case assumes AEO2012 Reference Case crude oil price projections has been assumed for the IEP Base Case • **2036-2050:** Assumed continued trends from AEO2012 Reference Case Scenario

PARAMETER	DESCRIPTION	SOURCE OF INFORMATION	UNIT	ASSUMPTION
Global Natural Gas Prices	The annual average Natural Gas import price	• International Energy Agency, 2011 World Energy Outlook • European Natural Gas Import Prices	**Original Units**: Real 2010 US dollars per Mbtu **IEP Units**: R/GJ	• **2012-2035:** Base Case assumes European Natural Gas Import Prices under the 'New Policies' Scenario • **2036-2050:** Assumed continued trends of 'New Policies' Scenario continue into the future

4.1 Discount Rate

The discount rate is an interest rate used to convert a future income stream to its present value. In the context of the IEP the use of the discount rate across time enables computation of social discount factors, which are to be used to convert the spot prices of various goods and services in the future into their present-value prices. The National Treasury evaluated two approaches on the determination of the appropriate social discount rate to use for long-term national planning, namely:

- The ethical considerations approach (based on the Stern report)
- The Economic Opportunity Cost of Capital (EOCK)

The National Treasury has recommended the use of the EOCK approach, which in summary is a weighted average of (i) forgone return on private investment; (ii) rate of time preference for forgone consumption; and (iii) Marginal economic cost of foreign borrowing. The EOCK in essence gives the social opportunity cost of capital (i.e., the next best use of an economy's resources). According to the National Treasury, this approach provides the right discount rate for determining the choice of various projects (i.e. generation technologies) and gives the correct measure of the opportunity cost of resources used in any given project.

While the formula is highly sensitive to certain parameters such as i) the savers' shares; (ii) the supply elasticity of household saving; (iii) the supply elasticity of the stock of foreign funds to SA; and (iv) the elasticity of demand for private sector investment, certain assumptions were made about the values of these parameters from existing studies.

Table 4-2 below provides the details of the EOCK equations and the values of the input parameters.

Table 4-2: EOCK Calculation for Social Discount Rate for the IEP

	EOCK		
Simple function: Weighted Average = αSOC + (1-α)SRTP	12.3%	assume α =	0.51

$$EOCK = f_1\gamma + f_2\pi$$

therefore

$$EOCK = \frac{\sum_i \varepsilon_i (S_i / S_p)\gamma_i - \sum_j \eta_i (I_j / S_p)\pi_j}{\sum_i \varepsilon_i (S_i / S_p) - \sum_j \eta_i (I_j / S_p)}$$

Economic Opportunity Cost of Capital (ECOK)

Ref	Description	Variables	Households	Business	Government	Foreign	
1	Savers: Share	S_i/Sp	0.1429	0.5055	0.0000	0.3516	
2	Nominal interest rate	i_i	0.1300		0.1156	0.0325	
3	Tax rate	t	0.3100		0.0000	0.0000	
4	Proportion of total borrowing responsive to foreign interest rate	k				0.4000	
5	Return on savings/nominal MC of foreign borrowing	ns = i*(1-t)	0.0897	0.0000	0.1156	0.0325	
6	Inflation rate	p	0.0570	0.0570	0.0570	0.0260	
7	Real return/real MC of foreign borrowing	rs = (ns-p)/(1+p)	0.0309	-0.0539	0.0555	0.0089	
8	Elasticities	ε	0.5000	0.0000	0.0000	1.5000	
	Group weight	ε*(Si/Sp)	0.0714	0.0000	0.0000	0.5274	
	Group weight *real return	ε*(Si/Sp)*rs	0.0022			0.0047	
	Sum of Group weights	A					0.5989
	Sum of Group weights * real return	B					0.00688
	Investors: Share	I_j/S_t		0.6108	0.1369		
	Nominal interest/earnings rate	ir					
	Real return on investment	rr = (ir-p)/(1+p)		0.2120	0.1563		
	Elasticity	η		-1.0000	0.0000		
	Group weight	η*(Ij/St)		-0.6108			
	Group weight *real return	η*(Ij/St)*rr		-0.1295			
	Sum of Group weights	C					-0.6108
	Sum of Group weights * real return	D					-0.1295
	EOCK	EOCK = (B-D)/(A-C)	11.3%				

Note: need to determine whether foreign investment and **government investment** crowds-out private investment

The calculations yielded a discount rate of 11.3% which will be assumed for all technologies throughout the planning horizon.

4.2 GDP Growth Rate

GDP is widely used as an indicator of total demand in the economy. GDP is a good proxy of the amount of energy demanded in the economy hence projections of GDP provide a sense as to the direction of energy demand going forward. The National Treasury provided a 20-year projection of domestic economic growth. The forecasts provided follow the same trajectory as the projections done by the National Treasury in respect of the Integrated Resource Plan (IRP 2010) - a high, moderate and low growth scenario, each of which is based on a high probability of realisation given certain assumptions.

The official forecast released by the National Treasury for the 2012 Budget, provides a 3 year base for each of the scenarios i.e. 2012 – 2014. Following the 2012 Budget forecast, the low-growth scenario assumes real GDP growth of 3.2 per cent per annum over the medium-term and 3.0 per cent per annum over the long-term. The main drivers of the low growth over the period are the assumptions of continued skills constraints and infrastructure bottlenecks. All risks to the low growth forecast are on the upside. The moderate growth scenario forecasts real GDP growth of 4.0 per cent per annum over the medium and long-term. The high growth scenario assumes an improved domestic outlook and recovery from the financial crisis with stronger commodity prices, reduced bottlenecks and higher global growth equilibrium. Over the long term, for this scenario, real growth is expected to be 4.6 per cent per annum over the medium-term and 5.0 per cent per annum over the long-term.

Table 4-3 shows the GDP growth forecasts for from the National Treasury 2012 Budget, while Table 4-4 shows the Low, Moderate and High GDP growth scenarios for the short, medium and long terms.

Table 4-3: National Treasury 2012 Budget Forecast

	2012	2013	2014
real GDP	2.7%	3.6%	4.2%

Table 4-4: GDP Forecasts for the IEP model

Low growth scenario

Short Term			*Medium Term*	*Long Term*
2012	**2013**	**2014**	**2015-2020**	**2021-2031**
2.7%	3.0%	3.3%	3.2%	3.0%

Moderate growth scenario

Short Term			*Medium Term*	*Long Term*
2012	**2013**	**2014**	**2015-2020**	**2021-2031**
2.7%	3.6%	4.2%	4.0%	4.0%

High growth scenario

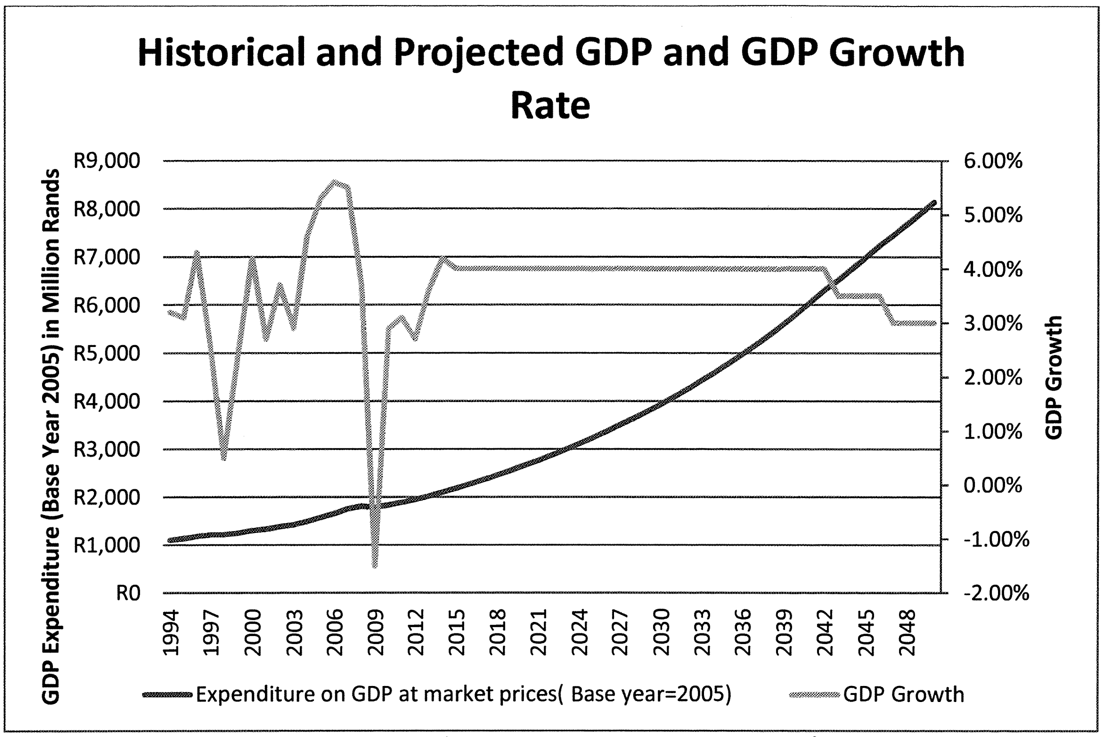
Short Term			*Medium Term*	*Long Term*
2012	**2013**	**2014**	**2015-2020**	**2021-2031**
2.7%	3.6%	4.2%	4.6%	5.0%

Table 4-5: Assumptions and Risks to the MTBPS forecast

Low growth assumption:	
National Treasury 2012 Forecast then growth of 2.9% over the forecast period	
Assumptions	**Upside Risks**
Continued skills constraints	Strong commodity price growth
Infrastructure bottlenecks	Reduced skills constraints
Low global growth	Reduced infrastructure bottlenecks
	Improved global growth outlook
Moderate growth assumption:	
National Treasury 2012 Forecast, followed by	
Assumptions	**Risks**
Continued skills constraints	Risks to the moderate forecast can be either up- or downside risks
Infrastructure bottlenecks	Upside risks to gorwth forecasts are the same as the risks faced in the low growth assumption
	Downside risks to growth forecasts are the same as the risks faced in the high growth assumption
High growth assumption:	
National Treasury 2012 Forecast,	
Assumptions	**Downside Risks**
Strong commodity price growth	Continued skills constraints
Reduced infrastructure bottlenecks	Infrastructure bottlenecks
Improved global growth outlook	Low global growth
Skills shortage alleviates	

The official GDP forecast released by the National Treasury for the 2012 Budget, have therefore been used for the IEP. The Moderate GDP Growth Rate Scenario will inform the Base Case demand projections over the planning horizon.

The graph below charts the GDP growth forecasts for the High, Moderate and Low growth scenarios.



Source: Historical Statistics South Africa (1994-2012), Projected Values National Treasury (2013-2050)

Figure 4-1: Projected National GDP Growth Rates

4.3 Global Oil Price Projections

As mentioned previously, South Africa's crude oil requirements are met through imports and as a net importer, the country is not sufficiently influential to affect the price of crude oil. More importantly, the country is also highly susceptible to the volatility of the global oil market. The Energy Information Administration (EIA) publishes the Annual Energy Outlook on an annual basis which includes, amongst other aspects, projections of global crude oil prices. Projections are made for high, moderate and low global oil price scenarios which are informed by various assumptions about the global geopolitical and macroeconomic environment.

The global oil price projections for the IEP have been taken directly from the Annual Energy Outlook 2012, which has projections up to 2035. The oil prices from 2036 and 2050 have been extrapolated using a straight line based on the average price increases of each of the three scenarios from 2012 to 2035. A summary of the key assumptions underpinning each of the three oil price scenarios is provided in the annexures and the details is also available in the EIA's Annual Energy Outlook for 2012. The global oil price projections for the IEP Base Case have been based on the Reference Case of the Annual Energy Outlook 2012.

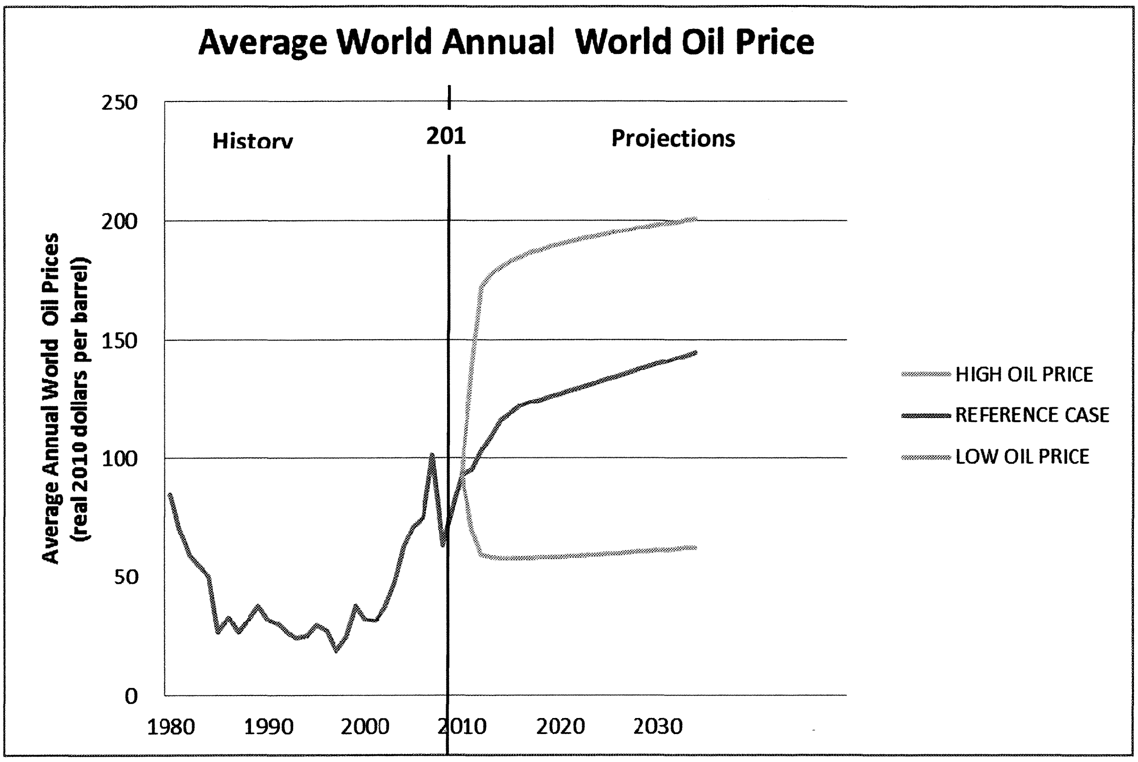


Figure 4-2: Average Annual World Oil Price Scenarios, Annual Energy Outlook 2012, US EIA

4.4 Natural Gas Price

The International Energy Agency (IEA) develops and publishes the World Energy Outlook on an Annual basis. The natural gas price projections are based on the projections for average gas import prices in Europe in the 2011 World Energy Outlook.

According to the World Energy Outlook, historically natural gas prices in the OECD have been closely correlated to oil prices through indexation clauses in long-term supply contract and also as a result of competition between gas and oil products in power generation and end-use markets. However different pricing mechanisms in different parts of the world lead to differences in the actual level of prices. When oil prices are high, oil-indexed gas prices also tend to be high (with a certain lag period). However gas prices which are driven by competition and supply/demand dynamics tend to be lower than oil-indexed prices as has been seen in Europe and the US.

The 2011 World Energy Outlook provides gas price projections for three scenarios: the Current Policies Scenario; the New Policies Scenario; and the 450 Scenario within three regions, namely United States, Europe and Japan. The price projections in the 2011 World Energy Outlook have been revised down from the 2010 release, primarily because of improved prospects for the commercial production of unconventional gas.

Given that South Africa currently imports most of its natural gas, it is assumed that in the foreseeable future, natural gas prices will be informed by the international supply and demand market.

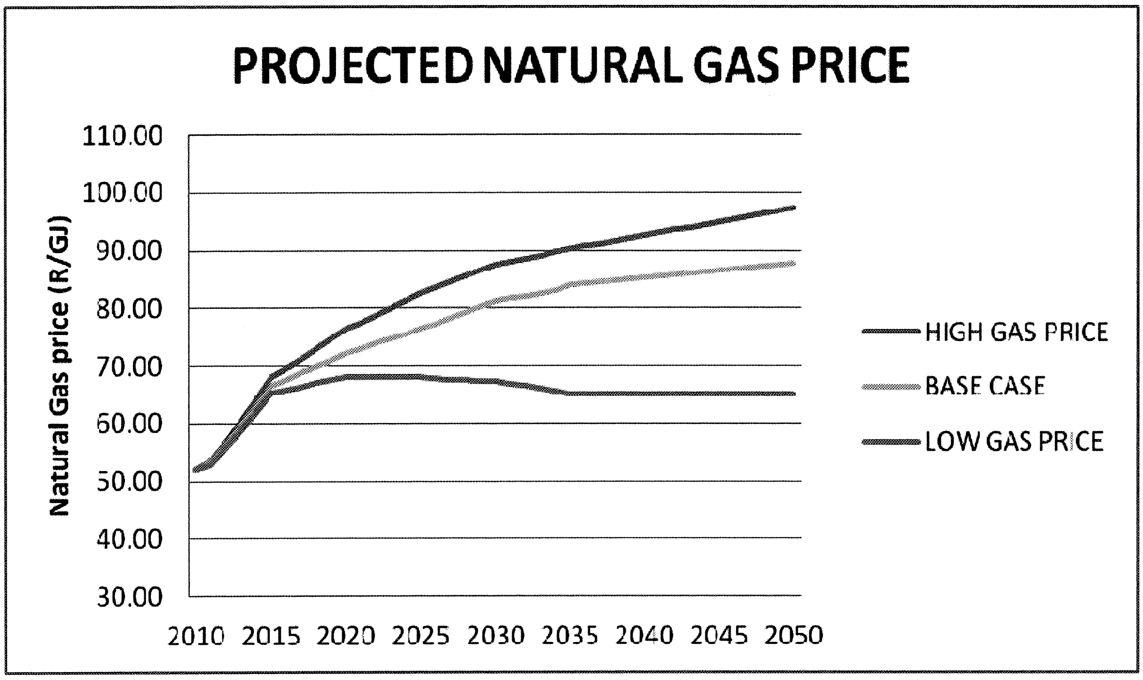


Figure 4-3: Natural Gas Price, IEA: World Energy Outlook 2011 (Average European Natural Gas Import Price)

SECTION 5: ENERGY DEMAND

5.1 Demand Modelling Approach

The economy of a country can be described broadly through three main categories, namely: primary, secondary and tertiary sectors. The primary sector is the sector of the economy making direct use of natural resources. This is contrasted by the secondary sector, which is characterised by the production of manufactured and other processed goods, and the tertiary sector which is characterised by the production of services. The economic grouping is based on the economic activities of the various sectors, and is therefore effective in quantifying and analysing the economic value-add of each of the sectors. However in order to effectively quantify energy consumption within each of the economic sectors, a grouping aligned to energy end-use becomes more constructive. While energy demand can be closely linked to economic activity, this approach also becomes effective in quantifying energy demand in those sectors whose economic activity may not always have a high level of correlation with energy demand (for example energy consumed in offices and public buildings).

Six demand sectors were considered, namely: agriculture; commerce; industry, mining; residential; and transport.

- The agricultural sector includes animal husbandry, crop farming, forestry and fishing.
- The commerce sector includes wholesale and retail, public services, financial and business services, hospitality, education, entertainment, information and communication. It does however exclude commercial transport.
- The transport sector includes passenger transportation (private and public) and freight transportation. While economically freight transport forms a part of commercial services, this has been separated and quantified separately for better clarity.
- The industrial sector includes all manufacturing (manufacturing and production of all goods and products including fast moving consumer goods) and also includes construction.
- The mining sector includes mining of all commodities through different mining techniques. (In the analysis mining is included within industry).
- The residential sector includes all personal dwellings (i.e. formal and informal households in rural and urban areas).

The table below provides a mapping of economic sectors to energy demand sectors with the key activity variable indicated in the last column.

Table 5-1: Mapping of economic sectors to energy demand sectors

ECONOMIC GROUPING	ECONOMIC SECTOR	ENERGY DEMAND SECTOR	SUB-SECTORS	SUB-SECTORS INCLUDED	ENERGY CARRIERS CONSIDERED	ACTIVITY VARIABLE
PRIMARY	Agriculture, forestry and fishing	Agricultural Sector	N/A	N/A	Electricity, Coal, Diesel	Value-Added in the Agriculture Sector
	Mining and Quarrying	Mining Sector	N/A	N/A	Electricity, Coal, Diesel	GDP
SECONDARY	Manufacturing	Industrial Sector (Excluding Mining) or Manufacturing Sector	Chemicals	N/A	Electricity, Coal, Natural Gas	Value-Added in the Secondary Sector
			Iron and Steel	N/A	Electricity, Coal, Natural Gas	Production Activity (Iron Ore Mined)
			Non-Ferrous Metals	N/A	Electricity, Natural Gas	Value-Added in the Secondary Sector
			Other Manufacturing	Non-Metallic Minerals, Food and Tobacco, Paper and Pulp, Construction, Machinery, Textile, Wood and Wood Products, Transport Equipment	Electricity, Coal, Natural Gas	Value-Added in the Secondary Sector
	Construction					
	Electricity, gas and water					
TERTIARY	Wholesale and retail trade; hotels and restaurants	Commercial Sector	N/A	N/A	Electricity, Coal, LPG, Residual Fuel Oil	Value-Added Tertiary Sector
	Finance, real estate and business services					
	General government services					
	Personal services					
	Storage and communication					
	Transport	Transport Sector	Private passenger transport	N/A	Diesel, petrol, electricity, aviation fuel	GDP/Capita
			Public passenger transport		Diesel, petrol, electricity, aviation fuel	GDP/Capita
			Freight transport		Diesel, petrol, electricity (rail)	GDP
HOUSEHOLDS	N/A	Residential Sector	N/A	N/A	Electricity, Coal, LPG, Paraffin	Population growth, Number of households and electrification rate

Gross Domestic Product (GDP) is widely used as an indicator of total demand in the economy and is therefore a good proxy to determine energy consumption. The National Treasury provided 20-year projections of domestic average potential economic growth for three scenarios (low growth, moderate growth and high growth) based on a set of assumptions. The moderate growth assumptions assume the steady growth of the economy, with continued skills constraints and infrastructure bottlenecks in the short- to medium-term. These projections have been used in the Integrated Energy Planning process and are taken as the baseline. The GDP growth assumptions based on the National Development Plan (NDP) have been used for the high-growth scenario, but the relevant outputs have not yet been analysed.

The population growth combined with the average household size provides a good basis for determining the number of households in the future. Energy demand in the residential sector is determined by estimating the average energy consumption by different household types.

In the transport sector, GDP per capita is used to estimate future demand for passenger transportation.

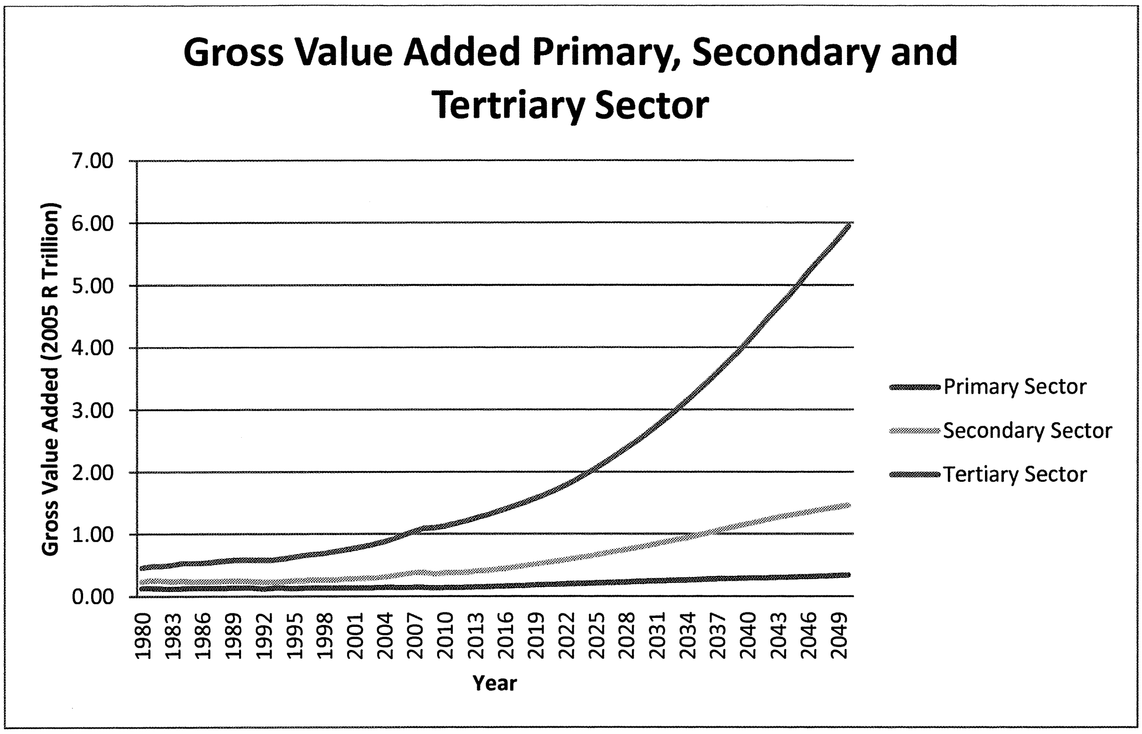
While the ultimate objective is to conduct demand projections for all energy services (cooking, lighting, industrial processes, transportation, etc.) within each major energy demand sector (residential, commercial, industrial and agricultural), due to paucity of energy consumption data at an energy end-use level, using the above-mentioned key drives as a basis, demand projections were conducted for each energy demand sectors (agriculture, commerce, industry, mining, residential and transport).

- For the agricultural, commercial, industrial , mining and residential sectors, energy demand was estimated and projected for individual energy carriers (i.e. electricity, natural gas, LPG, coal, diesel, etc.); and
- For the transport sector, energy demand was projected for energy end-use (i.e. mobility measured by passenger kilometres or freight tonne kilometers) as opposed to individual fuels (i.e. petrol, diesel, jet fuel, etc).This second approach makes it possible to quantify the extent to which different fuels can be used to meet the same end-use/need.

5.2 Analysis of Demand by Sector

As mentioned previously, GDP growth remains closely dependent on the supply of energy and is therefore a key indicator of potential future demand. In the short-term, the GDP growth rate for South Africa is projected to grow from 2.7% in 2012 to 3.6% 2013 and 4.2 % in 2013. In the medium-to-long-term this is projected to grow at an average rate of 4%. The assumed GDP growth projections used to inform the demand projection are illustrated in the graph below. However understanding the projected value-add or production of individual sub-sectors is important in deriving final demand for individual sectors and sub-sectors.

The average potential growth assumptions for the economy as well as the primary, secondary and tertiary sectors are represented in the graph in Figure 5-1. The demand for fossil fuels within the industrial sector (with the exception of mining) is assumed to be closely aligned with the growth of gross value added for the secondary sector. The growth in energy demand in the commercial sector was determined based on projected expansion of the tertiary sector.



Source: Historical values (1980-2010): StatsSA; 2011-2050 – Model Projections

Figure 5-1: Historical and Projected Gross Value Added Primary, Secondary and Tertiary Sector

5.2.1 Agricultural Sector

South Africa has a dual agricultural economy which comprises a well-developed commercial sector and a predominately subsistence-oriented sector in the rural areas. Primary commercial agriculture contributes about 3% to South Africa's gross domestic product (GDP) and about 7% to total formal employment. However, there are strong backward and forward linkages into the economy, so that the agro industrial sector is estimated to contribute about 12% to GDP (SA Yearbook 2011/12).

Since South Africa's re-admission into world-trade, the agriculture has undergone significant structural changes over the past 15 years some of which has seen the sector shift to large-scale intensive farming, as well as a shift from low-value, high-volume products intended for domestic consumption, such as wheat and milk, to high-value products intended for export, such as deciduous fruit, citrus and game. Intensive farming practices are highly dependent on water and fuel with the latter making up the second biggest expenditure item after farm feeds. On the other hand, land-reform could see the emergence of a large number of small-scale farmers, most likely to use traditional farming methods. Fuel usage (predominantly diesel) in the agricultural sector is primarily used for traction and other farm machinery as well as the transportation of agricultural produce and is the predominant energy source in the sector.

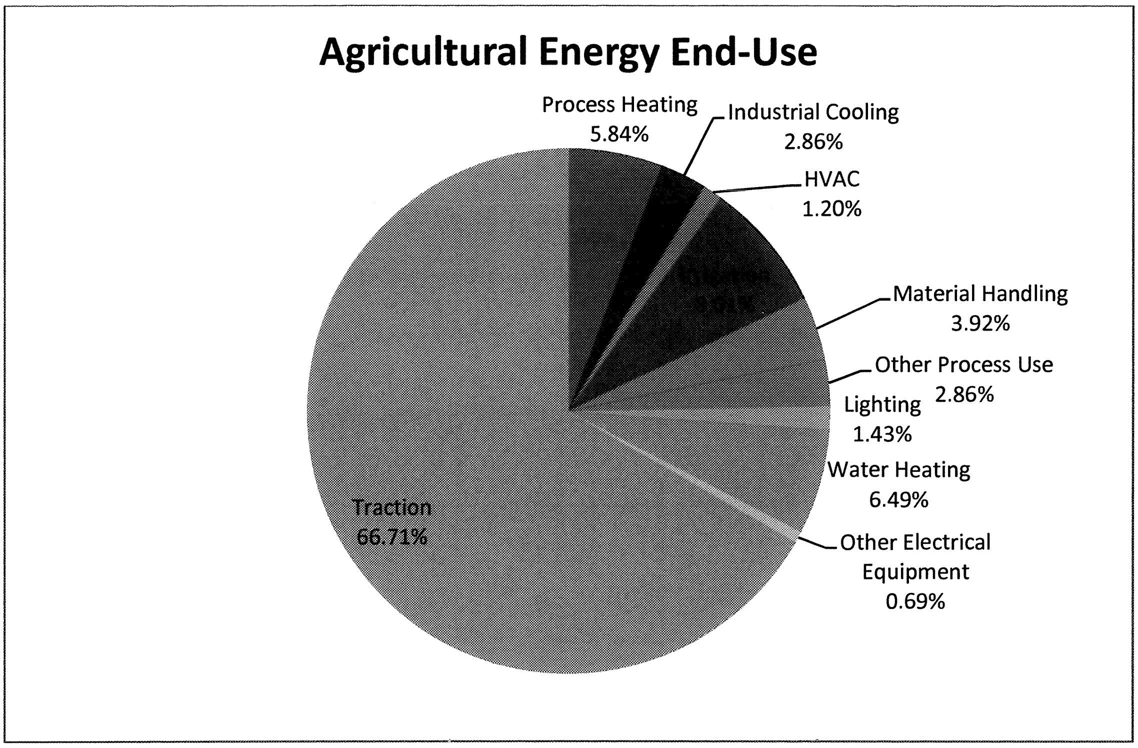


Figure 5-2: Energy End-Use within the agricultural sector

While small-scale farmers have emerged over the last few years, this growth has been slow and has had minimal impact of total energy demanded within the sector. A bulk of the demand has been from large-scale intensive farming wherein use of electricity and diesel has remained high.

Key drivers for energy demand in this sector include shifts to large-scale intensive farming practices and changes in the types of food crops farmed, the latter being highly influenced by changing diets of the population as income increases. It is likely that in future the share of electricity in this sector will grow, however the extent of the growth will be influenced by energy prices, while diesel is projected to continue playing a significant role. Energy demand in the agricultural sector will continue to be linked to growth and value-add of the sector.

With large-scale highly mechanised intensive farming, most efficiency gains resulting from improved machinery, equipment and production practices have been realised and the rate of further efficiency improvements will start to decline. The value-added in the agricultural sector is therefore assumed to continue to see growth into the future, however with the rate of increase slowing down.

Farming is assumed to remain vitally important to the economy and the development of the southern African region. The projected energy demand for the agricultural sector is depicted in Figure 5-3.

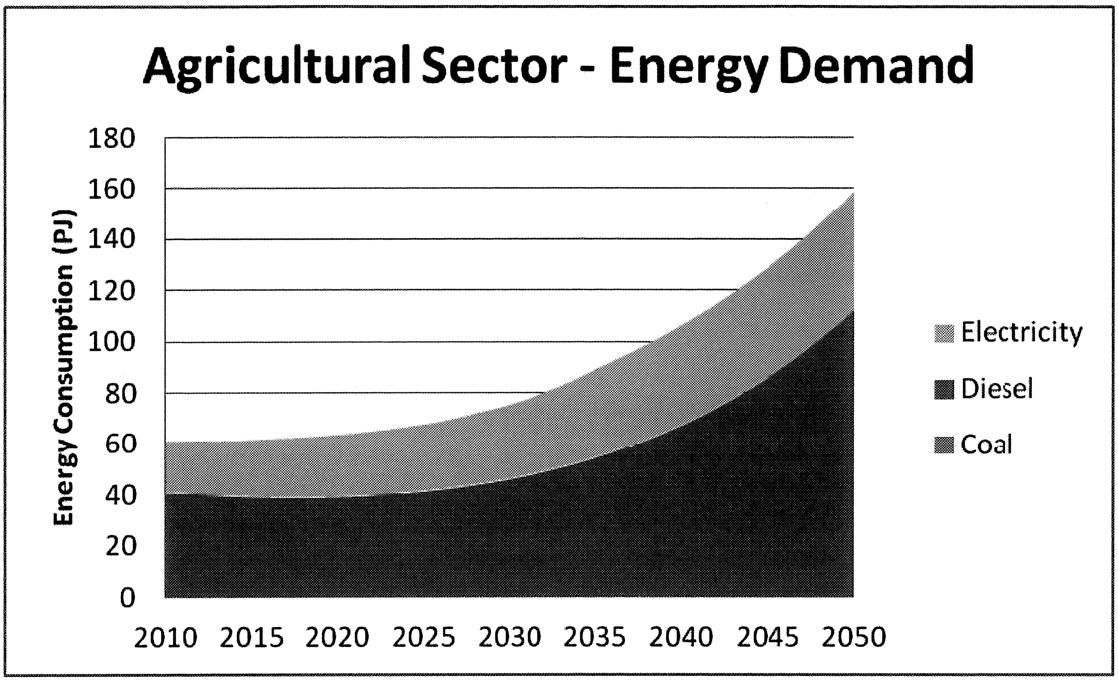


Figure 5-3: Projected Demand in the Agricultural Sector

The average energy demand growth rate is between 1% and 2% in the short-to medium term increasing to between 3% and 4% in the long-term. The intensity of energy end-use the sector declines in the short- to medium-term, but starts to increase in the longer terms as the rate of energy efficiency improvement in the sector start to decline.

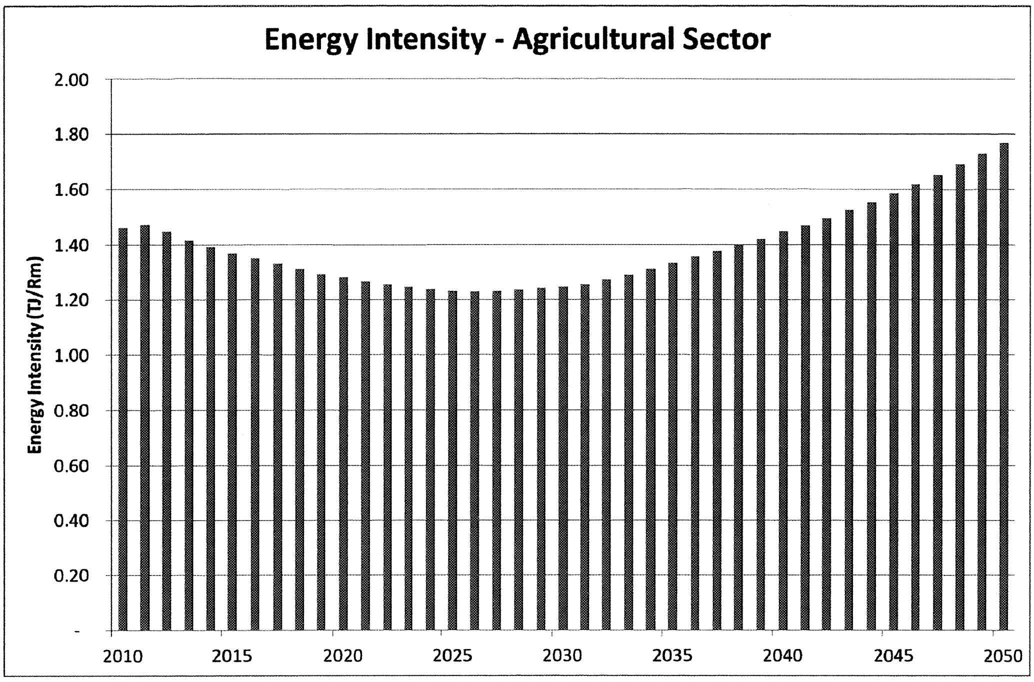


Figure 5-4: Energy intensity in the agricultural sector

5.2.2 Industrial Sector

South Africa is a highly energy intensive economy. According to the 2012 Energy Sustainability Index developed by the World Energy Council, the energy intensity of South Africa is 0.05 million British Thermal Units (BTU) per USD. The industrial sector which comprises of mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco, and other manufacturing consumes ~40% of the final energy demand in the country. The largest of these is iron and steel which consumes ~27% of the total energy used by the sector, followed by mining which consumes ~26%.

The majority of energy within the industrial sector is used for process heating. In energy intensive industrial sub-sectors such as iron and steel and chemicals process heating comprises 90% and 88% respectively. The use of energy for motor driven systems which are accounted for under pumps, compressors and material handling contribute the second largest share of total energy use at 14.73%. 'Other process use' encapsulates other processes whose exact end-use is not well defined and cannot be attributed to a specific purpose. Industrial cooling which is designated as deep mine cooling within the mining sub-sector is the third largest share.

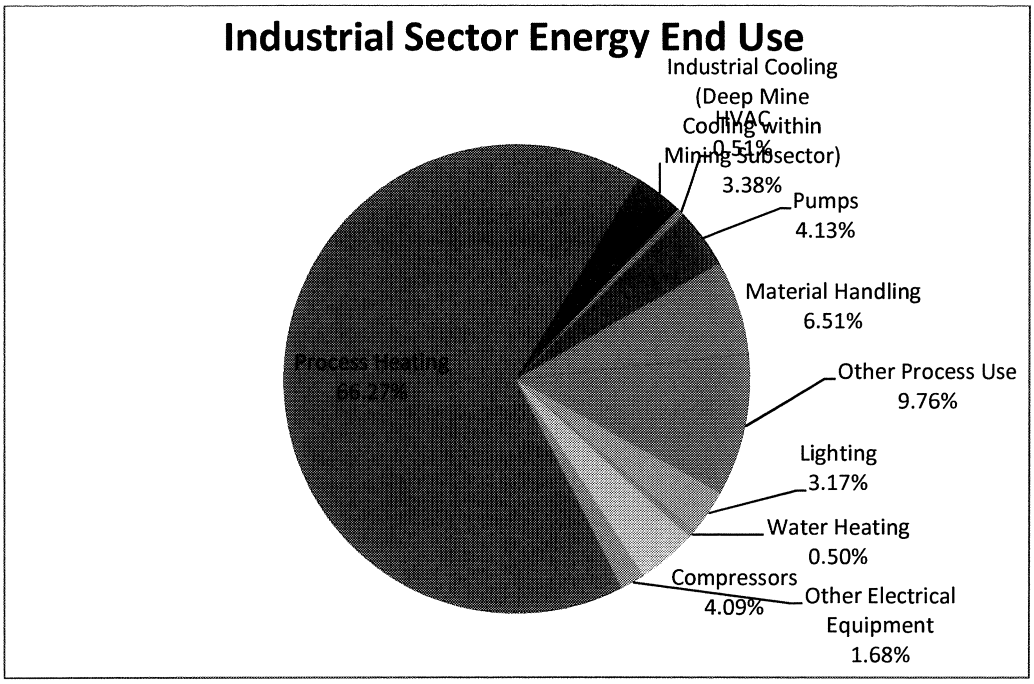


Figure 5-5: Break-Down of Energy End-Use in the Industrial Sector

While the use of fossils fuels within the industrial sector is used primarily towards process heating, the end-use of electricity is very diverse as indicated in the table below.

Table 5-2: Detailed electricity end-use in the industrial sector

End Use	Chemicals	Iron and Steel	Non-ferrous Metals	Other Manufacturing	Gold Mining	Coal Mining	Platinum Mining	Other Mining
Process Heating	4%	60%	23%	38%	2%	3%	2%	3%
Industrial Cooling/Deep Mine Cooling	8%	5%	9%	6%	15%	9%	15%	9%
HVAC	1%	1%	1%	2%	0%	1%	0%	1%
Pumps	26%	3%	9%	13%	17%	5%	17%	5%
Material Handling	15%	4%	5%	4%	27%	6%	27%	6%
Other Process Use	21%	21%	19%	14%	11%	58%	11%	58%
Lighting	4%	4%	11%	10%	4%	6%	4%	6%
Water Heating	0%	0%	0%	0%	4%	3%	4%	3%
Compressors	20%	4%	7%	11%	20%	5%	20%	5%
Other Electrical Equipment	1%	0%	17%	2%	1%	5%	1%	5%
Total	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**	**100%**

Source: Eskom IDM

5.2.2.1 Total Energy Demand within the Industrial Sector

Key drivers for potential changes in energy demand trends in the industrial sector will include economic and non-economic factors. The general loss of competitiveness characterised by relatively high input costs including high wages compared to competing countries such as China and India, has the potential of changing the structure of energy demand. In some instance it has resulted in the mechanisation of production processes. The loss of competitiveness has in some instances resulted in increased importation of finished products, thus reducing the size and demand pattern of the manufacturing sector in terms of its contribution to GDP. Non-economic factors include moves towards a low carbon economy; an increased focus on climate change and emissions associated with energy end-use; increases in energy prices and adoption of less energy-intensive technologies and practices.

The projected energy demand for the industrial sector is depicted in Figure 5-6.

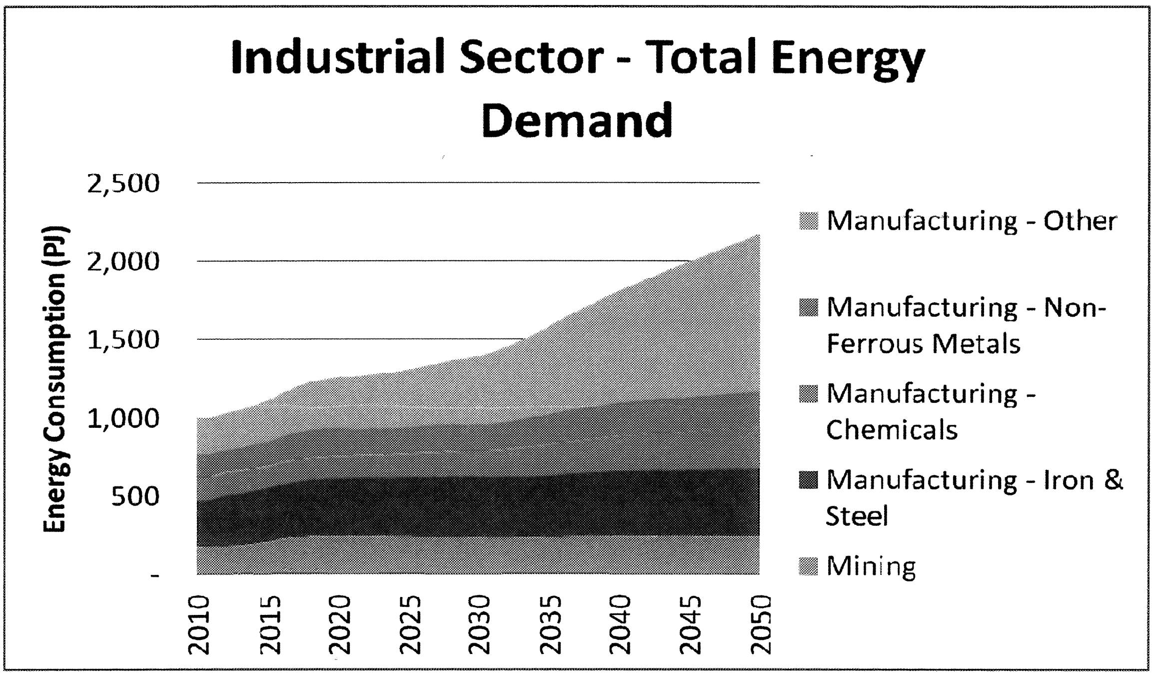


Figure 5-6: Total Energy Demand in the Industrial Sector

With an average annual energy demand growth rate of 2% over the planning period, the growth in energy demand for the industrial sector more than doubles from 2010 through to 2050 with most growth coming from 'Other Manufacturing. It is estimated that in 2010, the share of total energy demand within the industrial sector was from iron and steel with 30%, chemicals 15%, nonferrous metals 14%, other manufacturing' 23% and mining 18%.

In 2030 the share of individual subsectors to total energy demand reduces slightly in most sub-sectors with iron and steel accounting for 28%, chemicals 12%, nonferrous metals 12% and mining 17%. This share is taken by other manufacturing which takes up 31% of total energy demand within the sector. Further on in 2050 this trend continues with the iron and steel taking up 20%, chemicals 12%, nonferrous metals 10% and mining 11%. Other manufacturing continues to take up the most significant share of 46% by 2050. The reduction in the share of total energy demand from the mining sector is expected due to the fact that while production from mining is increasing overall there are sharp declines seen in the gold sector. For instance in 2007, gold mining accounted for close to 47% of the electricity demand within the mining subsector and from 2007 to 2050 the share of electricity demand for gold mining declines to 28%.

Demand in other manufacturing which includes, among others, sub-sectors such as textiles, paper and paper products, household appliances, beverages, and food processing, grows the most substantially.

5.2.2.2 Industry: Coal Demand

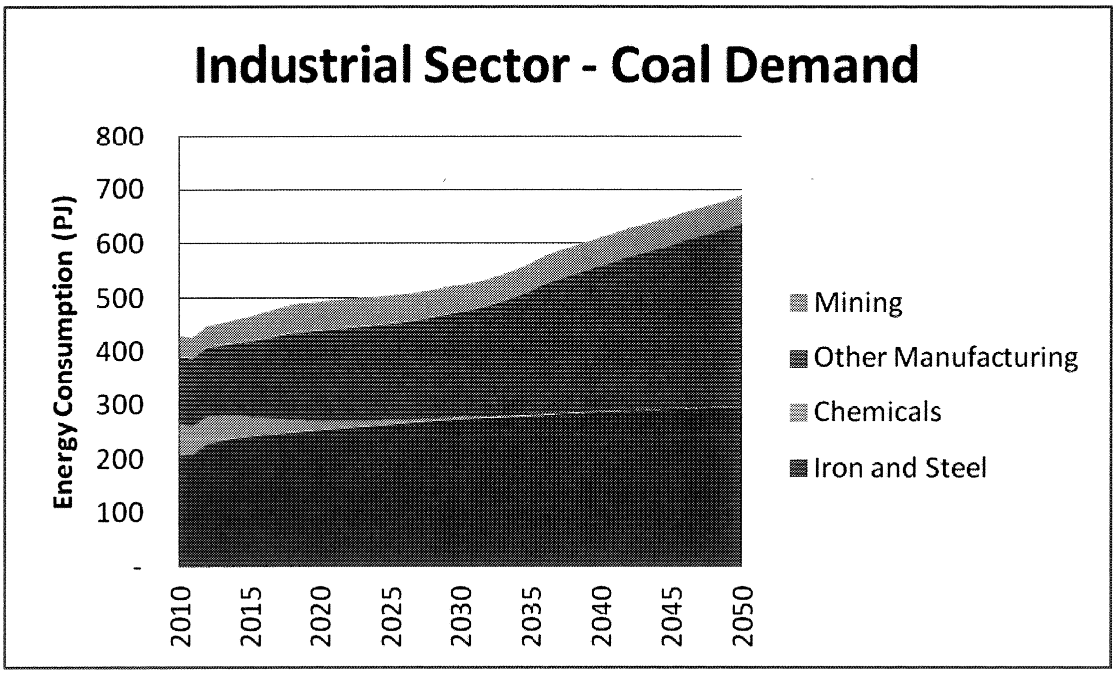


Figure 5-7: Projected Coal Demand in the Industrial Sector

From 1999 to 2010 coal consumption within the Chemical sector has declined by a cumulative 77% (DME, Energy balances 1999-2010) with steep drops occurring most recently in the last five years. Coal projections from 2010 to 2050 show similar trends with the total demand for coal, declining with an average of ~10% from 2010 to 2050 being replaced by natural gas and electricity consumption as depicted in Figure 5-8 and Figure 5-9 below. Despite the drops in coal demand in the chemical sector, coal consumption in the overall industrial sector grows with iron and steel increasing at an annual average rate of ~1% and 'Other Manufacturing' increasing at an annual average of ~3% between 2010 to 2050.

5.2.2.3 Industry: Natural Gas Demand

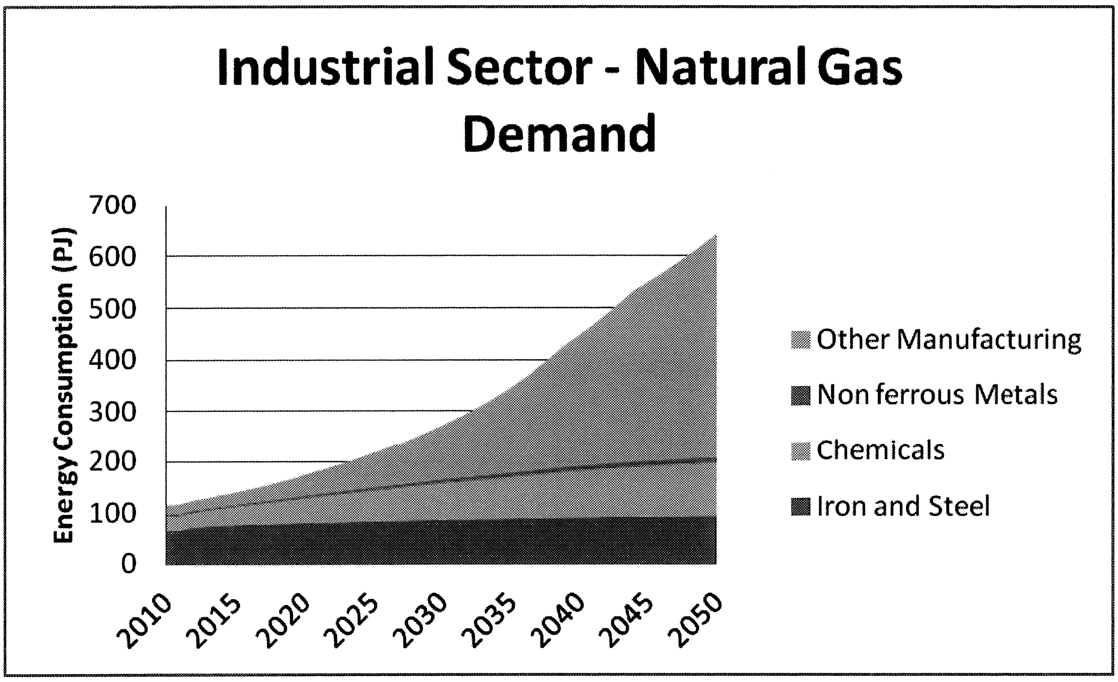


Figure 5-8: Projected Natural Gas Demand in the Industrial Sector

Natural gas usage within the industrial sector is primarily seen in 'Other Manufacturing' and Chemicals sectors. Most of the growth of natural gas within the industrial sector is accounted to Other Manufacturing which grows at an annual rate of ~8% 2010 to 2050 and the Chemicals sectors which grows at an annual average rate of ~2%from 2010 to 2050.

5.2.2.4 Industry: Electricity Demand

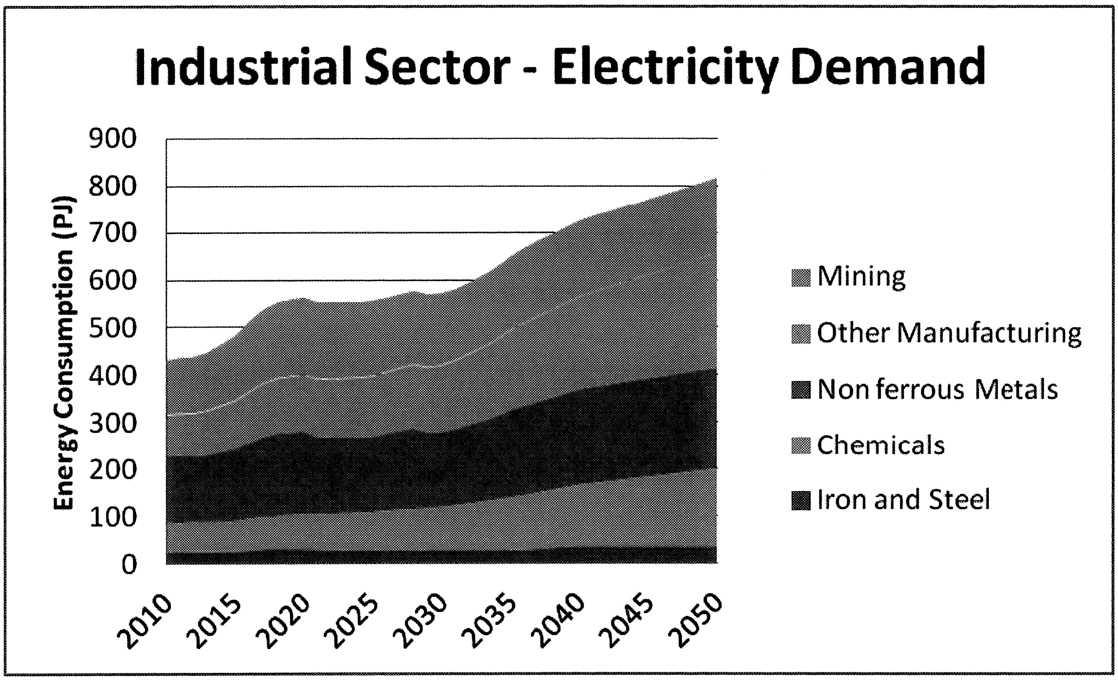


Figure 5-9: Projected Electricity Demand in the Industrial Sector

Total electricity demand doubles over the time period from 2008 to 2050. Over the same period electricity demand within the iron and steel sector shows an average growth rate just under 1%.

The use of electric arc furnaces which account for the bulk of electricity usage within the Iron and Steel sector is limited by the availability of scrap metal. The average annual growth rate of electricity within the nonferrous sector at ~1% from 2010 to 2050 is well below the growth experienced by other manufacturing which shows an average annual growth rate of ~2% and Chemicals at ~3%.

5.2.2.5 Industry: Liquid Fuel Demand

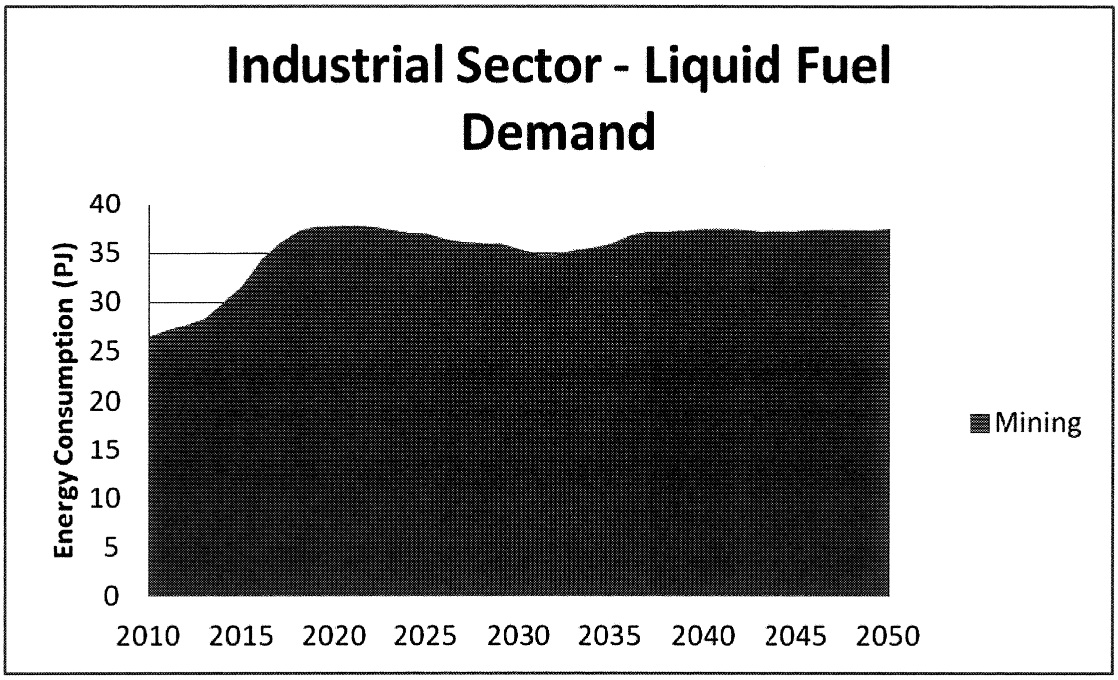


Figure 5-10: Projected Liquid Fuel Demand in the Industrial Sector

The use of petroleum products within the industrial sector is mostly limited to the mining sector. Material handling which accounts for ~26% of total energy end use within the mining subsector encompasses both diesel and electric equipment. In general, diesel fuel is used by rubber tyre or track vehicles that deliver material in batches while electricity powers continuous delivery systems such as conveyor belts or slurry lines.

5.2.3 Commercial Sector

The commercial sector comprises of the following economic sub-sectors: finance, real estate and business services; general government services; personal services; storage and communication; and wholesale, retail, motor trade and accommodation.

The commercial sector therefore largely comprises of the tertiary or services group of industries, but specifically excludes the transport sector. In this analysis the commercial sector therefore describes all industries within the tertiary sector excluding transportation of passengers and freight. The basis for the exclusion is that transportation demand requires a separate and focused analysis for energy consumption. However in describing the characteristics of the tertiary sector, transportation of goods and passengers are implicitly included.

For the last 100 years, there has been a substantial shift from the primary and secondary sectors to the tertiary sector in industrialised countries. The tertiary sector is the fastest-growing sector in developing countries including South Africa. As a result of a wealth of mineral resources and favourable agricultural conditions, South Africa's economy has historically been rooted in the primary sectors. However, over the past four decades, the economy has been characterised by a structural shift in output. Since the early 1990s, economic growth has been driven mainly by the tertiary sector and more recently South Africa is moving towards becoming a knowledge-based economy, with a greater focus on technology, e-commerce and financial and other services.

Some of the fastest growing tertiary sectors from the over the last couple of years include transport and financial services, with most value-add having occurred in information and communications technology; communications; retail as well as finance and business services.

As the commercial sector is highly characterised by people providing services, rather than machinery or equipment, energy requirements are predominately to increase levels of comfort and ensure sustenance of individuals. Energy end-use is therefore primarily used for space heating and cooling (~34%), followed by water heating (~21%), cooking (~17%) and lighting (~14%) and the remainder towards cool storage (~5%) and electrical equipment such as computers, printers, faxes, etc. (~9%).

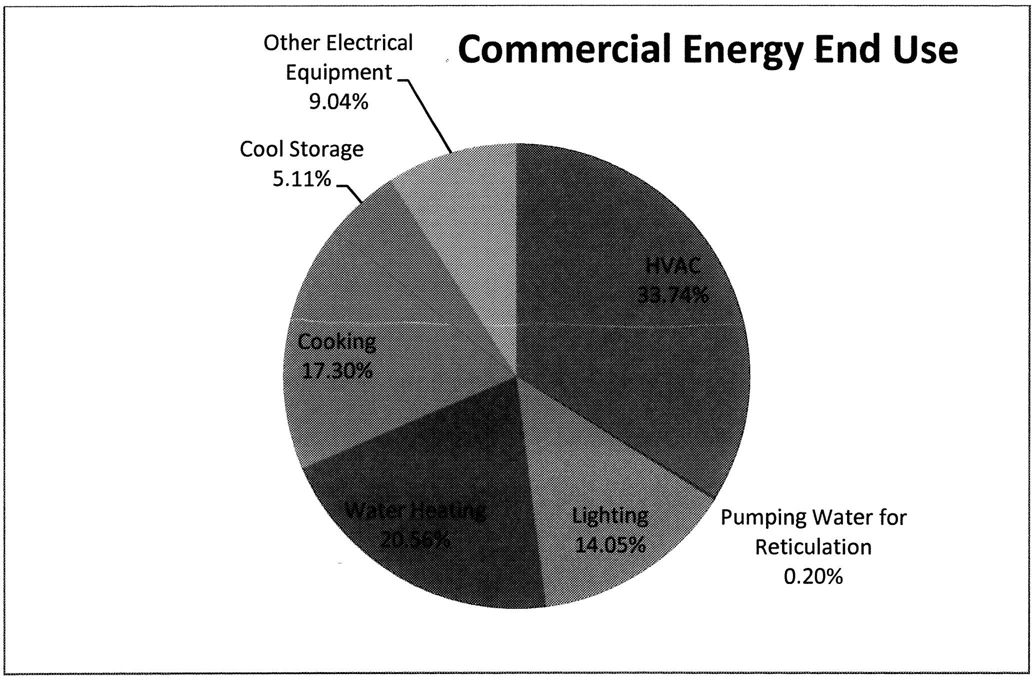


Figure 5-11: Energy End-Use within the Commercial Sector

Given the fact that the tertiary sector is predominant in highly-electrified urban areas, and that it is the most modern and convenient source of energy, electricity dominates total energy usage. It is also no surprise that the historical consumption of electricity has shown a steady increased aligned with the growth of the tertiary sector.

As economies develop, the commercial and public sector usually grow faster than other sectors – and this has been true for South Africa. Continued expansion of tertiary sector will see continued increases in the demand for energy, and more specifically electricity. Although energy demand in the tertiary sector is relatively low when compared to other industrialised countries, significant opportunities for improvements in energy efficiency exist especially through the heating and cooling of office buildings, office equipment and lighting. Water heating is slowly starting to see a shift to alternative energy sources such as solar and more energy efficient heat pumps. To this effect, the government has also introduced various legal and policy instruments aimed at improving efficiency. These include the National Building Regulations which include specifications and standards for the energy efficiency of new buildings as well as standards for the labelling of the efficiency of appliances. Various incentives schemes have also been introduced which will in encourage more energy efficient practices and behaviour from all industries including those that fall within the commercial sector. Therefore while energy demand in the tertiary sector will continue to grow, this will not follow the same trajectory as the economic growth of the sector, but should rather lag behind.

The projected energy demand for the commercial sector is depicted in Figure 5-12.

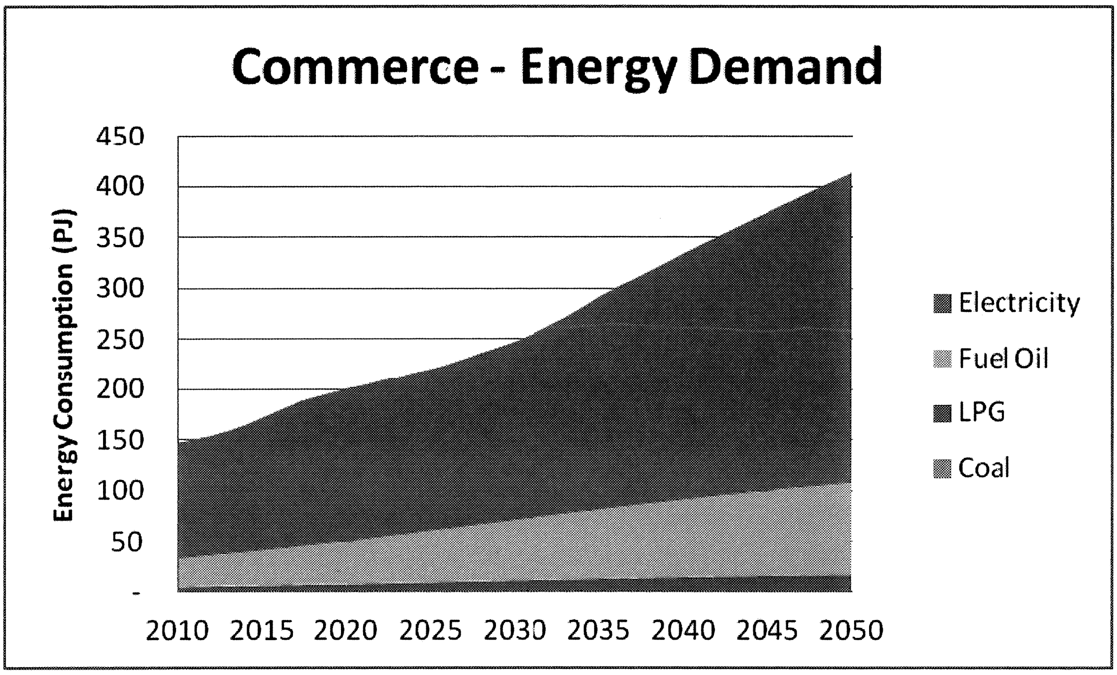


Figure 5-12: Projected Demand in the Commercial Sector

5.2.4 Transport Sector

Across Africa, roads remain the dominant mode of transportation, accounting for more than 90% of passenger and freight transport in Africa, compared with around 50% of freight in Europe. South Africa is a large country with an extensive network of road, rail and air transport (SA Yearbook, 2011/12). Land passenger transport is the biggest user of energy followed by land freight and then air transport. Transport energy demand consists overwhelmingly of liquid fuels. The dominant fuel for transportation is petrol (>50%), followed by diesel (~35%), jet fuel (~10%), and the lowest is electricity (<2%) primarily used in rail (see Figure 5-13).

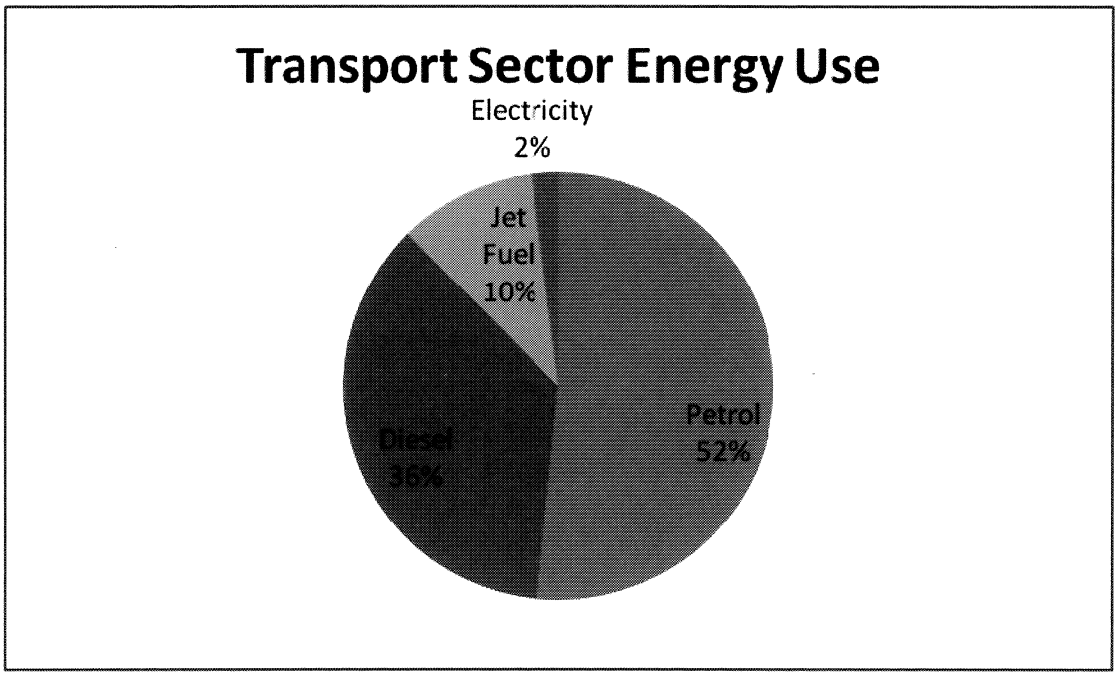


Figure 5-13: Energy End-Use within the Transport Sector

Demand for transport services is assumed driven by economic activity represented by GDP for freight and public transport and GDP per capita for private passenger transport. The graph below shows the projected GDP per capita based on the GDP growth and populations projections discussed previously.

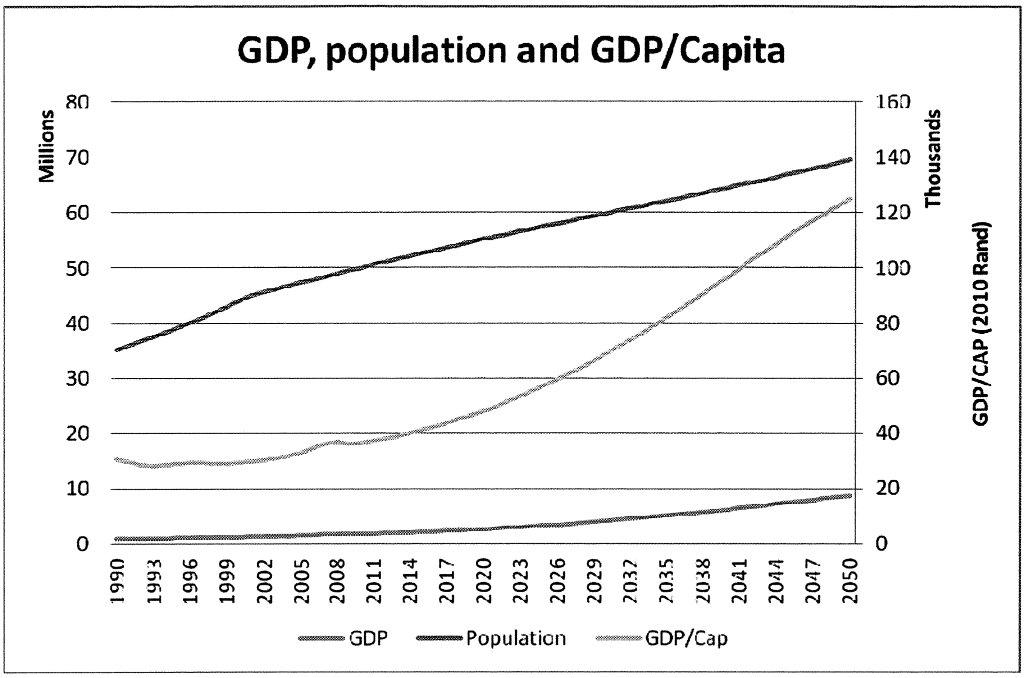


Figure 5-14: GDP, population and GDP/Capita for the IEP Base Case

5.2.5 Passenger Transportation

In line with global growth patterns, the key driver for continued demand is likely to be the desire for increased mobility. For passenger transportation this becomes possible when improvements in GDP per capita allow the move from mass and public modes of transport to small passenger vehicles. Other indirect factors which impact the mode of transport include quality of roads as well as safety, efficiency and reliability of public transport systems. More recent factors that could also change passenger movement patterns include government policy interventions, which aim to accelerate the improvement in public transport by establishing integrated rapid public transport networks. These will introduce priority rail corridors and Bus Rapid Transit (BRT) systems in cities. Transportation demand is largely met through liquid fuels, however the penetration of electric and hybrid vehicles could see demand shift from petroleum products to electricity in the future. Three vehicle categories were modelled for passenger transportation: Small Passenger Cars, Sport Utility Vehicles (SUVs) - which include bakkies and mini vans and Public Passenger Transport (Buses and Minibus Taxis).

5.2.5.1 Small Passenger Cars

Projected energy demand for private passenger cars is presented in Figure 5-15: Electric vehicles are selected by the model as a significant part of new vehicle fleet. The initial uptake of electric vehicles is slow due to the low base at which electric vehicles start. While electric vehicles have the lowest cost over the model period, based on the vehicle costs and the energy value chain there are practical limits to their adoption. The escalation of fuel prices coupled with the costs of investing in additional refining capacity to meet future liquid demand contribute to the update of electric vehicles in the later years of the modelled period. Petrol use for small passenger vehicles continues to dominate throughout the modelling period with the contribution of diesel diminishing by 2038. Use of electricity for small passenger vehicles is negligible and only starts to take off after 2035.

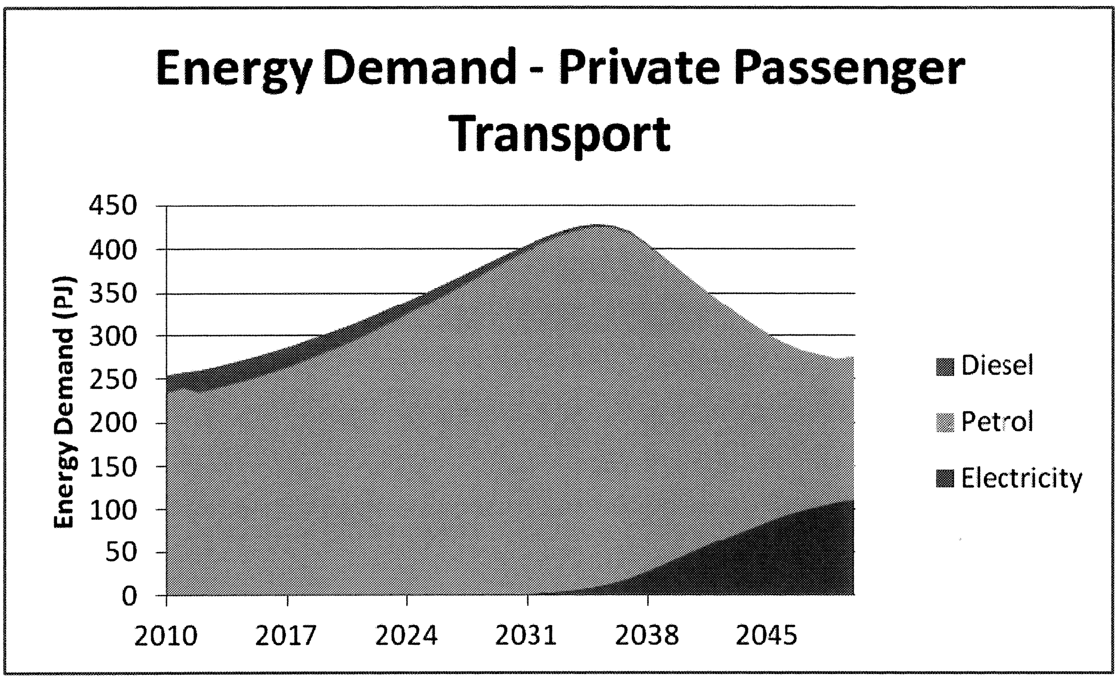


Figure 5-15: Projected energy use for small passenger cars

The results presented meet the electric vehicle targets set by the Department of Transport's National Transport Plan for the year 2050, i.e. 60% electric vehicles, based on the assumed penetration rates. Other aspects not considered which would impact on electric vehicle penetration rates are the required charging infrastructure, market conditions and range limitations of electric vehicles.

Diesel cars are not chosen by the model but new petrol vehicles are selected, mainly at the start of the modelling period but start to decline by 2050 as more electric vehicles enter the market.

From a policy perspective, based on the assumptions provided, the model output suggests that electric vehicles should be considered as they provide a least cost option for providing private passenger transport and result in lower end-use emissions for the transport sector. However further analysis on the possible penetration rate of electric vehicles in South Africa needs to be conducted. Where possible, this should take into consideration economic factors such as the capital cost of vehicles and the cost of fuels, as well as social factors such the value placed on different types of vehicles and associated social status that are difficult to quantify.

5.2.5.2 Sport Utility Vehicles (SUVs)

The category of vehicles classified as Sport Utility Vehicles (SUVs) includes bakkies and mini vans. The projected energy demand for SUVs is shown in Figure 5-16. The model chose petrol over diesel for these vehicles and by 2050 almost all vehicles in this class are assumed to use petrol. This class of vehicles is comprised primarily of small bakkies which are assumed to continue using petrol and the capital costs of diesel vehicles is less economical given the assumed distances travelled, however the rate at which use of diesel diminishes may be slower in reality. Electric drive trains were not considered as an option for SUV type vehicles.

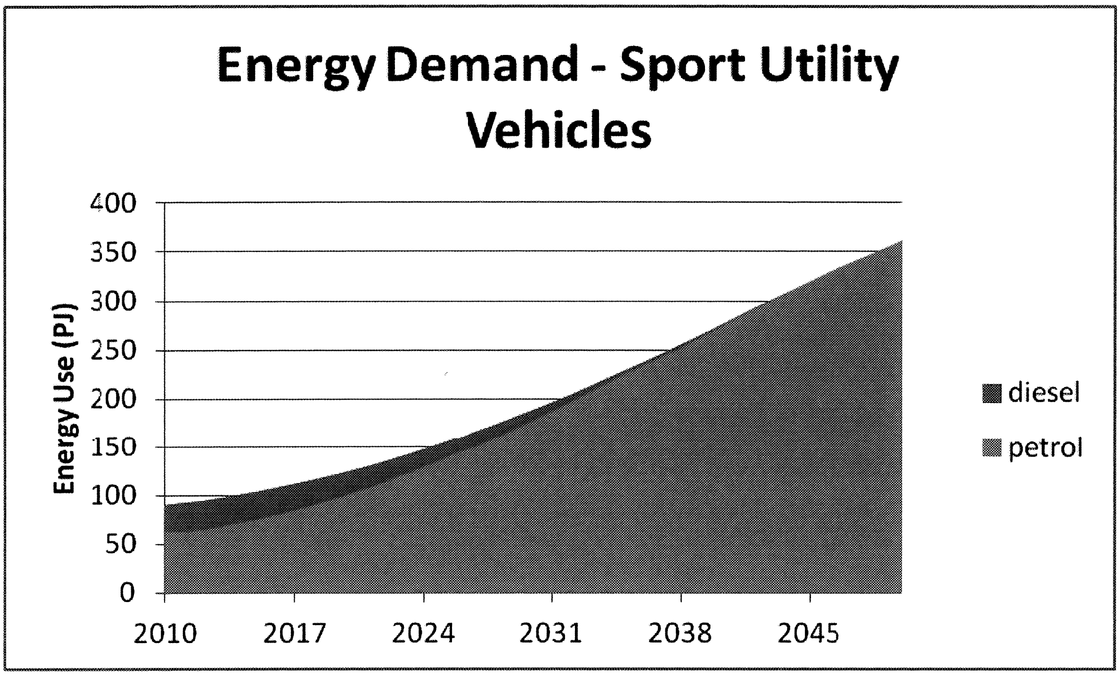


Figure 5-16: Projected energy use for SUVs

5.2.5.3 Public Passenger Transport

In the public transport sector (Figure 5-17) buses are the cheapest option to providing passenger kilometres. The model output indicates that scrapping most of the existing minibus taxi fleet and replacing them with new buses would be a better option of meeting future passenger mobility requirements. However that said the capital investment required combined with the possible public resistance to replacing minibus taxis with buses limit this as a practical solution and closer consideration of these options is needed. It may also be argued that buses do not provide the same type of service based on trip length, frequency of service and other conveniences to the same extent that minibus taxis are able to. The model reflects that diesel continues to be the most used fuel for buses by 2050.

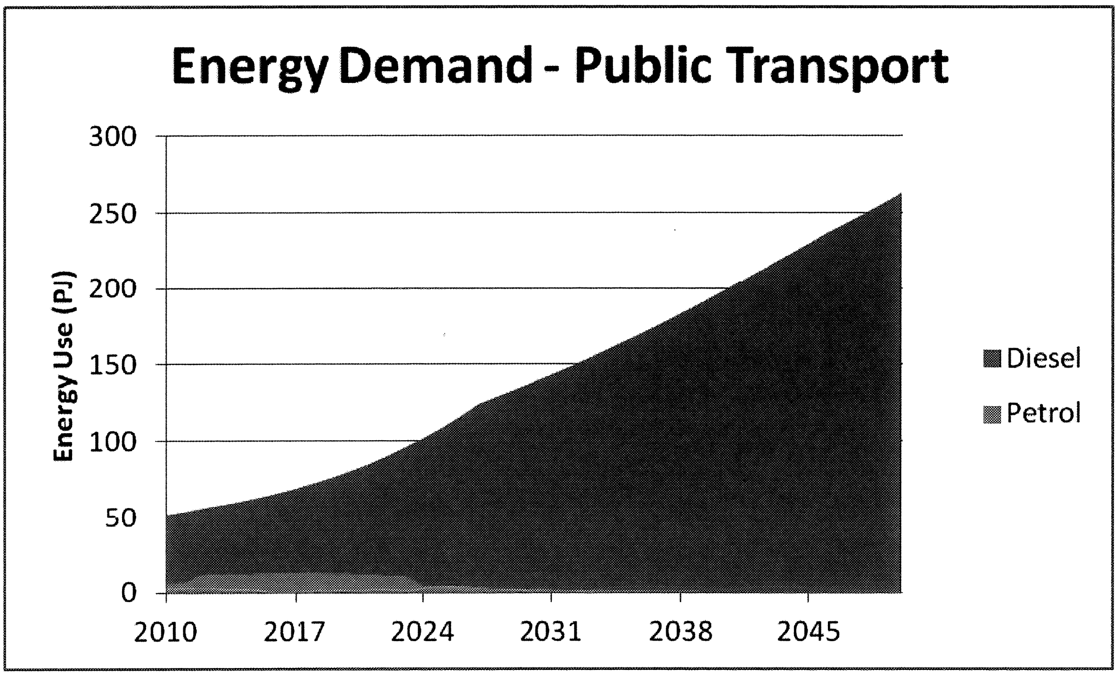


Figure 5-17: Projected energy use for public transport

5.2.6 Freight Transportation

In recent years the rail freight market has been losing its market share to road haulage, and presently it is estimated that 85% of total freight is hauled by road with the remainder being transported by rail. With the exception of coal and iron-ore most freight is hauled by road. Road freight transport with its higher reliability, flexibility, accessibility, security and shorter transit time, in comparison with rail freight transport, is preferred by the industrial sector and this has contributed to the increase in road haulage (Stander and Pienaar). However it also carriers with it negative externalities such as increased and rapid damage to roads, road congestion, air pollution and higher fuel/energy requirements.

Demand for freight haulage is highly linked to the value-add of the sector and overall economic growth and the assumptions about increased road haulage have informed the demand projections.

The projected energy demand for freight transport is depicted in Figure 5-18.

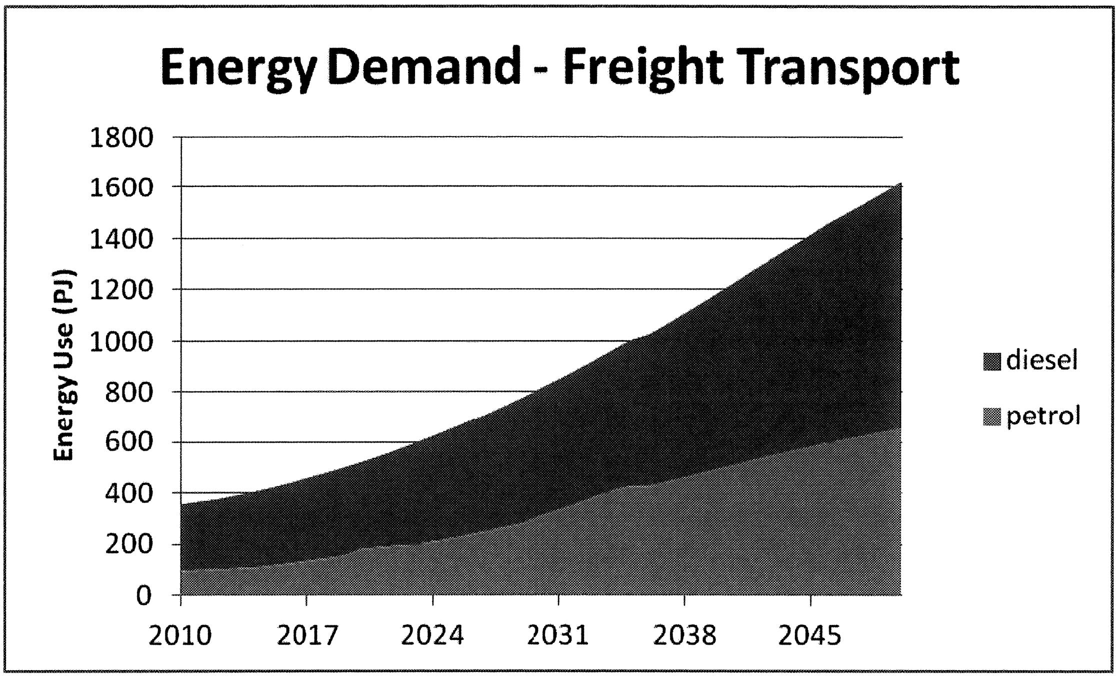


Figure 5-18: Projected energy demand for Freight Transport

Projections of new heavy and medium commercial vehicles correspond with historical trends and are directly related to the demand for these services as there are no alternative technologies considered.

While the shifting of freight from road to rail has significant advantages, including lower costs and fewer externalities, further analysis is required which will take into account the impact of the freight rail investment on shifting freight haulage from road to rail. Energy demand for freight transport will continue to be met through petrol and diesel into the foreseeable future. However it should be noted that government has now reviewed its rail investment programme to accelerate the shift of freight transport from road to rail and this will see an investment of about R63 billion by Transnet in the freight rail system over the next five years (SA Yearbook 2011/12). This could see a potential reduction in projected road freight haulage and a corresponding increase in rail freight transportation.

5.2.7 Residential Sector

Households consume ~20% of South Africa's total energy. This energy is provided from various sources including wood, dung and other vegetable matter, coal, paraffin, LPG, candles, electricity and natural gas. The main form of energy used is governed by availability, accessibility, cost of the energy carrier and costs of energy devices. In 2006, ~73% of energy consumed by South African households was in the form of electricity, 29% in the form of coal, and 7.4% in the form of petroleum products (mostly illuminating paraffin but also a small amount of LPG).

Use of energy in households is predominantly for cooking (~38%), followed by space hearing (~28%), water heating (~20%) and lighting (~5%), with the remainder primarily for other uses - predominantly electrical uses.

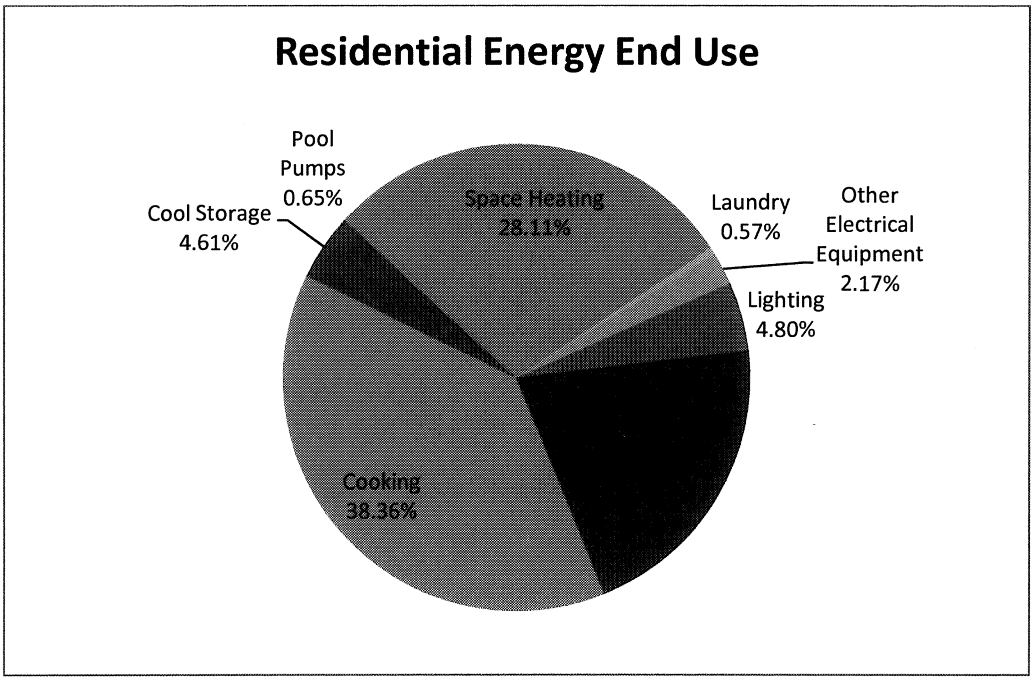


Figure 5-19: Energy End-Use in the Residential Sector

At the end of 2012, more than 75% of households (including informal households) in South Africa were electrified, totalling 9,809,136 households (www.energy.gov.za). The highest percentage (86%) of electrified households is situated in the Western Cape and the lowest percentage (60%) in the Eastern Cape (DoE, 2009). The percentage of households connected to the grid is projected to grow until 2033 to encompass 98% of total households within South Africa. After 2033 households which are not directly connected to the grid due to constraints of expensive electricity infrastructure cost will be able to access electricity through non-grid solar home systems.

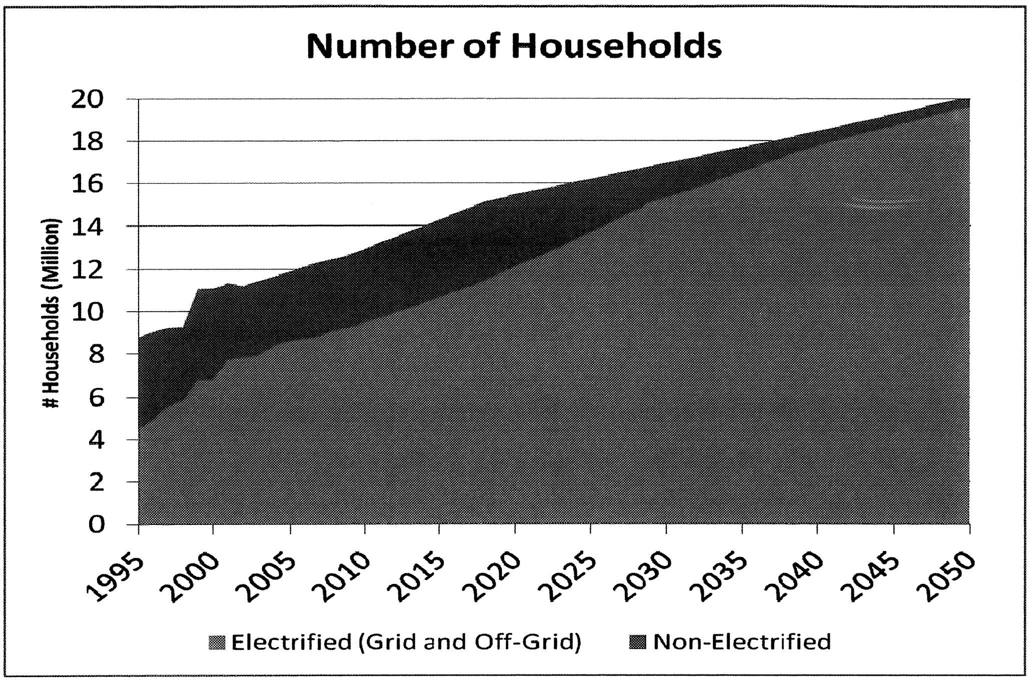


Figure 5-20: Projected number of electrified households

Increased electrification rates combined with continued developments in renewable energy technologies could see an increase in distributed electricity generation and a shift from use of other forms of energy (such as coal for cooking and space heating and illuminating paraffin for lighting) to electricity. However coal may continue to play a significant role in those areas situated close to mines and where coal is easily accessible and still relatively cheap.

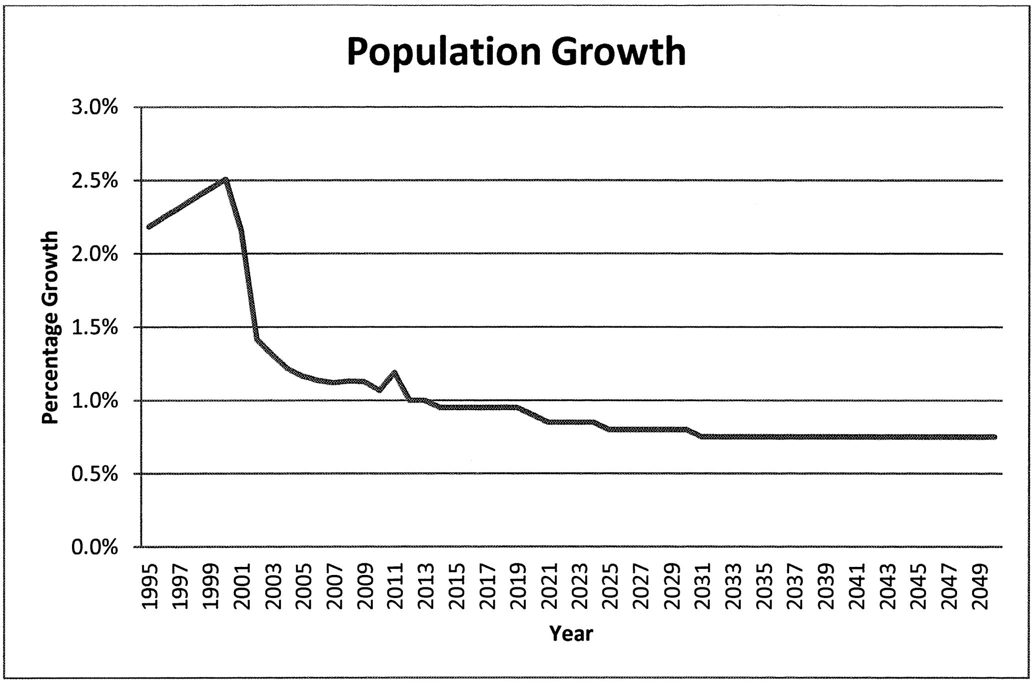


Figure 5-21: Projected population growth rate for South Africa

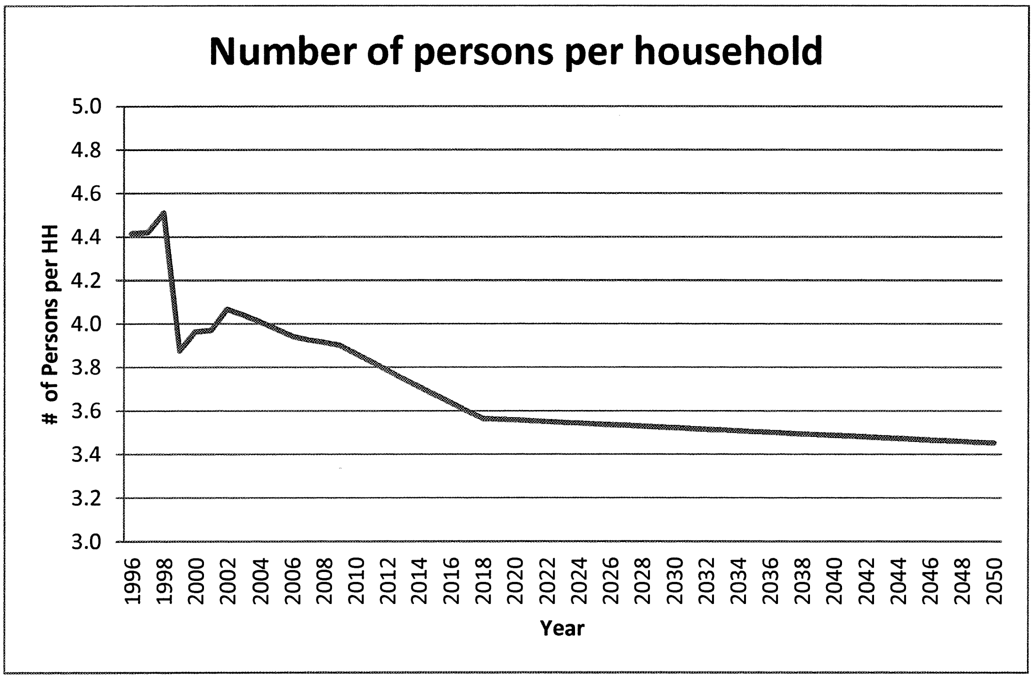


Figure 5-22: Projected number of persons per household

It is expected that, like the rest of the world, population growth will continue to be a key driver for energy demand in the household sector. The population growth rate in South Africa has been declining over the past 12 years and with increased urbanisation and household income, it is expected that it will continue to slow down and that the average number of persons per household will also decrease over time. Therefore while total energy demand is expected to increase as the population increases, the rate of increase is also expected to decline as a consequence. The composition of energy demanded or the forms of energy consumed will also change over time as household income and the number of electrified households increase. Increased urbanisation will also contribute towards the increase in the demand for electricity in the residential sector.

Based on the assumed population growth, projected number of households and the number of electrified households, the projected energy demand for the residential sector is depicted in Figure 5-23.

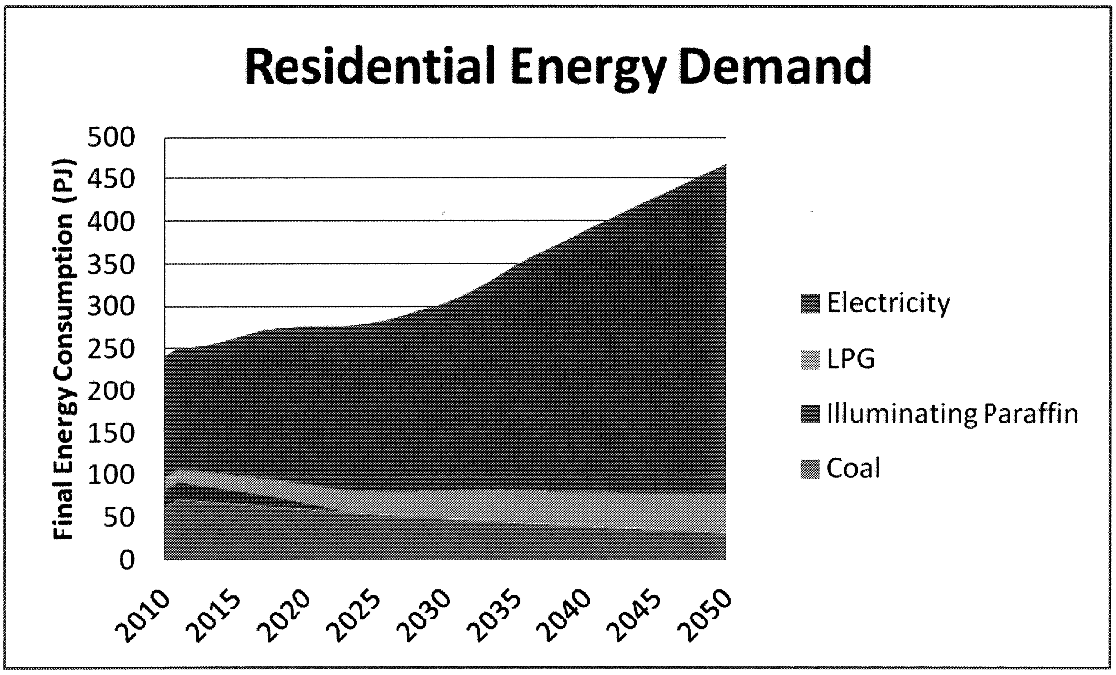


Figure 5-23: Projected Energy Demand for the Residential Sector

The decrease in coal usage continues while the use of cleaner forms of energy such as LPG and electricity increase and illuminating paraffin plays no role after 2022. Electricity continues to be the dominant energy carrier used within the residential sector with its share increasing substantially by 2050. However despite increased electrification, it is expected that coal will remain dominant in certain low-income households for the foreseeable future. Some of the key factors influencing the continued use of coal include the fact that it is relatively affordable fuel source (especially in communities close to mines) and it provides a dual utility (i.e. it provides thermal energy for space heating and cooking simultaneously).

While the general demand for electricity is expected to rise, ongoing increases in electricity tariffs could dampen this demand. Energy prices affect affordability of energy, especially in low-income households and the potential impact that this may have on future energy demand has not been factored and requires further analysis.

5.2.8 Total Energy Demand in all sectors

The projected energy demand within individual sectors is depicted in Figure 5-24.

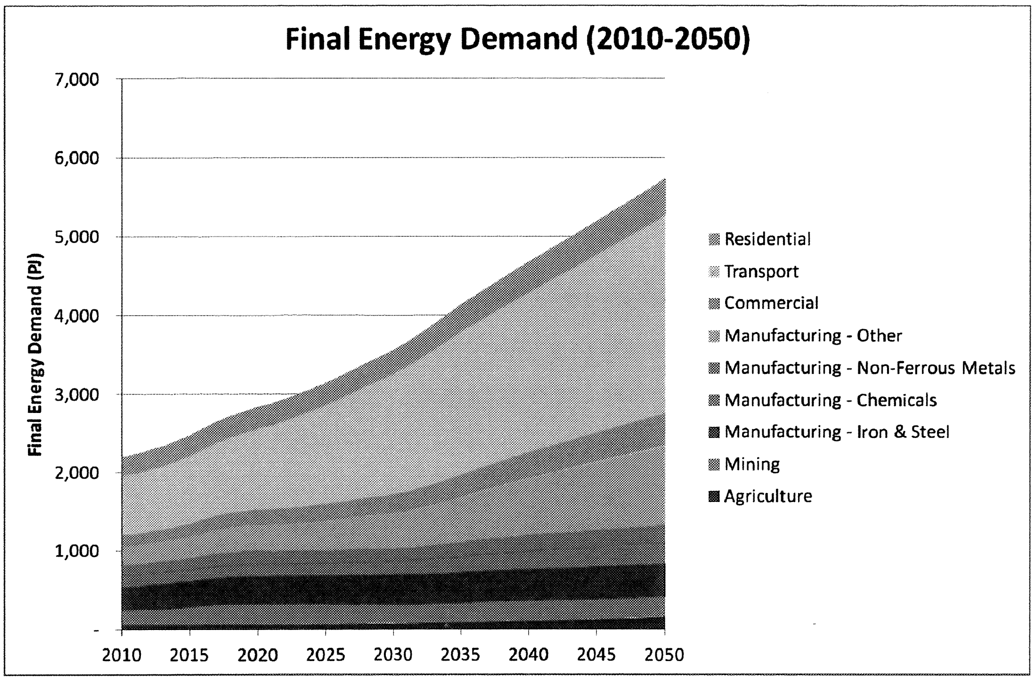


Figure 5-24: Projected demand within different sectors

The transport sector will continue to contribute the most significantly toward total energy demand. Demand for petroleum products therefore increases the most significantly between 2010 and 2050. This can be mostly attributed to the continued use of petrol and diesel vehicles into the foreseeable future with electric vehicles only starting to make a significant contribution for passenger transportation after 2030. Freight haulage, predominantly by road, contributes the most substantially to increases in transport demand and related fuel consumption.

Outside of the transport sector, the most significant energy demand increase is expected to be in industry (the manufacturing sector), followed by the commercial sector. The energy demand in the 'Other Manufacturing' sector is largely associated with projected economic growth, while the increase in energy demand within the commercial sector is associated with the continued expansion of the tertiary sector as South Africa moves to become more of a knowledge-based economy. Demand in the residential sector is largely informed by population growth coupled with increased urbanisation. As living standards improve, people also consume more energy; however energy efficiency interventions could see this trend start to slow down in the future.

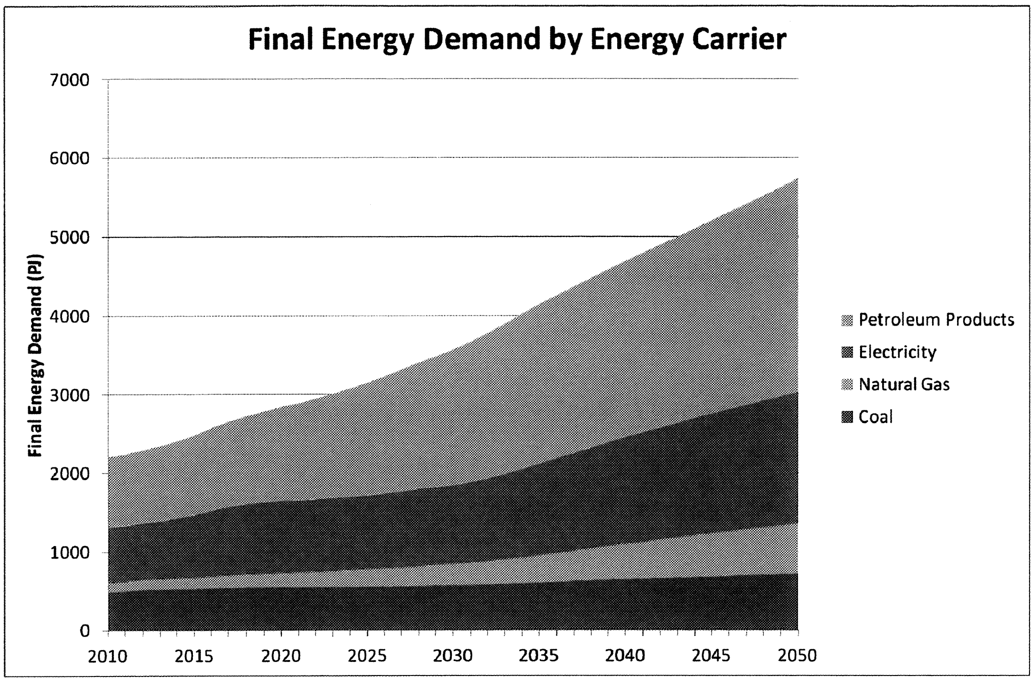


Figure 5-25: Total energy demand for different energy carriers

In line with the demand in different sectors depicted in Figure 5-24, demand for petroleum products increases the most significantly between 2010 and 2050 as this is primarily used within the transport sector. Demand for other petroleum products, is less significant, demand for LPG is expected to have a steady increase in the residential sector and although fairly minor ranks as the third largest increase between 2010 and 2050. Diesel consumption continues to increase in the mining sub-sector but only marginally when compared to electricity and natural gas. The use of illuminating paraffin is expected to decrease in future and to be negligible by 2025.

Demand for natural gas, although the least significant in terms of percentage share, shows the next most significant increase after that for petroleum products. Natural gas is primarily used within the industrial sector and the projected growth of the sector is a factor in this increase. Demand for electricity continues to rise as more houses become electrified and as the tertiary sector, largely comprised of commercial and public buildings continues to expand. In the industrial sector, the increase in electricity demand is largely attributed to the 'Other Manufacturing', non-ferrous and chemicals sub-sectors, with mining and iron & steel showing very little increase from current demand levels. Demand for coal continues to grow in the industrial sector, while in the residential sector it is expected to start declining as a result of ongoing electrification of previously non-electrified households and improvements in household income.

The share of energy demanded across different sectors in 2010, 2030 and 2050 is provided in the table below.

Table 5-3: Proportion of Current and Projected Final Energy Demand within different Sectors

SECTOR	2010	2030	2050	Change
Industry (Excluding Mining)	37%	33%	34%	⬇
Mining	8%	7%	4%	⬇
Agriculture	3%	2%	3%	▬
Commerce	7%	7%	7%	▬
Residential	11%	9%	8%	⬇
Transport	34%	43%	44%	⬆
TOTAL	**100%**	**100%**	**100%**	

5.2.9 Energy Intensity

Figure 5-26 and Figure 5-27 below show the changes in energy intensity for the different energy demand sectors relative to 2010 levels. Using 2010 as the base year (with an energy intensity index = 1), energy intensity index below 1 indicates an improvement or reduction in energy intensity relative to that in 2010, while an energy intensity index above 1 indicates an increase in energy intensity relative to that in 2010.

Figure 5-26 indicates an improvement in the energy intensity of the industrial, mining, commerce and transport sectors. Although energy demand increases in the tertiary sector (commerce and transport) the rate of increase is slower than projected economic growth and continues to decline throughout the planning period. The energy intensity in the mining sector increases initially (between 2010 and 2017) and starts to decline thereafter.

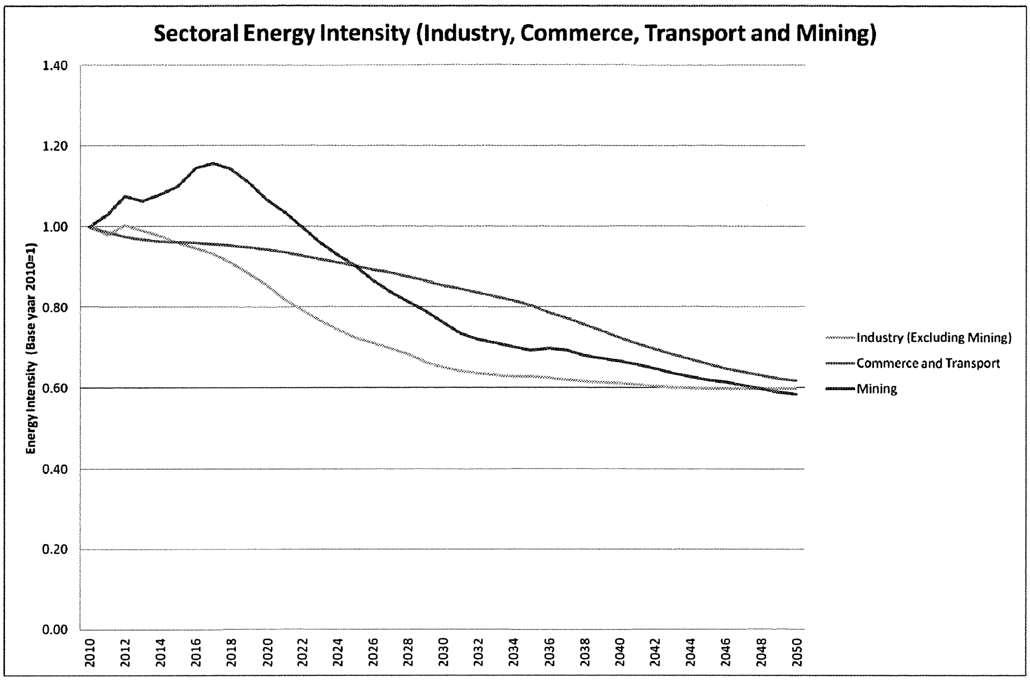


Figure 5-26: Energy Intensity Indices for the Industrial, Mining, Commercial and Transport Sectors

Unlike the sectors discussed above, energy intensity in the agricultural sectors worsens, followed by that in the residential sector (See Figure 5-27). In the agricultural sector, the significant increase in energy consumption is informed by large-scale intensive farming practices which continue to be adopted and the rate of future energy intensity improvements starts to decline. In the residential sector this is assumed to be influenced by the increasing population coupled with increased urbanisation and more energy consumption as household income increases.

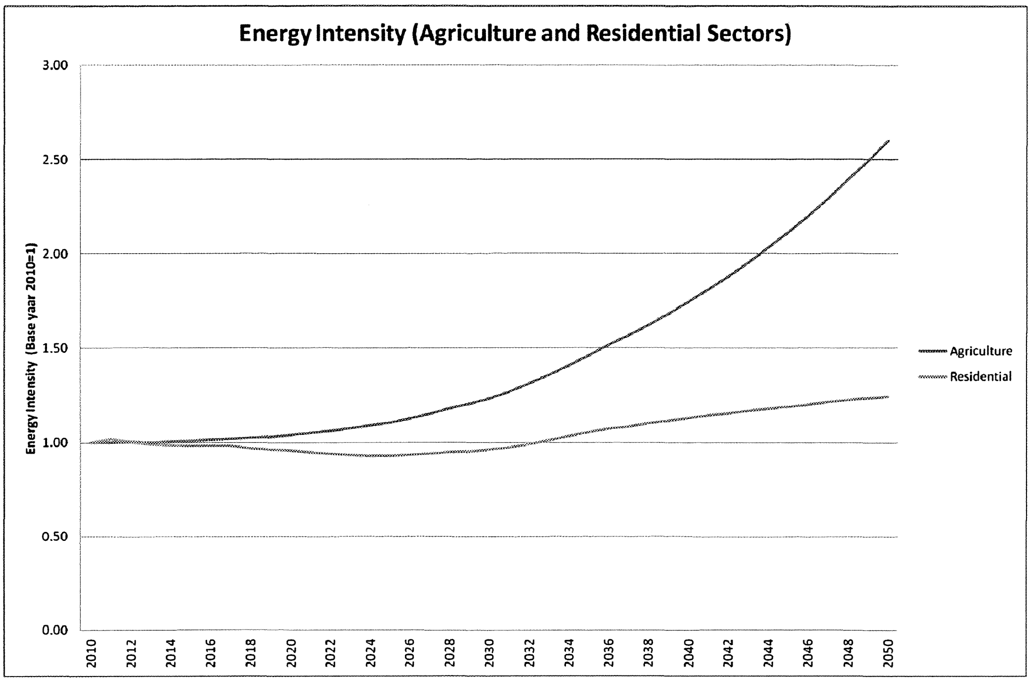


Figure 5-27: Energy Intensity Indices for the Agriculture and Residential Sectors

Figure 5-28 indicates an overall reduction in the intensity of the economy. Structural changes; significant changes in the level of activity; and technological and process improvements which have taken place within each of the sectors inform the projected demand and hence the reduction in energy intensity, Further analysis is required to quantify and separate the historical impact of structural changes, activity level changes and technological changes on energy intensity. Improvements in technologies, industrial processes and practices alone can play a significant role in future efficiency improvements and government policies, such as the recently published Draft National Energy Efficiency Strategy and interventions such the financial and tax incentives for energy efficiency could materialise in further reductions of energy intensity within these sectors.

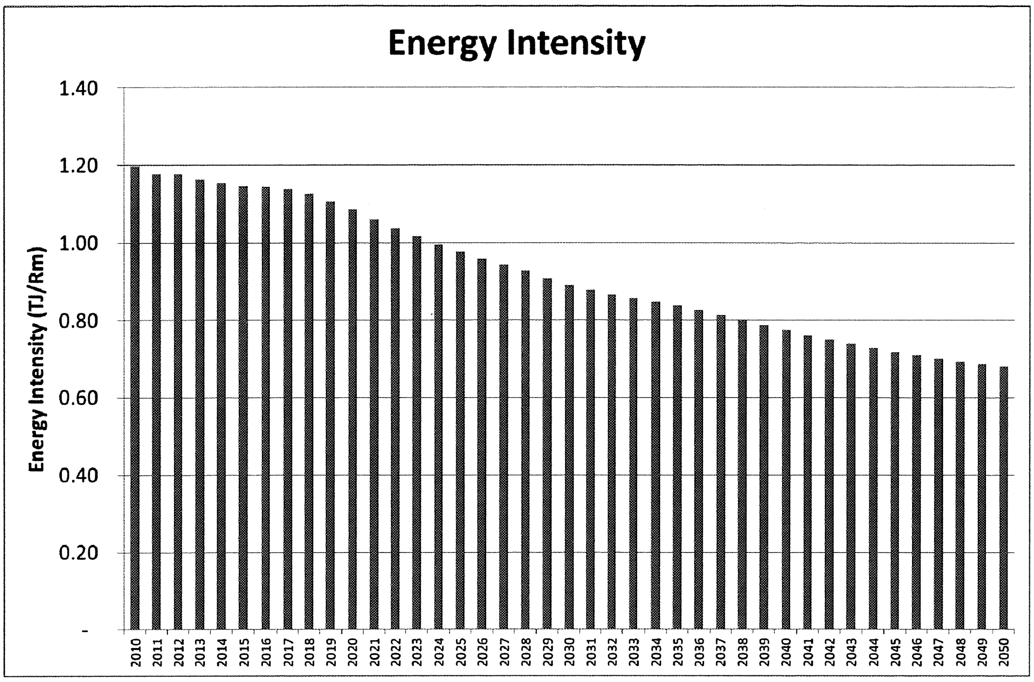


Figure 5-28: Energy intensity of the economy

SECTION 6: BASE CASE POLICY ASSUMPTIONS AND TEST CASES

This section provides the assumptions about key policies, costs and other factors which have an influence on energy supply options; and which can be represented and simulated by energy models. While many real world phenomena (physical, financial and economic) have an impact on the future optimal supply options, the selected models and modelling approaches simplify reality by considering only a subset of parameters which have a significant impact. Furthermore, only those assumptions (about real world phenomena) which can be translated into model parameters and quantified as parameter values need mention. This section is therefore limited in scope to those assumptions which inform the final values of the model parameters for the Base Case and the various Test Cases which were modelled.

The demand projections are a key input into the energy model and inform the required supply capacity. The underpinning objective of the energy planning process is to ensure that future energy supply options meet future energy demand. However in order to ensure a balanced consideration of all the eight objectives, different supply-side energy options are explored based on different sets of assumptions and constraints. As a starting point, the 'Base Case' is defined and serves as a basis to measure the extent to which current interventions within the energy sector can meet the constraints and targets set by various policies.

From this base, policy options which enable policymakers to consider alternative energy pathways that can be pursued are identified and evaluated. During the integrated energy planning process, various policy options (referred to as Test Cases) were identified and modelled. These Test Cases were informed by national government policies which are considered to be high-impact policies for the energy sector, and include the Integrated Resource Plan, National Development Plan, the National Climate Change Response Policy and the impending Carbon Tax Policy.

6.1 Base Case Assumptions

BASE CASE

- The Base Case encapsulates the state of energy demand and supply over the planning horizon, which is most closely informed by current energy market trends; the national macroeconomic outlook; assumed energy prices; existing energy infrastructure and the existing suite of policies and government programmes. Thus, while the IEP seeks to recommend an energy roadmap or policy pathway for the energy sector, this process is not conducted in isolation and should build on energy policies, strategies and plans which have already been adopted.
- **The Base Case, is therefore not a representation of the most likely future or most likely scenario, but is rather a simplistic representation of a future outcome that could materialise in light of current policies and macroeconomic trends. It represents a Business-As-Usual or Status Quo scenario where current trends continue into the future.**

Table 6-1: Key IEP Base Case Assumptions

PARAMETER	DESCRIPTION	ASSUMPTION
IEP Planning Horizon	The period over which key assumptions which inform demand projections and supply options are made	2010-2050
Base Year	The starting year on which projections are made. Any values/data prior to and including the base year are based on actuals. While any values/data after the base year are projections.	2010
Annual Emission Limit	This sets annual limits on allowable emissions	No emissions limit constraints are defined in Base Case
Emissions Penalty	This enables emission penalties (such as the carbon tax) to be imposed in the model	No emissions penalties (carbon taxes) are defined in Base Case
Renewable Energy Minimum Production Target (electricity generation)	This allows for renewable energy targets to be set in the model (i.e. minimum capacity of total energy mix that must come from renewable energy technologies)	No renewable energy targets are set in the Base Case. Only renewable energy technologies as per the 2011 and 2012 determinations are included (See Table 6-2).
Integrated Resource Plan		The Policy-Adjusted IRP (IRP2010), which was promulgated in March 2011, sets targets as to the share of electricity-generation capacity by various carriers. Several projects included in the IRP2010 have already been committed, while a window of decision-making still remains open for firm commitments to be made on others. It therefore follows that all projects which are already committed are included in the Base Case of the IEP, while alternative options may still be considered for those technologies or projects for which firm commitments are yet to be made. Electricity supply options included in the IEP Base Case are therefore informed by the

PARAMETER	DESCRIPTION	ASSUMPTION
		current commitments as defined in the IRP2010. These are Eskom's pre-IRP determinations as well as the 2011 and 2012 determinations (See Table 6-2).
Liquid Fuel Production		No constraints are defined for liquid fuel production
Technology Options		All technologies are considered and there are no model constraints on energy supply options

Table 6-2: Committed IRP2010 Build Plan

	New build options								Committed					Non IRP	
	Coal imports	Nuclear	Import hydro	Gas – CCGT	Peak – OCGT[1]	Wind	CSP	Solar PV	Coal	Other	DoE Peaker	Wind[2]	Other Renew.	Co-generation	TOTAL
	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW	MW
2010	-	-	-	-	-	-	-	-	380	260	-	-	-	-	640
2011	-	-	-	-	-	-	-	-	679	130	-	-	-	-	809
2012	-	-	-	-	-	-	-	300	303	-	-	400	100	-	1,103
2013	-	-	-	-	-	-	-	300	823	333	1,020	400	25	-	2,901
2014	500	-	-	-	-	400	-	300	722	999			100	-	3,021
2015	500	-	-	-	-	400	-	300	1,444				100	200	2,944
2016	-	-	-	-	-	400	100	300	722					200	1,722
2017	-	-	-	-	-	400	100	300	2,168					200	3,168
2018	-	-	-	-	-	400	100	300	723					200	1,723
2019	250	-	-	237	-	400	100	300	1,446						2,733
2020	250	-	-	237	-	400	100	300	723						2,010
2021	250		-	237	-										487
2022	250		1,143		805										2,198
2023	250		1,183		805										2,238
2024	250		283		-										533
2025					805										805
2026															-
2027															-
2028															-
2029															-
2030															-
Total	2,500	-	2,609	711	2,415	2,800	500	2,700	10,133	1,722	1,020	800	325	800	29,035

Eskom Commitments (Pre IRP)
2011 determinations
2012 determinations

6.2 Test Cases

Market activity alone does not deliver optimal solutions to the challenges faced by the energy sector, such as the guarantee of energy security, the reduction of GHG emissions, the reduction in energy intensity, or increasing energy efficiency within the economy. Thus, in some instances government intervention – through policy and regulation – is necessary to ensure the delivery of certain services to the public and the attainment of certain policy objectives.

Energy is an integral part of the economy and the energy sector is a key enabler for the attainment of national policy imperatives. It is therefore important to quantify and provide feedback on the extent to which the energy sector can contribute to the attainment of various national policy imperatives. It is equally important to quantify and provide feedback on the extent to which policy objectives outside the energy sector may impact on the attainment of energy sector imperatives.

In section SECTION 2: several policies, identified and described as "high-impact" policies, were discussed. These "high-impact" policies have a significant impact and influence on the development of energy policies as they require some level of intervention or deviation from the status quo from the energy sector. Therefore while the Base Case largely assumes that only prevailing policies are pursued to shape the future energy pathway, the effects of these "high-impact" policies on the future energy landscape is considered and the concept of different Test Cases to explore these possible policy impacts is introduced.

TEST CASE

- A Test Case will be defined as a **deviation from the status quo** where current trends do not continue into the future and **deviations are as a result of specific policy interventions**. A Test Case therefore defines a set of circumstances and resultant outcomes or impacts which is informed by the possible impacts of policies and policy interventions. A Test Case does not indicate what will happen but rather tests what could happen if a particular course of action is pursued.
- While Test Cases are sometimes also referred to as scenarios, within the context of the IEP and for the purposes of common interpretation, a Test Case is specifically differentiated from a Scenario in that a **Scenario is largely influenced by exogenous forces** which the policy maker has no control over, while **a Test Case seeks to test the possible implications of active policy interventions**.

This section provides a list of the Test Cases that were considered and modelled during the energy planning process. A brief background of the policy issues which led to the choice of these Test Cases is also provided.

6.2.1 Policy Issue: Climate Change and Emissions Reduction

According to the National Climate Change Response Policy (NCCRP), the energy sector contributed about 80 percent towards total carbon emissions for the country in 2000, of which the majority arose from electricity generation (40 percent of total emissions). Emissions from oil refining and production of synthetic fuels (CTL and GTL) were estimated to contribute 9 percent towards total emissions. Therefore, total emissions from the energy transformation and conversion processes contribute approximately 49% towards total emissions.

The President announced that South Africa will implement mitigation actions that will collectively result in a 34% and a 42% deviation below a 'Business As Usual' emissions growth trajectory by 2020 and 2025 respectively. The NCCRP defines these targeted reductions in total emissions as the 'Peak-Plateau-

Decline' emissions trajectory, and the work on further translation of these reductions by each sector is currently underway.

The extent to which this outcome can be achieved depends on the extent to which developed countries meet their commitment to provide financial, capacity-building, technology development and technology transfer support to developing countries. With financial, technology and capacity-building support, this level of effort will enable South Africa's GHG emissions to peak between 2020 and 2025, plateau for approximately a decade and decline in absolute terms thereafter.

The national emissions limits aligned with the "Peak-Plateau-Decline" trajectory are presented in Figure 6-1.

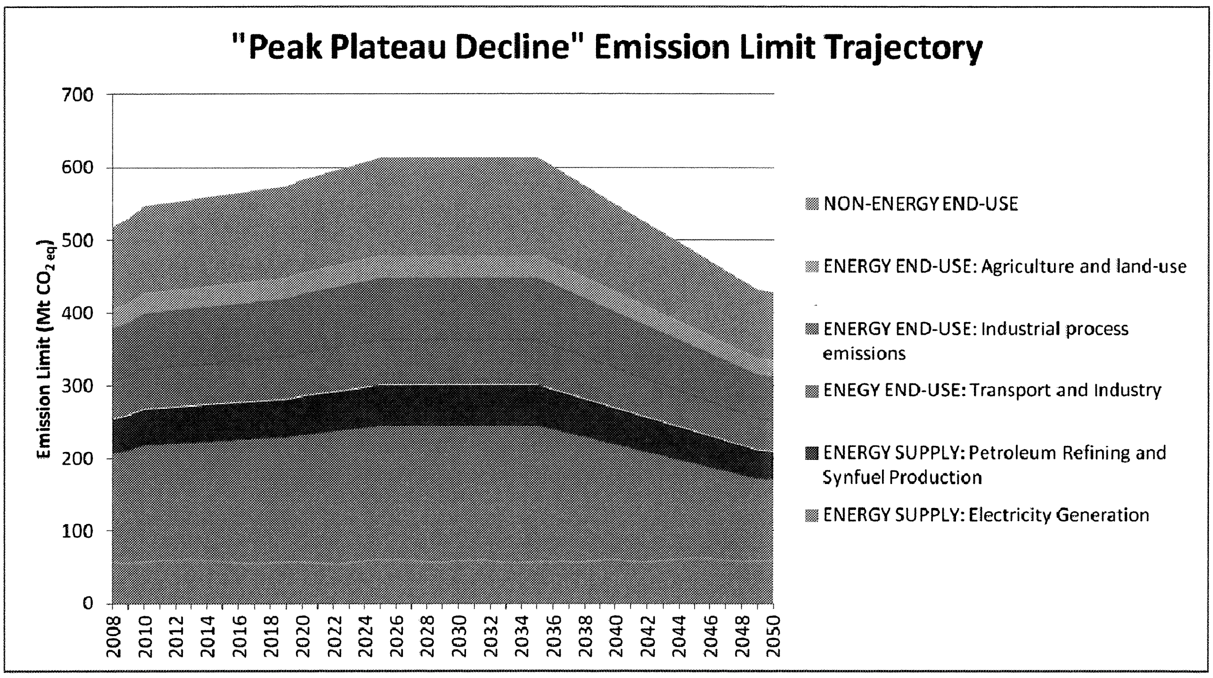


Figure 6-1: National CO_2 emissions limits for Peak-Plateau-Decline

In light of the above and in efforts to support the country's aspirations of reducing emissions, the National Treasury has published a draft Carbon Tax Policy Document which will introduce a carbon tax across all relevant sectors.

6.2.2 Policy Issue: Addressing Climate Change and the Role of Alternative Supply Options such as Nuclear and Natural Gas

Nuclear is seen as a viable electricity supply option in moving the country towards a low emissions trajectory. The IRP 2010 recommends power generation from nuclear power stations as a viable supply option and sees the capacity of nuclear power plants contributing approximately 20% towards the total energy mix by 2030 as compared to 5% in 2010. The nuclear policy sees nuclear technology playing a significant role in reducing emissions from electricity generation as well as contributing towards diversifying the energy mix.

One of the recommendations from the National Development Plan is that while clean-coal technologies (such as Carbon capture and Storage) are still in the nascent stage of development, natural gas should be considered as an alternative to coal, provided that the overall economic and environmental costs and benefits outweigh those associated with South Africa's dependence on coal, or with the alternative of nuclear power. All conventional and unconventional natural gas options should be considered and these include off-shore natural gas coal-bed methane and shale gas.

6.2.3 Policy Issue: The role of Renewable Energy Technologies in moving towards a low-carbon economy

The Renewable Energy White Paper sets a contribution target of 10 000 GWh of renewable energy towards the final energy consumption by 2013. Furthermore, the policy states that the renewable energy is to be utilised for power generation and non-electric technologies such as solar water heating and biofuels. The 10 000 GWh was estimated at approximately 4 percent (1 667 MW) of the projected electricity demand for 2013, which had been projected as 41 539 MW.

While the actual realisation of this target has lagged behind, government remains committed to increasing the share of renewable energy within the total energy mix of the country.

Given the rapid development of renewable energy technologies and the role that they can play in reducing emissions and providing both on-grid and off-grid supply options, these should be considered as an alternative options provided that the environmental and economic benefits outweigh those of other supply options.

6.2.4 Policy Issue: Liquid Fuels Supply Options under different crude oil price scenarios

While mobility is a key contributor to energy demand, developments in technology could see the move away from traditional modes of transport (e.g. liquid fuel powered passenger vehicles) to more efficient and less costly means of transport (e.g. electric trains and passenger vehicles, CNG buses). However the penetration of these modes of transport and the associated impact on the demand for liquid fuels is projected to only be felt in the long term (i.e. more than 20 years). Therefore for South Africa, it is assumed that traditional modes of transport (i.e. fuel-powered vehicles, with minimal penetration of electric and hybrid vehicles) will continue into the foreseeable future (Kruger, 2012). The continued reliance on liquid fuel and inherently crude oil presents with it various challenges.

As a net importer of crude oil, South Africa is a price taker in the oil market and its market is highly sensitive to fluctuating global oil prices.

The Department of Energy is in the process of introducing new fuel specifications (CF2) which will ensure a refined product with reduced sulphur content, thereby reducing the quantity of pollutants from the liquid fuel and transportation sectors. South Africa is currently also considering the construction of new refining capacity which would be aligned with these specifications.

The National Development Plan presents five different options that South Africa should consider and provides a high-level analysis of the advantages and disadvantages associated with each of the options presented:

1) Build a new oil-to-liquid refinery;
2) Build a new coal-to-liquid refinery;
3) Upgrade existing refineries or allow significant expansions of one or more of the existing refineries or both;
4) Import refined product; and/or
5) Partner with Angola or Nigeria to build a new refinery.

These options need to be analysed and evaluated such that decisions made in the short-term remain viable in the long-term.

Table 6-3: List of Test Cases

TEST CASE	DESCRIPTION	POLICY ISSUE
'Peak-Plateau-Decline' Emissions Limit Case	• Annual emissions limits for power generation and liquid fuel supply as derived from the 'Peak-Plateau-Decline' trajectory are set as the upper bound. • No carbon tax is imposed and emission constraints are met through energy supply options. • All supply options are considered (including nuclear and natural gas options).	This Test Case seeks to evaluate alternative energy supply technology options and the associated financial implications of ensuring that the energy sector meets the emission reduction targets defined in the National Climate Change Response Policy.
Emissions Limit - No Nuclear Build Programme Case:	• The emissions limits of the "Peak Plateau Decline" must be met. • The 9,600MW Nuclear Build Programme is explicitly excluded as a supply option.	Given the country's commitments to reduce carbon emissions, coupled with the public outcry from various interest groups regarding the role of nuclear technology in the energy mix, this Test Case seeks to assess the efficacy of ensuring security of supply while simultaneously ensuring that the emissions reduction targets are met without nuclear as a supply option.
Emissions Limit - Natural Gas (No Nuclear) Case	• The emissions limit of the "Peak Plateau Decline" trajectory must be met. • The Nuclear Build Programme is explicitly excluded as a supply option. • Natural gas options for electricity generation are explicitly included as a policy intervention.	This Test Case seeks to analyse the efficacy of including natural gas in the energy supply mix as a transitional fuel towards a low carbon economy and the implications of choosing this as a supply option over nuclear. In this context natural gas includes conventional gas, coal bed methane and shale gas.

Carbon Tax Case	• No emissions limit constraints are set. • A carbon tax of R120 per ton of CO_2-eq above the 60% tax-free threshold is set for the first five years. The carbon tax rate is increased by 10% per annum for a further five years and is absolute thereafter.[3]	This test case seeks to provide insight as to the efficacy of a carbon tax on the reduction of emissions to be within the "Peak-Plateau-Decline" trajectory. It also analyses the cost implications of a possible carbon tax on the energy sector as defined in the impending Carbon Tax Policy.
Renewable Energy Target Case	• No emission limit constraints are set. • Renewable energy options are gradually introduced into the energy mix from 2010 to 2030 such that by 2030, 10% of total energy output (electricity generation and liquid fuel production) is from renewable energy sources. • From 2031 onwards, the target of 10% is maintained as a minimum. (It should be noted that given the low load factors for most renewable energy technologies, the installed capacity would effectively be much higher than 10%).	This Test Case analyses the efficacy of setting renewable energy targets for reducing emissions within the energy sector. It also provides insight into the economic implications of renewable technologies as an alternative option in the energy mix.
Low Crude Oil Price Case **High Crude Oil Price Case**	• In these test cases sensitivity analyses of the low and high crude oil price scenarios are conducted to determine the most optimal liquid fuel supply options under each price scenario. • The prices of other commodities coal and natural gas are assumed to remain the same as for the Base Case. • No emissions limit constraints are set.	These sensitivity analyses seek to assess the best way of ensuring security of fuel supply in the country for different sets of crude oil price scenarios. (Note: Fuels pertain to final product and therefore includes fuel produced from conventional crude oil refineries as well as synfuels from coal to liquids (CTL) and GTL production processes). This therefore seeks to provide responses to the five liquid fuel supply options presented in the National development Plan.

[3] The actual value of the carbon tax is subject to review once the Carbon Tax Policy has been promulgated

SECTION 7: ANALYSIS OF MODEL OUTPUT

This section provides a summary of the results from modelling the Base Case and the Test Cases described in the previous section. The detailed analysis of the model output is provided in the Technical Report on Model Output (**Annexure A**). The section is structured as follows:

- Total Electricity Generation and Liquid Fuel Capacity by Technology Type
- Primary Energy Use: The sources of primary energy are discussed as well as the change in the primary energy mix within the particular Test Case.
- Discounted cost of plan: The discounted costs for all technology types for the planning period are provided.
- Overall Emissions and Water Usage: The implications for water demand and carbon dioxide emissions are presented for the whole energy supply sector.

7.1 Electricity Generation Capacity

Figures 7-1 through to 7-5 provide total capacity for electricity generation between 2010 to 2050 for the Base Case and several Test Cases for various technology types. The technology options for electricity generation for the High Oil Price and the Low Oil Price Test Cases remains the same as the Base Case as changes in crude oil price have little impact on electricity generation options.

- Coal technologies continue to play a role in the Base Case and all Test Cases however this is reduced significantly by 2030 as the existing fleet of coal technologies starts to be retired. The role of coal technologies continues to decline in the three Test Cases within emissions limits as no new coal power plants (besides Medupi and Kusile) are brought onstream. However in the Base Case and the Renewable Energy Target Cases new coal technologies continue to contribute to electricity supply (approximately an additional 50GW by 2050 in the Base Case and 30GW in the Renewable Energy Target Case).

- Solar plays a significant role in the Base Case and all Test Cases as the cost of solar technologies is projected to continue declining in the foreseeable future. Solar shows the biggest increase in contribution to the total energy mix in the Base Case and all Test Cases.

- The contribution of wind technologies reduces in the Base Case as other options are more cost effective in the absence of emissions limits or renewable energy targets and as wind technologies. However wind does play a significant role in the Emissions Limit and Renewable Energy Target Test Cases. Wind shows the second biggest increase in contribution in all Test Cases.

- A new nuclear plant is selected by the model in the Emissions Limit Case with no explicit exclusion of nuclear. Nuclear, together with Renewable Energy technologies are therefore viable options in reducing emissions in the Emissions Limit Test Cases.

- Biomass only features in the Renewable Energy Target Test Case in order to ensure that the renewable energy targets are met.

- Besides the natural gas options included as part of the ministerial determinations, new natural gas options do not feature prominently in the Base Case or any of the Test Cases. New natural gas only features in the Test Case where Natural Gas options are explicitly enforced.

- While coal-fired power plants with Carbon Capture and Storage (CCS) technologies were considered as an option, due to their relatively high cost the model does not select any CCS technologies in the Test Cases with emissions limits as other cheaper alternatives are available.

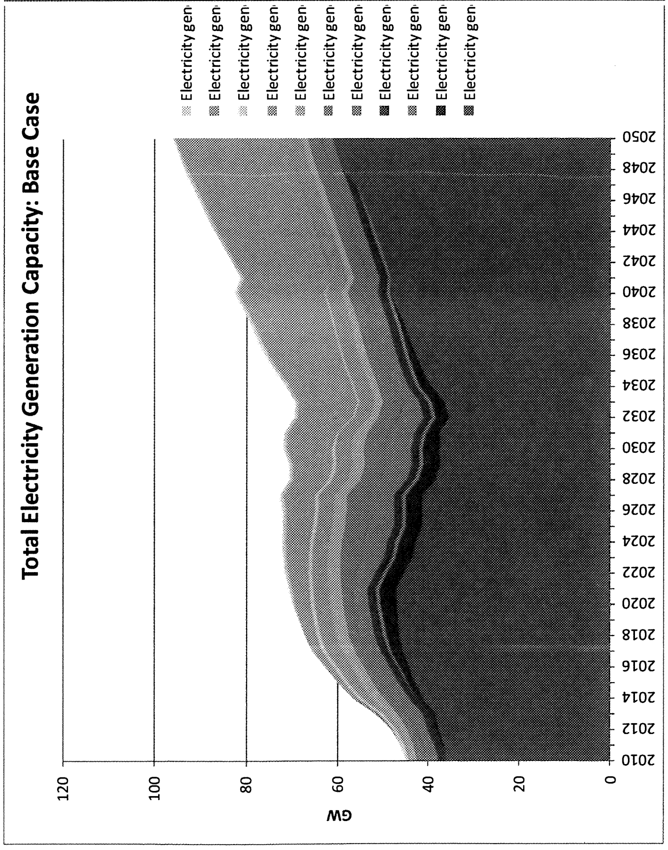


Figure 7-1: Electricity generation capacity: Base Case

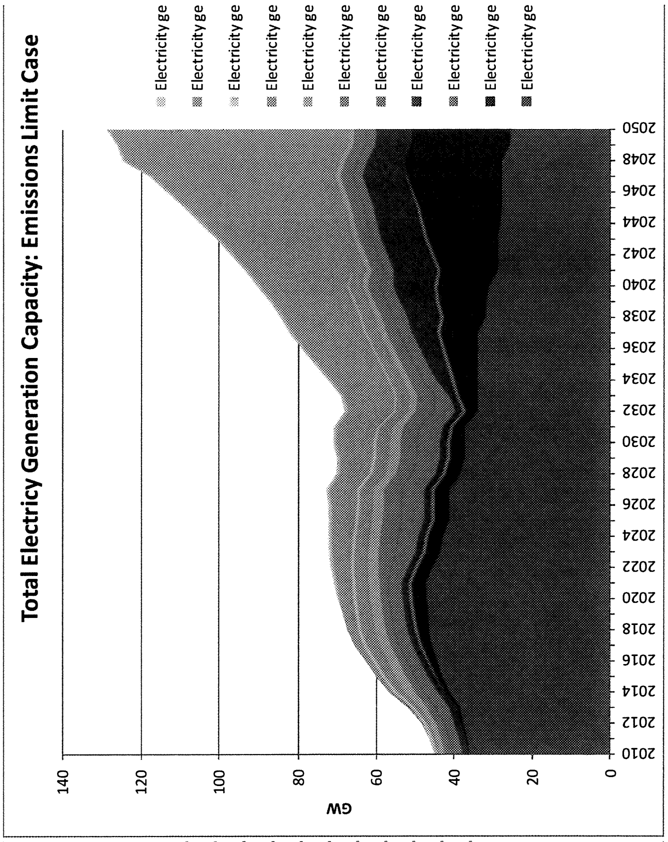


Figure 7-2: Electricity generation capacity: Emissions Limit Case

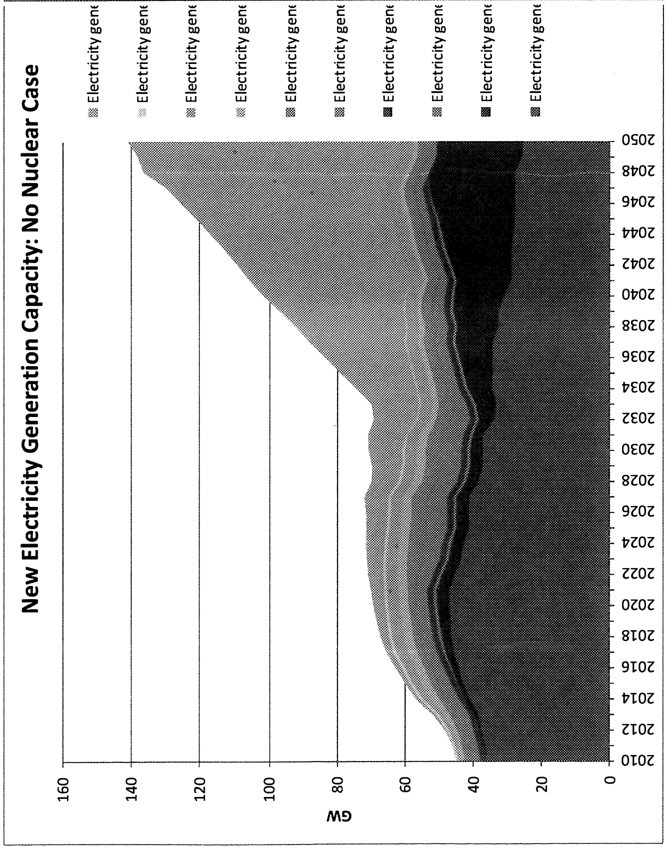


Figure 7-3: Electricity generation capacity: Emissions Limit – No Nuclear Case

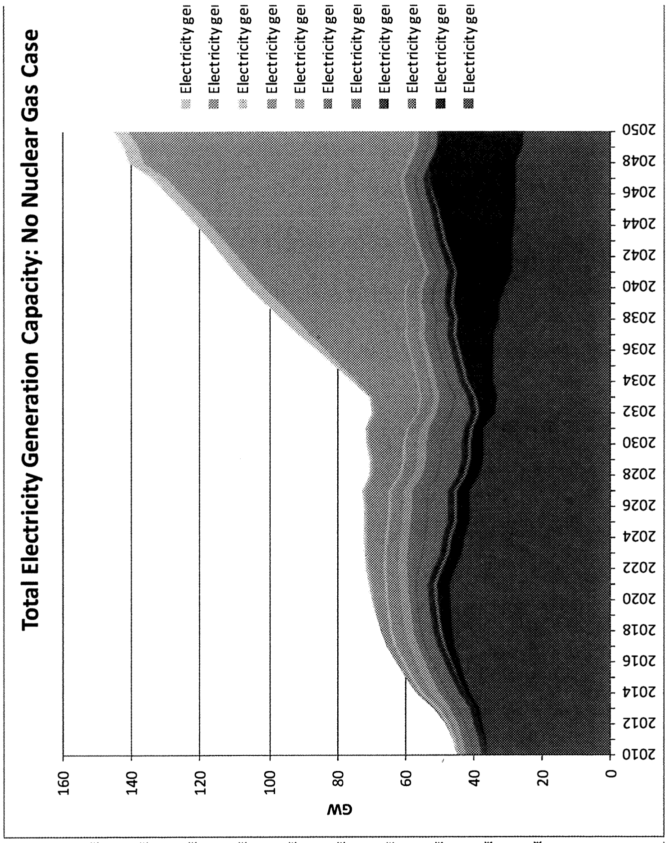


Figure 7-4: Electricity generation capacity: Emissions Limit – Natural Gas Case

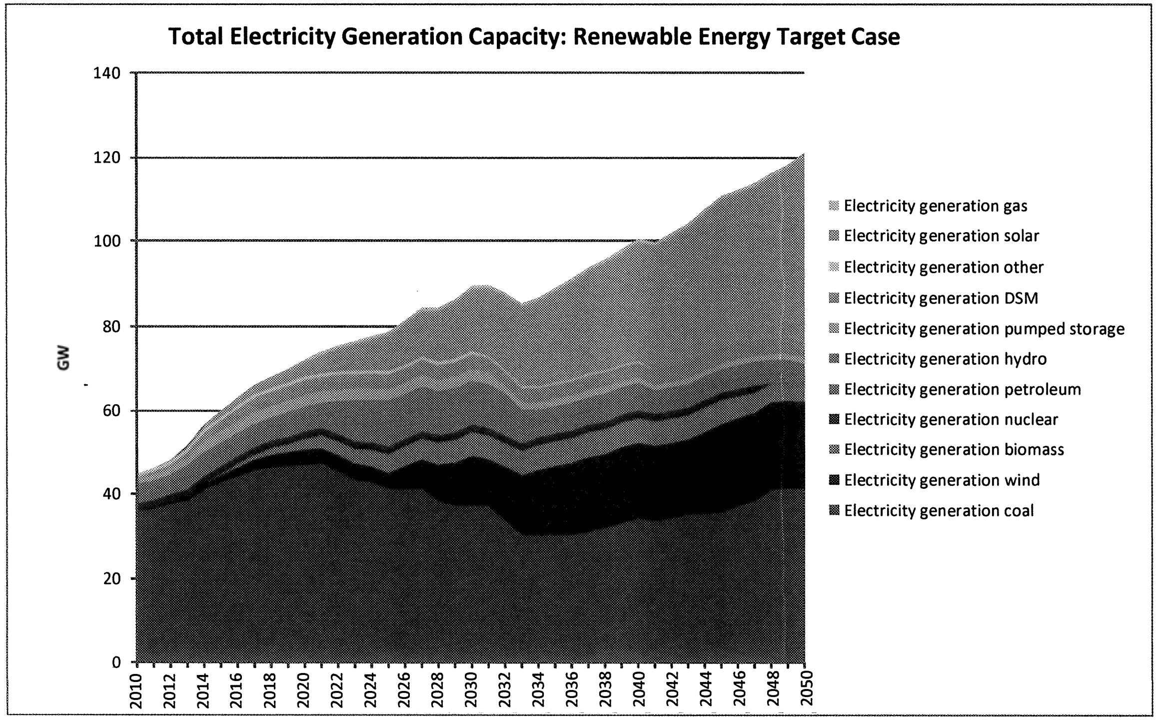
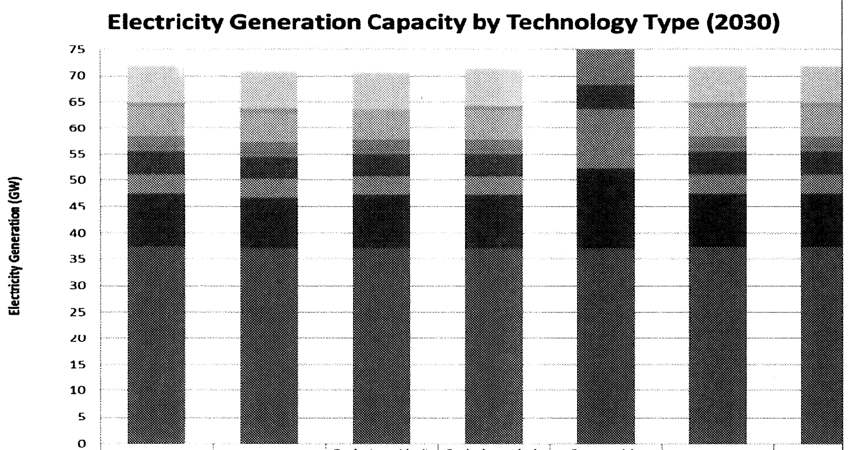


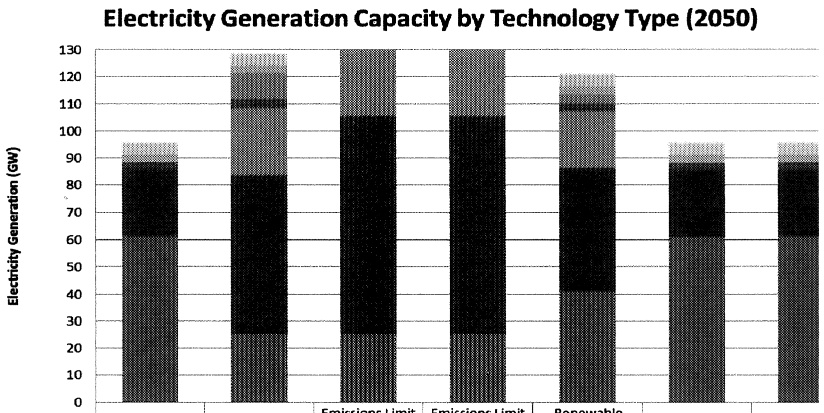
Figure 7-5: Electricity generation capacity: Renewable Energy Target Case

Figures 7-6 and 7-7 indicate the proportion of electricity generation by the various technology types at 2030 and 2050. While the share of electricity generation capacity by technology type is similar in all test cases in 2030, by 2050 there is a significant reduction in electricity generated from coal and this is replaced largely by solar, followed by wind technologies. The Emissions Limit Case with no technology constraints presents an electricity generation mix with the most diversity in terms of technology and nuclear plays a prominent role. Given the low load factors for most renewable energy technologies, the total installed capacity for the Test Cases with significant renewable energy technologies is higher than for those Test Cases without.



	Base Case	Emissions Limit Case	Emissions Limit - No Nuclear Case	Emissions Limit - Natural Gas Case	Renewable Energy Target Case	High Oil Price Case	Low Oil I Case
Other*	7.1	7.1	7.1	7.1	2.1	7.1	7.1
Gas	0.7	0.7		0.7	0.711	0.7	0.7
Petroleum	5.8	5.8	5.8	5.8	5.835	5.8	5.8
Nuclear	1.8	1.8	1.8	1.8	1.8	1.8	1.8
Biomass	0.9	0.9	0.9	0.9	5.799018851	0.9	0.9
Hydro	4.6	4.2	4.2	4.2	4.609	4.6	4.6
Wind	3.6	3.6	3.6	3.6	11.63878294	3.6	3.6
Solar	9.9	9.4	9.9	9.9	14.8	9.9	9.9
Coal	37.5	37.3	37.3	37.3	37.321	37.5	37.5

Figure 7-6: Electricity generation capacity by technology type (2030)



	Base Case	Emissions Limit Case	Emissions Limit - No Nuclear Case	Emissions Limit - Natural Gas Case	Renewable Energy Target Case	High Oil Price Case	Low Oil I Case
Other *	4.9	4.9	4.9	4.9	4.91	4.9	4.9
Gas	0.2	0.2		4	0.237	0.2	0.2
Petroleum	2.4	2.4	2.4	2.4	2.415	2.4	2.4
Nuclear		9.6					
Biomass					3.417120576		
Hydro	3.1	3.1	3.1	3.1	3.109	3.1	3.1
Wind		25	25	25	20.90722329		
Solar	24	58.1	80.1	80.1	44.99309098	24	24
Coal	61.2	25.4	25.4	25.4	41.20415853	61.1	61.2

Figure 7-7: Electricity generation capacity by technology type (2050)

7.2 Liquid Fuel Production

Figures 7-8 through to 7-12 provide total capacity for liquid fuel production between 2010 to 2050 for the Base Case and several Test Cases for various technology types. The exclusion of nuclear energy (i.e. Emissions Limit – No Nuclear Case) has no significant impact on the liquid fuels sector in comparison to the Emissions limit case. Likewise the enforcement of natural gas as a supply option (i.e. Emissions Limit – Natural Gas Case) also has no significant impact on the liquid fuel sector. The output from these two test cases therefore requires no further analysis in this section as the output is the same as that for the Emissions Limit Test Case.

- In the Base Case and all Test Cases, the model selects new refining capacity to meet future liquid fuel demand from as early as 2020.
- New conventional crude oil refineries are a viable option in the Base Case and all Test Cases, however additional capacity in the outer years is reduced for the Emission Limit Test Cases. It is assumed that existing conventional refineries are not retired within the modelling period and that their operational life is extended through continued maintenance, occasional upgrades (usually related to fuel specifications) and the low cost of maintaining the existing refineries relative to the cost of crude oil processed.
- In the Base Case and test cases without emissions limits, the cost of producing liquid fuels from coal are lower than both conventional refineries and gas to liquids as presented in the assumptions. In these test cases coal to liquids is built to the maximum constraint set in the input parameters of 80 000 barrels per day, after which conventional refineries are added to provide for the liquid fuels demand. In the Emissions Limit Test Case, new coal to liquid plants are restricted to their high carbon emissions and a new plant only features after 2040 when the existing coal to liquids plant is decommissioned and the use of electric vehicles reduces overall emissions below the emissions limits therefore providing scope for the more cost-effective coal to liquid plant. In the absence of a carbon tax, the total discounted cost of providing liquid fuels from coal to liquids is lower than both conventional refineries and gas to liquids.
- The total liquid fuel production slows down by 2034 and plateaus to 2040 after which it declines as a result of electric vehicle penetration.
- No new Gas-to-Liquid (GTL) plants are selected by the model. This is partially informed by the relative costs of new GTL plants as compared to conventional crude oil refineries

- In the absence of emissions limit constraints, the model output shows very little sensitivity to different crude oil price assumptions with conventional refining capacity increasing in the outer years.

- All supply shortfalls are met via imports in all Test Cases.

- In 2012 the Department of Energy has published Regulations on the Mandatory Blending of Biofuels with Petrol and Diesel. The regulations require a minimum concentration of 5% biodiesel blending and between 2% and 10% for bio-ethanol blending. The requirement for biofuel blending has not been explicitly included in the model but will have negligible impact on the liquid fuel supply options for the Base Case and the various Test Cases.

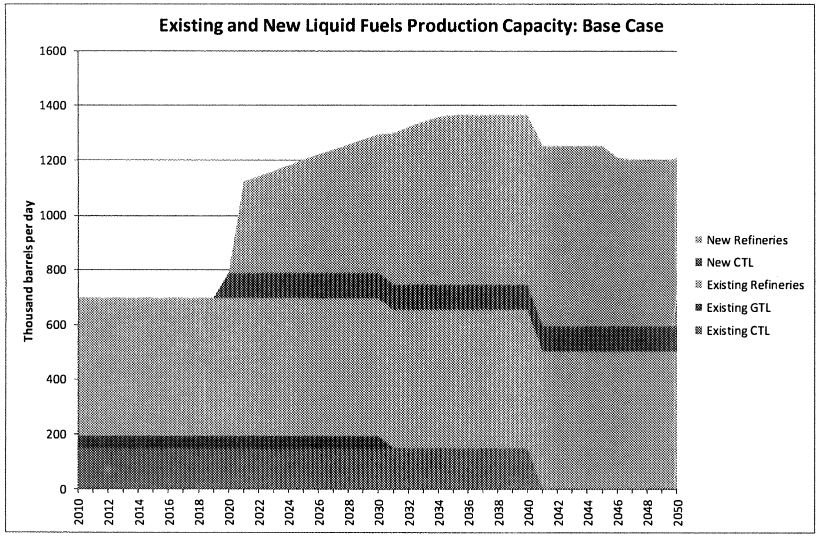


Figure 7-8: Total capacity in liquid fuel production: Base Case

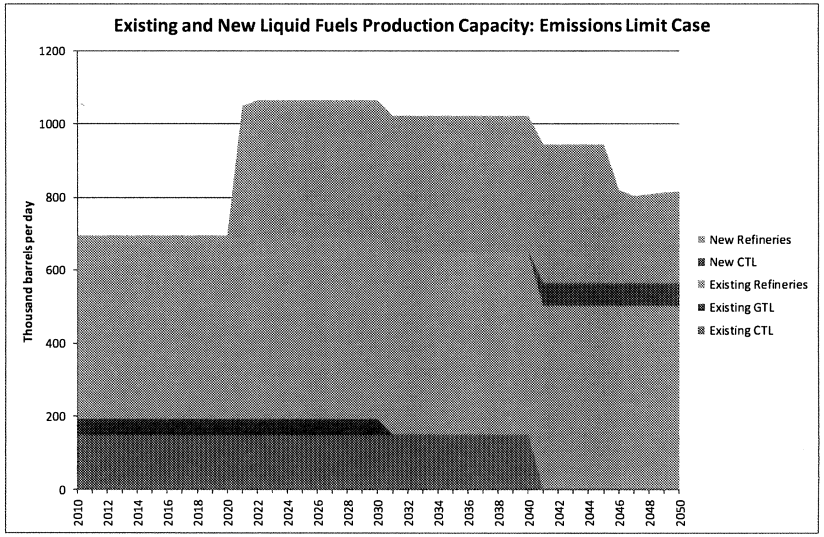


Figure 7-9: Total capacity in liquid fuel production: Emission Limit Case

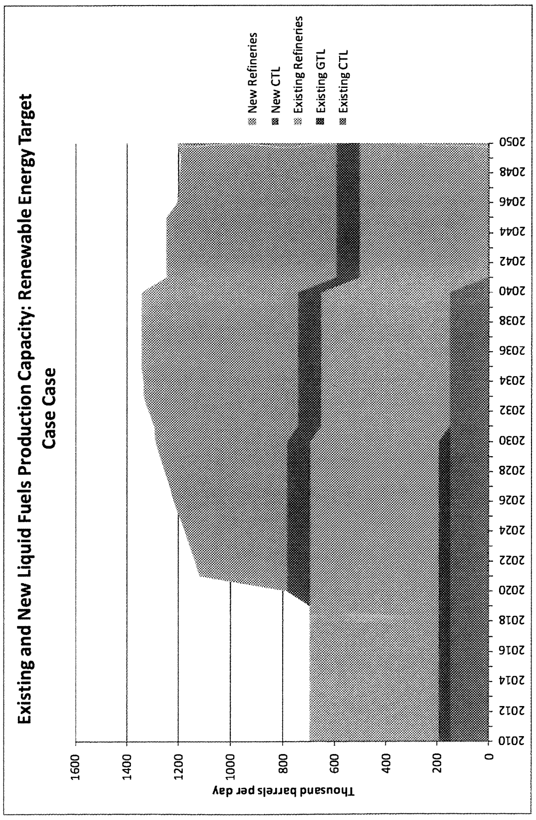


Figure 7-10: Total capacity in liquid fuel production: Renewable Energy Target Case

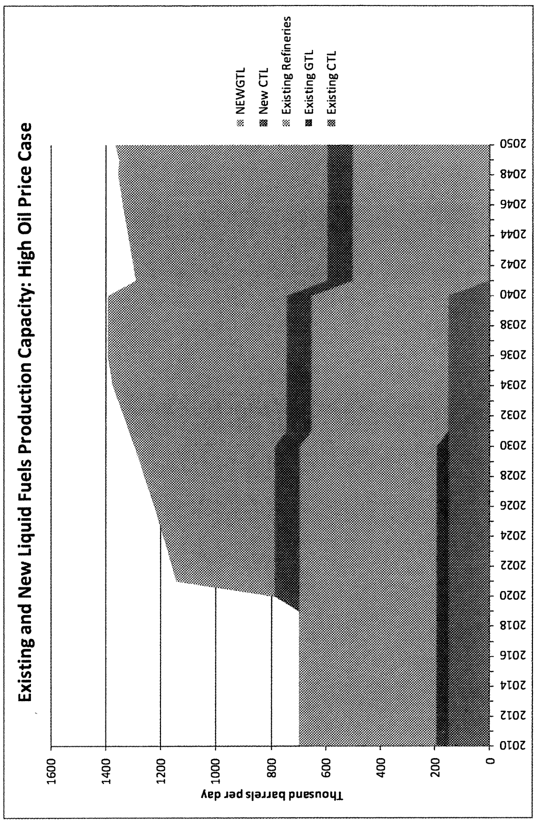


Figure 7-11: Total capacity in liquid fuel production: High Oil Price Case

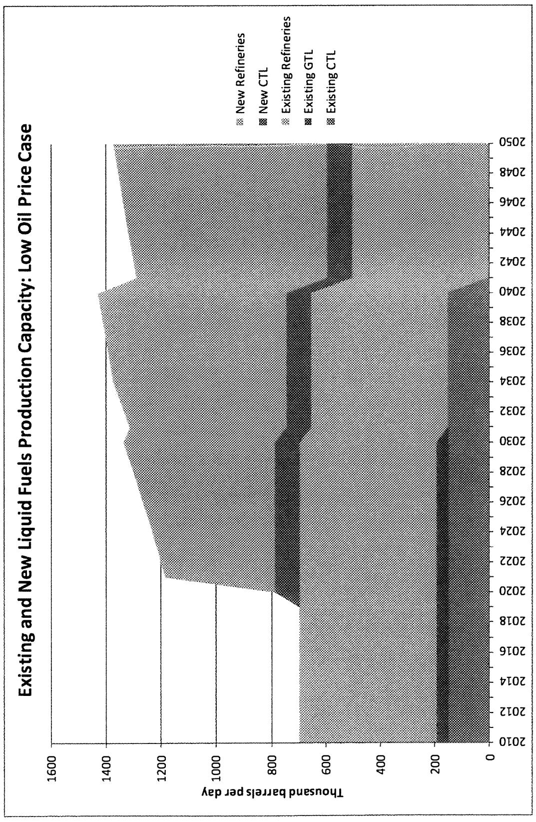
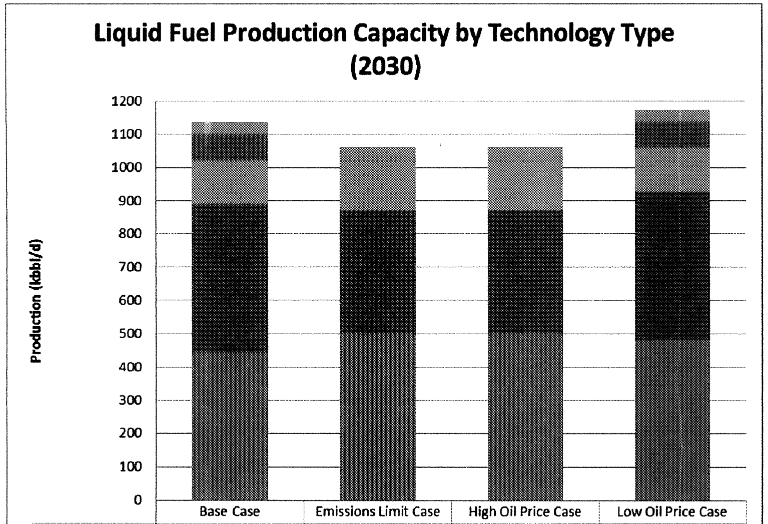


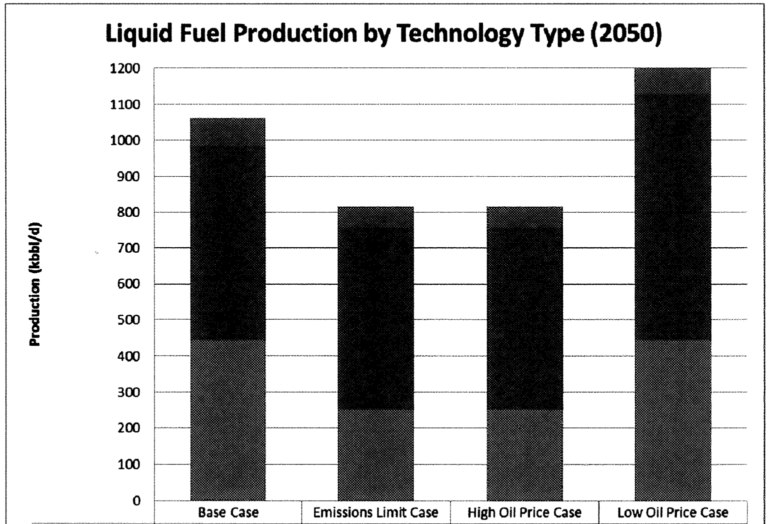
Figure 7-12: Total capacity in liquid fuel production: Low Oil Price Case

While figures 7-8 to 7-12 present total installed capacity, Figures 7-13 and 7-14 indicate the proportion of liquid fuel production from different refining technologies at 2030 and 2050. In the Base Case and the Low Oil Price Test Cases, existing refineries operate close to their technical capacity, while for the Emissions Limit Test Cases and the High Oil Price Case activity is reduced due to carbon emissions constraints and the cost of production due to high crude oil prices respectively.



	Base Case	Emissions Limit Case	High Oil Price Case	Low Oil Price Case
New GTL				
Existing GTL	37	42	42	37
New CTL	79			79
Existing CTL	132	149	149	132
New Refinery	444	369	369	444
Existing refinery	446	503	503	483

Figure 7-13: Liquid fuel production by technology type (2030)



	Base Case	Emissions Limit Case	High Oil Price Case	Low Oil Price Case
New GTL				
Existing GTL				
New CTL	79	61	61	79
Existing CTL				
New refinery	538	503	503	683
Existing refinery	444	251	251	444

Figure 7-14: Liquid fuel production by technology type (2050)

7.3 Primary Energy Use

- Coal loses its share in the primary energy mix in the Base Case and all three Test Cases however this is pronounced in the Emissions Limit Cases.

- Transport demand continues to increase which results in an increase in the demand for liquid fuel. In the Base Case and the Test Cases without emissions limits this demand is met through local production (primarily crude oil refining and limited production of synfuels from coal and gas). The share of crude oil in the primary energy mix therefore increases in these Test Cases.

- In the Emissions Limit Test Cases, local production of liquid fuel is displaced with imports and this sees an increase in the share of petroleum products in the primary energy mix. In the High Crude Oil Price Case, the import of final product surpasses crude oil imports and the inverse is the case in the High Crude Oil Price Case.

- Imported natural gas plays an increasing role in all Test Cases throughout the planning; however this is not prominent in comparison to other primary energy sources.

- New nuclear only features in the Emission Limit Test Case without technology constraints

- Solar technologies are viable and play a prominent role in all Test Cases however the share contribution is reduced in the Renewable Energy Target Case as Wind – which is included earlier in this Test Case reduces new renewable energy technologies in the future.

- New biomass only features when a renewable energy target is set.

7.4 Discounted Costs

The total discounted cost represents all the costs of the energy system discounted to a single number for comparison purposes. It is the main variable used to compare the various test cases developed for the Integrated Energy Plan.

A large dependence on imported energy (crude and liquid fuels) in all test cases can be observed from an analysis of costs related to the energy system as presented in **Error! Reference source not found.**. Imports increase from about 70% to 80% of the total energy supply costs for the Base Case between 2010 and 2050, 80% to 90% in the Emissions Target Test Case and the No Nuclear Test Case and 70% to 80% in the Renewable Energy Target Test Case.

The total discounted cost for the Emissions Limit Test Case and the No Nuclear Test Case are both 4.8% more than the Base Case. The increase in costs is largely attributed to an increase in the share of imported energy and the use of technologies which are less carbon intensive and as the activity of coal to liquids and coal fired power plants is minimised.

The Renewable Energy Target Test Case is 1% more than the Base Case over the planning period. The difference is informed by the cost of renewable energy technologies which are enforced into the system in order to meet the minimum renewable energy target of 10% in the Renewable Energy Target Test Case.

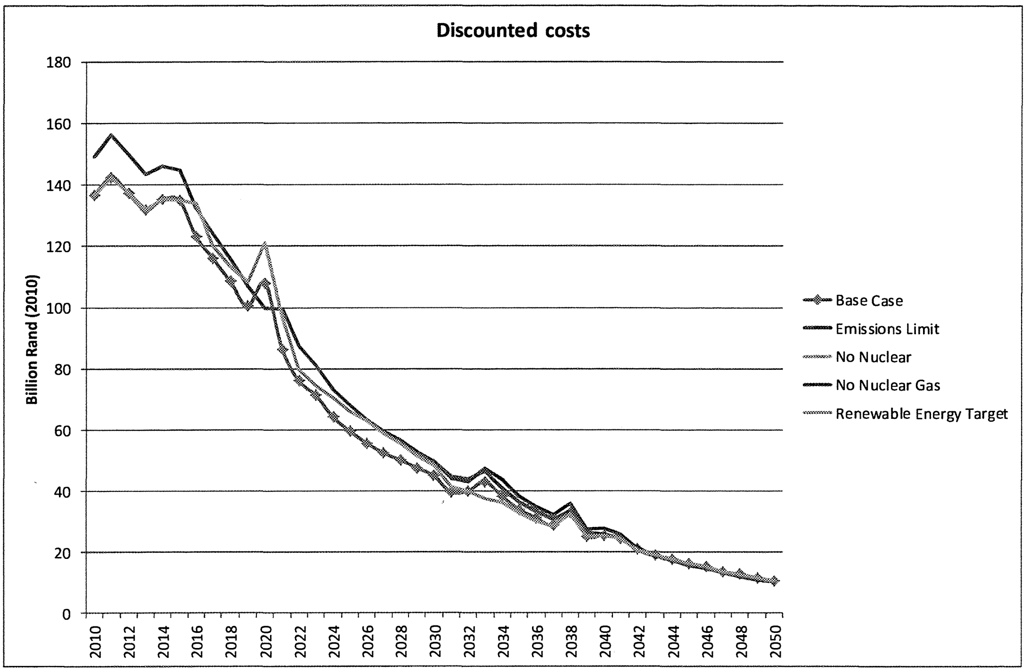


Figure 7-15: Discounted costs for all Test Cases

7.5 Emissions

Carbon dioxide emissions for the test cases are presented in Figure 7-16. These emissions are primarily driven by the use of coal for transformation but considerable amounts of coal are also used in other parts of the economy. The abatement cost for meeting the emissions limit for the Emissions Limit Test Case and the No Nuclear Test Case are both R41/t (in 2010 Rand). Placing emissions limits on energy production (i.e. refineries and electricity generation) results without emissions constraints or emissions penalties on energy end-use (i.e. demand-side emissions controls) results in greater use of imported energy. Emissions resulting from energy end-use therefore continue growing unconstrained. Therefore national emissions limits cannot be met without addressing final demand for energy carriers.

Fuel switching between final energy carriers was only modelled for the transport sector and this allows for the switching from fuel-powered vehicles to hybrid and electric vehicles.

- Emissions for the Base Case continue to increase.

- Emissions are reduced for the Renewable Energy Target Test Case however the reduction is not significant enough for them to be below the levels required by the "Peak Plateau Decline" Emissions Trajectory.
- The carbon emissions associated with energy supply (electricity generation and liquid fuel production) for all the test cases with emissions limits are within the "Peak Plateau Decline" Emissions Trajectory as this is set as a constraint. The reduction in the use of coal has the most significant impact on this reduction and the emissions constraints resulted in a 7.5 billion tonnes (or 31%) reduction in carbon dioxide emissions over the 40 year period as compared to the Base Case.

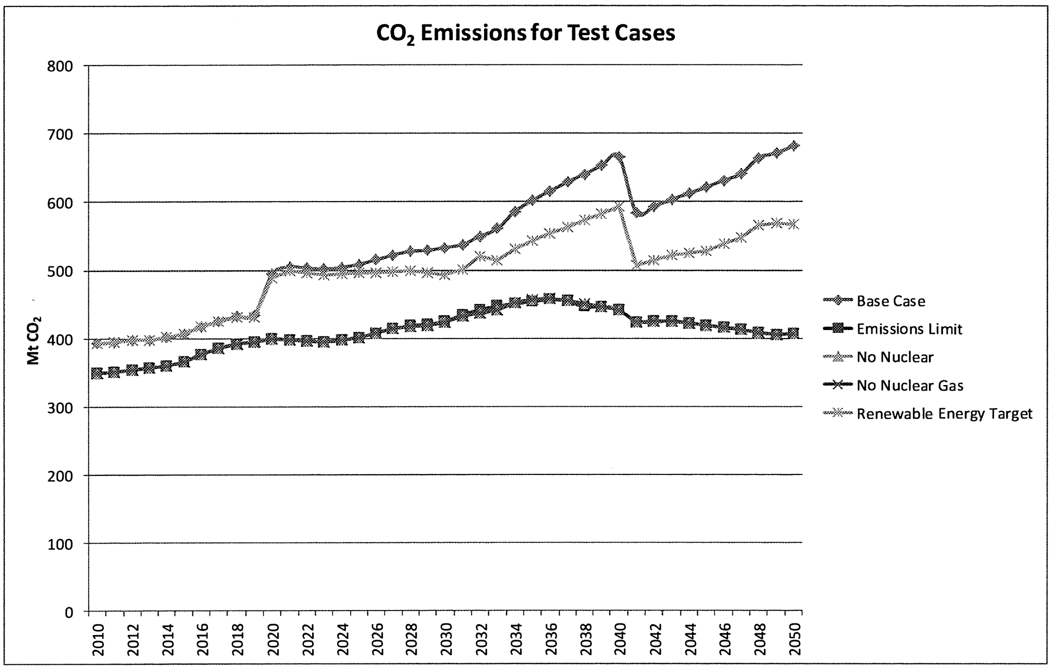


Figure 7-16: CO_2 emissions for all Test Cases

7.6 Water Use

Water used in the various test cases is shown in Figure 7-17. Coal to liquid plants use large qualities of water as can be seen in a comparison of the Base Case and the Emissions Limit Test Cases. There is very little difference in water consumption for the Emissions Limit Test Case and the No Nuclear Test Case. The small difference is because nuclear is assumed to use sea water whereas the CSP technologies require fresh water. In general the test cases which have limited coal to liquid activity have a reduced demand for water. In the long term, water demand is also reduced as a result of dry cooling in electricity generation and the increased penetration of renewable energy technologies which use less water.

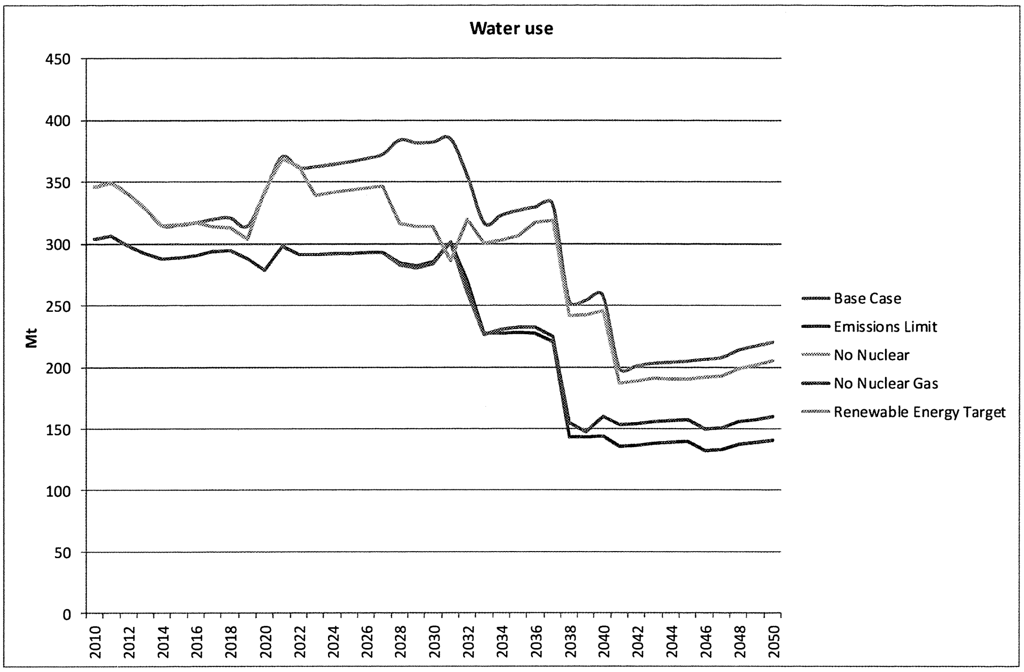


Figure 7-17: Water use for the test case

SECTION 8: WAY FORWARD

8.1 Quantitative Analyses

Sections 5 and 9 outline the output from the econometric modelling (demand projections) and supply optimisation (energy models) respectively. The primary output from the quantitative analyses is **an optimal energy and technology mix for South Africa** throughout the planning horizon within a given set of constraints (as defined by the assumptions of the base case and each of the test cases). Such output includes the following:

- A combination of supply-side technologies, energy resources and secondary energy carriers/fuels to meet the projected energy demand;
- For the proposed mix of supply-side technologies (energy mix), the following were provided and were used as a basis for comparing the output from the Base Case with those of the various Test Cases:
    - Costs (total and average per unit of output)
    - Primary energy resource usage
    - Total production of secondary energy carriers/fuels
    - Emissions (total and average per unit of output)
    - Water usage (total and average per unit of output); and
- For individual technologies included in the proposed energy mix
    - Capacity
    - Activity of each technology.

The output from the quantitative analyses or energy modelling relies heavily on a sound fact base, data and key input assumptions which have been made. An overview of the energy sector and the macroeconomic environment has been provided in section 4, while the assumptions are summarised in sector 5. Detailed information on model assumptions and modelling approaches are provided in the detailed Demand Modelling Report and the Optimisation Modelling Report.

8.2 Qualitative Analyses

The key objective of the technical analyses is to obtain an energy system which has the least cost to the economy, given emission limits and fresh water constraints. The optimised solutions/outputs were provided for the Base Case and for each of the Test Cases (already discussed in Section 5). While it is highly desirable that the outputs from the quantitative analyses provide an optimal solution (energy mix) with the least cost to the economy, the least amount of emissions, and the minimal requirement for water, it is unlikely that such output will provide a single solution which meets all of these criteria simultaneously. For example, a solution optimised for least cost might not be the solution which results in the least emissions or lowest water usage; and a solution optimised for minimal emissions might not be the most economical for South Africa. Therefore, in addition to the technical analyses, choosing a particular strategy or set of policy options requires human judgment.

In addition to the above-mentioned requirements, other objectives (as outlined in Section 3) also had to be met. To ensure that the final recommendations of the IEP take into consideration both the output of the technical analyses and other socio-economic factors, a Multi-Criteria Decision Analysis (MCDA) approach will be adopted. The strength of this approach lies in the fact that it has wide application in policy analysis and evaluation. It ensures that during the screening process, value judgments about the socio-political, environmental and economic attributes of a policy can be included because it allows tradeoffs, co-benefits and compromise solutions to complex policy and planning problems.

There are many MCDA techniques that can be applied and the specific technique chosen for the IEP is the weighting and scaling method (This is described in more detailed in appendix 1). This is a *'compensatory'* method that allows for the evaluation of tradeoffs between the attributes of each candidate policy alternative. In using this technique, attributes are grouped or 'bundled', with each group receiving a weighting that represents a contribution to the overall score, based on the importance of the group of attributes to the decision-making body. This approach has been used before for the selection of sites for nuclear repositories, integrated resource planning, the selection of power generation facility sites, developing national energy policy, and for water resource planning.

To determine the weighting of each criterion in the list of criteria, a rating scale is applied and the relative importance and resultant weight of each criterion is determined through a consultative process with the relevant stakeholders to ensure that consensus is reached on the weighting given to each criterion.

The list of criteria was based on the list of objectives described in section 3 and is included in Appendix 1. While this approach cannot and does not aim to remove subjectivity in its entirety, it aims to minimise personal sentiment from the analysis process in that once the list of criteria has been decided upon and weighted, the same set of criteria is used consistently to evaluate all alternative options.

8.3 Revisions emanating from stakeholder consultations

The Draft Integrated Energy Planning Report provides preliminary model output and a basis for stakeholder consultation. During the stakeholder consultation process, it is anticipated that various inputs will be received which will provide information for further analysis to be conducted. Some of the assumptions, (for example, GDP growth rates) may need to be revised based on the latest national forecasts. Some of the work which needs to be done includes, but is not limited to the following:

- Assess the impact of Transnet Freight Rail's rail expansion plan on displacement of freight haulage from road to rail and the impact that this may have on projected demand
- Further analysis on the constraints of the natural gas infrastructure on the ability to meet projected demand for natural gas, particularly in the industrial and commercial sectors.

8.4 Making Final Recommendations

The core purpose of the IEP is to provide a roadmap of the future energy landscape of South Africa. In order to achieve this, the IEP is therefore a multi-faceted, long-term energy framework which has multiple objectives:

- Guide the development of energy policies and, where relevant, set the framework for regulations in the energy sector;
- Guide the selection of appropriate technologies to meet energy demand (i.e. what types and size of new power plants and refineries should be built); and
- Guide the investment in and development of energy technology and infrastructure in South Africa.

The Draft Integrated Energy Planning Report is not intended to provide recommendations but presents model output from the Base Case and various Test Cases. This output gives insight on the possible implications of pursuing alternative energy policy options. Once the implications of all the alternative options have been explored and evaluated against each of the eight (8) key objectives, final recommendations will be made in the form of the Final IEP Report.

The Integrated Energy Planning Policy Working Group will be reconstituted and a workshop will be conducted to determine the relative weights of each of the criteria, before the output from the models are obtained. This same working group will then evaluate the model output which will inform the final recommendations presented to the IEP Steering Committee.

8.5 High-Level Timeline

Once the Draft Integrated Energy Planning Report has been published, various public stakeholder consultations will take place over a period of three months. The input obtained from this process will inform the revision of key planning assumptions which will emanate in the revision of the demand projections, the base case optimisation as well as the optimisation of the different test case. An alternative scenario, based on GDP growth projections aligned with the National Development Plan will also be conducted. Once all input has been obtained and the analysis work has been completed, the final report will be tabled in Cabinet for approval before finally being published in the Government Gazette.

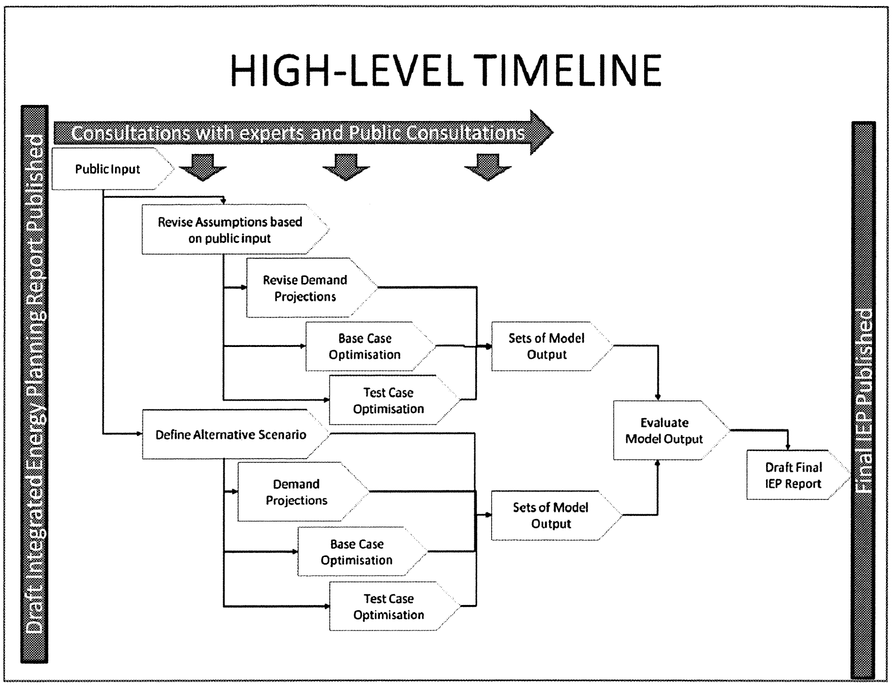


Figure 8-1: High-Level IEP Timeline

8.6 Areas of Further or Ongoing Analysis

As already described in section 2, the IEP process is not a once-off event but is rather a process of ongoing review and enhancement. This therefore requires ongoing and further research, collection of further data to enhance supporting evidence, and analysis. There are a multitude of factors and phenomena that have to be considered in order to ensure that a tangible output can be produced within a reasonable timeframe, and thus it is important to prioritise the focus areas. The prioritisation is largely informed by the timeframe within which key policy decisions need to be made, and/or by the availability of reasonable supporting evidence on which key planning assumptions can be made. The process therefore (by design) will always require further analysis as new questions arise and the dynamic nature of the macroeconomic environment is continually at play.

Some of the areas which should be explored further are as follows:

- The impact of energy prices on demand, taking into consideration other concurrent changes such as household income
- The impact on energy costs, employment and output if South Africa imports electricity from the region
- Possible scenarios on the potential exploitation of shale gas in the Karoo

- The detailed implications of NATMAP and in particular Transport Sector Alternative Policy Shifts
    - Alternative mode use and shifting of goods and people to mass transport (i.e. passengers from vehicles to buses or rail; freight from trucks to rail)
    - Advanced transport technology innovations such as rail powered by renewable energy
    - Non-motorised transport
- In-depth implications of the transport sector collaborative alternative policy shifts, which include land use management, including an increase in urban settlement densities and corridor developments;
- Technological advancement and potential penetration rates of electric vehicles in South Africa, including their broader implications

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APPENDIX 1: POST-MODELLING MULTI-CRITERIA DECISION ANALYSIS (MCDA) TECHNIQUE

1.1 Analysing Policy Options and Choosing the Option which Offers the Best Solution

Multi-Criteria Decision Analysis (MCDA) techniques are useful in helping the policymaker choose the right policy options, sometimes, among competing alternatives. These techniques are used to screen policy options and ideally identify a set of optimal solutions, such that a feasible option exists which is just as good in all objectives and strictly better in at least one. During the screening process, value judgments about socio-political, environmental and economic attributes of a policy can be included. Therefore, MCDA methods can be used to identify tradeoffs, co-benefits and compromise solutions to complex policy and planning problems.

1.2 Determining Evaluation Criteria from the Key Objectives

The key objectives of the Integrated Energy Plan (IEP) are described in the Main 2012 Integrated Energy Planning Report. As discussed in the document, the attainment of these objectives has conflicting implications in certain instances. An objective mechanism to determine their relative importance has therefore been devised and is described herein. In addition, because the output from the Base Case and the various Test Cases may be divergent, a consistent and transparent method of evaluating the model output and making recommendations is necessary. The key objectives inform the criteria which will be used to evaluate the key outputs from the Base Case and the various Test Cases. Table A-1 provides a list of the objectives, the respective criteria against which the attainment of each objective will be quantified and the unit of measure which will be applied.

Table A-1: Key Objectives of the IEP and Evaluation Criteria

#	KEY OBJECTIVE	CRITERION	UNIT
1	Security of supply	All projected energy demand is met. Calculated reserve margin of 19% achieved and maintained	Percentage
2	Minimise cost of energy	Total cost	Million Rands (Rm)
3	Increase access to energy	Based on expert judgement	Rating on scale of 0 to 10
4	Diversify supply sources and primary energy carriers	Diversity of energy mix	Rating on scale of 0 to 10
5	Minimise emissions from energy sector	• Total annual CO_2 emissions from electricity generation and liquid fuel production • Annual CO_2 emissions from electricity generation and	• Megatons of Carbon Dioxide (Mt/CO_2) • Megatons of Carbon Dioxide equivalent per PetaJoule ($Mt\ CO_2/PJ$)

		liquid fuel production per unit of energy output or per unit of GDP	or per Million Rands GDP (Mt CO_2/Rm GDP)
6	Improve energy efficiency/Reduce Energy Intensity	• Annual energy intensity (Units of energy per unit of GDP)	• Petajoules per Million Rands GDP (PJ/ Rm GDP)
7	Promote localisation, technology transfer and job creation	• Total number of direct permanent jobs • Number of indirect and/or contract/temporary jobs	Job years
8	Water conservation	• Total annual fresh water use for electricity generation and liquid fuel production • Annual fresh water use for electricity generation and liquid fuel production per unit of energy output	• Megatons of water (Mt water) • Water use per unit of energy output (Mt water /PJ)

1.3 Computing Weights of Criteria Using a Comparison Matrix

The technique used for the IEP is the weighting and scaling method, which will be employed after the results from the modelling were completed. The technique chosen is a 'compensatory' method that allows for the evaluation of tradeoffs between the attributes of candidate alternatives. In this technique, attributes are grouped or 'bundled', with each group receiving a weight that represents a contribution to the overall score, based on the importance of the group of attributes to the decision-making body. This approach has been used before to select sites for nuclear repositories, integrated resource planning, selection of power generation facility sites, developing national energy policy, and in undertaking water resource planning.

To determine the weighting of each criterion, a rating scale will be applied as defined in Table A-2 below.

Table A-2: Rating Scale for the Criteria

Scale	Definition	Explanation
0.33	Significantly less important	
0.5	Less important	Experience and judgment slightly favour one activity over another
1	Of equal importance	Two activities contribute equally to the objective
2	More important	Experience and judgment strongly favour one activity over another
3	Significantly more important	The evidence favouring one activity over another is of the highest possible order of affirmation

Once the rating scale had been defined, the criteria will be evaluated against one another to determine the relative importance of each criterion against the others. This exercise will be conducted during a multi-stakeholder forum including representatives from different policy units. For the purposes of the IEP, this process will be conducted by the Intergovernmental Integrated Energy Planning Policy Working Group or IEP Steering Committee. The output from this process will enable the weight of each of the criteria to be determined.

Because input to determine the weight involves multiple stakeholders, the resultant weighting of each criterion should be unbiased. A comparison matrix, similar to the example shown in Table A-3, will be used to assign weights to the criteria, indicating the relative importance of the criterion in the columns compared with the criterion in the rows. To ensure consistency and transparency when assigning weights, the criteria in the *rows* are assumed to be *constant* whereas the criteria in the *columns* are *variables.* This is important because values are assigned by comparing criteria in the rows with those in the columns. As such, each individual criterion appearing in each row was compared with all the criteria appearing in each of the columns. The total scores for each of the criteria (reflected in the second last row) are then used to determine the weighted averaged which reflects the relative importance of the criteria.

Table A-3: Example of a Comparison Matrix Depicting the Weighting of Criteria

	Comparison Matrix									
Criteria	**C1**	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**TOTALS**	**WEIGHTS**
C1	1	0.5	0.33	0.5	0.5	1	0.5	0.5	4.83	6%
C2	2	1	0.33	2	0.5	2	0.5	0.33	8.66	11%
C3	3	3	1	2	2	3	2	0.33	16.33	20%
C4	2	0.5	0.5	1	0.5	2	0.5	0.5	7.5	9%
C5	2	2	0.5	2	1	2	0.5	1	11	14%
C6	1	0.5	0.33	0.5	0.5	1	0.33	0.5	4.66	6%
C7	2	2	0.5	2	2	3	1	1	13.5	17%
C8	2	3	3	1	0.5	2	2	1	14.5	18%
TOTAL	**15.03**	**10.03**	**3.99**	**11**	**7.5**	**16.03**		**7.33**	**80.98**	**100%**

Note: This is an example, and NOT the actual scoring

1.4 Scoring the Output against the Criteria

Once the relative weights of the criteria have been determined, the next step is to evaluate the actual model output (i.e. the output from the various Test Cases against the Base Case) against each of the criteria. The key idea is to construct preference scales representing the extent to which each set of model outputs meets the criteria described in Table A-1.

A relative preference scale is used and the same method is applied for evaluating all Test Cases. However the rating scale for the criteria whose scores can be calculated and determined directly from the model output will differ from those criteria more reliant on expert judgment.

The relative preference scale method is anchored on either end by the highest and lowest score against a criterion:

- **For the criteria whose scores can be calculated and determined directly from the model output:** Assuming 'n' Test Cases are being evaluated against one another, the Test Case with the highest points meeting a particular criterion is assigned a score of 'n', and the Test Case with the lowest points meeting a particular criterion is assigned a score of 0. Scores are assigned to the remaining Test Cases so that differences in the numbers represent differences in strength of meeting the particular criterion; and
- **For the criteria whose scores may not be easily calculated directly from the model output:** The rating scale will be set from 0 to 10, with 0 representing the output which least meets the criteria and 10 representing the output which most meets the criteria. In these instances, expert judgement will be used by the evaluating panel.

The scoring guide for scoring each Test Case against each criterion is provided in Table A-4.

Table A-4: Scoring Guide Against Each of the Criteria

#	KEY OBJECTIVE	LOWEST SCORE	HIGHEST SCORE
1	Security of supply	All projected energy demand is met	• All projected energy demand is met • Reserve margin of 19% achieved
2	Minimise cost of energy	Model output (plan) with highest cost	Model output (plan) with the lowest cost
3	Increase access to energy	Policy proposals do not promote access to energy (0 to 10 rating scale)	Policy proposals which promotes access to energy (0 to 10 rating scale)
4	Diversify supply, sources, and primary energy carriers	Model output (plan) with most diversity of: • Primary energy sources	Model output (plan) with most diversity of: • Primary energy sources

		• Supply sources (0 to 10 rating scale)	• Supply sources (0 to 10 rating scale)
5	Minimise emissions from energy sector	• Model output (plan) with the most annual and planning period emissions • Model output with the highest emissions per unit of energy output	• Model output (plan) with the least annual and planning period emissions • Model output with the lowest emissions per unit of energy output
6	Improve energy efficiency	Policy proposals do not promote energy efficiency (0 to 10 rating scale)	Policy proposals promote energy efficiency (0 to 10 rating scale)
7	Promote localisation, technology transfer, and job creation	Model output (plan) with least potential for job creation, measured by: • Number of direct permanent jobs • Number of indirect and/or contract/temporary jobs	Model output (plan) with most potential for job creation, measured by: • Number of direct permanent jobs • Number of indirect and/or contract/temporary jobs
8	Water conservation	Model output (plan) with the most water usage requirements on an annual basis and over the planning period	Model output (plan) with the least water usage requirements on an annual basis and over the planning period

An example of the scoring is presented in Table A-5 below. The Base Case and all Test Cases are listed in the left column and the criteria and their associated weights are reflected in the first and second rows. (In practice it is advisable to remove the weights on the criteria when scoring the Test Cases against the criteria). Therefore a score between 0 and 'n' (or 0 and 10) will be assigned to the Base Case or a Test Case, depending on the observed evidence and where applicable a value judgement of how it achieved a particular criterion, e.g. how Test Case 1 is measured using criterion C1 or C2, etc.

Table A-5: : Example of Policy Analysis Matrix to Assign Scores and Weights

CRITERIA	C1	C2	C3	C4	C5	C6	C7	C8	
WEIGHTS	6%	11%	20%	9%	14%	6%	17%	18%	WEIGHTED AVERAGES
Base Case	7	5	10	9	8	2	7	6	7.25
Test Case 1	5	6	8	7	6	5	5	8	6.57
Test Case 2	8	6	4	7	9	5	7	7	6.50
Test Case 3	8	5	5	7	8	4	5	4	5.54

1.5 Examining the Results, Agreeing on the Way Forward and Making the Final Choice

The options will be ranked according to the weighted average of all the preference scores. These total scores also give an indication of how much better one option is over another against the given criteria. An MCDA can yield surprising results that need to be digested before decisions are taken. It may be necessary to establish a temporary decision system to deal with unexpected results and to consider the implications of new perspectives revealed by the MCDA. This temporary system should consist of a series of working meetings which eventually produce recommendations to the final decision-making body. At the working meetings, participants should be given the task of examining the MCDA results, testing the findings for their validity, working through the possible impacts for the organisation, and formulating proposals for the way forward.

1.6 Conclusion

The Integrated Energy Planning Policy Working Group will be reconstituted and a workshop will be conducted to determine the relative weights of each of the criteria, before the output from the models are obtained. This same working group will then evaluated the model output which will inform the final recommendations presented to the IEP Steering Committee.

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