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DEPARTMENT OF ENERGY

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Integrated Energy Plan

INTEGRATED ENERGY PLAN

DEPARTMENT OF ENERGY

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Abbreviations

BAT	Best Available Technology
bbl	Barrel
CCGT	Combined-Cycle Gas Turbine
CCS	Carbon Capture and Storage
CHP	Combined Heat and Power
CNG	Compressed Natural Gas
CO_2	Carbon Dioxide
CO_2-eq	Carbon Dioxide Equivalent
CSP	Concentrated Solar Power
CTL	Coal-to-Liquid
DMR	Department of Mineral Resources
DoE	Department of Energy
DoT	Department of Transport
DSM	Demand-side Management
EEDSM	Energy Efficiency Demand-side Management
EETMS	Energy Efficiency Target Monitoring System
GDP	Gross Domestic Product
GHG	Greenhouse Gas
GJ	Gigajoule
GTL	Gas-to-Liquid
GW	Gigawatt
GWh	Gigawatt Hours
Hg	Mercury
HVAC	Heating, ventilation, and air conditioning
HySA	Hydrogen South Africa
IEP	Integrated Energy Plan
INEP	Integrated National Electrification Programme
IPAP	Industrial Policy Action Plan
IPP	Independent Power Producer
IRP2010	Integrated Resource Plan - 2010
km	Kilometre
kt	Kiloton
kWh	kilowatt hour
LNG	Liquefied Natural Gas
LPG	Liquefied Petroleum Gas
MBtu	Million British Thermal Units
MJ	Megajoule
Mt	Million Tons

Mtoe	Million Tons of Oil Equivalent
MW	Megawatt
MWe	Megawatt Electric
MYPD	Multi-Year Price Determination
NATMAP	National Transport Master Plan
NCCRWP	National Climate Change Response White Paper
NDP	National Development Plan
NIPF	National Industrial Policy Framework
NO_x	Nitrogen Oxide
NWRS2	National Water Resource Strategy 2
OCGT	Open-Cycle Gas Turbine
PJ	Petajoule
PM	Particulate Matter
PPD	Peak-Plateau-Decline
PV	Photovoltaic
REIPP	Renewable Energy Independent Power Producer
SANEDI	South African National Energy Development Institute
SO_x	Sulphur Oxide
SWH	Solar Water Heater
UCG	Underground Coal Gasification

Executive summary

Energy is essential to many human activities and is critical to the social and economic development of a country. 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 macroeconomic environment, developments in new technologies and changes in national priorities and imperatives, amongst other factors. Since change is on-going, the plan must remain relevant.

… South Africa needs to grow its energy supply to support economic expansion …

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. From the myriad of factors which had to be considered and addressed during the Integrated Energy Planning process, eight key objectives were identified:

- Objective 1: Ensure security of supply;
- Objective 2: Minimise the cost of energy;

- Objective 3: Promote the creation of jobs and localisation;
- Objective 4: Minimise negative environmental impacts from the energy sector;
- Objective 5: Promote the conservation of water;
- Objective 6: Diversify supply sources and primary sources of energy;
- Objective 7: Promote energy efficiency in the economy; and
- Objective 8: Increase access to modern energy.

The IEP analyses current energy consumption trends within different sectors of the economy (i.e. agriculture, commerce, industry, residential and transport) and uses this to project future energy requirements, based on different scenarios. The scenarios are informed by different assumptions on economic development and the structure of the economy and also take into account the impact of key policies such as environmental policies, energy efficiency policies, transport policies and industrial policies, amongst others. The IEP then determines the optimal mix of energy sources and technologies to meet those energy needs in the most cost-effective manner for each of the scenarios. The associated environmental impacts, socio-economic benefits and macroeconomic impacts are also analysed. The IEP is therefore focused on determining the long-term energy pathway for South Africa, taking into account a multitude of factors which are embedded in the eight objectives.

Four key scenarios were developed, namely the Base Case, Environmental Awareness, Resource Constrained and Green Shoots scenarios:

- The **Base Case** Scenario assumes that existing policies are implemented and will continue to shape the energy sector landscape going forward. It assumes moderate economic growth in the medium to long term.
- The **Environmental Awareness** Scenario is characterised by more stringent emission limits and a more environmentally aware society, where a higher cost is placed on externalities caused by the supply of energy.
- In the **Resource Constrained** Scenario, global energy commodity prices (i.e. coal, crude oil and natural gas) are high due to limited supply.
- The **Green Shoots** Scenario describes an economy in which the targets for high economic growth and structural changes to the economy, as set out in the National Development Plan (NDP), are met.

All the above-mentioned core scenarios include the implementation of the 9.6 GW New Nuclear Build Programme, a policy decision that was outlined in the Integrated Resource Plan 2010 (IRP2010) and mentioned by the President in his 2014 State of the National Address.

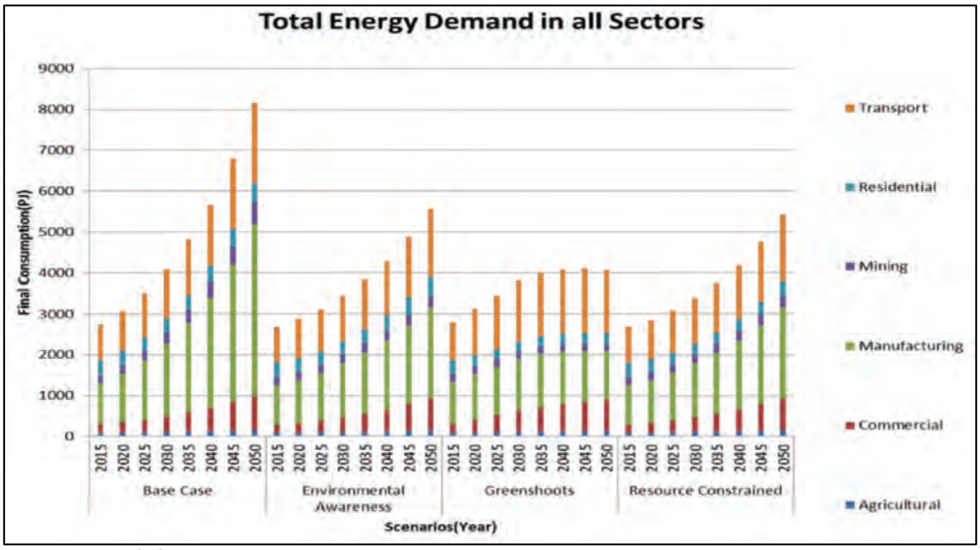
In addition to the above-mentioned scenarios, three sensitivity analyses were conducted:

- **Big Solar Water Heaters:** This sensitivity analysis tests the impact of pursuing the more aggressive introduction of solar water heaters into households.
- **No Shale Gas:** The four core scenarios assume an optimistic outlook on the role of shale gas in the South African economy. The underpinning assumptions are that economically recoverable volumes of shale gas are extracted and that shale gas is competitively priced and available to the local market. The scenarios also assume that the relevant legislation and regulations have been developed and promulgated to enable safe exploitation of shale gas. The No Shale Gas sensitivity analysis examines the case where shale gas cannot be economically extracted or is not competitively priced.
- **Nuclear Relaxed:** The economic growth projection assumptions made during the development of the IRP2010 have not materialised and the economic growth outlook has been revised downwards. This has had a downward impact on projected electricity demand. Due to the fact that the New Nuclear Build Programme adds substantial capacity (9.6 GW) to the energy mix and there have been indications that the scale and pace of the programme should not have an adverse impact on the economy, a sensitivity analysis was conducted to assess the impact of relaxing the 9.6 GW New Nuclear Build Programme and using the model to optimise the least cost energy system by considering alternative options. This effectively allows for the timing and commissioning of new nuclear plant in the most optimal manner.

Analysis of energy demand

The transport sector will continue to make the highest demand on energy (Figure 0-1). Freight haulage, predominantly by road, is the greatest contributor to increases in transport demand and related fuel consumption. Petrol and diesel vehicles will continue to be used in the foreseeable future, with electric vehicles only starting to make a significant contribution to passenger transportation after 2030.

Outside of the transport sector, the most significant energy demand increase is expected to be in the industrial sector (manufacturing), followed by the commercial sector. The increase in energy demand within the commercial sector is associated with continued expansion of the tertiary sector as South Africa moves towards becoming 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.

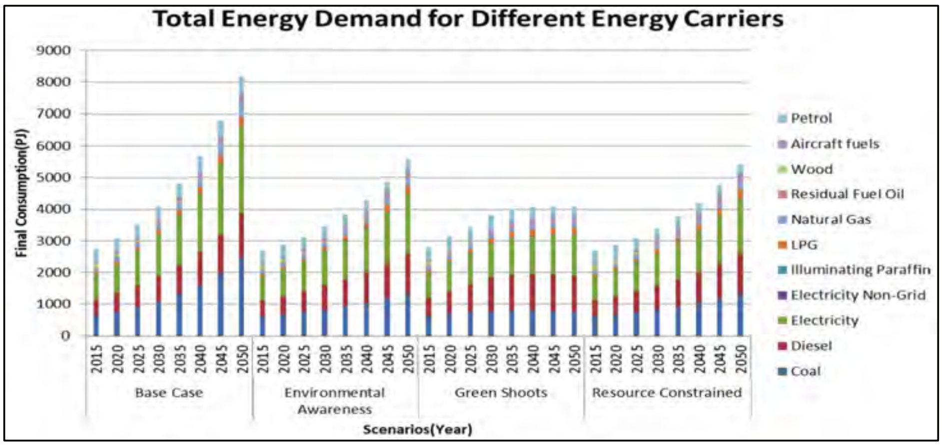


Source: DoE Analysis

Figure 0-1: Projected demand within different sectors

In line with the demand in different sectors depicted in Figure 0-1, demand for petroleum products increases the most significantly between 2015 and 2050 as this is primarily used within the transport sector (Figure 0-2). Demand for other petroleum products is less significant, although the demand for LPG is expected to increase steadily in the residential sector and whilst fairly minor, ranks as the third largest increase between 2010 and 2050. Diesel consumption continues to increase in the mining 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. 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 the increase in households and improvements in household income.



Source: DoE Analysis

Figure 0-2: Total energy demand for different energy carriers

Analysis of supply-side energy options against objectives

Objective	High-level summary of scenario results
Ensure security of energy supply	The objective of optimisation modelling is to ensure that all demand is met. Within all scenarios, the projected demand is met and therefore the objective of ensuring security of supply (which is the underpinning objective) is assumed to have been met.
Minimise the cost of energy	While all scenarios seek to ensure that costs are minimised within the constraints and parameters of each scenario, when total energy system costs are considered, the Base Case Scenario presents the least cost option, followed by the Environmental Awareness, Resource Constrained and Green Shoots scenarios respectively. Total costs are mostly comprised of imports of final petroleum products. When total electricity system costs are explored in isolation, however, this picture changes. • **Electricity sector system costs:** The Green Shoots Scenario presents the lowest total cost for electricity generation. This is followed by the Resource Constrained and Base Case scenarios while the Environmental Awareness Scenario is the most costly. • **Liquid Fuel Supply (Combined production and imports):** When total liquid fuel system costs are considered the profiles are similar to those of the total energy system costs.

Objective	High-level summary of scenario results
Promote job creation and localisation potential	The potential number of jobs created within each of the scenarios changes year-on-year. Cumulatively, the Base Case Scenario presents the greatest job creation potential, followed by the Resource Constrained, Environmental Awareness and Green Shoots scenarios respectively. In all scenarios, approximately 85% of total jobs are localisable. • In the case of electricity generation, most jobs arise from solar technologies followed by nuclear and wind, with natural gas and coal making a smaller contribution. • In the case of liquid fuel, most jobs arise from new Gas-to-Liquid (GTL) plants and to a smaller extent from Coal-to-Liquid (CTL) plants, with no additional jobs arising from new crude oil refining as no new crude oil refining capacity comes on line.
Minimise negative environmental impact	The Environmental Awareness Scenario, due to its stringent emission constraints, shows the lowest level of total emissions over the planning horizon. This is followed by the Green Shoots, Resource Constrained and Base Case scenarios respectively. This result is similar when emissions are considered in terms of individual pollutants.
Minimise water consumption	The results for water consumption across the four scenarios are similar to those for emissions, with the Environmental Awareness Scenario showing the lowest level of water consumption and the Base Case Scenario showing the highest.
Diversify supply sources and primary energy carriers	All scenarios present a fairly diversified energy mix across the electricity and liquid fuel sectors. It is important to note that none of the scenarios include crude oil going forward because the importation of refined petroleum products is considered the least cost option.
Promote energy efficiency (reduce energy intensity of the economy)	The Green Shoots Scenario, which is characterised by a significant structural shift in the economy, presents the greatest reduction in energy intensity. This is largely the result of the greater contribution made by a less energy intensive commercial sector to the economy in this scenario. It is followed by the Environmental Awareness, Resource Constrained and Base Case scenarios respectively.
Promote energy access	Energy access is informed by the ability to provide energy as well as the availability of that energy when required. The ability to provide electricity to all South African citizens is made possible by connecting new households to the grid where it is cost-effective to do so and by introducing off-grid technologies where it is not. Therefore an energy mix that includes technologies which are suitable for off-grid application presents the greatest potential to increase energy access. Presently solar energy technologies (e.g. rooftop solar Photovoltaic (PV) panels and other solar home systems) show the greatest potential in this regard. The Base Case Scenario comprises the largest share of renewable energy technologies, followed by the Environmental Awareness, Resource Constrained and Green Shoots scenarios respectively. It should be noted that in addition to the supply-side renewable energy technologies, the Base Case and Resource Constrained scenarios assume the introduction of 1 million solar water heaters by 2030, and the Environmental Awareness and Green Shoots scenarios assume the introduction of 5 and 10 million solar water heaters by 2030 respectively.

Recommendations

Cost of energy

Many factors contribute to total energy system costs. Demand-side energy management interventions and improvements in energy efficiency contribute to total energy system cost reductions by reducing the demand for energy. However, the cost of implementing these programmes needs to be accounted for and has not been factored into the total system costs. When considering the supply-side technology options only, the capital costs, operating and maintenance costs as well as fuel costs have been taken into account (Figure 0-3).

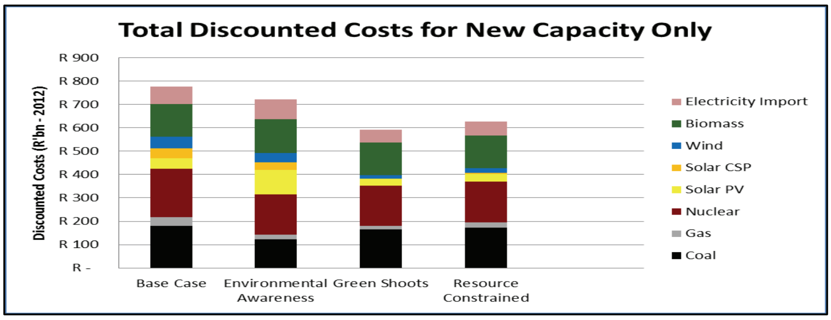


Figure 0-3: Total Discounted Cost of New Generation Capacity

New electricity generators should be brought online through a competitive bidding process, where the ability to generate electricity at low cost is a key criterion.

The implementation of a new nuclear programme should be conducted in a manner that poses the least cost to the energy system. The implementation of the 9.6 GW New Nuclear Build Programme, as espoused in the IRP2010, should be reviewed such that the scale and pace of the programme has a less severe impact on electricity tariffs than an accelerated build programme.

The price of petroleum products is influenced by global crude oil prices. As such, South Africa is a price taker, having little to no influence on the market. Where possible, maximum (i.e. capped) retail prices should continue to be implemented for fuels such as LPG and

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natural gas to encourage a switch away from electricity.

Energy mix

South Africa should continue to pursue a diversified energy mix which reduces reliance on a single or a few primary energy sources.

- **Coal:** Coal should continue to play a role in electricity generation; however investments need to be made in new and more efficient technologies (e.g. new supercritical pulverised fuel power plants with flue-gas desulphurisation). Investments should also continue on the testing of underground coal gasification. New coal-to-liquid (CTL) plants are not competitive if South Africa is to achieve the objective of moving towards a low carbon economy, and despite the beneficiation targets, no new investments are encouraged in this regard. Long-term investment in research and test injections for Carbon Capture and Storage (CCS) should continue to be pursued. Given the significant investments required for this technology, South Africa should establish strategic partnerships with countries that have made advancements in the development of CCS technologies (e.g. Norway) as well as those that have abundant coal resources and therefore similar objectives in terms of exploiting their coal resources responsibly (e.g. Australia).

- **Nuclear:** Power generation from nuclear needs to play a more significant role in the provision of new baseload generation, depending on the cost of nuclear reactors and the financing thereof. The first unit of the New Nuclear Build Programme should be brought on line by 2030, however additional capacity should be implemented at a scale and pace that will not have a negative impact on the economy and additional capacity can be brought online after 2030 in a well-spaced out manner. However given the long lead-times associated with construction of nuclear plants, planning with regard to the New Nuclear Build Programme should progress and a decision on a vendor/country partnership should be expedited.
- **Natural Gas:** Natural gas presents the most significant potential in the energy mix. The use of natural gas in Combined Cycle Gas Turbines (CCGT) in the electricity sector, GTL plants in the liquid fuel sector and for direct thermal applications in the industrial and residential sectors, positions it as a viable option in the energy mix. Local exploration to assess the magnitude of recoverable shale and coastal gas needs to be pursued in line with the relevant regulations. Co-operation with neighbouring countries also needs to be pursued and partnerships developed for joint exploitation and beneficiation of natural gas within the region. The short-term and long-term infrastructure requirements to enable the uptake of a natural gas market should be analysed in the Gas Utilisation Master Plan (GUMP).
- **Crude Oil and Imports of Final Liquid Fuels:** The low contribution of crude oil in the energy mix for all the scenarios has been informed by the assumption that lower priced gas (mainly comprising natural gas) will be available, and no externality costs will be imposed on imported refined product.
  - Should the levels of economically recoverable shale gas be insignificant, however, such that no investment in shale gas extraction is viable, crude oil will have to be imported.

- Should externality costs have to be included in the price of imported fuels, the cost of imported fuels will further increase and will in turn have a negative impact on the balance of payment.
- Therefore in order to ensure security of supply and to reduce the negative impact on the balance of payments due to increased imports of refined product, new refinery capacity will be essential in the medium to long term. Such capacity should meet the new fuel specifications.

- **Solar:** Solar PV and CSP with storage present excellent opportunities to diversify the electricity mix, to produce distributed generation and to provide off-grid electricity. Solar technologies also present the greatest potential for job creation and localisation. Incentive programmes and special focused programmes to promote further development in the technology, as well as solar roll-out programmes, should be pursued.
- **Wind:** Wind also presents an alternative source of power, however this is limited to windy areas on the coast.
- **Biomass:** Biomass can play a role as a feedstock for cogeneration and in the provision of electricity close to the source.

Job creation

… The proposed energy mix promotes the creation of jobs …

The proposed energy mix promotes the creation of jobs. Primary energy extraction has the highest potential for job creation and localisation efforts. Local exploration of shale gas needs to be pursued. In the electricity generation sector clean energy technologies like nuclear, solar and wind have great potential for job creation and skills development in the country.

Environmental considerations

Energy policies should support the pursuit of low emission limit targets. Ongoing work by the Department of Environmental Affairs to determine Desired Emissions Reduction Outcomes (DEROs) should proceed. New technologies should be implemented for all coal-fired power plants to ensure that environmental legislation is met. Furthermore, all new coal-fired power plants should be dry-cooled to conserve water in alignment with the National Water Resource Strategy 2.

Demand

Various demand-side levers can be considered in order to reduce energy intensity within different sectors of the economy. Improvements in end-use technology and fuel-switching are some of the alternative options.

- **Agricultural Sector:** Government should develop and implement a package of specifically designed policies and energy savings measures to promote energy efficiency, which may include the promotion of high quality and relevant information on proven practices for energy efficiency that is appropriate for emerging farmers.
- **Commercial Sector:** A database should be developed on energy consumption in both public and commercial buildings and efficiency indices for the evaluation of relevant policy measures such as the Energy Efficiency Strategy.
- **Industrial Sector:** Energy intensive users should submit Energy Management Plans to the DoE in line with the relevant draft regulations. All organisations identified in terms of the regulations should submit the required data on energy consumption. The population of the national Energy Efficiency Target Monitoring System (EETMS) with this data will enable ongoing monitoring of energy consumption patterns and efficiency improvements across all sub-sectors.
- **Residential Sector:** To address challenges in all households, policy initiatives should constructively differentiate between low income and high income households.
  - Fuel switching away from electricity to LPG (especially for space heating and cooking) and diversifying the household energy mix should be encouraged in high-income households.
  - The implementation of the Electrification Programme, including both grid connection and off-grid solar systems, should continue. An integrated household energy strategy, which amongst other factors looks into the safe use of fuels in low income households, needs to be developed with civil society and local government representatives.
- **Transport Sector:** The improvement of the fuel economy of vehicles (i.e. vehicle technology efficiency) combined with fuel quality improvement, will make the most significant impact on projected future fuel demand. A GTL plant is a viable option if shale and local gas exploration yields economically recoverable resources. Since demand is projected to grow substantially in this sector, a GTL plant will help reduce reliance on imported liquid fuels (diesel and petrol).

- For passenger transportation, non-motorised transport and mass transport (buses and trains) should be promoted. Variable pricing schemes such as electronic tolling systems should be used to penalise/incentivise inefficient/efficient vehicles.
- For freight transport, high penalties should be imposed on heavy vehicles to encourage a shift from road to rail. Greater investment should be made in rail infrastructure to improve the rail network and encourage the use of rail for long distance haulage.

The national EETMS should be expanded to include energy consumption data for all sectors, including transport.

Energy access

Solar technologies feature fairly prominently in the energy mix. This should be supported by the implementation of mini-grid, off-grid and distributed generation. Solar PV technologies in urban and rural areas should continue to play a role and regulations pertaining to small-scale distributed power, which can be fed back to the grid, need to be developed. The Solar Water Heating Programme should continue to be implemented aggressively in both rural and urban areas.

… Research and development should focus on innovative solutions …

Research and development

Research and development should focus on innovative solutions and in particular on solar energy, as this has the greatest potential to address electricity challenges for small-scale energy consumers in a fairly short timeframe. Solar energy also has the potential to address the need for energy access in remote areas; create semi-skilled jobs; and increase localisation. More funding should be targeted at long-term research focus areas in clean coal technologies such as CCS and UCG as these will be essential in ensuring that South Africa continues to exploit its indigenous minerals responsibly and sustainably. Exploration to determine the extent of recoverable shale gas should be pursued and this needs to be supported by an enabling legal and regulatory framework.

Other considerations

The mandate of government agencies accountable to the DoE must be clarified and streamlined. Adequate funding should be provided to ensure that their mandates are achieved. The role that the South African National Energy Development Institute (SANEDI) should play in conducting studies on collecting data and providing insight on the impact of technology development for different energy end-use technologies within the different demand sectors needs to be supported. SANEDI also needs to play a more significant role in the identification and building of human capacity, especially in the areas of energy modelling, planning, statistics, and renewable energy technology and energy efficiency.

Section 1: Background and introduction

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 solid facts. 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 (e.g. 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, the introduction of new technologies, and the effects of macroeconomic factors.

… 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 solid facts …

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 (NDP) and its supporting pillars which include, *inter alia* the New Growth Path and the Industrial Policy Action Plan. 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 White Paper;
- The National Transport Master Plan (NATMAP 2050); and
- The proposed Carbon Tax Policy.

Today's choices about how energy is produced and consumed 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.

For example, the increase in private vehicle ownership, coupled with inadequate oil refining capacity and constrained 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, increased volatility in global crude oil prices and increases in coal prices, together with potential new 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 sustainable and 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.

… Today's choices about how energy is produced and consumed will determine the sustainability of the future energy system and consequently of socio-economic progress …

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 matters 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. These are, or will be, covered in detail as follows:

- Electricity infrastructure (transmission and distribution) is dealt with in other plans and the Integrated Resource Plan (IRP) should assess these in detail, taking into consideration the grid planning currently conducted by Eskom;
- Electricity supply is dealt with in the IRP;
- Liquid fuels will be dealt with in the 20-Year Liquid Fuel Infrastructure Roadmap which will cover logistical matters relating to pipelines and storage facilities for petroleum products.
- The Gas Utilisation Master Plan (GUMP) will take into consideration the bottlenecks and capacity constraints of the current natural gas infrastructure.

All the above will inform the integrated energy planning process and will enable overall enhancement through ongoing periodic iterations to ensure alignment.

1.2. Energy policy considerations

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

The 1998 White Paper on the Energy Policy of the Republic of South Africa (Energy White Paper) is the primary policy document which guides all subsequent policies, strategies and legislation within the energy sector. It provides specific policy statements on what government intends for the energy system as a whole and sets out five key objectives (see Table 0-1). 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);
- The Electricity Basic Services Support Tariff (Free Basic Electricity) Policy, 2003 (Free Basic Electricity Policy); and
- The Integrated Resource Plan 2010 (IRP2010).

Table 0-1: 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 black people 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.

Objective	Description
Stimulating economic development	• Government will encourage competition within energy markets. • 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 the 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 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 to 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.

1.3. Key policy issues

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 greenhouse gas (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 as well as 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.

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.

One of the key elements during the energy planning process is to ensure alignment and identify synergies between various government policies. This section identifies some of the key policy issues that have been considered during the energy planning process.

1.3.1. Economic growth and development

National Development Plan

The National Development Plan, which was published in November 2012 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 technologies 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 supply 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% of the population should enjoy access to electricity by 2030.

The NDP proposes diversity by way of 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.

New Growth Path

The New Growth Path of 2011 (NGP) is a more specific policy element which 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 NGP targets 300 000 additional direct jobs by 2020 through the greening of 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.

… According to the National Climate Change Response White Paper (NCCRWP), the energy sector contributed to about 80% of total carbon emissions for the country in 2000…

1.3.2. Environmental sustainability

National Climate Change Response Policy

According to the 2010 National Greenhouse Inventory Report, the energy sector contributed more than 80% of total carbon emissions for the country in 2000. The majority of emissions were from energy industries (63.6%), followed by 10.8% from transport and 9.8% from manufacturing industries and construction. The main source of emissions in the energy sector is CO_2 from fossil fuel combustion (GHG Inventory, 2014).

During the 16th United Nations Framework Convention on Climate Change (UNFCCC) Conference of Parties (COP 16), the President of South Africa announced that South Africa would implement mitigation actions that would collectively result in a 34% deviation below a 'Business As Usual' emissions growth trajectory by 2020 and a 42% deviation by 2025, subject to relevant support from more developed countries. The NCCRWP defines these targeted reductions in total emissions as the 'Peak-Plateau-Decline' emissions trajectory, and work on further translation of these reductions by each sector is currently under way.

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 such support, South Africa's GHG emissions will peak between 2020 and 2025, plateau for approximately a decade and decline in absolute terms thereafter.

Carbon Tax Policy

In light of the above, and in an effort to support the country's aspiration to reduce emissions, the National Treasury published a Carbon Tax Policy Paper for public comment in May 2013. The policy paper outlines the primary objective of the proposed carbon tax, which is to reduce GHG emissions across all relevant sectors and facilitate the transition to a Green Economy. In the policy paper, carbon taxation and emission trading schemes are identified as the two main economic policy instruments available for putting a price on carbon and curbing GHG emissions.

The policy 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 tax 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 in emissions.

The proposed carbon tax design incorporates tax-free thresholds that take into account the competitiveness concerns of locally based and trade-exposed carbon-intensive sectors and businesses, as well as distributional concerns, such as the impact on low-income households. These thresholds are subject to periodic review.

In terms of the energy sector, the Carbon Tax Policy Paper proposes the following:

- The electricity supply industry has been allocated a basic tax-free threshold of 60%; and
- The petroleum industry (including crude oil refining, coal-to-liquid and gas-to-liquid sub-sectors) has been allocated a basic tax-free threshold of 60% with a further maximum additional allowance of 10% for trade exposure.

The policy paper proposes an initial carbon tax of R120 per ton of Carbon Dioxide Equivalent (CO_2-eq) above the tax-free thresholds with effect from January 2015. This tax is increased at a rate of 10% per annum for five years (i.e. up until 31 December 2019). A revised regime, with lower tax-free thresholds and a revised rate which will be announced at a later point, will commence on 1 January 2020.

National Water Resource Strategy 2

The Second National Water Resource Strategy (NWRS2) has been developed as mandated by the National Water Act (Act No. 36 of 1998). The NWRS2 emphasises the strategic value of water and its necessity for growth and development, the environment, health and wellbeing of the people of South Africa. The well-developed water management and infrastructure framework of the country has resulted in a perceived sense of water security (urban and growth areas). As a consequence, despite the fact that South Africa is a naturally water stressed country, the resource has not received the relevant priority status and attention. Wastage is high, with approximately 37% of water lost to the system, and further loss due to pollution and degradation. In addition to this the strategy purports that water is currently inadequately financed.

While on a national scale, the energy sector only consumes approximately 2% of total water used, the energy sector is highly dependent on reliable supplies of water for the generation of electricity (steam generation and cooling processes), and an elaborate and sophisticated network of water transfer and storage schemes has been developed specifically to support the sector and ensure high levels of reliability. The provision of water for the energy sector is therefore a significant cost driver. The water sector on the other hand, is highly dependent on a constant and reliable supply of electricity to 'move water'. The deployment of more water-efficient technologies (such as dry-cooled, coal-fired power plants) is required. Energy production capacity is expected to increase, with the DoE planning significant investment in new power generation capacity. Current plans include the building of dry-cooled, coal-fired power stations which will be more water efficient. However, these power stations are located in water-scarce areas and, despite their design, are likely to strain available water resources. The return to service of older power stations, which are wet-cooled, has further burdened available water resources.

The IEP has taken into account and considered the associated costs of:

- The emission limit reduction targets set by the NCCRWP and concomitant commitments made by the President;
- The implications of the proposed carbon tax on future energy options and its efficacy in reducing emissions;
- Wet-cooled older power stations, some of which have been returned to service in order to address current electricity constraints; and
- Ensuring that all new coal-fired power plants are dry-cooled to minimise the constraints on water.

… Sufficient, reliable and cost-effective energy supply is therefore a key contributor to the successful implementation of various elements of the industrialisation policy …

1.3.3. Industrialisation

National Industrial Policy Framework

The National Industrial Policy Framework (NIPF) articulates South Africa's overarching approach to industrial development, providing a strong basis for the policy certainty that must underpin it. The NIPF vision for South Africa's industrialisation trajectory is, amongst other factors:

- To facilitate diversification beyond our current reliance on traditional commodities and non-tradable services. This requires the promotion of increased value-addition per capita, characterised particularly by movement into non-traditional tradable goods and services that compete in export markets;
- The long-term intensification of the country's industrialisation process and movement towards a knowledge economy;
- The promotion of a more labour-absorbing industrialisation path, with a particular emphasis on tradable labour-absorbing goods and services and economic linkages that catalyse employment creation;
- The promotion of a broader-based industrialisation path, characterised by greater levels of participation of historically disadvantaged people and marginalised regions in the mainstreams of the industrial economy; and
- Contributing to industrial development on the African continent, with a strong emphasis on building its productive capabilities.

In addition to the above, it is indicated that although the NIPF aims to improve growth and employment conditions across much of the economy generally, its primary focus is on the relatively low skill-intensity industries, including non-traditional tradable goods and services in the primary, manufacturing and services sectors of the economy.

Sufficient, reliable and cost-effective energy supply is therefore a key contributor to the successful implementation of various elements of the industrialisation policy.

Industrial Policy Action Plan and Beneficiation Strategy

The Industrial Policy Action Plan (IPAP) is developed to provide a programme of action to ensure implementation of the NIPF objectives. IPAP 2015/16–2017/18 (which is the seventh iteration of IPAP to date) is also informed by the vision set out for South Africa's development, provided by the National Development Plan. The overriding goal of the IPAP in this policy context is to prevent industrial decline and support the growth and diversification of

South Africa's manufacturing sector. The balance of international evidence is that manufacturing is the engine of growth and employment for all economies that have achieved high gross domestic product (GDP) and employment growth. Manufacturing can generate significant job creation directly, as well as indirectly, in a range of primary and service sector activities.

In alignment with the NIPF, the Beneficiation Strategy (DMR, 2011) provides a framework within which to translate the country's comparative advantage, inherent in its mineral resources endowment, into a national competitive advantage and presents opportunities for South Africa to continue sustainable growth of its economy beyond mining. It 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. Much like the NIPF, 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 fired power stations, where more than 50% 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, has a material impact on sustaining current beneficiation initiatives and poses a major threat to future prospects of growth in mineral value addition. Therefore successful implementation of the Beneficiation Strategy depends on intensive co-ordination across a range of departments, including the DoE.

The Beneficiation Strategy outlines five value chains, of which energy is one, which have been 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 and development by the Department of Science and Technology with respect to fuel cell technology needs to continue.

The DST has developed the National Hydrogen and Fuel Cell Technologies (HFCT) Research, Development and Innovation Strategy, which was approved by Cabinet in May 2007. The Strategy was formally launched in September 2008 and branded Hydrogen South Africa (HySA). The vision of the HySA Strategy is to create knowledge and human resource capacity and to develop high level commercial activities in HFCT, utilising local resources.

The HySA Strategy is geared towards the development and deployment of HFCT, with the aim of establishing South Africa as an exporter and provider of high-value products into the growing international and local hydrogen and fuel cell markets.

The overall goal of the HySA Strategy is to develop and guide innovation along the value chain of HFCT in South Africa and to capture 25% of the global hydrogen and fuel cell catalyst demand by 2020.

Coal: Given that coal is currently the most abundant and affordable of all fossil fuels, the Beneficiation Strategy sees this as continuing to play a vital role in meeting energy demand world-wide and also in South Africa. The Beneficiation 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 Beneficiation 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 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 complete nuclear fuel elements containing the enriched uranium from the northern hemisphere for its own power generation purposes. This is due to South Africa being able to access more competitively priced nuclear fuel in the global market. 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 a uranium enrichment and fuel fabrication facility;
- Plan for comprehensive waste treatment and mine rehabilitation; and
- Finalise the uranium policy with all relevant stakeholders.

Other areas: The Beneficiation Strategy document highlights other 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 cogeneration potential, where possible.

> *… Transportation in South Africa is almost totally dependent on petroleum liquids, with less than 5% of the energy used in transport being in the form of electricity …*

1.3.4. Energy demand management

National Transport Master Plan

A significant portion of South Africa's transportation needs are met through liquid fuels. Transport-related policies therefore have a significant impact on the growth in transport demand and the inherent demand for liquid fuels. 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% of the energy used in transport being in the form of electricity. This makes the transport sector extremely vulnerable to the availability of oil and the cost of oil and therefore the cost of fuel. Almost 92% 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 PetroSA GTL plant) (DoE, 2012).

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 onto rail.

National Energy Efficiency Strategy

The National Energy Efficiency Strategy was last published in 2005 and sets targets for energy efficiency improvements in several sectors. The strategy is currently undergoing a third review process and new targets for 2016–2030 will be set for different sectors. In addition to this, the DoE has released draft regulations which will provide the data requirements for legal entities that use more than 400 Terajoules (TJ) to develop Energy Management Plans (EMPs). Progress towards the implementation of the EMP must be submitted to the Department on an annual basis and thereafter updated and submitted every five years. The submission of such plans and the implementation of the Energy Efficiency Target Monitoring System (EETMS) will enable ongoing monitoring of energy efficiency improvement and benchmarking of different sectors.

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

1.3.5. Energy equity

Household Electrification Strategy

Energy equity refers to the accessibility and affordability of energy supply across the population. The Universal Access to Energy Strategy aims to have 90% of homes electrified by 2030, with the remaining 10% being connected through off-gird solutions (primarily solar home systems).

According to the New Household Electrification Strategy for South Africa, energy is critical in improving the well-being of the poor who need it for cooking and lighting, heating water, transportation and the production of goods and services. Energy access affects quality of life by contributing to better public services, such as health care and education, and improving the possibilities for income generation and employment. The provision of adequate, affordable, and reliable energy services is therefore necessary to enable development and to achieve the Millennium Development Goals (MDGs).

The strategy identifies electricity as the mainstay that gears development activities leading to the improvement in the quality of life and the eradication of energy poverty. In this regard energy is the basis for delivering a host of energy services such as clean illumination in the home and in schools; the ability to operate life-saving equipment in clinics; the running of industries and productive small businesses; and providing modern communications technology.

Although significant progress has been made with regard to electrification (access more than doubled from 36% of the population in 1994 to over 84% all households in 2012), according to the 2011 Census statistics, there were still 2.2 million households without electricity.

… The IEP needs to consider the impact of grid and off-grid electrification in terms of future energy demand as well as the opportunities presented by different energy technologies in increasing access to energy…

Several challenges have led to this backlog including costs associated with providing grid connections to areas remote from the main transmission infrastructure. The strategy advocates the implementation of innovative non-grid technologies to ensure access to areas where network infrastructure will take a number of years to reach. However challenges around the sub-optimal use of non-grid electrification in the overall electrification programme in the country would need to be identified and addressed. The IEP needs to consider the impact of grid and off-grid electrification in terms of future energy demand as well as the opportunities presented by different energy technologies in increasing access to energy.

1.4. The objectives of the IEP

Based on the key polices identified in the previous section, the IEP takes a balanced view of the objectives of various policies. 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 have been taken into consideration in order to develop long-term energy sector response strategies which are sustainable.

Taking the Energy White Paper, the National Energy Act and the various high-impact policies, amongst others into consideration, eight key objectives were identified for the IEP and are reflected in Figure 0-1.

Figure 0-1: Key IEP objectives

These objectives are the key criteria against which the different policy alternatives and proposals made in the IEP are evaluated. Each of the objectives depicted in Figure 0-1 is described in Table 0-2 below.

Table 0-2: Key objectives of the IEP

Objective	Description
Ensure 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% 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, sustainable 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 again been adopted 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 a more competitive economy.
	The objective of the IEP is to identify and highlight the mix of energy supply and demand technology options and energy resources and sources that minimise the total cost of energy, while meeting the projected energy demand subject to a boundary of conditions.
Promote job creation and localisation	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. 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.
	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 and which can be mass produced locally.
Minimise negative environmental impact by the energy sector	Energy planning needs to be done in such a manner that it does not impair government's goals of minimising adverse impacts on the environment. 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 tons of carbon dioxide equivalent (Mt CO_2-eq), mainly from energy generation and deforestation. In comparison, South Africa produced about 440 Mt CO_2-eq, or about 1% of the global figure. South Africa's emissions are large relative to its population and economy.
	The IEP identifies a mix of technology options whose combined emissions will ensure that South Africa remains within the constraints identified in the National Climate Change Response White Paper. Environmental legislation such as the National Environment Act and the Air Quality Act are also taken into consideration by ensuring that pollution from the energy sector is kept to a minimum.
Minimise water consumption	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 particularly for 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 is responsible for about 2% of total national water consumption. However, overall conservation of water by the energy sector reduces not only water consumption but also the demand for energy, as energy is required to move water.

Objective	Description
	The Department of Water Affairs advocates the introduction of dry-cooled power plants in the inland region, which will ensure a reduction in water consumption, and this has been taken into account in the IEP. The IEP further highlights the estimated water usage associated with the various technology options.
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 nuclear and renewable energy (including imported hydropower from neighbouring countries). The role that natural gas can play in the transition to a low carbon future should also be considered. Diversifying the energy mix is necessary in order 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 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.
Improve energy efficiency (reduce energy intensity of the economy)	Energy efficiency relates to the economical and efficient production and use of an energy carrier or resource. It results in achieving the same quality and level of some 'end uses' of energy (e.g. 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.
	While the 2013 National Energy Efficiency Strategy 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 these options (supply- and demand-side) making them more efficient and therefore contributing overall efficiency improvements.
Promote energy access	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 cleaner forms of energy. The more available the usable energy, 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.

Section 2: Overview of the energy sector

According to the 2014 Energy Sustainability Index, developed by the World Energy Council, South Africa ranked 83rd on the Energy Sustainability Index out of 129 countries. This was partly informed by its ranking at 42nd on energy security, which is an improvement over the previous two years; a ranking of 85th on energy equity, which declined over the last two years; and a placing of 129th in terms of environmental impact mitigation, which remains the lowest score for the past three years. According to the report, the drop by two places was mostly driven by the continued poor performance on the environmental sustainability dimension and the drop in energy equity. The low performance in environmental sustainability is due to the electricity sector's heavy reliance on coal and hence its high emission rates; while increasing petroleum prices, coupled with rising electricity tariffs, informed the low score on energy equity (WEC, 2014).

2.1. Primary energy supply

Primary energy supply in South Africa is dominated by coal (~71%), followed by crude oil (~15%). Nuclear, natural gas and renewable energy (including hydro and biomass) have historically played a less significant role in the total energy mix, collectively contributing to the remaining ~11% (DoE, 2014).

A closer examination of the electricity generation industry (DOE, 2010) reveals that 90% of electricity was generated from coal, followed by nuclear and hydro at 5% and 4.5% 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% towards the total installed capacity for electricity generation. Imported crude oil dominated the primary supply of liquid fuels, followed by imported natural gas. Production of fuel from renewable energy sources and waste remained in its infancy and had not really taken off.

… Primary energy supply in South Africa is dominated by coal (~71%), followed by crude oil (~15%)…

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

2.1.1. 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% of world production (SA Coal Roadmap, 2010). Globally the five largest users of coal are China, USA, India, Japan, and South Africa and account for about 82% of its use. Coal is the second most important primary energy source after oil globally, with power generation being responsible for the largest absolute use of coal.

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).

According to the coal reserve and resource study conducted by the Council for Geo-Science in 2011, South Africa has in excess of 66 billion tons (Bt) of coal resources and reserves remaining (Eskom, 2015). At the current production rates it is estimated that coal supply is in excess of 200 years. More than 70% of these resources lie in the Waterberg Coalfield in the Limpopo Province, however there is only one operating colliery in that coalfield at present.

... Eskom generates 92.8% of South Africa's electricity, with the remaining 7.2% being generated by municipalities and Independent Power Producers (IPPs) …

While approximately 26.2% of South African produced coal is exported, the remainder contributes to approximately 80% of the country's total primary energy requirements. Eskom generates 92.8% of South Africa's electricity, with the remaining 7.2% being generated by municipalities and Independent Power Producers (IPPs). Within the liquid fuel sector, approximately 30% of South Africa's total liquid fuel requirements were produced from coal by Sasol, but in recent years this has slowly begun to decline, as gas is also being used as feedstock to meet the increasing demand.

The use of coal going forward will be impacted by price and more so by environmental challenges. The combustion of coal results in the emission of various harmful gases and particulate matter into the atmosphere and also produces a significant amount of waste. The mining activities associated with the extraction of coal also have dire consequences for the environment.

Unless new technologies, aimed at reducing the carbon intensity of coal, are developed and put into use, the international competitiveness of South African exports could potentially be negatively affected. In the short- to medium-term, however, coal will continue to play an important role in the country's energy mix.

Underground Coal Gasification (UCG) is a process whereby coal, which has not yet been mined, is heated *in situ* under controlled conditions to release synthetic gas (syngas). The syngas is then brought to the surface and can be used directly for power generation. This process avoids the need for coal mining, transportation, preparation as well as disposal of ash, all of which have a tremendous impact on cost, labour and the environment. This in turn would help to reduce the cost of electricity.

The process can also be applied to coal that would not normally be mined due to various factors, including depth. Since up to three quarters of South Africa's coal may not be mineable, UCG could help to increase South Africa's 'coal supply' and could function in parallel with conventional mining. Extraction rates for UCG have been proven to be high (at about 83%) compared to less than 25% in conventional mining.

Eskom's UCG project, located near Majuba Power Station, was commissioned in January 2007. Initial co-firing in unit 4 at Majuba Power Station was achieved in October 2010. The design phase for a 100–140 megawatt electric (MWe) open-cycle gas turbine (OCGT) demonstration plant using UCG gas is currently under way (Eskom, 2015).

UCG technology therefore allows countries that are endowed with coal to continue to utilise this 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 feedstock. While the process has 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. The development of this technology and the viability of its implementation are still at a nascent stage and ongoing research needs to be undertaken.

2.1.2. 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 for the production of liquid fuels, with a small percentage used towards lubricants, bitumen, solvents and other petrochemicals. As is the case elsewhere in the world, liquid fuels are primarily used to meet the country's mobility needs. As a net importer of crude oil, and a developing country, South Africa is not in position to influence the price of crude oil. The South African liquid fuels industry is highly impacted by global developments and fluctuations in the crude oil price and the economy as a whole is therefore extremely vulnerable to the volatility of the global oil market.

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-Organisation for Economic Cooperation and Development (OECD) nations, including China and India, which offsets 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 growth, 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. Globally, Compressed Natural Gas (CNG), Liquefied Natural Gas (LNG) and electricity play a significant role as primary fuels in the transport sector.

2.1.3. 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.

2.1.4. Natural gas

Natural gas plays a relatively small part (roughly 3%) 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 from 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 and 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 location of the Rovuma Basin is further north on the coast of Mozambique and the importation of gas from these fields by pipeline or through LNG infrastructure should be explored. The Government of Mozambique has 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).

… Despite extensive drilling along South Africa's coastline, only marginal conventional gas discoveries have been made, with limited future prospects …

Due to South Africa's limited LNG infrastructure, there are no other sources for possible gas imports. South Africa does, however, have the opportunity to explore options relating to the new gas discoveries in Mozambique.

Despite extensive drilling along South Africa's coastline, only marginal conventional gas discoveries have been made, with limited future 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.

A recent report by the Energy Information Administration (EIA) however, has estimated unconventional gas resources (shale gas and coal bed methane) in the Southern Karoo Basin of 485 Tcf. Further exploration is required to determine the extent of this recoverable resource. The perceived environmental risks associated with extracting 'tight' gas such as shale gas are considered to be significant, since the process (called hydraulic fracturing) requires substantial amounts of water. This 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 licences 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, it was not possible to quantify the extent of the shale gas resource accurately. It is 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. Bearing in mind that the construction of the PetroSA Mossel Bay plant was founded on 1 Tcf of natural gas, if even a fraction of the estimated 485 Tcf is proven, it 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. Compared to oil, transporting gas by pipeline is relatively expensive because of the additional capital-intensive equipment needed to overcome the lower energy density of gas. However, these challenges can be overcome if there is a sizeable off-taker.

Natural gas has significant potential both for power generation as well as direct thermal uses. The power generation and liquid fuel sectors could be the main drivers behind the large-scale introduction of gas in South Africa. Construction of a combined-cycle gas turbine (CCGT) plant which has a relatively short lead time, together with the augmentation of gas supply to the existing PetroSA plant in Mossel Bay could help fast track the introduction of bulk gas at competitive prices in the short to medium term. Co-firing of existing old coal fired power stations with gas is an option that should be explored. A further option for the introduction of gas to the market is the introduction of Floating Storage and Regasification Units. These could be moored at key coastal points to receive LNG from ships for power generation and industrial use. This would help South Africa to reduce GHG emission, as natural gas has lower carbon content than coal.

The direct use of gas in energy intensive industries as an alternative to electricity and other fossil fuels should also be explored as it provides an efficient thermal energy source. 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.

2.1.5. Renewable energy

South Africa is well endowed with renewable energy (RE) resources in the form of radiation from the sun, and wind in coastal and mountainous areas, which have in the past remained largely untapped. South Africa generally receives abundant sunlight to support a sustainable solar power industry. The Northern Cape is one of the world's highest solar radiation areas; and much of South Africa's coastal region and its mountainous terrain is suitable for wind power.

In 2003, a 10-year target of 10 000 gigawatt hours (GWh) (the equivalent of 0.8 million tons of oil equivalent [Mtoe]) was set for RE, which was the envisaged industry contribution to final energy consumption by 2013. By 2008, the nascent RE industry contributed less than 8% of South Africa's primary energy supply. The IRP2010, which was promulgated in March 2011, envisaged electricity generated from hydropower maintaining its share of 5% and other RE technology forms contributing up to 9% (from an almost negligible amount) by 2030. Total installed capacity of RE technologies would be in the magnitude of 26.3% of total installed capacity by 2030.

Following the promulgation of the IRP2010, the DoE embarked on an aggressive Renewable Energy Independent Power Producer (REIPP) programme which has seen a steady increase in the share of RE technologies in the energy mix. In August 2011, subsequent to the Ministerial Determination of the same month providing for the procurement of 3 725 MW of RE capacity from IPPs, the DoE initiated the IPP Procurement Programme to procure renewable energy generation from the private sector in a series of rounds (commonly referred to as Bid Windows). In December 2012 further Ministerial Determinations were announced for the procurement of 3 200 MW of RE generation from IPPs. To date the DoE has procured over 4 000 MW of renewable energy across Bid Windows 1 to 3.5 under the REIPP Programme. The DoE has entered into the following agreements with IPPs in the energy sector:

… South Africa is well endowed with renewable energy resources in the form of radiation from the sun, and wind in coastal and mountainous areas, which have in the past remained largely untapped …

- Bid Window 1: 28 Agreements entered into on 05 November 2012;

- Bid Window 2: 19 Agreements entered into on 09 May 2013; and
- Bid Window 3: 17 Preferred bidders announced on 4 November 2013 and 15 agreements entered into on 11 December 2014

A further 77 bids were received under Bid Window 4. The total capacity of these bids exceeded 5 000 MW which by far exceeds the 1 105 MW capacity available for allocation. The average bidding prices have declined with each bid window for the various technologies.

Table 0-1 shows the total allocation for each type of technology from the bids awarded in rounds 1 to 4 of the REIPP procurement process.

Table 0-1: Total allocation for renewable energy technologies through the REIPP Programme

Technology	MW capacity allocated in Bid Window 1	MW capacity allocated in Bid Window 2	MW capacity allocated in Bid Window 3	MW capacity allocated in Bid Window 4	MW capacity remaining
Solar Photovoltaic	632 MW	417 MW	435 MW	415 MW	626 MW
Onshore Wind	634 MW	563 MW	787 MW	676 MW	660 MW
Concentrated Solar Power	150 MW	50 MW	200 MW	N/A	–*
Small Hydro (≤ 40 MW)	–	14 MW	–	5 MW	116 MW
Landfill Gas	–	–	18 MW	–	7 MW
Biomass	–	–	16 MW	25 MW	19 MW
Biogas	–	–	–	N/A	60 MW
Total	**1 416MW**	**1 044MW**	**1 456MW**	**1 121 MW**	**1 488 MW**

** 200 MW was allocated in the March 2014 CSP Bid Window*

Source: Presentation by DoE on REIPP bid Window 4, April 2015

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 kilowatt hours per square meter (kWh/m^2) (16 and 23 megajoules per square meter [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% 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 substantially 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, namely concentrated solar power (CSP), also known as solar thermal energy, and solar photovoltaic (PV) energy. 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 the 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. The PV technologies which have become commercialised are PV thin-film and PV crystalline.

A 2011 Pew Center report from the US put the levelised cost (the total lifecycle cost of producing electricity using a specific technology) of electricity generation from 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 baseload, 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 for solar power have primarily been the heating of water for households and the provision of PV electricity for houses, schools and clinics in rural communities. Solar energy technologies are also starting to grow 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 in 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 embarked on an aggressive solar water heating programme with the target being the installation of 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.

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 meters per second (m/s) and power exceeding 200 Watt per square metre (W/m^2). Moderate inland 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 volt (V).

The Klipheuwel Wind Farm near Cape Town is an Eskom demonstration plant which is being

… 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 in the coming years …

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 14%, 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. 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

… Government remains committed to exploring options for importing clean hydropower that is developed in the region …

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 DoE 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.

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. As a water-scarce 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 for the free trade of electricity between Southern African Development Community (SADC) member countries. Government remains committed to exploring options for 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 will be the world's largest hydropower scheme and is the centrepiece of a continent-wide power system which is being developed in multiple phases.

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 cogeneration).

In the forestry sector, the volume of waste remaining in the forests is substantial. This waste 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, 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 approximately 2.4 million tons (Mt) of pulp and 2.7 Mt 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 Mt of wood per year. These estimates suggest that present wood consumption is unsustainable because it is being consumed faster than it is replenished.

Bagasse

… There is high potential for the production of biofuels from energy crops such as sugarcane, sugar beet, sunflowers and canola …

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 Mt per year, which yields about 7 Mt 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 food crops makes it uneconomical to transport over long distances and hence they need to be used either close to where they are produced, or 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 has been 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 DoE has 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 Landfill, and the EnviroServ Chloorkop Landfill Gas Recovery Project.

2.1.6. 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. A 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.

Developments to establish a hydrogen economy in South Africa are progressing and through the Department of Science and Technology's HySA various projects are being undertaken to develop technologies for cost effective and safe hydrogen production, delivery, transportation, storage and electricity generation via fuel cells as well as the development of codes and standards. Projects are executed through local and international collaborative research and include the following themes:

- Combined Heat and Power (CHP);
- Stand-alone Power Systems and Uninterruptible Power Supplies (UPS);
- Hydrogen Fuelled Vehicles (HFVs);
- Hydrogen Storage (Compressed, Metal Hydrides, etc.); and
- Renewable Hydrogen Production.

Section 3: Summary of key assumptions

This section presents a summary of assumptions for the key parameters that inform the IEP analysis, namely:

- Macroeconomic assumptions (GDP, discount rate and energy commodity prices);
- Demographic assumptions (population growth);
- Socio-economic assumptions (job and localisation potential of different technologies);
- Technology costs; and
- Externality costs.

A detailed analysis for each of these assumptions can be obtained in the annexures.

3.1. Macroeconomic assumptions

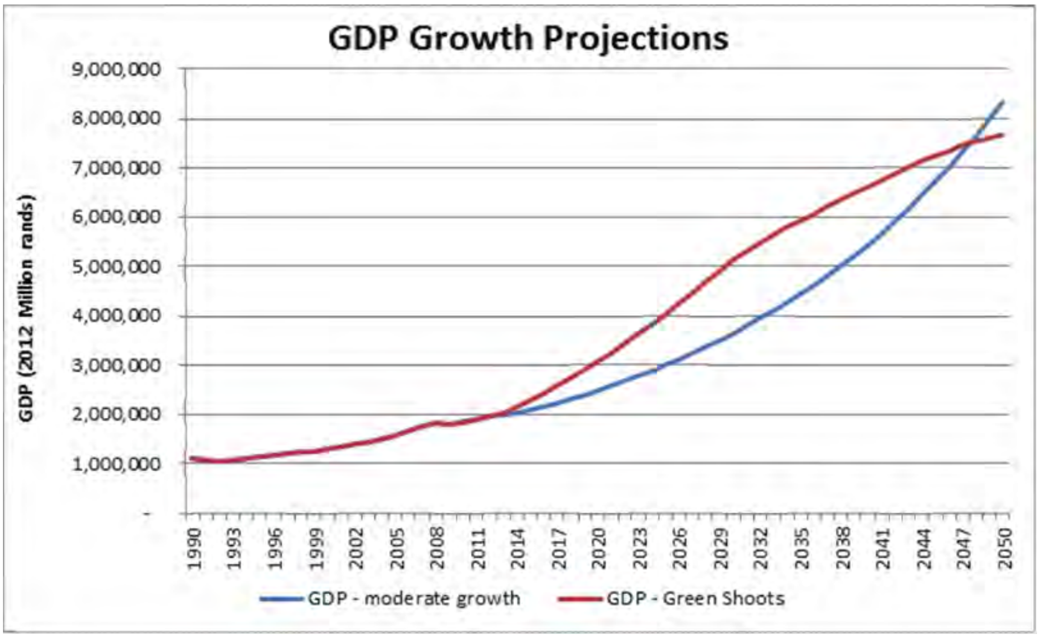
A detailed analysis of the macroeconomic assumptions can be obtained in ANNEXURE B.

Parameter	Description	Source of information	Unit	Assumption
GDP	• Average potential economic growth over planning period • Average potential economic growth over planning period	• National Treasury • IRP2010	• Percentage per year • Percentage per year	• See Table 0-1 • Green Shoots
Discount Rate	• The rate at which future benefits and costs decline is important 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	• 8.4%
Crude Oil Price	• The annual average global spot price of crude oil	• International Energy Agency, 2014 World Energy Outlook	• **Original units:** Real 2012 US dollars per barrel (US$/bbl) – update • **IEP units:** R/gigajoule (GJ)	• Base Case: Assumes the crude oil projections of the 'New Policy Scenario' • The Resource Constrained Scenario: Assumes the crude oil prices of the 'Current Policy Scenario'

Parameter	Description	Source of information	Unit	Assumption
Petroleum Product Prices	• Price at which petroleum products are sold to the market	• DoE analysis (derived from crude oil price)	• R/GJ	• Petroleum product prices were derived from the crude oil price projections mentioned above
Natural Gas Price	• The annual average natural gas import price	• International Energy Agency, 2014 World Energy Outlook • European Natural Gas Import Prices	• **Original Units:** Real 2012 US dollars per million British thermal units (MBtu) • **IEP Units:** R/GJ	• Base Case: Assumes the natural gas projections of the 'New Policy Scenario' • The Resource Constrained Scenario: Assumes the natural gas prices of the 'Current Policy Scenario'
Coal Prices ***Fluidised Coal*** ***Pulverised Coal***		• EPRI report • EPRI report	• R/GJ • R/GJ	• Fixed at R15/GJ throughout the planning horizon • Fixed at R7.50/GJ throughout the planning horizon
Shale Gas Extraction	• Capital costs for primary energy production • Fixed costs for primary energy production	• PetroSA • PetroSA	• R/GJ/annum • R/GJ/annum	• Fixed R372/GJ per annum throughout the planning horizon • Fixed R6/GJ per annum throughout the planning horizon

Table 0-1: GDP growth projections

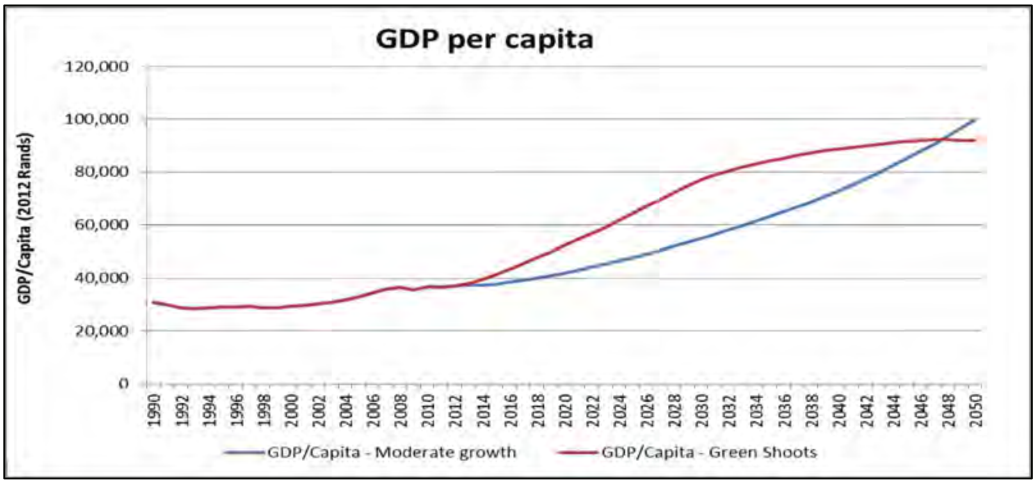
	Short term				Medium term	Long term
	2014	*2015*	*2016*	*2017*	*2018–22*	*2023–50*
Low Growth	1.5	1.8	2.3	2.5	2.8	3.0
	2.4	*2.5*	*2.9*		*3.1*	*3.0*
Moderate Growth	1.8	2.7	3.2	3.5	3.7	4.2
	3.0	*3.2*	*3.5*		*3.7*	*4.0*
High Growth	2.0	3.3	3.7	4.0	4.9	5.5
	3.3	*3.6*	*4.0*		*4.9*	*5.4*



Source: DoE Analysis

Figure 0-1: GDP growth projections

The graph below shows different scenarios for the projected GDP per capita based on the GDP growth and population projections.



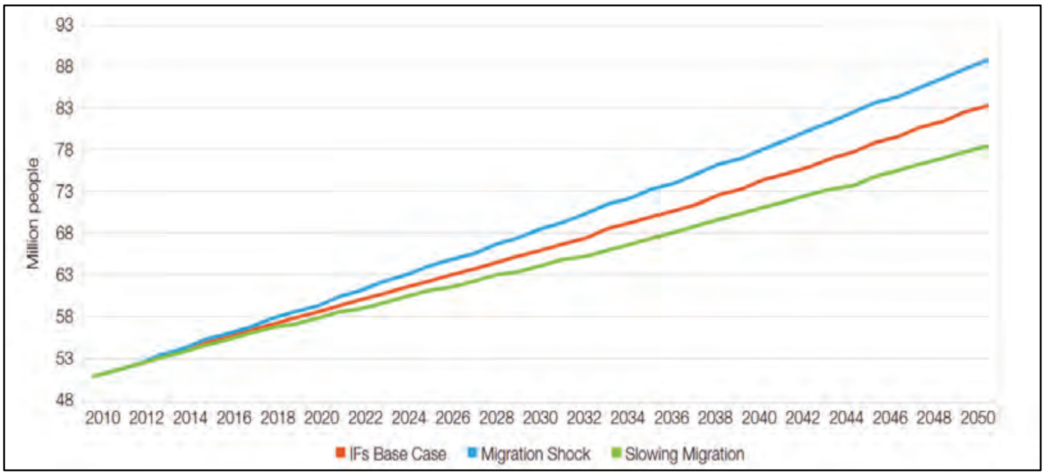
Source: DoE Analysis

Figure 0-2: Moderate growth and Green Shoots GDP/Capita

3.2. Demographic assumptions

A key driver of energy demand is population size and expected growth. A detailed analysis of demographic and macroeconomic assumptions can be obtained in ANNEXURE B.

Parameter	Description	Source of information	Unit	Assumption
Population Growth	Growth of the national population taking into account three key drivers: Fertility Rate, Life Expectancy and Migration	Institute for Security Studies	Million people	See Figure 0-3 below



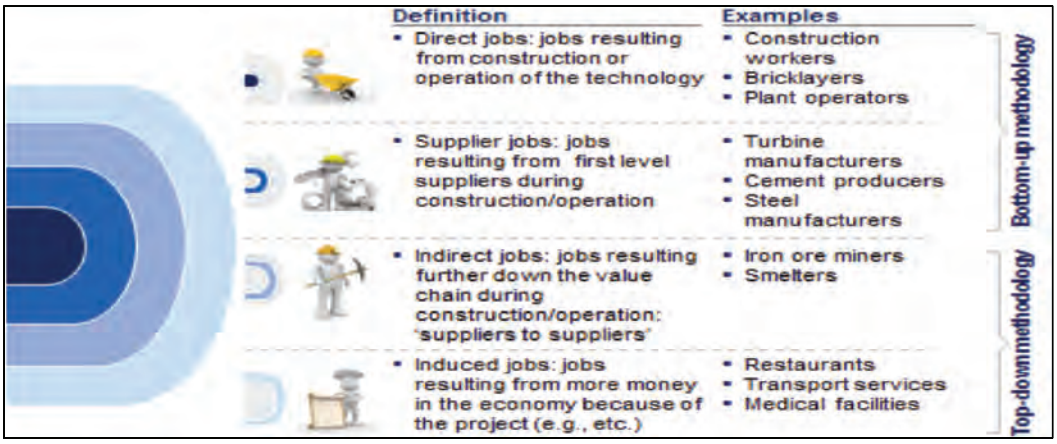
Source: ISS (2013)

Figure 0-3: RSA population growth projections

3.3. Socioeconomic assumptions

The job creation potential of the energy sector is summarised in this section. A detailed analysis of the socioeconomic assumptions can be obtained in ANNEXURE B. Job creation potential within the electricity sector is based on the output from a study conducted by McKinsey & Company (McKinsey & Company, 2014), while job creation potential for the liquid fuel sector is based on several studies conducted by independent consultants on behalf of PetroSA (PetroSA, 2012). Direct, indirect, supplier jobs and induced jobs were considered in estimating the number of jobs created by the deployment of different technologies.

Table 0-2: Job categories



Definition	Examples
• Direct jobs: jobs resulting from construction or operation of the technology	• Construction workers • Bricklayers • Plant operators
• Supplier jobs: jobs resulting from first level suppliers during construction/operation	• Turbine manufacturers • Cement producers • Steel manufacturers
• Indirect jobs: jobs resulting further down the value chain during construction/operation: 'suppliers to suppliers'	• Iron ore miners • Smelters
• Induced jobs: jobs resulting from more money in the economy because of the project (e.g., etc.)	• Restaurants • Transport services • Medical facilities

Source: McKinsey and Company, 2014

For the electricity sector, further analysis was done to determine the localisation potential. This was determined based on two criteria: Sufficiency of demand for required goods or services within the economy; and the ability of the country to supply this particular spend component.

- **Sufficiency of demand:** Localisation requires sufficient long-term demand to justify investing in the resources to deliver the goods or services. Demand was assessed based on whether or not sufficient demand existed in a 5 GW installation of any given technology. If the demand did not exist, further assessment was conducted incrementally to determine whether demand could be created through adjacent industries (e.g. mining and oil and gas), and if not whether there was sufficient demand in sub-Saharan Africa to justify building new capacity. If the demand could not be created at the first three levels it was then assumed that to have sufficient economic rationale to build an industry, South Africa would need to participate in the global market and therefore would need to be globally competitive.
- **Ability to supply:** In determining the ability to supply a particular spend component (material or service), a qualitative analysis of the time and effort required to build sufficient skills, infrastructure, capital plants and regulatory frameworks to ensure sufficient supply was conducted. The time and effort required was categorised into short, medium and long term. Short term indicates that sufficient skills and the required infrastructure exist or could be developed fairly quickly and that an enabling regulatory framework exists. Long term indicates that more time and effort would be required in order to establish sufficient supply.

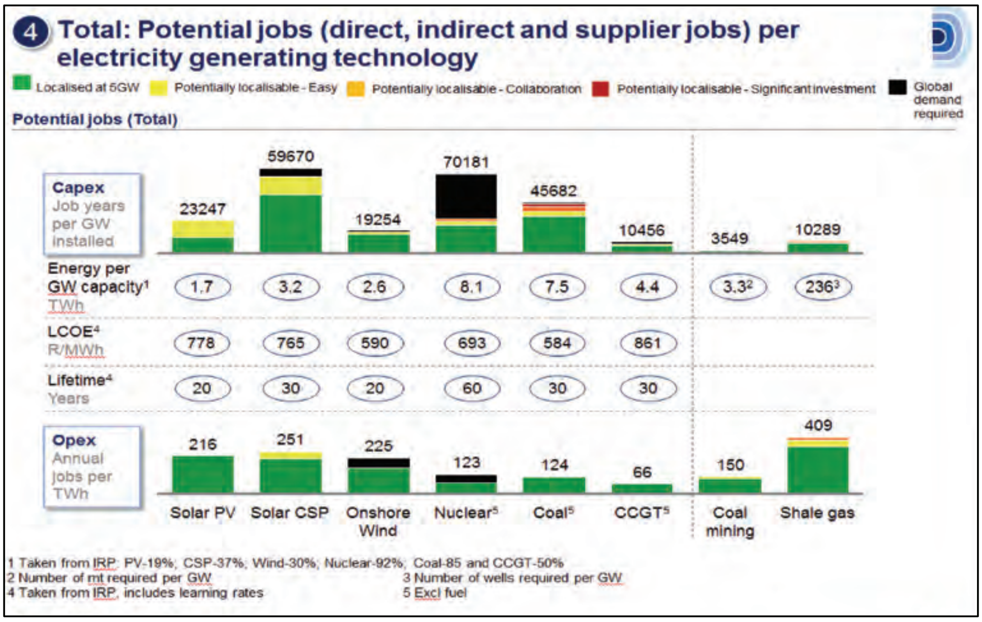
To differentiate between the localisation potential of electricity generating technologies, five different colour indicators (red, black, green, yellow and orange) were used and are described in the table below.

Table 0-3: Levels of localisation potential

Localisation potential	Description
Localisable	The current policy framework is conducive for localisation; local supply of the required skills set is available; and there is sufficient demand for raw material to justify local production
Potentially localisable	The current policy framework exists or could be developed and implemented within a fairly short timeframe (3–5 years)
Collaboration	The current policy and regulatory framework could be developed and implemented within five years and some targeted investments would need to be made
Significant investment required	Regional co-operation and partnerships would need to be developed in order to create demand beyond South Africa's borders
Global demand required	Some of the required technology components can be localised, but South Africa would need to be competitive in exporting the technologies and services to the global market

Source: McKinsey and Company, 2014

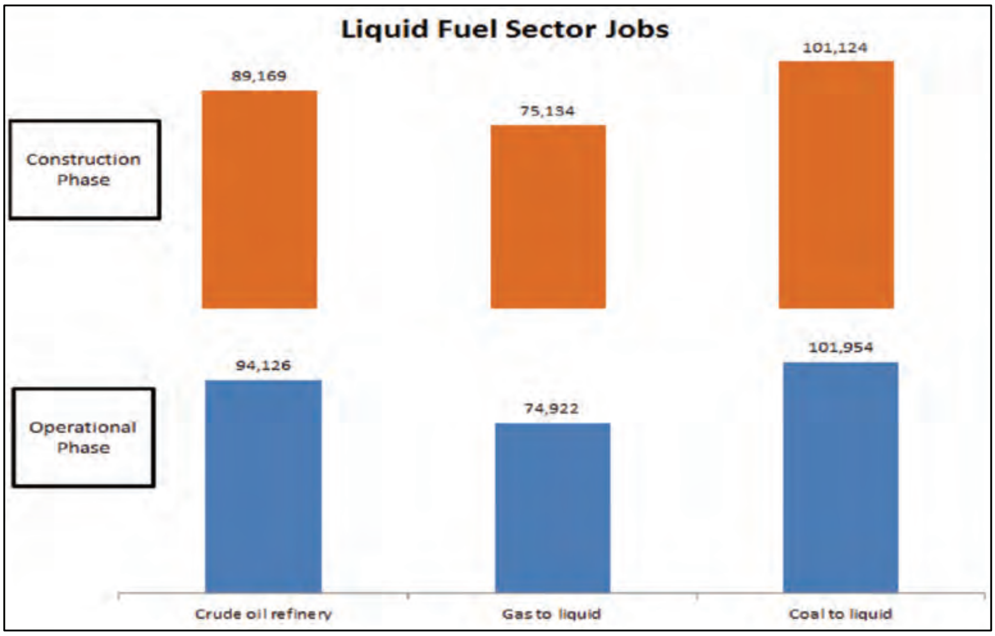
3.3.1. Electricity sector jobs



Source: McKinsey and Company, 2014 (The figures for shale gas extraction include reticulation infrastructure which will be required)

Figure 0-4: Job creation potential for electricity generation technologies

3.3.2. Liquid fuel sector jobs



Source: PetroSA, 2012

Figure 0-5: Job creation potential for liquid fuel technologies

3.4. Technology costs

This section summarises capital costs for electricity generation and liquid fuel production technologies. Learning rates have been assumed for electricity generation technologies. The detailed reports on technology costs and other technology assumptions are included in ANNEXURE A.

3.4.1. Electricity generation

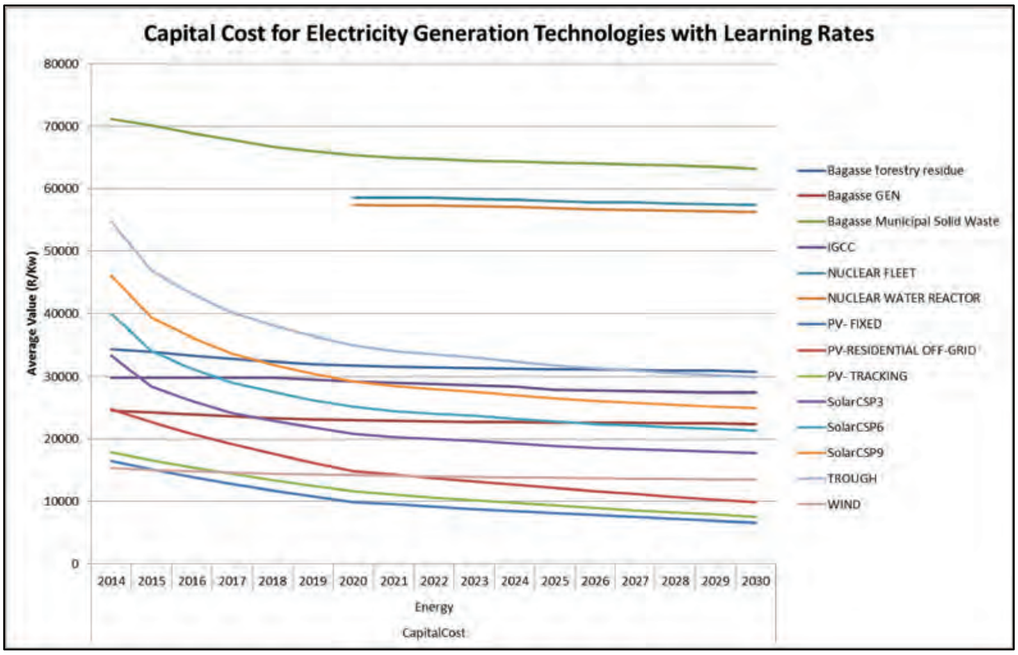


Figure 0-6: Capital costs for electricity generation technologies with learning rates

3.4.2. Liquid fuel production

Table 0-4: Capital and fixed costs for liquid fuel production technologies

Unit: Rm/PJ out/annum **Sector:** Energy **Technology type:** Transformation

Technology name	Parameter	
	Capital cost	Fixed operating cost
New coal liquefaction	386.38	25.71
New gas to liquids	230.61	7.91
New conventional crude oil refineries	133.27	7.27
Residual coal liquefaction		25.71
Residual gas to liquids		34.94
Residual conventional crude oil refineries		0.63

3.5. Externality costs

An externality cost is a cost imposed on society due to the activities of a third party, resulting in social, health, environmental, degradation or other costs. These costs may be beneficial (e.g. a mine builds a fire break between its operations and the neighbouring farm from which the farmer then directly benefits in terms of safety and security).

In this IEP iteration, however, only the negative externalities related to the different energy sources associated with power stations, refineries, vehicles, mining, shale gas and gas have been considered. These relate to air pollution (caused by pollutants such as nitrogen oxide [NO_x], sulphur oxide [SO_x], particulate matter [PM] and mercury [Hg]), climate change (caused by excess CO_2) and water use. With the exception of water (where the true water cost is estimated), the 'cost of damage' approach was used to determine the externality costs.

For the purpose of these statements, overall cost to society is defined as the sum of the imputed monetary value of costs to all parties involved.

Externality costs were calculated for different types of pollutants based on the estimated cost of damage caused by those pollutants. The final values were derived from various studies which were conducted and are indicated in the table below. The detailed reports which informed the cost of externalities are included in ANNEXURE C.

Table 0-5: Externalities costs

Externality	Description	Value	Unit	Source
CO_2	Carbon dioxide	0.27	2012 Rand/kg	ANNEXURE C1: Vivid Economics (2014)
SO_2	Sulphur dioxide	7.60	2012 Rand/kg	ANNEXURE C2: FRIDGE Study (2013)
NO_x	Nitrous oxide	4.50	2012 Rand/kg	ANNEXURE C2: FRIDGE Study (2013)
Hg	Mercury	41484.00	2012 Rand/kg	ANNEXURE C3: Cukrowska (2011)
PM	Particulate matter	11.30	2012 Rand/kg	ANNEXURE C2: FRIDGE Study (2013)
$PM_{Transport}$	Particulates in transport sector	280.70	2012 Rand/kg	ANNEXURE C2: FRIDGE Study (2013)

Section 4: Scenarios

Four core scenarios were considered during the planning process. While the objective was to develop and analyse a set of scenarios that would be as mutually exclusive as possible, there may be some level of interdependency within the key underpinning assumptions which form the basis of the scenarios. Although the scenarios themselves are not intended to test the impact of specific policy interventions, they are characterised by an environment in which certain national policy imperatives are dominant and shape the future economic landscape.

A 'Business as Usual' scenario is encapsulated in the Base Case, while three other scenarios, namely the Resource Constrained, Environmental Awareness and Green Shoots scenarios are also considered.

4.1. Base case

The Base Case can be referred to as the 'Business as Usual' scenario. It is assumed that all existing and appropriate government policies relevant to the energy sector have shaped the energy sector landscape and will continue to do so in the future. Economic growth is perceived to be increasing at moderate rate in line with the moderate National Treasury GDP projections described earlier. As a consequence immigration increases at a moderate rate. In line with prospects within the economy, the unemployment rate continues at the current rate as there are no perceived changes in the structure of the economy.

… Global crude oil prices continue to increase at the current (moderate) growth rate which then translates to moderate price increases for refined petroleum prices …

Global crude oil prices continue to increase at the current (moderate) growth rate which then translates to moderate price increases for refined petroleum prices. Efforts to develop co-operation regionally do not show much improvement and as such the import of primary energy (i.e. natural gas) and power imports continue at the current rates.

Motor vehicles and light delivery truck fuel efficiency improves moderately at an annual average rate of 1.1% whilst trucks and buses improve their fuel efficiency at an annual average of 0.8%. Electric vehicles do enter the market, however as this is not policy-driven they are assumed to have a maximum 20% penetration rate by 2050.

The mitigation of climate change remains one of the primary policy imperatives and the Peak-Plateau-Decline emission limits are adopted as the norm. The national emission reduction targets are translated across all economic sectors and all externality costs associated with carbon emissions and other pollutants are accounted for. Although no carbon tax is assumed, the externality cost of carbon is calculated based on the carbon tax rate advocated in the proposed Carbon Tax Policy.

The 9.6 GW New Nuclear Build Programme as envisaged in the IRP2010 has been included in the Base Case and all the core scenarios.

4.2. Resource constrained

The main characteristics of this scenario are high commodity prices, in particular those of crude oil and natural gas. High crude oil prices lead to higher than usual increases in petroleum product prices which have an impact on inflation. Domestic economic growth is then severely impacted and remains lower than expected.

The low to moderate economic growth results in reduced immigration into South Africa slowing down population growth. The demand for products and services domestically also remains low and would impact the energy demand growth in all sectors.

There is a marked improvement in the adoption of more energy efficient technologies as a consequence of high energy prices and also due to more aggressive policy interventions. Cars and SUVs have an annual average efficiency improvement of 2.5% while trucks and buses have an average annual improvement of 1%. As electricity price increases are also high in this scenario, electric vehicles enter the market at a maximum penetration rate of 20%.

… There is a marked improvement in the adoption of more energy efficient technologies as a consequence of high energy prices and also due to more aggressive policy interventions …

4.3. Environmental awareness

In this scenario there is greater awareness and a more concerted effort to reduce greenhouse gases than in other scenarios. More countries at a global level adopt policies that aim to achieve the emission reduction targets that seek to keep the average annual temperature increases below the 2˚C threshold. For South Africa this means that there are more aggressive interventions to curb the effects of climate change and the lower Peak-Plateau-Decline emission limits become the order of the day. A higher cost is placed on externalities associated with carbon, with the cost placed at R270/ton.

Individual consumers pursue alternative sources of energy and there is an increased uptake of solar water heaters, primarily in new houses.

4.4. Green shoots

The Green Shoots scenario is characterised by the high economic growth outlook and significant structural changes envisaged in the National Development Plan. The economy is assumed to grow at an annual average rate of 5.7% to 2030, with a slight and steady slowdown from then until 2050. The structure of the economy shifts from a resource-driven to a manufacturing- and a services-driven economy as the country's 're-industrialisation' objectives materialise. This results in higher demand for energy in these two sectors as compared to other scenarios.

… The Green Shoots scenario is characterised by the high economic growth outlook and significant structural changes envisaged in the National Development Plan …

There is a more aggressive uptake of alternative energy sources such as solar water heaters, rooftop PV panels and electric vehicles by individual consumers, which are made possible by the higher average household income levels envisaged in this scenario. While awareness of climate change is a key policy imperative in this scenario, this is balanced with stimulating the growth of the economy.

4.5. Summary of scenarios

Table 0-1: Summary of scenarios

Indicators	Scenarios: Base case	Resource constrained	Environmental awareness	Green shoots
GDP	Treasury moderate GDP growth	Treasury moderate GDP growth	Treasury moderate GDP growth	National Development high GDP growth
Demand-side levers				
DSM	1 million SWH	1 million SWH	5 million SWH	10 million SWH
Energy efficiency	Business as usual	High energy efficiency	High energy efficiency	High energy efficiency
Vehicle efficiency (new vehicle improvement per annum)				
Cars and SUVs	1.10%	2.50%	2.50%	2.50%
Trucks and buses	0.80%	1.00%	1.00%	1.00%
Electric vehicle penetration rate (% per annum)	20%	20%	20%	40%
Prices of energy commodities	Moderate	High	Moderate	Moderate
Climate change				
CO_2 emissions limit	PPD* upper limit	PPD upper limit	PPD lower limit	PPD upper limit
CO_2 externality costs	• R48–120/t 2015–2019 • R120/t onwards	• R48–120/t 2015–2019 • R120/t onwards	R270/t 2015–2019	• R48–120/t 2015–2019 • R120/t onwards
Carbon tax	None	None	None	None

* *"Peak-Plateau-Decline" emission trajectory from NCCRWP*

Section 5: Analysis of demand

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 with 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).

… in order to effectively quantify energy consumption within each of the economic sectors, a grouping aligned with energy end-use becomes more constructive …

Five demand projections were conducted according to five sectoral groupings, namely the agricultural, commercial, industrial, residential and transport sectors. These are described briefly below:

- The agricultural sector includes animal husbandry, crop farming, forestry and fishing.
- The commercial sector includes wholesale and retail, public services, financial and business services, hospitality, education, entertainment, information and communication. It does however exclude commercial transport.
- The industrial sector includes all manufacturing (manufacturing and production of all goods and products including fast moving consumer goods) as well as construction and mining.
- The residential sector includes all personal dwellings (i.e. formal and informal households in rural and urban areas).
- 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.

Table 0-1 provides a mapping of economic sectors to energy demand sectors with the key activity variable indicated in the last column.

Table 0-1: Mapping of economic sectors to energy demand sectors

Economic grouping	Economic sector	Energy demand sector	Sub-sectors	Subsectors included	Energy carriers considered	Activity variable
Primary	Agriculture, forestry and fishing	Agricultural Sector	N/A	N/A	Electricity, coal, diesel	GDP
	Mining and quarrying	Mining Sector	N/A	N/A	Electricity, coal, diesel	Value-added in the Mining Sector
Secondary	Manufacturing	Industrial Sector (excl. mining) or Manufacturing Sector	Chemicals	N/A	Electricity, coal, natural gas	Value-added in the Manufacturing Sector
			Iron and steel	N/A	Electricity, coal, natural gas	Value-added in the Manufacturing Sector
			Non-ferrous metals	N/A	Electricity, coal, natural gas	Value-added in the Manufacturing 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 Manufacturing 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	GDP
	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/capita
Households	N/A	Residential Sector	N/A	N/A	Electricity, coal, LPG, paraffin, wood	Population growth, number of households, electrification, urbanisation and household income

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. Where data was available, value added by the sector was used to estimate energy demand.

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

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

… GDP is widely used as an indicator of total demand in the economy and is therefore a good proxy to determine energy consumption …

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, due to paucity of energy consumption data at an energy end-use level, the above-mentioned key drivers were used as a basis and demand projections were conducted for each energy demand sector as follows:

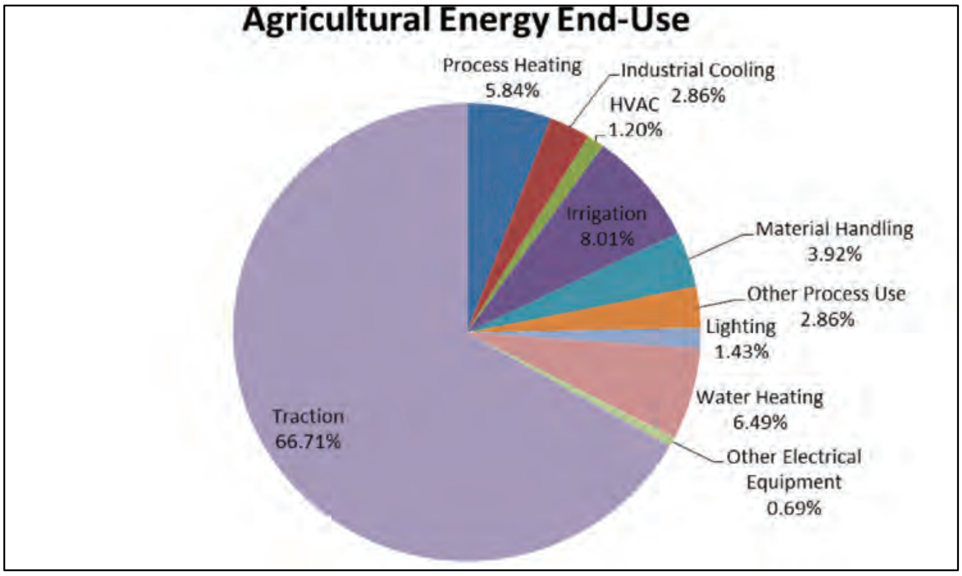
- For the agricultural, commercial, industrial and residential sectors, energy demand was estimated and projected for individual energy carriers (e.g. electricity, natural gas, LPG, coal, diesel, etc.).
- For the transport sector, energy demand was projected for energy end-use (i.e. mobility measured by passenger kilometres or freight tonne kilometres) as opposed to individual fuels (e.g. 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.

An analysis of demand within each of the scenarios described in 0is described in this section. It should be noted that where demand projections are substantially similar per scenario, they are grouped together in the representative Figures.

5.1. 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 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 agricultural sector has undergone significant structural changes. Over the past 15 years the sector has shifted to large-scale intensive farming, and has shifted 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 largest expenditure item after farm feeds. On the other hand, land reform could result in the emergence of a large number of small-scale farmers, who are most likely to use traditional farming methods. Fuel (predominantly diesel) is the prime energy source used in the sector and is primarily used for traction and other farm machinery as well as the transportation of agricultural produce.

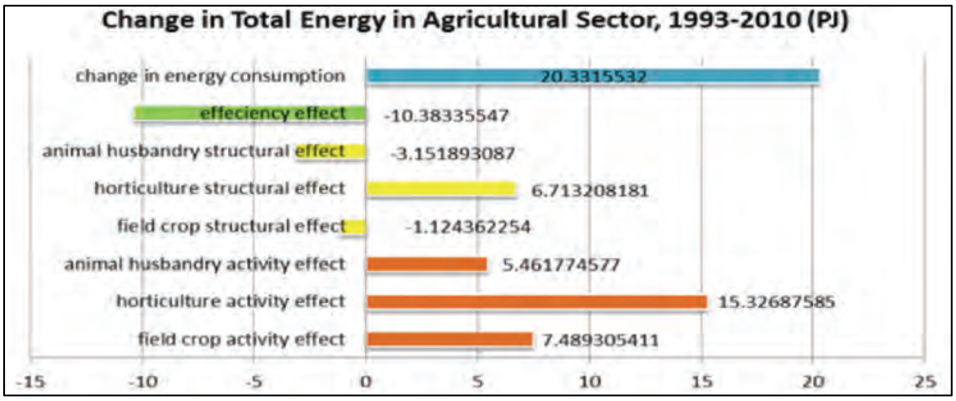


Source: DoE Analysis

Figure 0-1: 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 on total energy demand within the sector. The bulk of the demand has been from large-scale intensive farming where the 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 changes in diet among the population as incomes increase. It is likely that in future the share of electricity in this sector will grow, with the extent of the growth being 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.

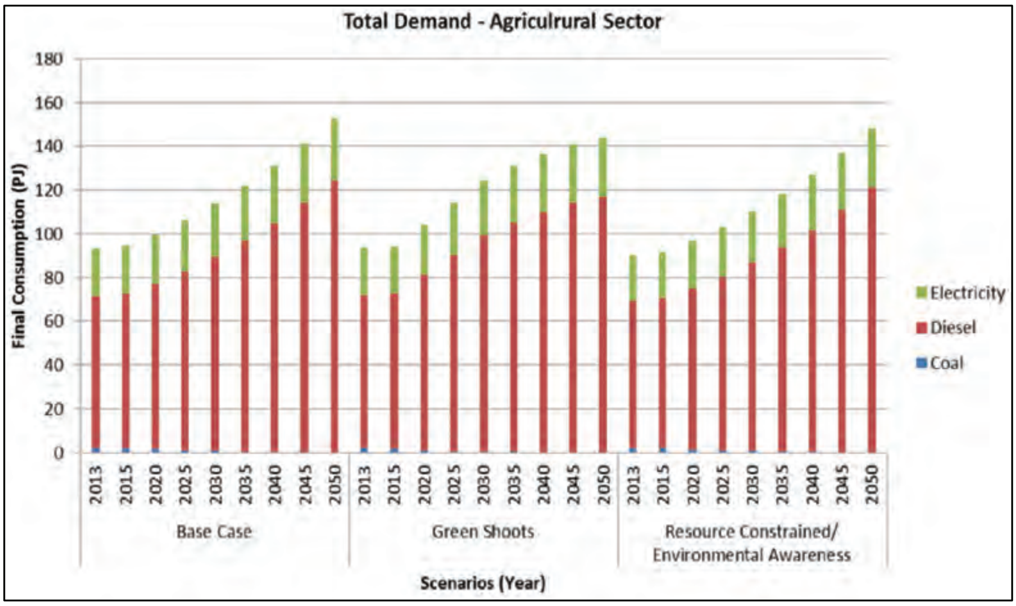
With large-scale, highly mechanised, intensive farming, most efficiency gains resulting from improved machinery, equipment and production practices have been realised and the rate of further efficiency improvements will start to decline. The value-add of the agricultural sector is therefore assumed to 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. In order to understand these pathways of energy demand in the sector, it is helpful to understand historical patterns of total energy change which are due primarily to three drivers and are therefore used in assessing energy efficiency using decomposition analysis (Ang, B.W., Zhang, F.Q., Choi, K-H, 1998). The drivers are the level of activity, structural changes and energy intensity in the sector relative to the other sectors. The relationship between these drivers is described by the following effects; activity effect, structural effect and efficiency effect. Figure 0-2 provides a graphical representation of the full decomposition analysis results for 2010 relative to the 1993 baseline.



Source: DoE Analysis

Figure 0-2: Decomposition analysis results for change in energy consumption in the agricultural sector

Total energy consumption in 2010 had increased by 20.33 petajoules (PJ) relative to 1993. This change is composed of the sum of: a 28.28 PJ increase due to greater level of activity, a 2.44 PJ increase due to structural changes and a 10.38 PJ decrease due to energy efficiency improvements. This means that over the 17-year period, if all other factors had remained constant, improvements in efficiency alone would have led to a 10.38 PJ decrease in energy consumption, which is 15.13% of the 1993 baseline figure. This is equivalent to a compound annual decrease of about 0.01% in energy consumption attributable to efficiency improvements. This compounded annual decrease of (0.01%) is then used to estimate energy improvements in the projected energy demand presented. The projected energy demand for the agricultural sector is depicted in Figure 0-3.

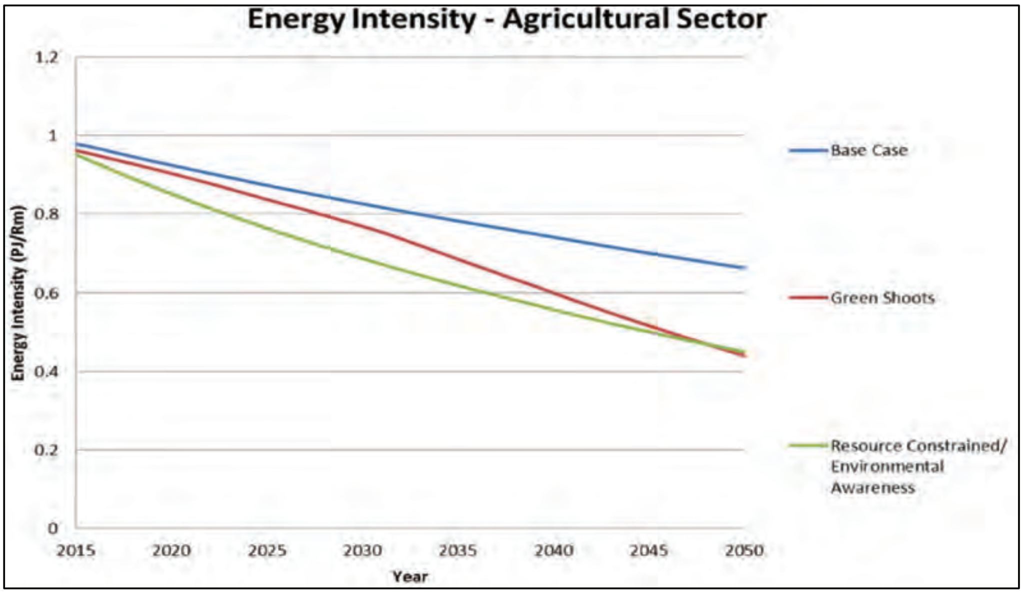


Source: DoE Analysis

Figure 0-3: Projected demand in the agricultural sector

The main driver behind energy demand projections is the gross domestic product and the detailed information behind these assumptions is presented in 0The energy demand projections are based on four scenarios explained in 0The fuel mix in all these scenarios shows that diesel is the most used energy carrier, mainly because the sector is characterised by traction which accounts for 66.71% of energy use. This trend is likely to continue due to the Biofuel Industrial Strategy. The strategy targets new and additional land which is approximately 1.4% of arable land in South Africa (DME, 2007), implying more traction in the sector and therefore an increase in diesel consumption. The demand for diesel is followed by demand for electricity to supply energy services for irrigation and heating, ventilation and air conditioning (HVAC). The demand for coal is very small and this is likely to continue throughout the modelling period. An overall observation is that the total energy demand in this sector will continue to increase as there is high potential for economic growth.

In this sector, energy use per rand of gross domestic product is used as a measure of energy intensity. The average energy demand growth rate for both the Base Case and Resource Constrained/Environmental Awareness scenarios is between 1% and 2% in the short to medium term, increasing to between 2% and 3% in the long term, in line with the GDP assumptions described earlier. The average energy demand growth rate for the Green Shoots Scenario is between 2% and 3% in the short to medium term, decreasing to between 2% and 1% in the long term. The growth patterns for all the scenarios are similar to those of the corresponding GDP growth rates as GDP is the main driver behind the energy demand projection.



Source: DoE Analysis

Figure 0-4: Energy intensity in the agricultural sector

In this sector, the energy intensities for the four scenarios (i.e., Base Case, Resource Constrained, Environmental Awareness and Green Shoots) show a declining trend, which is mainly attributable to the introduction of energy efficient technologies in the sector. The respective overall average reductions in energy intensities in the aforementioned scenarios are slightly more than 1.1%, 2.2% and 2.1% over the modelling period. A similar pattern of decline is also reflected in both the short- to medium-term periods.

5.2. Commercial Sector

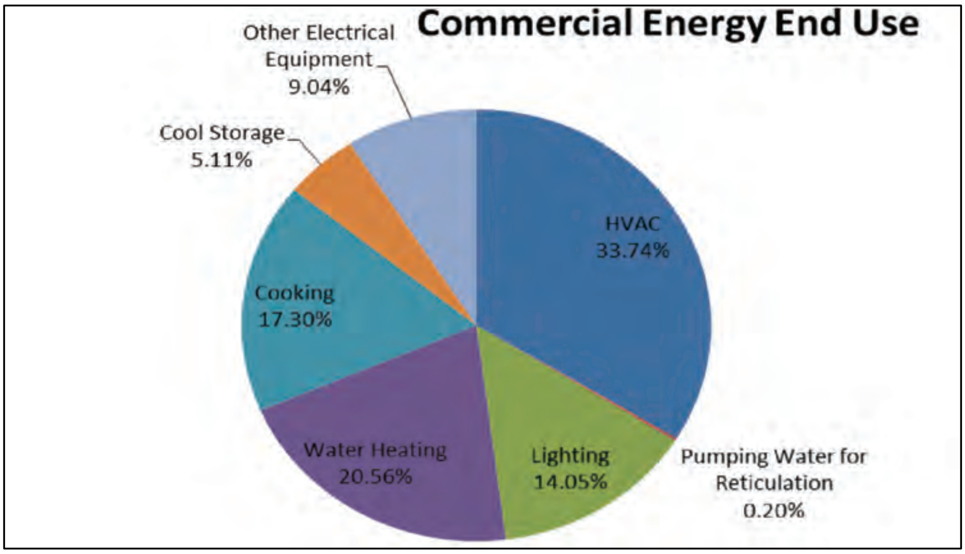
The commercial sector comprises the following economic sub-sectors: finance, real estate and business services; general government services; personal services; storage and communication; and wholesale, retail, motor trade and hospitality.

The commercial sector therefore largely comprises the tertiary services group of industries, but specifically excludes the transport sector (transportation of passengers and freight). The basis for the exclusion is that transportation demand requires a separate and focused analysis for energy consumption.

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 also the fastest-growing sector in developing countries including South Africa. South Africa's economy was historically rooted in the primary sectors due to the wealth of mineral resources and favourable agricultural conditions. 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 over the last few years include transport and financial services, with the 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 the provision of services rather than machinery or equipment, energy is predominately required to increase levels of comfort and ensure the sustenance of individuals. Energy end-use is therefore primarily for heating, ventilation and air conditioning (HVAC) (~34%), followed by water heating (~21%), cooking (~17%) and lighting (~14%), with the remainder being used for cold storage (~5%) and electrical equipment such as computers, printers, faxes, etc. (~9%).



Source: DoE Analysis

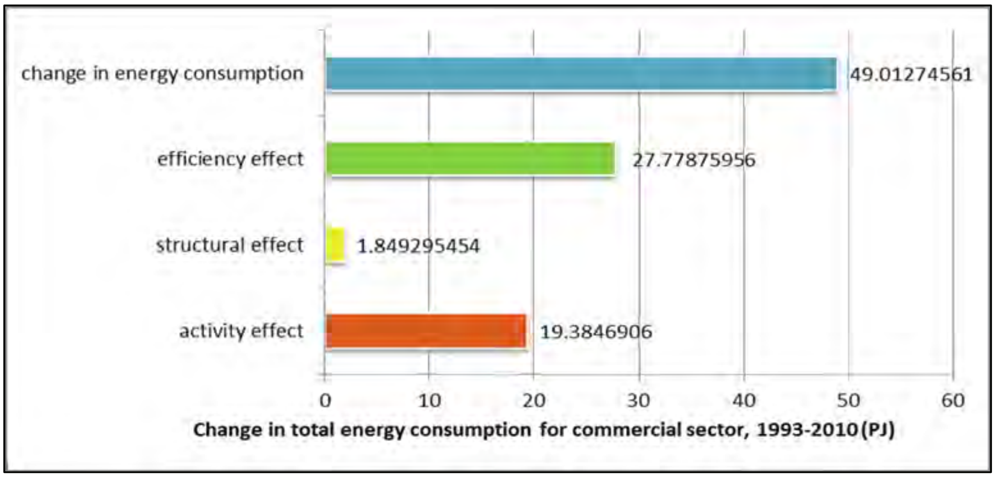
Figure 0-5: Energy end-use within the commercial sector

Given that the tertiary sector is predominantly located in highly-electrified urban areas, and that electricity is the most convenient source of energy for the sector, electricity dominates total energy usage. It is also no surprise that the historical consumption of electricity has shown a steady increase aligned with the growth of the tertiary sector. Figure 0-6 provides a graphical representation of the full decomposition analysis results for 2010 relative to the 1993 baseline.

The analysis shows that energy efficiency contributed more than 50% to the change in total energy consumption. Total energy consumption in 2010 had increased by 49.01 PJ relative to 1993. This change is composed of the sum of:

- A 19.38 PJ increase due to greater level of activity; a
- A 1.85 PJ increase due to structural changes; and
- A 27.78 PJ increase due to energy efficiency reduction.

This means that over the 17-year period, if all other factors had remained constant, reduced efficiency within the sector would have resulted in an increase of 27.78 PJ in energy consumption, which is 84.01% of the 1993 baseline figure. This is equivalent to a compound annual increase of about 0.45% in energy consumption attributable to energy efficiency reductions. This compound annual increase indicates that more measures must be taken to improve energy efficiency in the sector.

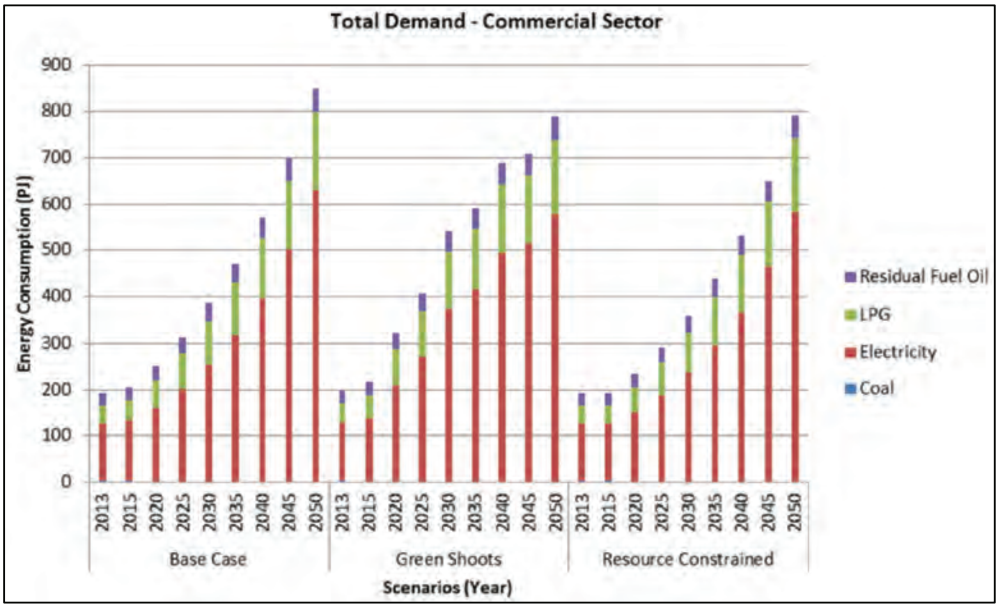


Source: DoE Analysis

Figure 0-6: Decomposition analysis results for energy consumption in the commercial sector

As economies develop, the commercial and public sectors usually grow faster than other sectors – and this has been true for South Africa. Continued expansion of the tertiary sector will see a continued increase 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 in terms of the heating and cooling of office buildings, office equipment and lighting. Water heating is slowly shifting to alternative energy sources such as solar and more energy efficient heat pumps. However, government has introduced various legal and policy instruments aimed at further 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 incentive schemes have also been introduced which will encourage more energy efficient practices by all industries, including those that fall within the commercial sector. If these policy interventions are successfully implemented, even though energy demand in the tertiary sector will continue to grow, it should 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 below.

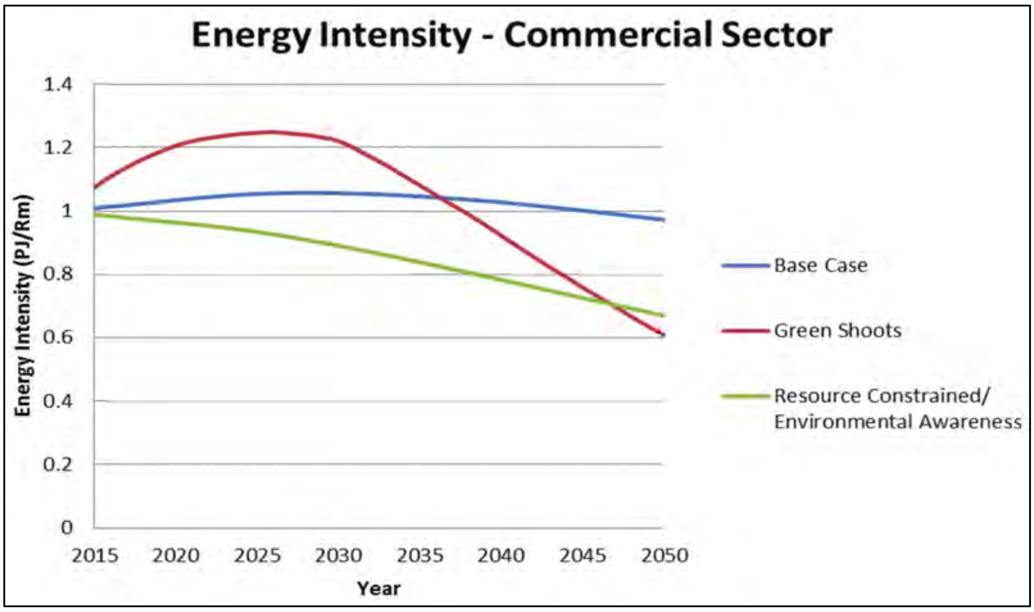


Source: DoE Analysis

Figure 0-7: Projected demand in the commercial sector

In this sector, the main driver behind energy demand projections is GDP. The projections are based on the four scenarios, but represented in three categories due to corresponding growth rates between the Resource Constrained and Environmental Awareness scenarios. The average energy demand growth rate for both the Base Case and Resource Constrained/Environmental Awareness scenarios is between 1% and 2% in the short to medium term, increasing to between 2% and 3% in the long term. This is in line with the percentage increase of the GDP growth rates outlined earlier. The average energy demand growth rate for the Green Shoots Scenario is between 2% and 3% in the short to medium term, decreasing to between 2% and 1% in the long term. The growth patterns for all the scenarios are similar to those of the corresponding GDP growth rates as GDP growth is the main driver behind the energy demand projections.

The dominant energy carriers in the commercial sector include electricity, liquefied petroleum gas (LPG), residual fuel oil and coal. The fuel mix in all these scenarios shows electricity to be the most used energy carrier, mainly because the sector has begun shifting towards tertiary sector activities, which are characterised by the use of electrical technologies. The demand for electricity is followed by the demand for LPG which is an alternative source of energy to electricity for providing energy services such as HVAC. The demand for coal and residual fuel oil is very small and this is likely to continue throughout the modelling period. However, an overall observation is that the total energy demand in this sector will continue to increase, as the potential for economic growth and economic structural changes within the sector is high. Figure 0-8 illustrates the energy intensity in the sector, which is based on the energy use per rand of GDP as a measure.



Source: DoE Analysis

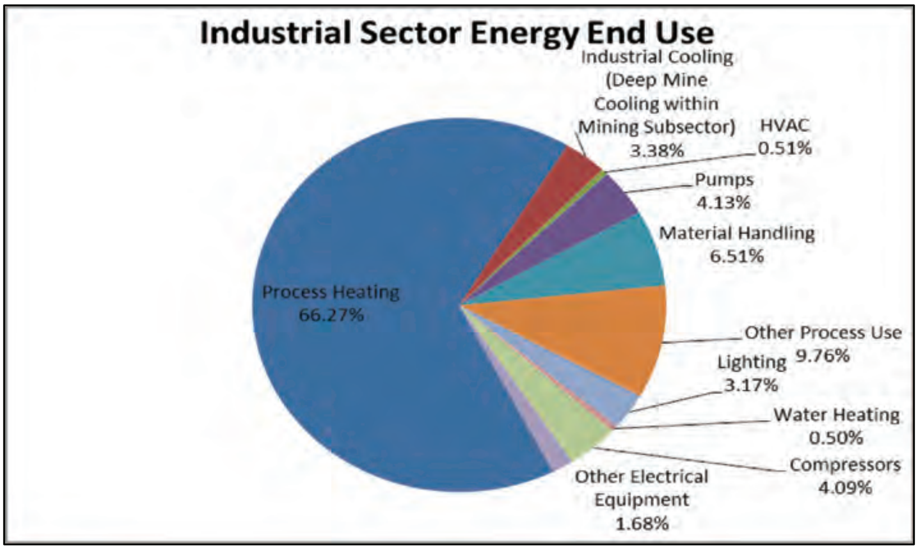
Figure 0-8: Energy intensity in the commercial sector

In the commercial sector, energy intensity for the Resource Constrained/Environmental Awareness scenarios shows a steady decline of about 1.07% over the modelling period, whereas the Base Case and Green Shoots scenarios, in the short to medium term, reflect an average increase of about 0.74%, thereafter decreasing by about 20% in the medium to long term. In this sector, the increase in energy intensity is mainly attributed to economic structural changes and changes in climate. It is important to note that building design has an impact on the future energy needs of the commercial sector. The major portion of building stock in the short to medium term will comprise existing buildings, which are not subject to compulsory energy efficiency regulations. The retrofitting of existing buildings, beyond superficial improvements, is therefore likely to result in only a slight decrease in energy intensity for the commercial sector. Compulsory building regulations are directed at new buildings and thus the effect of more efficient technologies will only be felt in the longer term. In addition, energy efficiency benefits may take some time before they are realised due to the increase in the use of technologies such as laptops, printers, etc. Another contributing factor to energy intensity in the sector is climate, with the number of 'cooling degree days' in winter and 'heating degree days' in summer causing a noticeable increase in energy intensity. This phenomenon is likely to affect energy intensity at least until the midyear of the modelling period.

5.3. Industrial Sector

South Africa is a highly energy intensive economy. The 2012 Energy Sustainability Index quantifies the energy trilemma (security, equity and environmental sustainability) and ranks countries comparatively in terms of their ability to provide a secure affordable and environmentally-sustainable energy system (WEC, 2013). The 2013 Energy Sustainability Index, developed by the World Energy Council, ranks South Africa at 79th position, midway between the other BRICS (Brazil, Russia, India, China and South Africa) countries. In comparison, Brazil ranks 34th, Russia 54th, China 78th and India 115th. The industrial sector, which comprises 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 consumers is iron and steel at ~27% of the total energy used by the sector, followed by mining which consumes ~26%.

Within the industrial sector, most energy is used for process heating. In energy intensive industrial sub-sectors such as iron and steel and chemicals, process heating accounts for 90% and 88% respectively of total energy consumed.



Source: DoE Analysis

Figure 0-9: Energy end-use within the industrial sector

The use of energy for motor-driven systems, which are accounted for under pumps (4.13%), compressors (4.09%) and material handling (6.52%), accounts for 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 therefore be attributed to a specific purpose. Industrial cooling, which is designated as deep mine cooling within the mining sub-sector, accounts for the third largest share. While the use of fossil fuels within the sector is primarily for process heating, the end-use of electricity is very diverse across the sub-sector, as indicated in Table 5-2.

Table 0-2: Electricity end-use within 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%**

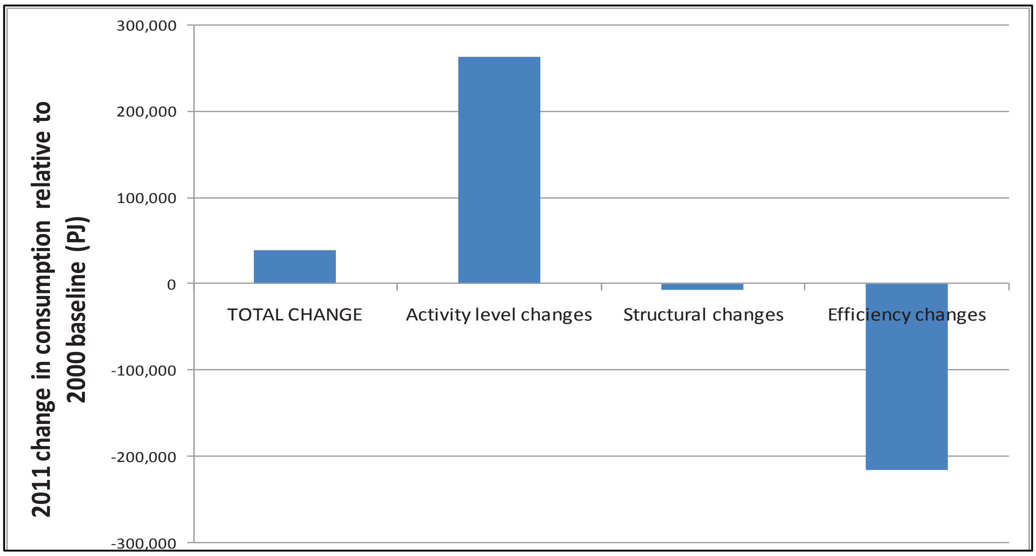
Source: Eskom IDM

The National Energy Efficiency Strategy (NEES) includes a 15% target for improvement in energy efficiency within the industrial sector which means a 15% reduction in the amount of energy required to produce the same output. Measuring change in energy efficiency at the industrial sub-sector level, however, is a complex process with no single universally applicable approach. In the case of mining and industry, for example, output may be quantified in either physical units (typically tonnes of output) or in economic units (value-added measured in Rand).

For the period 2000–2010, data was available only at the aggregate level – energy consumption data in the form of Energy Balance Tables from the DoE, and output data in the form of GDP estimates from Statistics South Africa. Output is thus necessarily quantified in economic units, and energy intensity (energy consumption per unit of economic output) must serve as a proxy for energy efficiency. There are several reasons why energy intensity, at an aggregate level, is an imperfect proxy for energy efficiency. The most important of these is that it includes the effect of structural change. However, structural change can be quantified and separated out using a process known as 'decomposition analysis'.

Figure 0-10 provides a graphical representation of the full decomposition analysis results for 2011 relative to a 2000 baseline. Total energy consumption in the industry and mining industrial sub-sectors in 2011 had increased by 39.5 PJ relative to 2000. This change is composed of the sum of:

- a 263 PJ increase due to greater levels of activity;
- a 7.5 PJ decrease due to structural changes; and
- a 216 PJ decrease due to efficiency improvements.

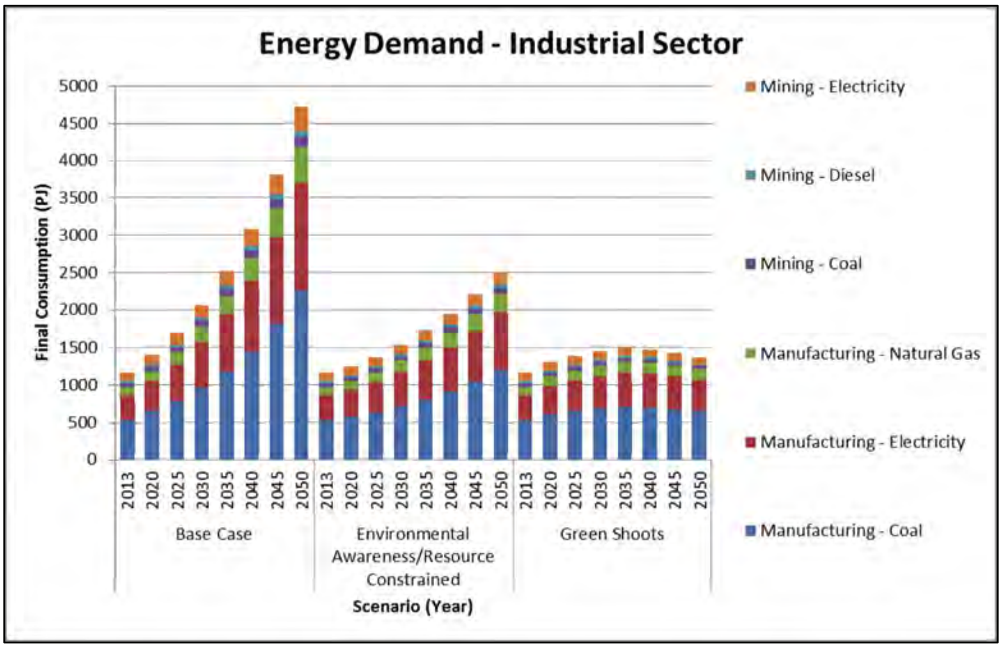


Source: DoE 2014

Figure 0-10: Decomposition analysis results for energy consumption in the industrial sector

Over the eleven-year period, if all other factors had remained constant, improvements in efficiency would have led to a 216 PJ fall in energy consumption, which is 20.8% of the 2000 baseline figure. This is equivalent to a compounded annual decrease of about 2.1% in energy consumption, attributable to efficiency improvements.

The main drivers for the projected demand within the manufacturing sub-sector are the gross value added for manufacturing and improvements in energy efficiency over time. With regards to the mining sub-sector the gross value added for mining as well as the rate of improvement in energy efficiency were used as drivers. Four scenarios, Base Case, Resource Constrained, Environmental Awareness and Green Shoots, were considered for the industrial sector in which the key drivers were changed.



Source: DoE Analysis

Figure 0-11: Projected energy demand for the industrial sector

The projected energy demand for the industrial sector is depicted in Figure 0-11 for the Base Case, Green Shoots, Resource Constrained, and Environmental Awareness scenarios. In all scenarios coal continues to dominate the fuel mix for the manufacturing sector as process heating is the primary end-use within manufacturing sub-sectors such as iron and steel and chemicals. Electricity is the mainly dominant energy carrier used within the mining sub-sector as electricity is key for ensuring deep mine cooling. The use of petroleum products within the industrial sector is mostly limited to the mining sub-sector. Material handling, which accounts for ~26% of total energy end-use within the mining sub-sector, encompasses both diesel and electrical 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.

The Base Case Scenario is premised on a moderate growth in both the gross value added for the manufacturing and mining sub-sectors. The Base Case is characterised by no new energy efficiency capital investment improvements beyond those funded through the multi-year price determination (MYPD) process, as part of the Eskom Demand-side Management Programme. The Base Case scenario for the industrial sector experiences a four-fold increase in energy demand in line with the four-fold increase in gross value added by the manufacturing and mining sub-sectors.

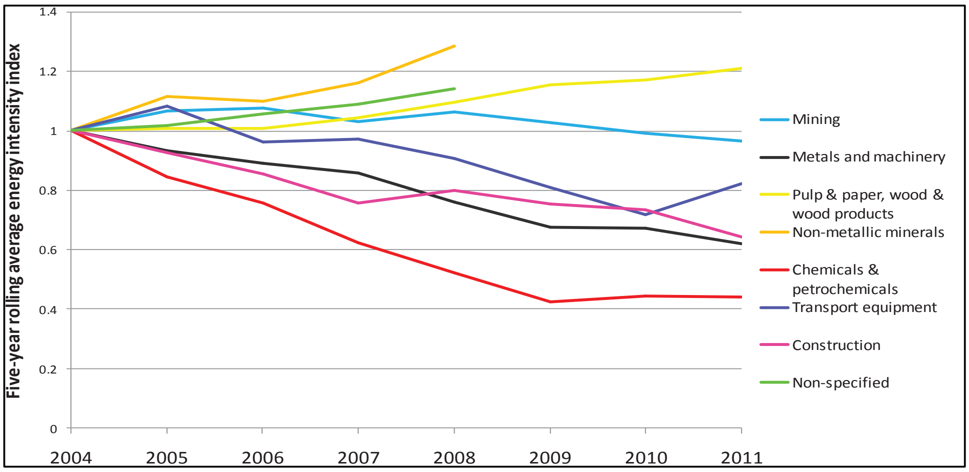
… The Base Case Scenario is premised on a moderate growth in both the gross value added for the manufacturing and mining sub-sectors …

The Resource Constrained scenario is characterised by moderate economic growth, coupled with high energy prices due to the high oil price. According to the United Nations Industrial Development Organisation (UNIDO), the drivers of energy efficiency can vary from industry to industry and in most sectors high prices can be the key driver for energy efficiency. Implementing Best Available Technology (BAT) offers potential energy savings equivalent to an energy efficiency improvement of 1.7% a year (UNIDO, 2010) and this improvement is expected within the Resource Constrained Scenario. Similar to the Base Case, the Environmental Awareness Scenario is characterised by moderate economic growth. The energy efficiency improvements are similar to those within the Resource Constrained Scenario, such that BAT is implemented despite the fact that energy prices are moderate in comparison with those of the Resource Constrained Scenario. Within the Resource Constrained/Environmental Awareness scenarios the energy demand only doubles over the planning period despite the four-fold increase in gross value added. This is due to the energy efficiency improvements in the industrial sector over the same time period.

The Green Shoots Scenario is characterised by accelerated economic growth in the short to medium term with a decline in the later years. Energy efficiency improvements within the Green Shoots Scenario are attributed to the penetration of BAT. In the short and medium terms, economic growth leads to a growth in overall energy demand. In the long term the energy requirements decrease due to the reduction in economic growth attributed to both manufacturing and mining.

Energy intensity (the ratio of energy consumption to gross value added) in the industry and mining sub-sectors decreased from 3.08 MJ/R in 2000 to 2.16 MJ/R in 2011 (DoE, 2014). This represents a compounded annual reduction of 3.2% in energy intensity. Trends in energy intensity within the sub-sectors are illustrated in

Figure 0-12. In order to make these trends easier to observe, the graph shows five-year rolling averages which smooth out the wide fluctuations in energy intensity that are often seen between consecutive years. Note that, because a five-year rolling average has been used, the base year for the trends displayed in this graph is 2004, with energy intensity being expressed as an index relative to this base year.



Source: DoE 2014 (Energy Efficiency Target Monitoring System: First Monitoring System Report)

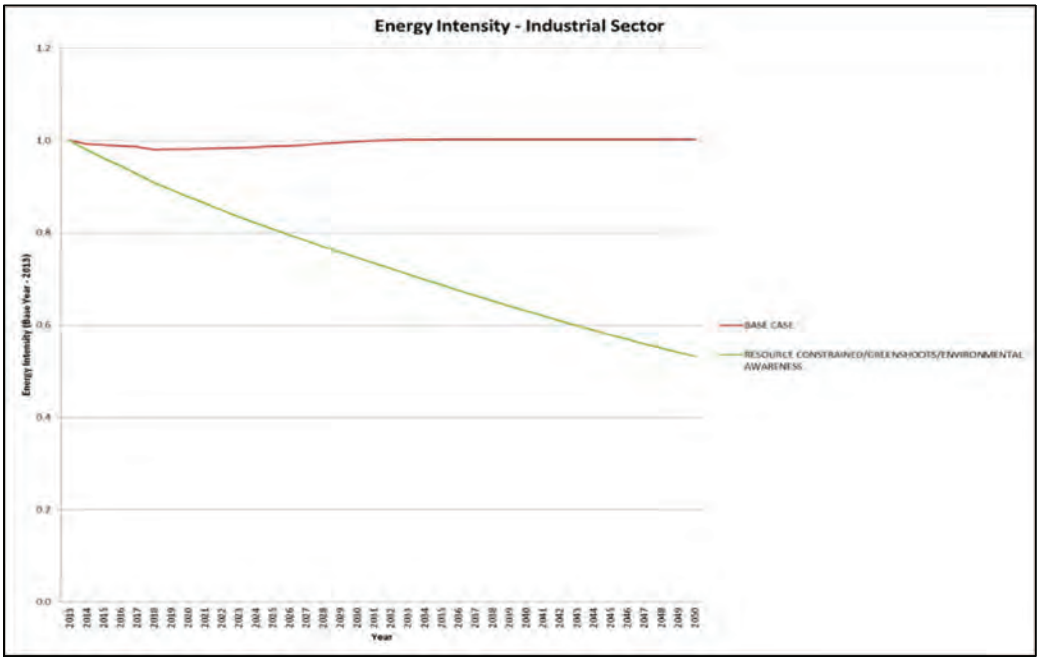
Figure 0-12: Five year rolling average of energy intensity in the industrial sub-sectors

The main trends are the following:

- An increase of nearly 30% in energy intensity in the non-metallic minerals sub-sector until 2008;
- A smaller but still significant increase in energy intensity in pulp and paper and the ‘Non-specified’ category;
- A fall of almost 60% in energy intensity in the chemicals and petrochemicals sub-sector;
- Significant decreases of 20-40% in energy intensity in metals and machinery; transport equipment; and construction; and
- The energy intensity of mining, when calculated as a five-year rolling average, remains fairly constant.

Figure 0-13 shows the changes in energy intensity for the industrial sector relative to 2013 levels. Using 2013 as the base year (with an energy intensity index = 1), an energy intensity index below 1 indicates a reduction in energy intensity relative to that in 2013, while an energy intensity index above 1 indicates an increase in energy intensity relative to that in 2013.

The energy intensity for the Base Case Scenario reduces in the short term due to Demand-side Management (DSM) interventions which are currently funded, but after 2030 benefits from the DSM Programme diminish and cannot be sustained without further funding. The energy intensity for the Resource Constrained, Environmental Awareness and Green Shoots scenarios reduces over time due to the penetration of BAT within the industrial sector. The rate of improvement is based on international benchmarks but may vary according to local circumstances. For instance sub-sectors which are early adopters of more efficient technologies will show a slower rate of improvement over the long term.



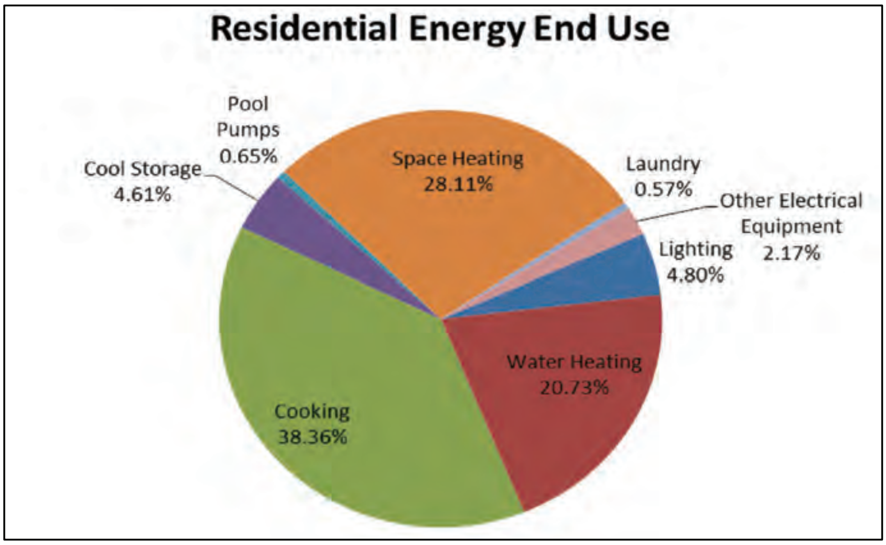
Source: DoE Analysis

Figure 0-13: Energy intensity in the industrial sector

5.4. 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 the cost 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 heating (~28%), water heating (~20%) and lighting (~5%), with the remainder for other, predominantly electrical, uses.

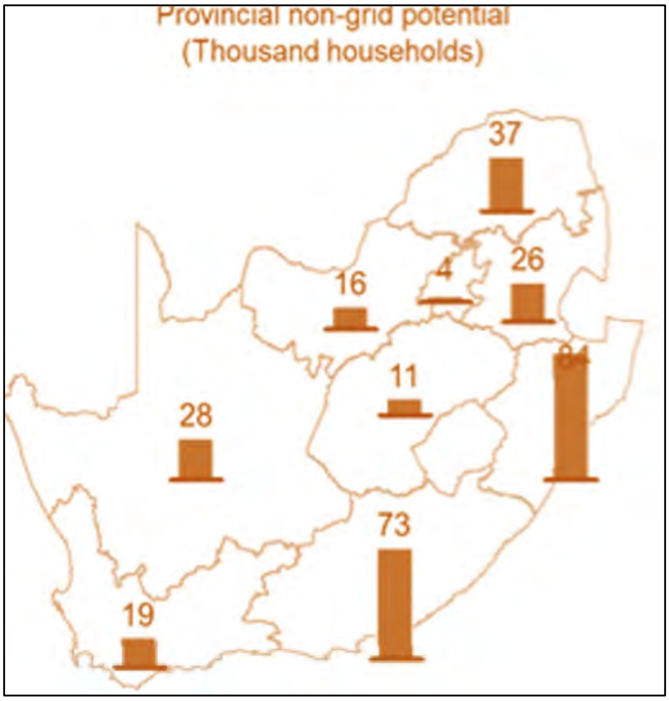


Source: DoE Analysis

Figure 0-14: Energy end-use in the residential sector

Given that water heating is responsible for over 20% of residential energy within households there have been a number of policies implemented to reduce the use of electricity and wood for water heating in the household sector. Currently government is implementing the One Million Solar Water Heater (SWH) Programme and within the National Development Plan possible targets of an additional 4 million have been mentioned, which when added to the current programme would mean 5 million SWH by 2030. Within the four scenarios different penetration rates for solar water heaters have been tested to gauge the possible efficacy of the programme. The enforcement of the Building Regulations (SANS 10400-XA) is included within all scenarios for hot water heating for all new households. The regulation states that 50% of all hot water in new houses needs to be produced by methods other than electrical element heating. This means that conventional geysers may no longer be used, and must be replaced by solar water heating systems (which still partially use electricity), or alternatively by a heat exchange type heat pump.

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). In June 2013 Cabinet approved the implementation of the New Electrification Strategy which redefined universal access as 97% of households, because full electrification is unlikely to be possible due to the growth and delays in the process of formalising informal settlements. Of the 97% of households, 90% will be connected to the grid, with the remainder using high quality non-grid solar home systems or other possible technologies. As illustrated in Figure 5-15 below, the areas with the highest potential for non-grid solutions are located in Kwazulu-Natal and the Eastern Cape.

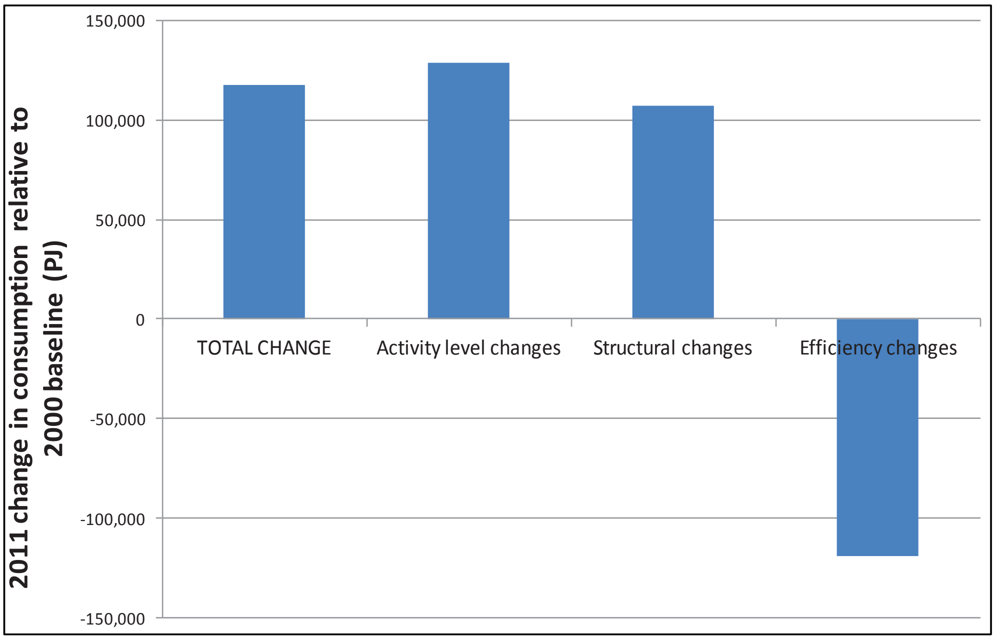


Source: DoE 2012 National Household Electrification Strategy

Figure 0-15: Provincial non-grid potential

Increased electrification rates, combined with continued developments in renewable energy technologies, are expected to encourage an increase in distributed electricity generation and a shift from use of other forms of energy (such as illuminating paraffin for lighting) to electricity. Figure 0-16 provides a graphical representation of the full decomposition analysis results for 2011 relative to the 2000 baseline. Total energy consumption in the residential sector in 2011 had increased by 117 PJ relative to 2000. This change is composed of the sum of:

- A 129 PJ increase due to greater levels of activity (i.e. increased number of households);
- A 107 PJ increase due to structural changes (i.e. increases in living standards); and
- A 119 PJ decrease due to efficiency improvements (encompassing behavioural and lifestyle changes as well as technological changes).



Source: DoE 2014

Figure 0-16: Decomposition analysis results for energy consumption in the residential sector

The key drivers for future energy demand in the residential sector are policies, urbanisation, electrification rates, household income and population growth/household growth. The future number of households was derived by dividing the population growth by the total number of persons per household. According to Statistics South Africa, in 2011 the number of persons per household was 3.4 persons and this was kept fixed from 2013 to 2050, hence household size was not a factor in the change in household energy consumption. Four scenarios, Base Case, Resource Constrained, Environmental Awareness and Green Shoots, were considered for the residential sector, in which the key drivers were changed.

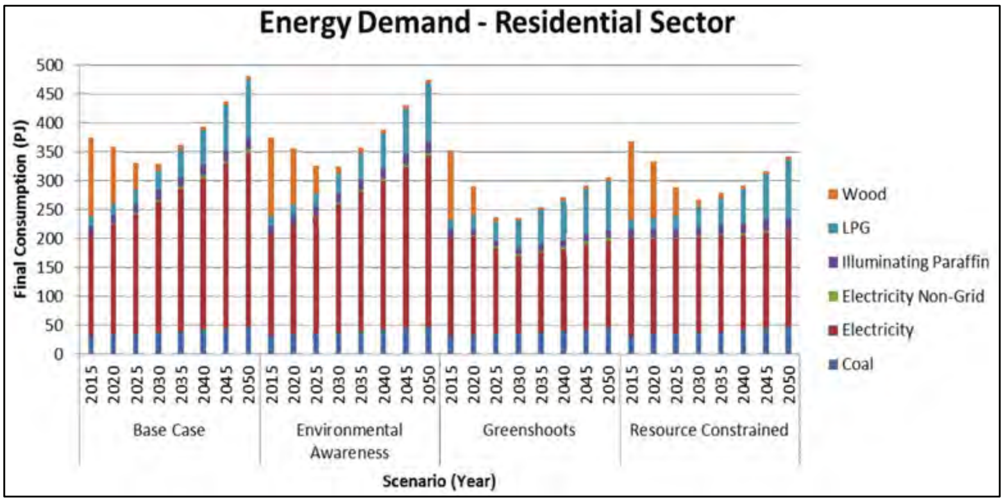
The Base Case is characterised by a moderate growth in gross domestic product which contributes to a similar increase in household income. The One Million Solar Water Heater Programme is implemented as expected. The National Building Regulations were implemented from 2011, so that all new households comply with the standards set for water heating. Over and above the improvements encouraged as part of the MYPD 3 process, energy efficiency improvements are negligible due to the lack of investment in more efficient technologies.

As in the Base Case, the Resource Constrained Scenario is characterised by moderate economic growth which leads to a moderate increase in household income over time. The penetration of more efficient technologies for electric lighting, cooking, space heating, water heating, and electrical appliances also occurs and has an impact on the energy intensity. As in the Base Case, the Environmental Awareness Scenario is characterised by moderate economic growth which leads to a moderate increase in household income. The energy efficiency improvements are similar to those in the Resource Constrained Scenario. Within the residential sub-sector the existing Solar Water Heater Programme is extended to 5 million solar waters by 2030.

The Green Shoots Scenario is characterised by accelerated economic growth in the short to medium term, with a decline in the later years which translates into an overall increase in household income. This is higher than experienced in the Base Case in the short and medium term, but lower in the long term. Energy efficiency improvements for electrical appliances in the Green Shoots scenario are similar to those in the Resource Constrained and Environmental Awareness scenarios. The Solar Water Heater Programme is extended past 2019 with up to 10 million solar water heaters by 2030.

The composition of energy demanded and the forms of energy consumed change over time as household income and the number of electrified households increase. Increased urbanisation also contributes to the increase in demand for electricity and other cleaner forms of energy, such as LPG, in the residential sector. The driver which has the greatest impact on future fuel mix is household income, which is likely to result in increased ownership of electrical appliances, thus contributing to electricity demand.

The increase in non-grid electrification is primarily due to the targets set in government's New Household Electrification Strategy which defines universal access to electricity at 97% of which 7% of households are served by off-grid solutions.



Source: DoE Analysis

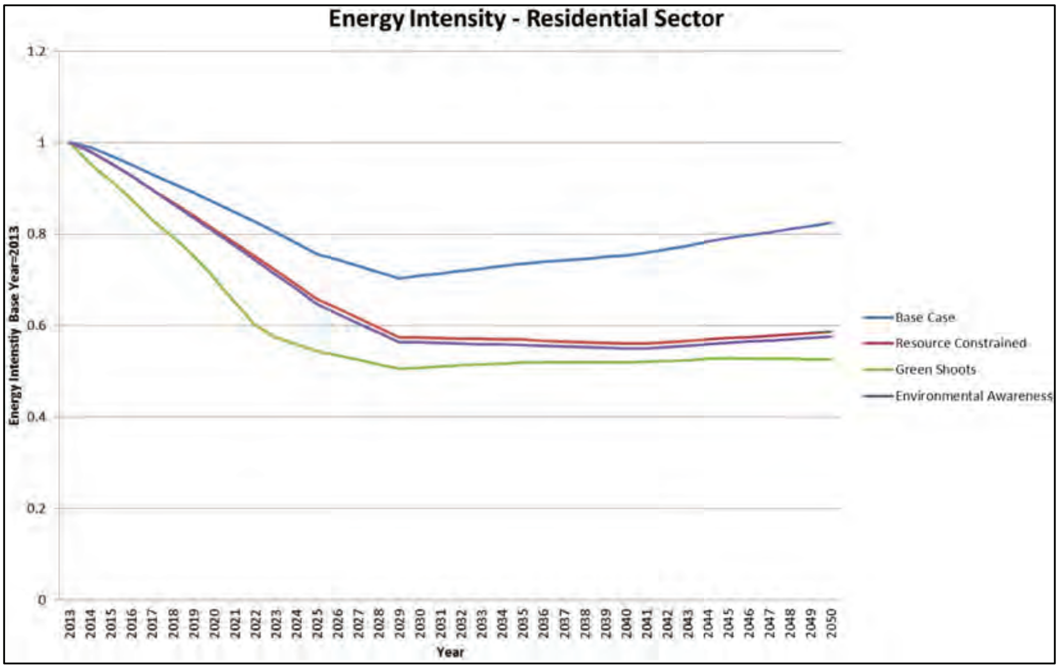
Figure 0-17: Projected demand in the residential sector

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 a relatively affordable fuel source (especially for communities close to mines) and it is 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, the penetration of solar water heaters coupled with building regulations will reduce the rate of increase.

The use of solid fuels (coal and wood) for thermal purposes such as cooking, water heating and space heating declines the fastest in the Green Shoots Scenario due to the faster increase in household income. In addition the Solar Water Heating Programme is extended from 1 million to 10 million in the Green Shoots scenario and hence contributes to the movement of households that could not switch from solid fuels to cleaner forms of energy without government assistance.

The decline in illuminating paraffin shows similar trends, with the Green Shoots Scenario experiencing the sharpest decline. However over the long term there will be a residual number of households which will continue to use illuminating paraffin.

In the short term, energy intensity also decreases fastest in the Green Shoots Scenario as this scenario has the greatest increase in household income. The increase in household income leads to households moving away from solid fuels such as wood and coal for end uses such as cooking. The energy required for cooking using a cleaner fuel such as LPG or electricity is lower and thus contributes to lower intensity. In addition, energy efficiency improvements in electrical appliances such as refrigerators and washing machines will reduce the impact of the steady rise in ownership. In the long term the increase in household income in the Green Shoots Scenario slows as a result of reduced GDP growth and in line with this the rate of increase in ownership of electrical appliances also slows.



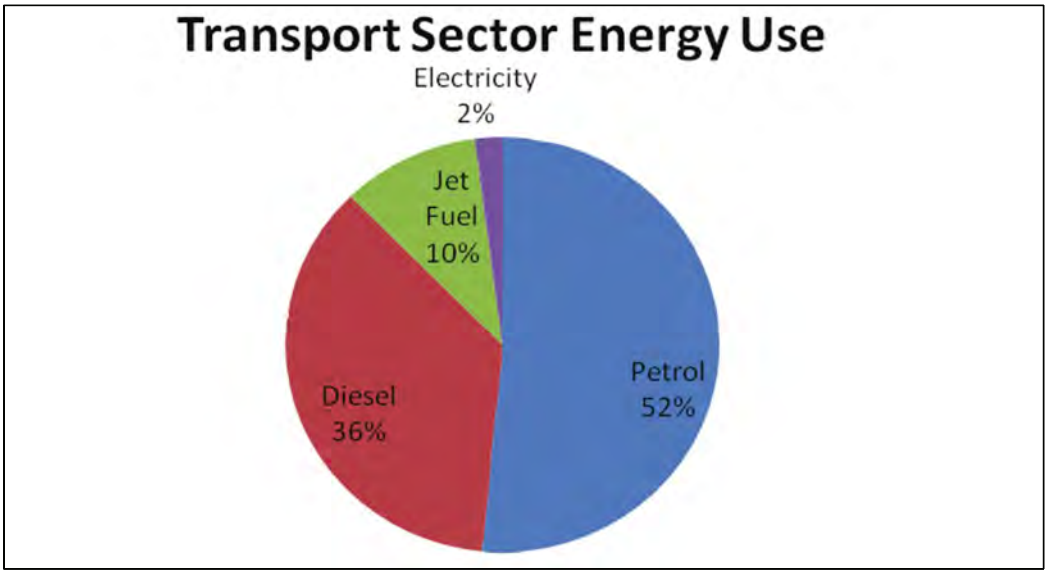
Source: DoE Analysis

Figure 0-18: Energy intensity in the residential sector

In the Resource Constrained Scenario, energy intensity is lower than in the Base Case Scenario due to higher levels of energy efficiency, but higher than in the Green Shoots Scenario due to the slower increase in household income as well as the difference in the uptake of solar water heaters (one million SWH in the Resource Constrained Scenario by 2030, versus 10 million in the Green Shoots Scenario in the same period). As households switch from using solid fuels and electricity to solar energy to provide water heating, the energy intensity of households will reduce. When comparing the Resource Constrained Scenario with the Environmental Awareness Scenario the impact of energy efficiency is greater than the impact of the Solar Water Heater Programme. Thus despite the penetration of 4 million more SWH in the Environmental Awareness scenario the difference in energy demand is marginal. When the number of SWH increases from 5 million to 10 million in the Green Shoots Scenario, the impact of the SWH Programme is felt due to the fact that SWH are available to replace electric geysers. In the 1 million and 5 million SWH Programme, the majority of SWH are used to replace households using wood and illuminating paraffin for water heating.

5.5. Transport Sector

Across Africa, roads remain the dominant mode for 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 road, rail and air transport network (SA Yearbook, 2011/12). Land passenger transport accounts for the greatest use 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%) and jet fuel (~10%), with the lowest being electricity (<2%) which is primarily used in rail transport (see Figure 0-19).



Source: Energy Digest, 2010

Figure 0-19: Energy end-use within the transport sector

Demand for transport services is assumed to be driven by economic activity represented by GDP for freight and public transport and GDP per capita for private passenger transport.

Figure 0-20 and Figure 0-22 show the results of the decomposition analysis results for changes in energy consumption in passenger transport and freight transport, respectively. The overall total energy consumption in the sector increased by 466.83 PJ between 1993 and 2010. Passenger and freight transport respectively contributed to increases of 11.96 PJ and 454.87 PJ of energy consumption. The activity effect alone resulted in an increase in energy consumption of 651.8 PJ. This is accounted for by growth in both passenger transport and freight transport.

… The overall total energy consumption in the sector increased by 466.83 PJ between 1993 and 2010…

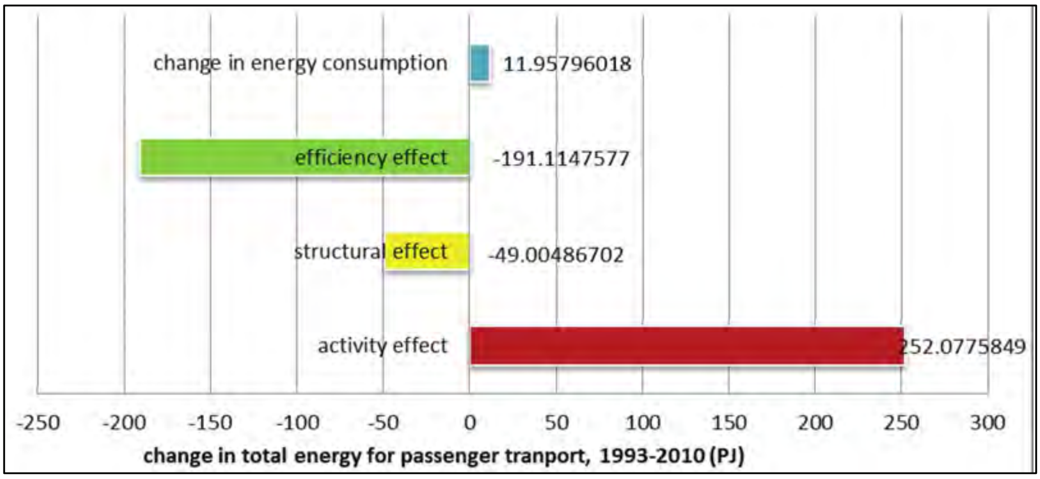
In this sector, energy services are projected based on the concept of a “vintage stock model” which allows for the time-related effect of new technologies entering and old ones leaving the market. The energy services considered are passenger kilometres and tonne-kilometres. The passenger kilometres are calculated based on the stock of vehicles on the road multiplied by annual average kilometres travelled. The stock of vehicles on the road is determined by sales units of vehicles multiplied by remaining vehicles from the previous years. Tonne-kilometres are determined by tonnes multiplied by annual average kilometres travelled.

5.5.1. Passenger transportation

Figure 0-20 shows the changes of energy consumption in passenger transport. The total energy consumption in 2010 had increased by 11.96 PJ relative to 1993. This change is composed of the sum of:

- A 252.08 PJ increase due to greater level of activity;
- A 49 PJ decrease due to structural changes; and
- A 191.11 PJ decrease due to energy efficiency improvements.

This means that over the 17-year period, if all other factors had remained constant, improvements in energy efficiency would have led to a 191.11 PJ fall in energy consumption.

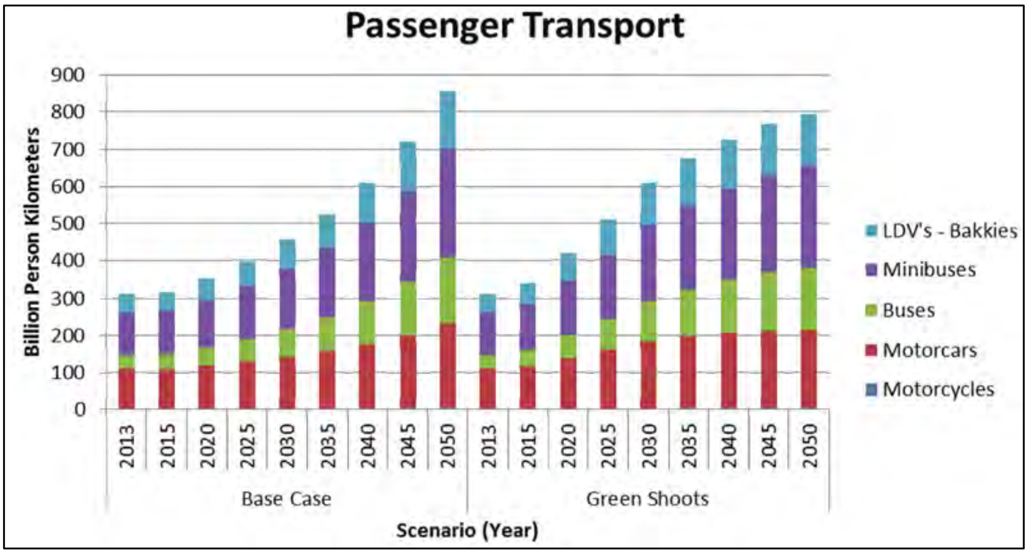


Source: DoE Analysis

Figure 0-20: Decomposition analysis results for energy consumption in the passenger transport sub-sector

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 for the move from mass and public modes of transport to small passenger vehicles. Other indirect factors which affect the mode of transport include quality of roads as well as safety, efficiency and reliability of public transport systems. More recent factors that could change passenger movement patterns 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.

Figure 0-21 presents the passenger kilometres over the modelling period from 2013 to 2050. The two economic growth rates used to project these services are based on moderate GDP growth rates (the Base Case Scenario) and high GDP growth rates (the Green Shoots Scenario). The passenger-kilometres for the Base Case Scenario grow at an annual rate of 2.8%, from approximately 311 billion passenger-kilometres in 2013 to approximately 855 billion passenger-kilometres in 2050 and the passenger kilometres for the Green Shoots Scenario grow at an annual rate of 2.6%, from approximately 311 to 795 billion passenger-kilometres over the same period. The fuel mix corresponding to these passenger-kilometres is presented in Figure 0-24, Figure 0-25, and Figure 0-26 and presents detailed information about energy consumption in the transport sector across the scenarios.



Source: DoE Analysis

Figure 0-21: Projected energy services for passenger transport

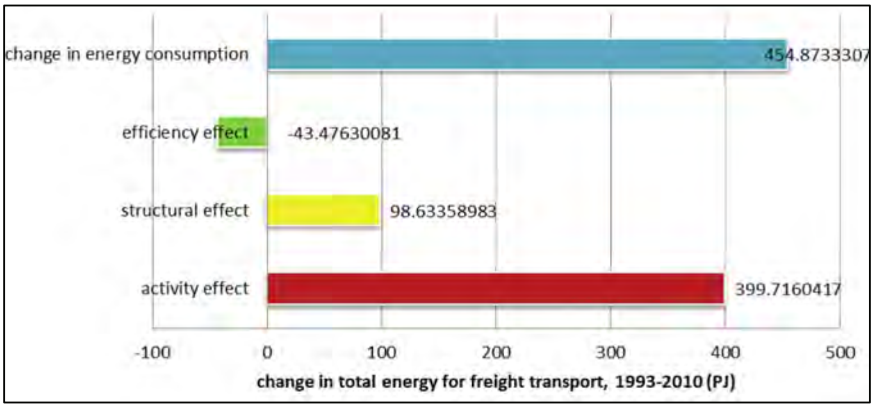
5.5.2. Freight transportation

In recent years the rail freight market has lost market share to road haulage. Currently, it is estimated that 85% of total freight is hauled by road, with the remainder being transported by rail. In fact, 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, 2002). However, it also carries with it negative externalities such as increased and rapid damage to roads, road congestion, air pollution and higher fuel/energy requirements.

The decomposition analysis results show that energy efficiency declined by almost 50 basis points in terms of total energy consumption. Total energy consumption in 2010 increased by 49.01 PJ relative to 1993. This change is composed of the sum of:

- A 19.38 PJ increase due to greater level of activity;
- A 1.85 PJ increase due to structural changes; and
- A 27.78 PJ increase due to energy efficiency reduction.

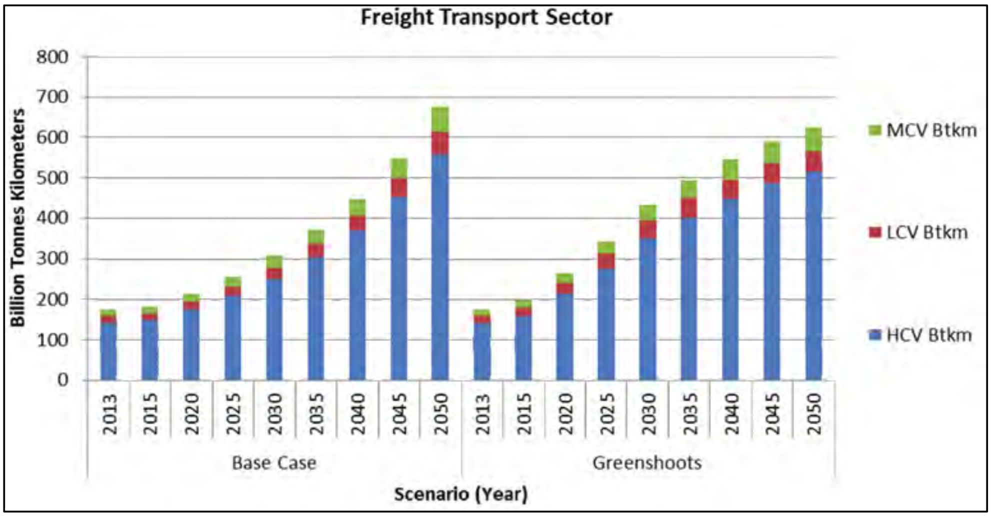
This means that over the 17-year period, if all other factors had remained constant, the reduction in energy efficiency would have led to a 49.01 PJ increase in energy consumption.



Source: DoE Analysis

Figure 0-22: Decomposition analysis results for energy consumption in the freight transport sector

Demand for freight haulage is strongly linked to the value-add of the sector and overall economic growth, together with assumptions about increased road haulage, have informed demand projections. The projected energy services for freight transport are depicted in Figure 0-23 and projections for the services (tonne-kilometres) are presented for the Base Case and Green Shoots scenarios of economic growth. The freight tonne-kilometres in the sector grow at an annual rate of 3.7% in the Base Case Scenario, from 175 billion tonne-kilometres in 2013 to 676 billion tonne-kilometres in 2050. In the Green Shoots scenario, the services grow at an annual rate of 2.6%, from 175 billion tonne-kilometres in 2013 to 623 billion tonne-kilometres in 2050.



Source: DoE Analysis Fuel Demand in Transportation

Figure 0-23: Projected energy services growth for freight transport

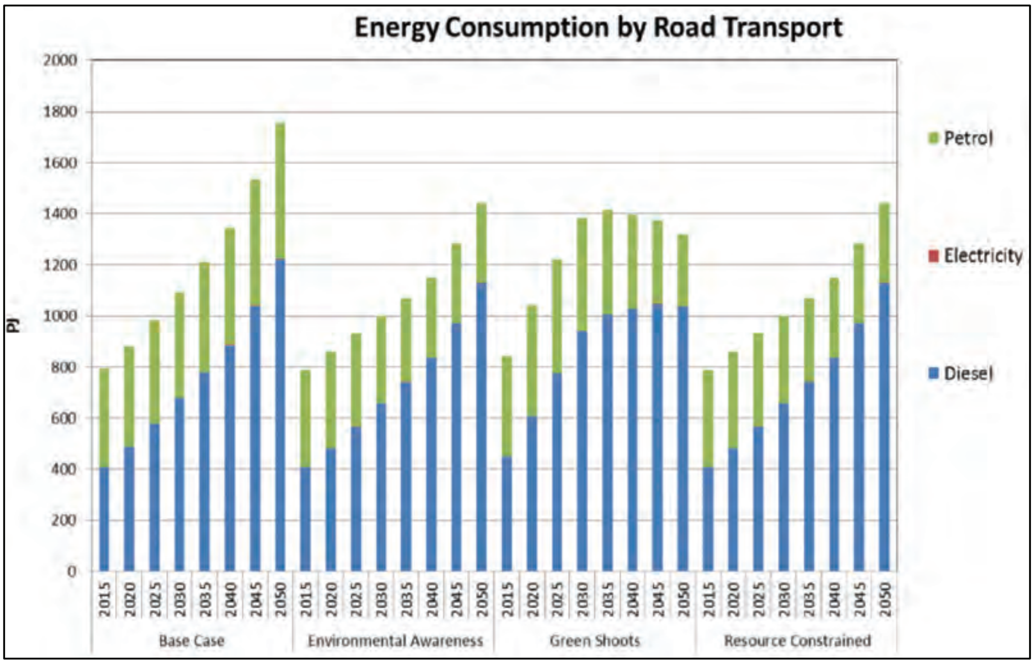
Sections 0 and 0 outlined the projections for energy services in the form of passenger-kilometres and tonne-kilometres. The following section presents the corresponding projections for energy carriers for these services.

Liquid fuel demands are predominantly driven by the road transport sector. The demands for petrol, diesel and electricity for road transport in each of the scenarios are shown in Figure 0-24.

In all scenarios, the share of diesel increases from 50% in 2014 to approximately 85% in 2050. In absolute terms, diesel demand triples but petrol demand halves. Electricity used for electric vehicles constitutes a very small share in the last few time intervals. This has a modest impact on petrol requirements but less impact on electricity because of the relative sizes of the two sub-sectors (electricity demand is more than double the demand for liquid fuels in terms of energy) and the higher efficiency of electric vehicles compared to conventionally powered vehicles (85–90% for electric compared with 20–30% for conventionally powered vehicles).

… In all scenarios, the share of diesel increases from 50% in 2014 to approximately 85% in 2050…

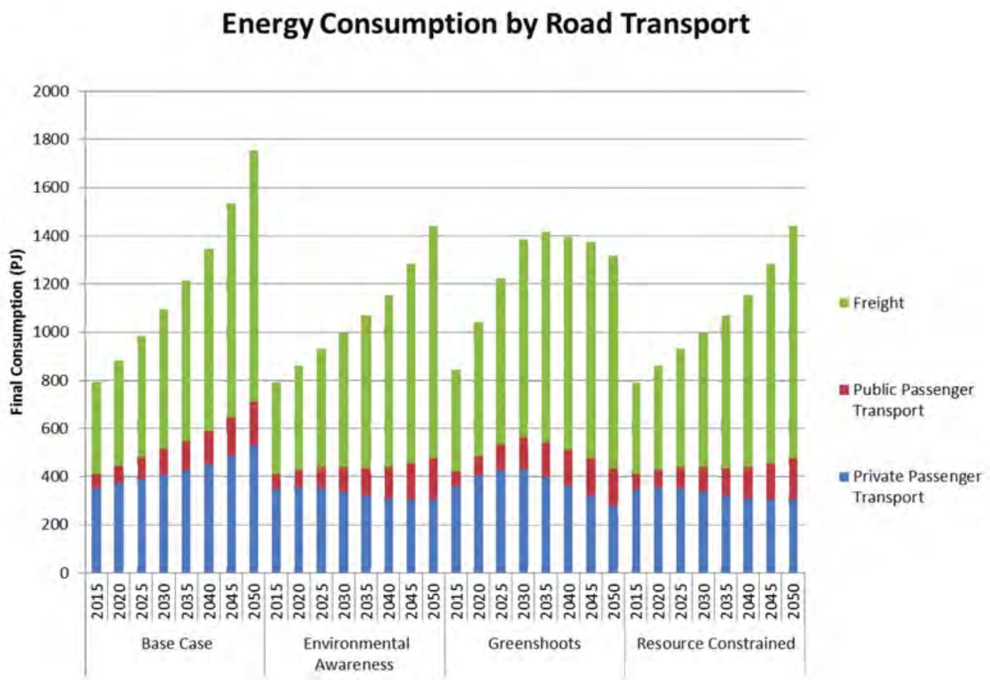
The increase in the demand for diesel is related to the types of vehicles which use diesel. Most road freight, and a significant share of public transport, is fuelled by diesel. For these technologies the rate of energy efficiency improvement, as defined in the assumptions, is lower than for private vehicles. (The Environmental Awareness, Green Shoots and Resource Constrained scenarios assume an average annual fuel economy improvement for new cars and SUVs of 2.5% and 1.1% for freight and public transport. The Base Case Scenario uses 1% and 0.8% respectively.)



Source: DoE Analysis

Figure 0-24: Total energy consumption by transport sector by fuel

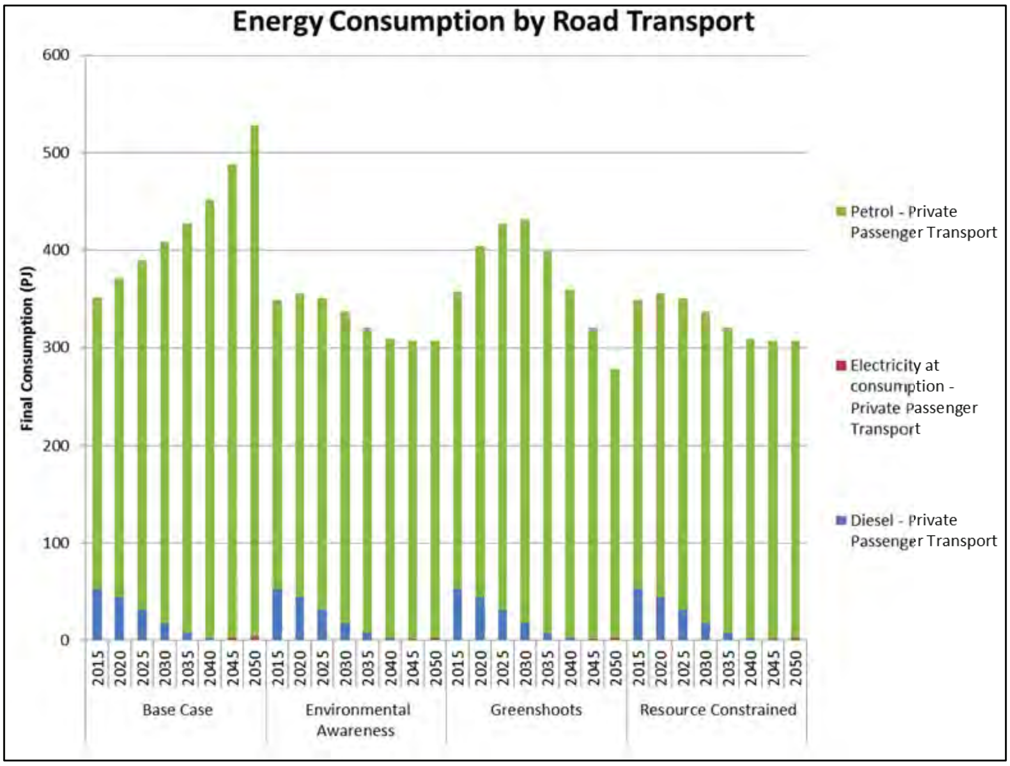
The shares of energy used in transport by vehicle category (private passenger, public passenger and freight) are provided in Figure 0-25. Freight and public transport vehicles have less room for efficiency improvements because transport companies and public transport operators use efficiency as a criterion to minimise operating costs. Private vehicles, however, are subject to individual preferences and owners are likely to prioritise other features, such as comfort and safety, ahead of fuel economy.



Source: DoE Analysis

Figure 0-25: Total energy consumption by transport sector and category of transport

Further consumption details for private passenger vehicles are provided in Figure 0-26. The factor with the most significant impact on fuel demand is the energy efficiency (or fuel economy) of vehicles as evident when comparing the Base Case Scenario with the other scenarios. This suggests an important role for vehicle energy efficiency within energy policy, as a mechanism to manage liquid fuel demand. Vehicle efficiency improvements are equivalent to providing virtual refineries but fuel quality improvements are needed to enable these more efficient vehicles. Implementation of clean fuels would reduce dependence on imported crude oil, reduce refining capacity requirements and improve the quality of the environment.



Source: DoE Analysis

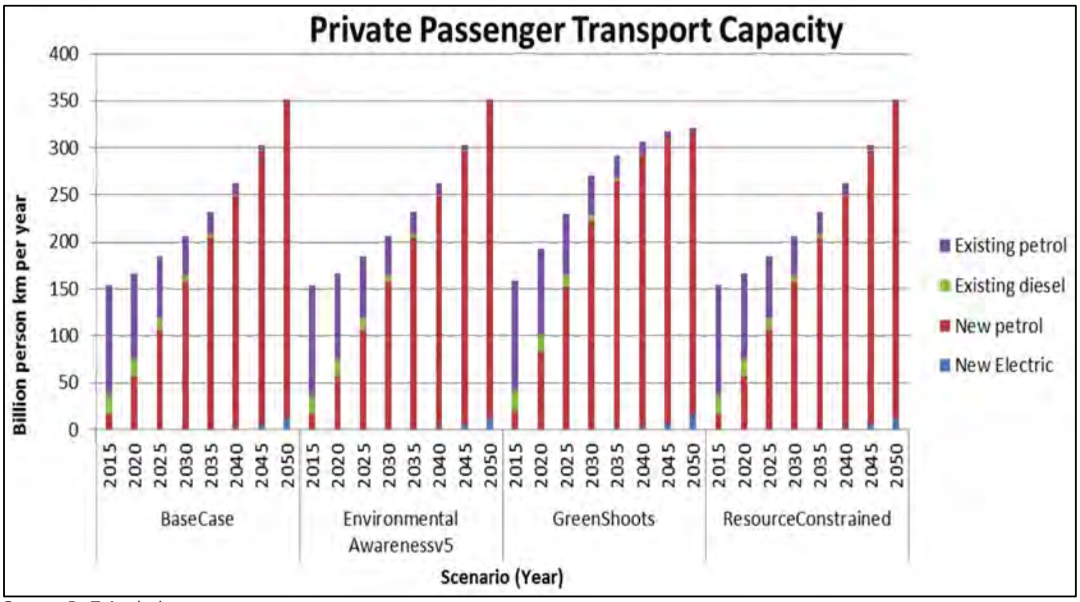
Figure 0-26: Energy consumption by private passenger vehicles and fuel type

5.5.3. Transport fleet structure

The private passenger vehicle fleet (defined in terms of the person-kilometres travelled per year) is disaggregated by technology type as presented in Figure 0-27. The fleet structure for freight and public transport is assumed to stay unchanged and alternative technology options were not considered beyond aggregate efficiency improvements. The future transportation demands for the various Integrated Energy Plan (IEP) scenarios were determined using demand modelling, based on correlations between transport demand and economic development assumptions (GDP growth). The Base Case, Environmental Awareness and Resource Constrained scenarios have the same demand trajectory because they are based on the same economic growth projections. The Green Shoots scenario, with a higher initial growth rate, has a higher demand for transport services in the first 25 years but this declines in the last decade.

Electric vehicles are present in all the scenarios and in all time intervals, but they only begin to make a significant contribution after 2040 at about 1% of the fleet. This increases to approximately 4% by 2050, but is far from the National Transport Master Plan (NATMAP) target of 60%. The lower crude oil prices that are currently experienced, and are expected to continue in the short term, have the effect of delaying the switch from conventional petrol and diesel vehicles to electric vehicles due to their higher capital outlay costs.

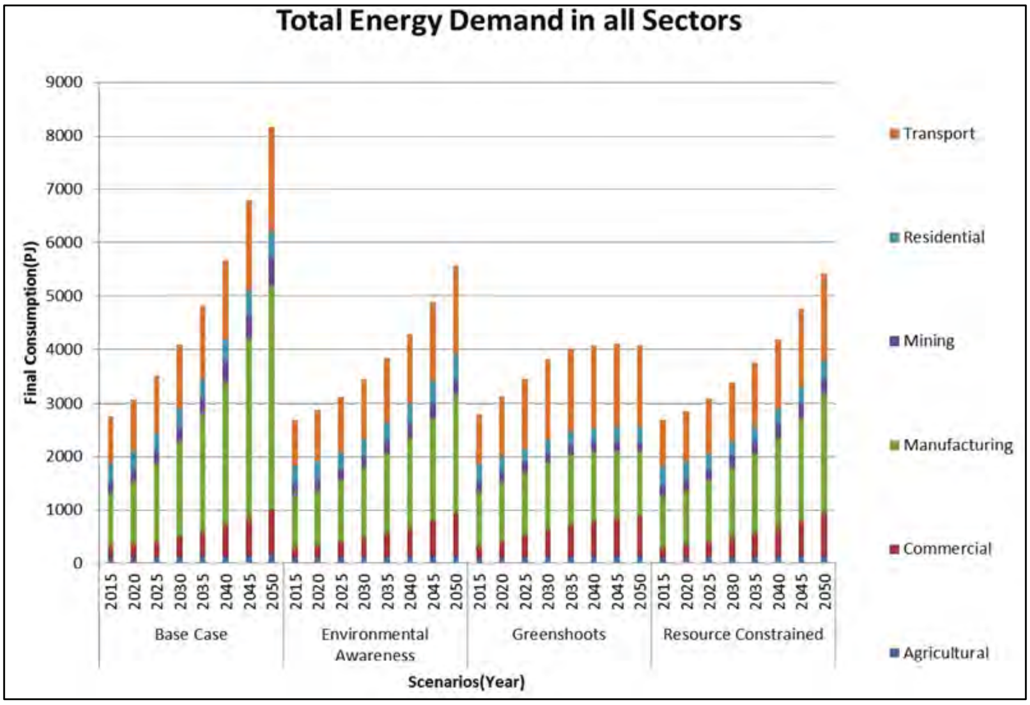
While the demand for transportation as a service is the same for the Base Case, Environmental Awareness and Resource Constrained scenarios, the shares of petrol, diesel and hybrid vehicles vary after 2030. This impacts on the demand for liquid fuels as described in the previous section. The Base Case and Resource Constrained scenarios have similar technology shares throughout the modelled period. Petrol vehicles dominate the fleet while other hydrocarbon technologies barely play a role at all in 2040.



Source: DoE Analysis

Figure 0-27: Private passenger transport capacity by technology type

5.6. Total energy demand in all sectors



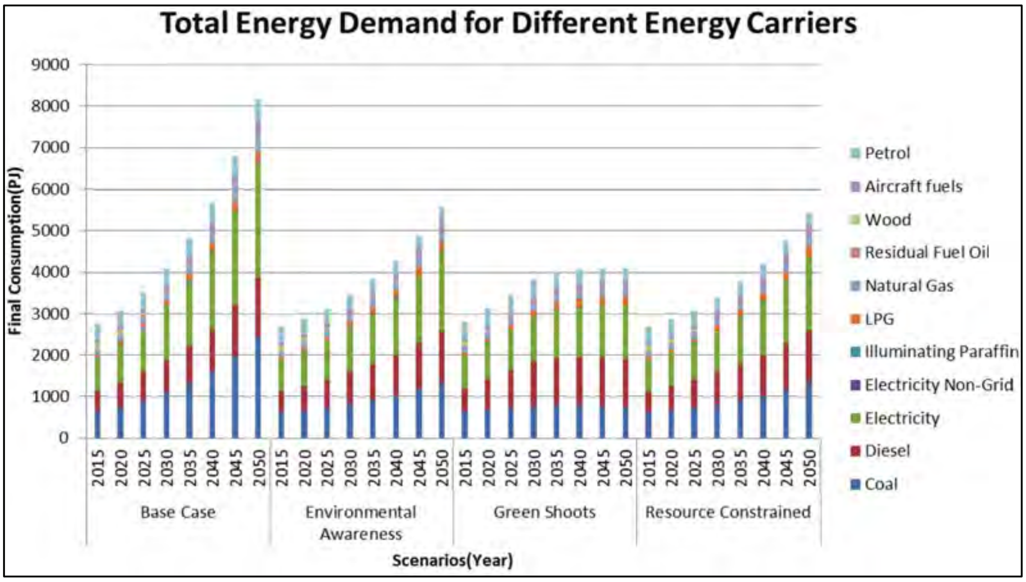
Source: DoE Analysis

Figure 0-28: Projected demand within different sectors

Of all the sectors, the transport sector will continue to make the most significant demand on total energy supply. Consequently, demand for petroleum products increases significantly between 2015 and 2050. This is attributed to the continued use of petrol and diesel vehicles in the foreseeable future, with electric vehicles only starting to make a noticeable contribution to passenger transportation after 2030. Freight haulage, predominantly by road, is the greatest contributor 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 the industrial (manufacturing) sector, followed by the commercial sector. The increase in energy demand in the commercial sector is associated with the continued expansion of the tertiary sub-sector, as South Africa moves towards becoming a more knowledge-based economy. Demand in the residential sector is largely informed by population growth, coupled with increased urbanisation. As living standards improve, people consume more energy; however, energy efficiency interventions could see this trend start to slow down in the future.

While the demand for petrol increases the most significantly between 2015 and 2050, as depicted in Figure 0-29, demand for other petroleum products is less significant. Demand for LPG, however, is expected to show a steady increase in the residential sector and although fairly minor, ranks as the third largest increase between 2015 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.



Source: DoE Analysis

Figure 0-29: Total energy demand for different energy carriers

Demand for natural gas, although the least significant in terms of percentage share, 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. 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 demand across different sectors in 2010, 2030 and 2050 is provided in Table 0-3 to Table 0-6 below.

Within the manufacturing sub-sector the total share of final consumption grows in all scenarios except in the Green Shoots Scenario, due to a reduction in the sub-sector's share of GDP post 2030. In the Resource Constrained and Environmental Awareness scenarios the percentage share of final consumption (41% and 40% respectively) is similar due to the assumptions regarding energy efficiency improvements. In comparison the manufacturing sub-sector's consumption increases to 51% of final consumption given that energy efficiency improvements are not made over the planning period.

For the mining sub-sector the share of final consumption decreases in all scenarios except in the Base Case Scenario. This is due to the fact that in the Green Shoots, Resource Constrained and Environmental Awareness scenarios energy efficiency improvements are implemented, whereas in the Base Case Scenario they are not. Furthermore, the mining sub-sector's final consumption also decreases due to a reduction in its share of GDP post 2030.

The share of final consumption for the agricultural sector remains relatively constant across the three scenarios with the exception of the Base Case scenario. This is due to the fact that in the Green Shoots, Resource Constrained and Environmental Awareness scenarios energy efficiency improvements are balanced out by rebound effects whereas in the Base Case scenarios energy efficiency improvements are not implemented. The decline in the Base Case is due to lack of production activities in the sector.

The share of final energy consumption increases in all scenarios for the commercial sector, despite energy efficiency improvements. This is mainly due to the structural shifts in the economy and climate change. In recent years, the economy has shown a shift towards the services sub-sector and as the economy grows this trend is likely to continue. As a result, energy efficiency benefits may take some time before they are realised due to the increased use of technologies such as laptops, printers, etc. Another contributing factor to energy consumption in the commercial sector is the current weather conditions, which are likely to continue. As noted previously, the greatest effect on energy consumption in this regard is the number of cooling degree days in winter and heating degree days in summer.

Within the residential sector the share of final consumption decreases across all scenarios albeit at different rates. With regard to the Base Case Scenario, the decrease in the residential sector's share is due largely to growth in the manufacturing sub-sector which increases up to 51% due to the lack of energy efficiency improvements implemented as well as the implementation of Building Regulations post 2011. Within the Green Shoots Scenario the larger decrease in comparison to the Resource Constrained and Environmental

Awareness scenarios (despite similar assumptions on energy efficiency) is due to a more aggressive penetration of Solar Water Heaters (10 million by 2030).

Within the transport sector the share of final consumption decreases in all scenarios except in the Green Shoots Scenario which is characterised by high GDP growth. Energy efficiency improvements, which range from 1% to 2.5%, contribute to the decline in the share of final consumption.

Table 0-3: Base Case Scenario: Proportion of final energy demand by sector

Sector	2015	2030	2050	Change
Industry (excl. mining)	37%	43%	51%	↑
Mining	7%	7%	7%	—
Agriculture	3%	3%	2%	↓
Commerce	7%	9%	10%	↑
Residential	14%	8%	6%	↓
Transport	32%	29%	24%	↓
Total	**100%**	**100%**	**100%**	

Table 0-4: Environmental Awareness Scenario: Proportion of final energy demand by sector

Sector	2015	2030	2050	Change
Industry (excl. mining)	36%	38%	40%	↑
Mining	7%	6%	5%	↓
Agriculture	3%	3%	3%	—
Commerce	7%	10%	14%	↑
Residential	14%	9%	9%	↓
Transport	32%	32%	29%	↓
Total	**100%**	**100%**	**100%**	

Table 0-5: Green Shoots Scenario: Proportion of energy demand by sector

Sector	2015	2030	2050	Change
Industry (excl. mining)	37%	33%	30%	↓
Mining	7%	5%	4%	↓
Agriculture	3%	3%	3%	—
Commerce	8%	13%	18%	↑
Residential	13%	6%	8%	↓
Transport	33%	39%	37%	↑
Total	**100%**	**100%**	**100%**	

Table 0-6: Resource Constrained Scenario: Proportion of final energy demand by sector

Sector	2015	2030	2050	Change
Industry (excl. mining)	36%	39%	41%	⬆
Mining	7%	6%	5%	⬇
Agriculture	3%	3%	3%	▬
Commerce	7%	11%	15%	⬆
Residential	14%	8%	6%	⬇
Transport	32%	33%	30%	⬇
Total	**100%**	**100%**	**100%**	

Section 6: Analysis of supply-side options

This section analyses the output of the optimisation modelling executed for the Integrated Energy Plan (IEP). The modelling was undertaken using the indicators for the eight IEP objectives (i.e. cost of the energy system; jobs within the energy sector; CO_2 and pollutant emissions; water consumption; diversity of supply and primary sources; energy intensity; and energy access) across the four core scenarios (i.e. Base Case, Resource Constrained, Environmental Awareness and Green Shoots).

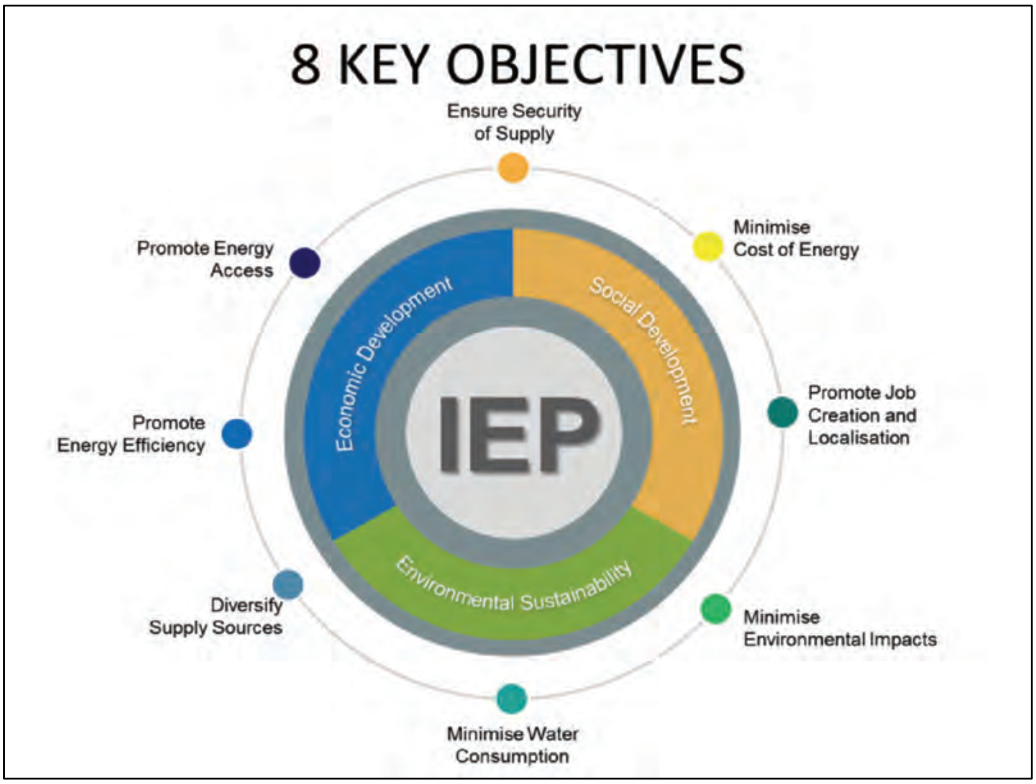


Figure 0-1: Eight key objectives of the IEP

6.1. New capacity requirements

Total capacity requirements for electricity generation and liquid fuel production for the four scenarios are discussed in this section. Total capacity requirements include the residual capacity and the accumulated new capacity for each sector.

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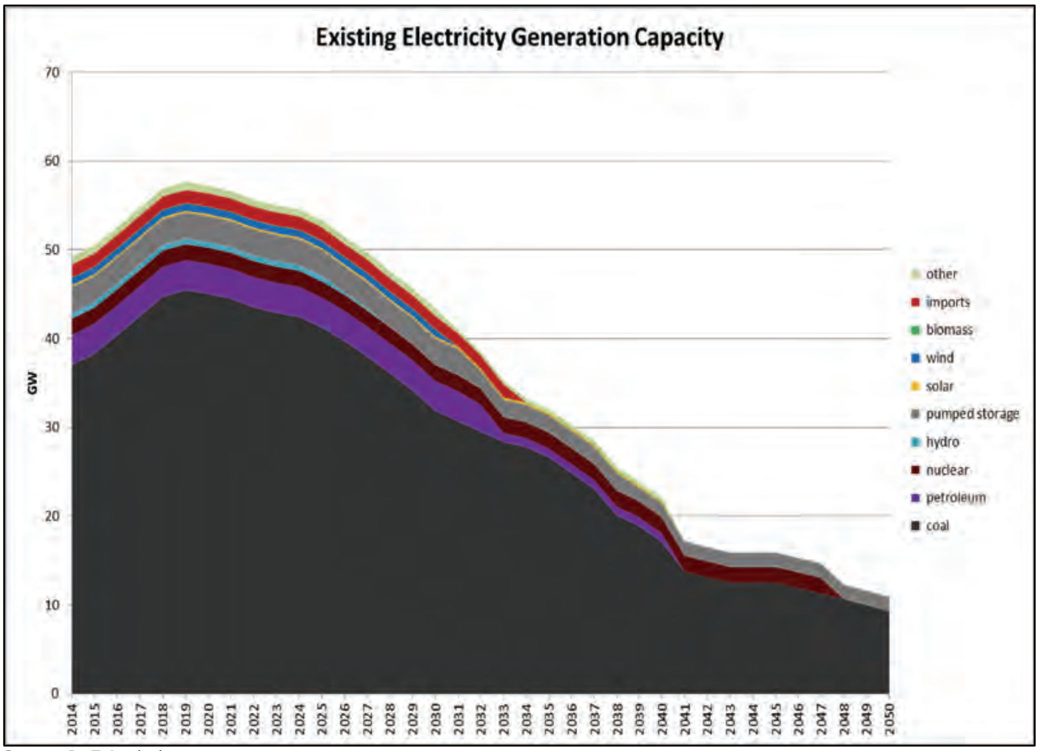
6.1.1. Electricity generation capacity

Existing electricity generation capacity is shown in Figure 0-2. Existing capacity starts to decline notably from 2025, with significant plant retirement occurring in 2031, 2041 and 2048. By 2050 only 20% of the current electricity generation capacity remains. This means that large investments are required in the electricity sector in order to maintain an adequate supply in support of economic growth.



Source: DoE Analysis

Figure 0-2: Total existing electricity generation capacity

Accumulated new electricity generation capacity by scenario is shown in Figure 0-3, accumulated new generation capacity by 2050 is provided in Figure 0-4, while total generation capacity is provided in Figure 0-5. The electricity generation system remains constrained in the short term (i.e. within the next five years) with the only new technologies that can be rapidly deployed to address the constraint being those with short lead times, such as biomass and solar. New capacity added during this time is mostly from the DoE's Renewable Energy Independent Power Producer (REIPP) Programme. By 2020, various import options become available and some new coal capacity is added along with new wind, solar and gas capacity.

The Base Case assumes that the 9.6 GW New Nuclear Build Programme is embarked upon and the first unit comes on line by 2026, with the last unit commissioned by 2031, in line with the IRP2010. Throughout the period after 2020, dependence on imported capacity gradually increases to between 11 and 16 GW depending on the scenario. These imports comprise mostly hydro generation from neighbouring states but also include up to 8.5 GW of gas and up to 1.5 GW of coal generation capacity.

The small amounts of local coal powered generation capacity introduced into the mix between 2020 and 2050 comprise both new capacity and existing plants where the plant life has been extended (an additional ten years is given as an option). The new capacity is introduced in the medium term and the life extensions occur post 2030 when the relevant plants reach the end of their originally planned operational lifespans. Of the eleven coal powered plants considered as options for life extension, only three were determined to be viable in the Base Case and Resource Constrained scenarios (Kendal, Lethabo and Matimba) and only one in the Green Shoots and Environmental Awareness scenarios (Matimba). Additional life extensions are limited by carbon limits and carbon price within the scenarios. Further analysis and consultation need to be conducted by Eskom with relevant government departments and stakeholders to determine the economic viability and environmental impact associated with life extensions. Nuclear (over and above the 9.6 GW New Nuclear Build Programme) and solar technologies start contributing significant generation capacity by 2030 due to greenhouse gas (GHG) emission limits and the costs associated with externalities which make new coal fired plant uneconomical.

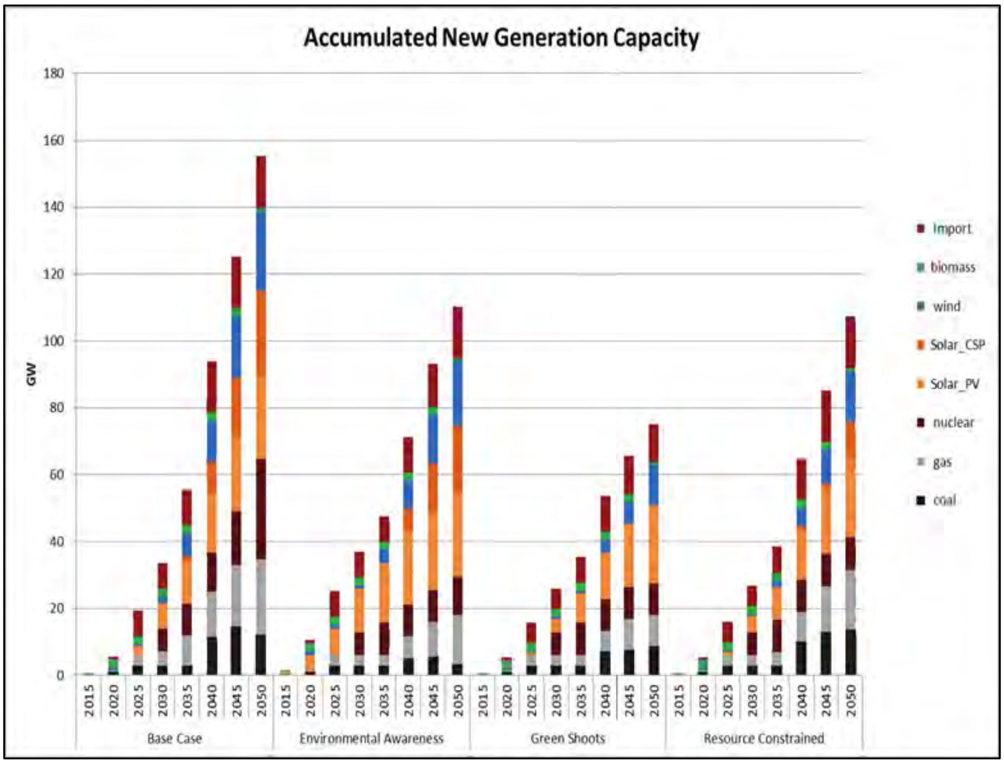
… The mix of generation capacity technologies by 2050 is considerably more diverse than the current energy mix, across all scenarios …

The mix of generation capacity technologies by 2050 is considerably more diverse than the current energy mix, across all scenarios. The main differentiating factors between the scenarios are the level of demand, constraints on emission limits and the carbon dioxide externality costs.

The Base Case and Environmental Awareness scenarios have the highest solar capacity additions – in the Base Case Scenario this is influenced by higher electricity demand and tighter emission constraints after 2035 and in the Environmental Awareness Scenario this is primarily due to the lower emission constraints and the higher penalties for externalities.

For the same reasons mentioned above, the Base Case Scenario has the highest nuclear capacity additions. While the Base Case, Environmental Awareness and Resource Constrained scenarios have the same economic growth assumptions, the Base Case Scenario has the highest electricity demand and consequently the highest new capacity requirement, but is characterised by the combination of a slower penetration of solar water heaters, slow improvement in energy efficiency (including vehicle efficiency), and moderate increases in energy commodity prices.

While the Green Shoots Scenario has the most optimistic economic growth projections, most economic growth is a consequence of the commercial sector expanding faster than the primary sub-sector. This is coupled with aggressive implementation of the Solar Water Heater Programme (10 million by 2030), high energy efficiency improvements and a high vehicle penetration rate. These combined factors result in a less energy intensive economy and thus a significantly reduced demand for electricity.



Source: DoE Analysis

Figure 0-3: Accumulated new electricity generation capacity by scenario

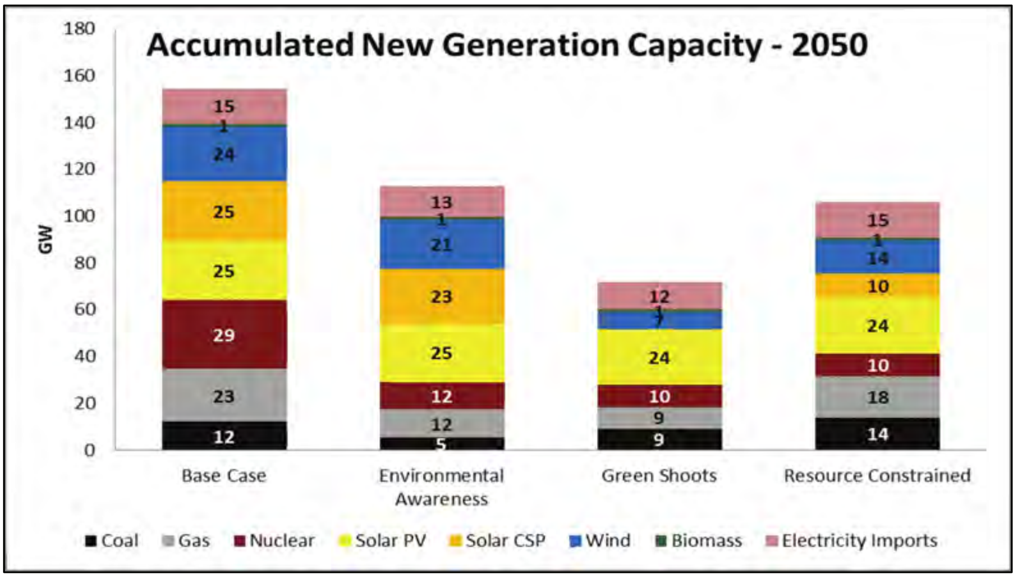
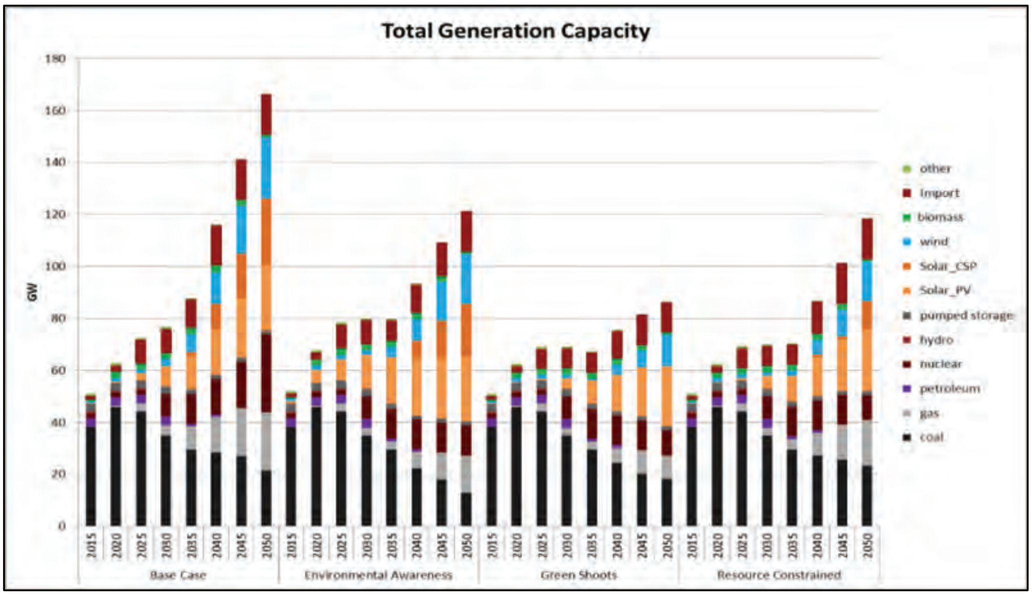


Figure 0-4: Accumulated new generation capacity by 2050

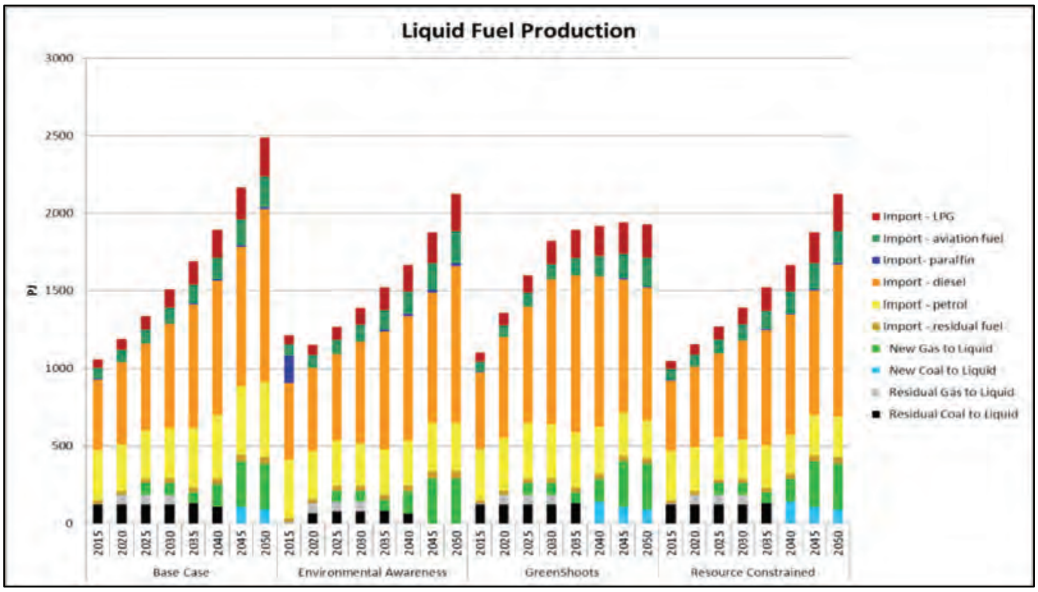


Source: DoE Analysis

Figure 0-5: Total electricity generation capacity

6.1.2. Liquid fuel production and supply

Demand for liquid fuels is met through various sources which include local production from crude oil, gas-to-liquid (GTL) and coal-to-liquid (CTL). Supply shortfalls are met through the importation of final refined products. The sources of liquid fuel production for each scenario are shown in Figure 0-6.



Source: DoE Analysis

Figure 0-6: Liquid fuel production

As with new electricity generation capacity requirements, the Base Case Scenario has the most significant requirement for new liquid fuel production capacity. This is followed by the Environmental Awareness and Resource Constrained scenarios. Faster vehicle efficiency improvements together with a higher penetration of electric vehicles in the Green Shoots Scenario result in reduced fuel intensity for the transport sector and consequently decoupling of economic growth from fuel demand. All four scenarios assume the presence of economically recoverable shale gas and that shale gas is moderately priced. These two assumptions combined would make new crude oil refining capacity unlikely to be economically viable in the short to medium term. The model results therefore suggest the importation of refined petroleum products as a more cost effective option.

When considering the possibility of shale gas, GTL is a viable option based on the assumed costs of local extraction. All scenarios assume that the extraction of shale gas will be approximately R40 per GJ, although considerable externality costs are added to this in the modelling to accommodate emissions in the extraction value chain. Higher international energy prices in the Resource Constrained Scenario favour local energy resource extraction and beneficiation in the longer term. Methane emissions from the shale gas value chain can represent a significant external cost if not properly controlled and will need to be addressed through appropriate regulation to enable this option.

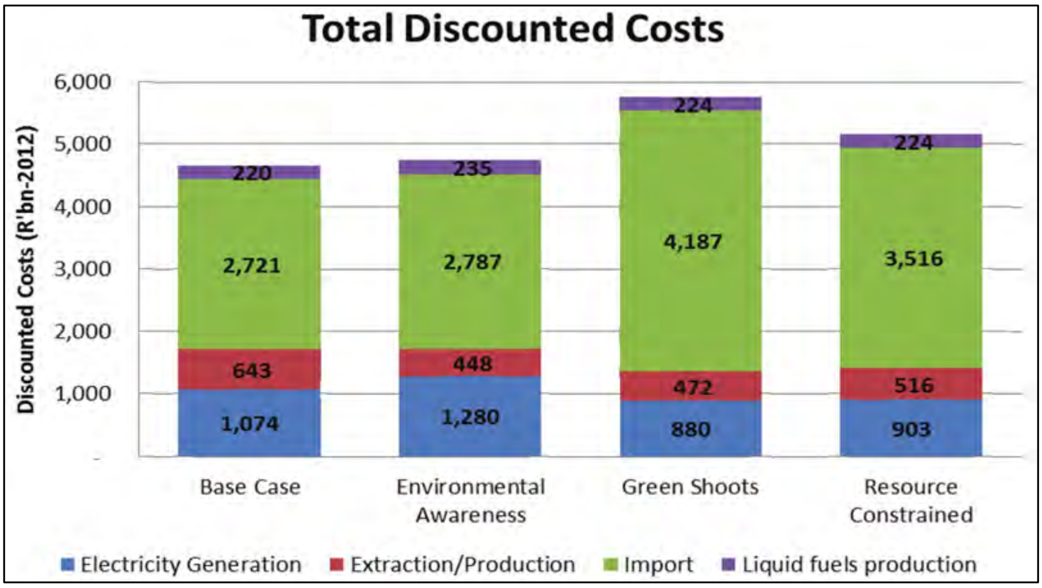
While the existing refineries are not likely to be retired based on operational life (normal maintenance and upgrades generally extend the life of refineries), some older and less efficient refineries may become less economically viable before 2050.

… In the Base Case, Resource Constrained and Green Shoots scenarios, existing CTL is likely to be maintained throughout the period considered but there are unlikely to be any new investments in CTL …

In the Base Case, Resource Constrained and Green Shoots scenarios, existing CTL is likely to be maintained throughout the period considered but there are unlikely to be any new investments in CTL due constraints resulting from carbon emissions and the external costs related to greenhouse gas and pollutant emissions. In the Environmental Awareness Scenario existing CTL is forced out of operation due to the very tight emission limits imposed on liquid fuel production, compounded by a much higher carbon price.

6.2. Costs

Energy system costs are divided into cost components representing different parts of the energy value chain from primary energy supply (imports and extraction) to the production of the end product, energy. The cost components for the IEP scenarios are provided in Figure 0-7. Imports include imported electricity and imports of refined product.

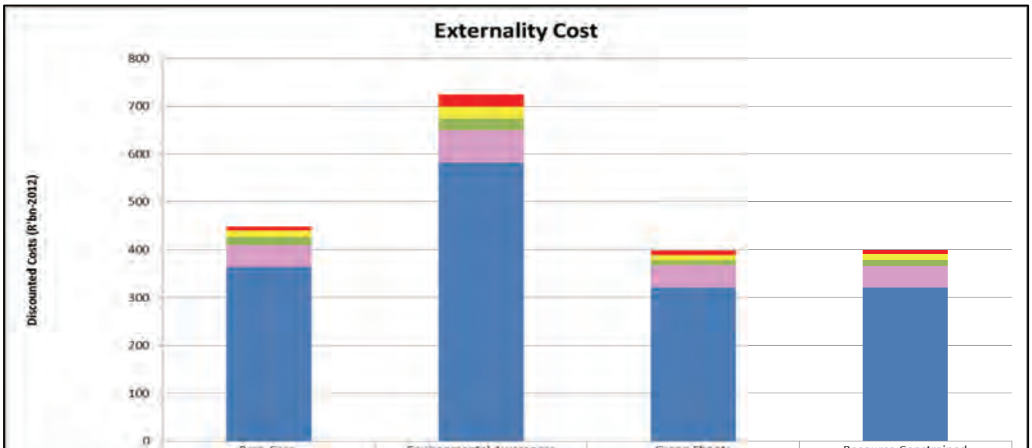


Source: DoE Analysis

Figure 0-7: Total discounted energy system costs (2014-2050)

The major energy system costs arise from imports of petroleum products. Imports of electricity from neighbouring countries contribute towards import costs but are comparatively small (less than 2%). Local energy resources are favoured, because imported energy impacts not only on the national balance of trade but also on energy security due to geopolitical risks. It is assumed that shale gas extraction in South Africa will be cheaper than imports of gas within all the scenarios considered (see inputs and assumptions). The resultant import costs over the modelled period shown in Figure 6-7 are slightly lower than those currently experienced, which are in the region of 70-75% of energy costs.

Externality costs were included in the modelling of the energy system and represent the damage costs caused by pollutants, more specifically CO_2, NO_x, SO_x and particulate matter. Such damage costs seek to quantify the negative impacts of various pollutants on society. Examples include the effect of carbon emissions on the climate; deterioration of health and mortality due to fires and inhalation of poisonous fumes from the combustion of harmful fuels; waste handling of spent nuclear fuels; and disaster management in the event of leaks or spills. Externality costs have the effect of making technologies which use fuels that have high levels of pollutants relatively more costly and are shown in Figure 0-8 for the four core scenarios. The Environmental Awareness Scenario has the highest total externality costs of R725 billion over the modelled period, followed by the Base Case Scenario (R448 billion), the Resource Constrained Scenario (R399 billion) and lastly the Green Shoots Scenario (R398 billion). While the Environmental Awareness Scenario indicates high externality costs, it has low volumes of emissions but allocates higher value to the environment as reflected in the higher carbon dioxide penalty cost of R270/t which results in the high internalised cost. Electricity generation accounts for approximately 80% of the externality cost in all scenarios. This is followed by liquid fuel production which accounts for approximately 10% of the cost. Extraction and imports make up the remaining 10% of the externality cost with liquid fuel imports contributing 2% towards the cost.



	Base Case	Environmental Awareness	Green Shoots	Resource Constrained
Liquid Fuel Imports	8	26	10	8
Electricity Imports	14	25	11	12
Extraction	17	24	10	12
Liquid Fuel Production	45	68	45	45
Electricity Generation	364	582	322	321

Source: DoE Analysis

Figure 0-8: Externality Cost

A detailed analysis of the key factors that contribute to the cost structure for new electricity generation capacity is described in the following sub-section.

6.2.1. Electricity generation costs

The total discounted cost for new electricity generation is shown in Figure 0-9. While coal and biomass contribute a fairly small share towards total generation capacity, as shown in Figure 0-5, higher externality costs in the case of coal, and technology costs in the case of biomass, mean that these technologies contribute more towards total energy system costs. The Environmental Awareness Scenario, with its higher externality costs (R270/ton throughout the planning period as opposed to a range of R48-R120/ton for other scenarios) has the highest total energy system cost when existing plants are taken into account. However when only new electricity generation capacity is considered (see Figure 0-10) the profile of the comparative costs is similar to the new generation capacity which is added (see Figure 0-3) and the Base Case Scenario reflects the highest total new capacity energy system cost. New plants are assumed to be more efficient – hence the total cost of capacity from new coal plants is less than that of existing plants.

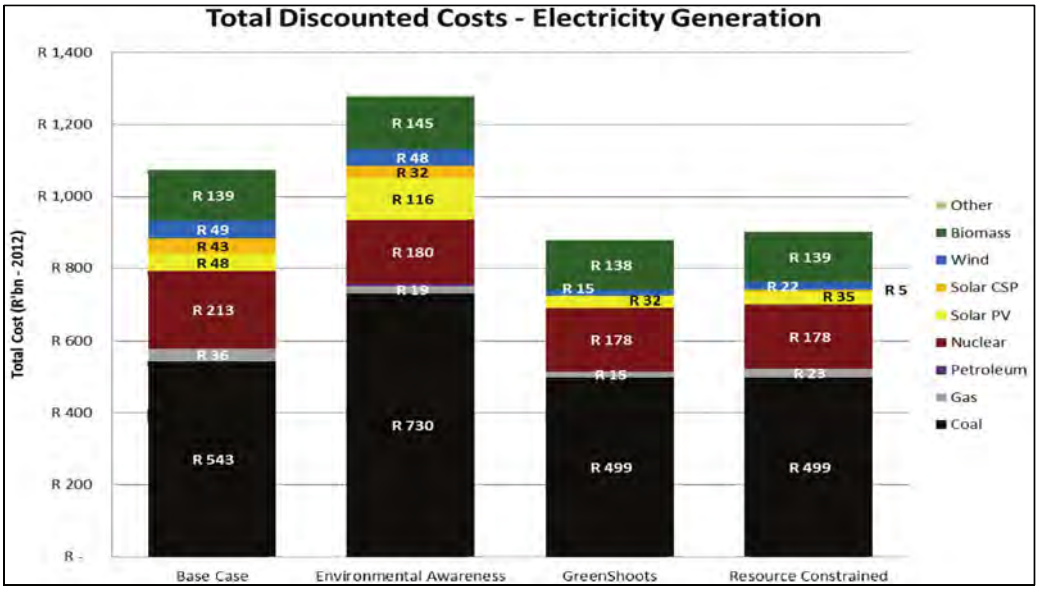


Figure 0-9: Discounted generation costs for electricity

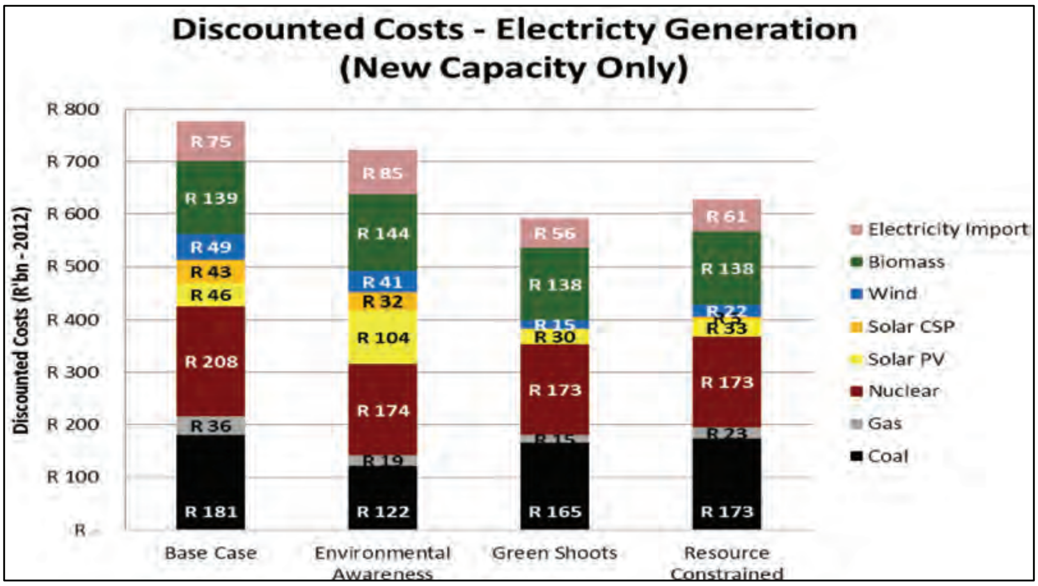


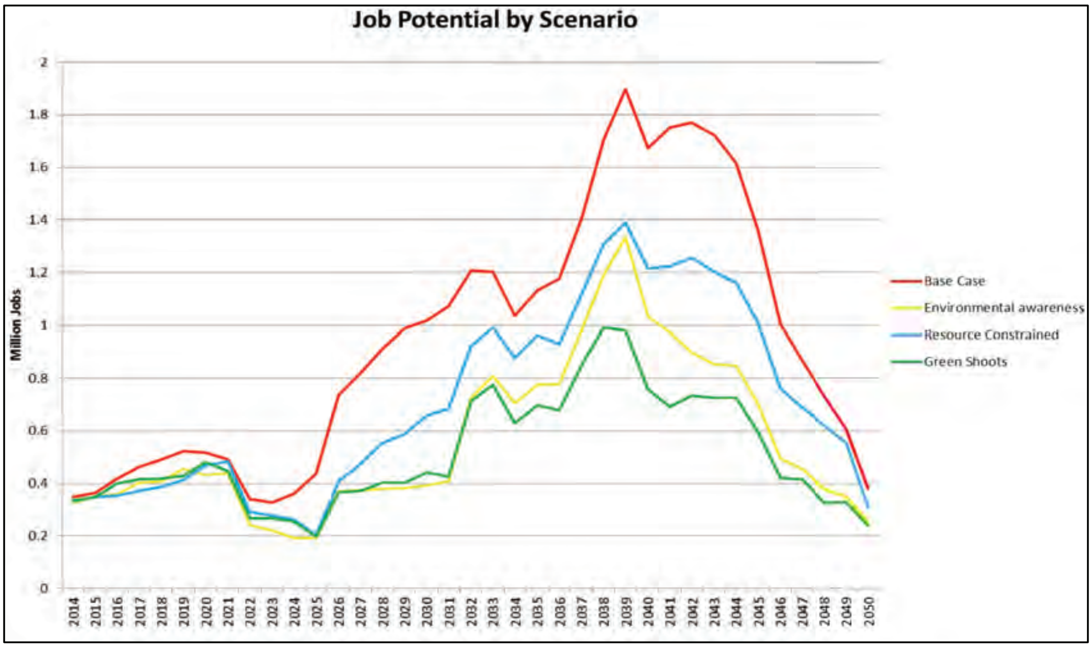
Figure 0-10: Cumulative discount cost for new electricity generation capacity

6.3. Jobs

The maximum number of potential jobs within the energy sector by year for each of the scenarios is presented in Figure 0-11. The decline in the number of jobs indicated from 2040 to 2050 is the result of the modelling timeframe and methodology, which only considers infrastructure capacity requirements to 2050 (i.e. there is no construction activity (or jobs created) in the lead up to 2050 for capacity requirements beyond 2050). In addition, all jobs related to construction are evenly distributed over the lead-time of the technology as an approximation within the IEP modelling. There is little difference in the job potentials for the scenarios in the first eight years of the modelling period however in the longer term, the differences become more pronounced.

- In the Green Shoots Scenario, the jobs are a result of GDP growth, which is higher in the short term but slows down in the longer term thus reducing the demand for energy compared to the other scenarios.
- In the Resource Constrained Scenario, higher energy prices reduce the importation of energy while increasing dependence on local energy resources. This has the effect of encouraging improvements in energy efficiency. The combined effect is a lower demand for energy than in the Base Case Scenario and hence a lower requirement for investments and jobs within the energy sector.
- The Environmental Awareness Scenario is constrained by tight emission limits and high externality costs which create an aggressive energy efficiency drive and a switch towards renewable energies. Demand for energy will essentially be lower than the Base Case and Resource Constrained scenarios.

… The number of potential jobs in the energy sector is dependent on the circumstances assumed in the scenarios and the level of investment in the various energy technologies …



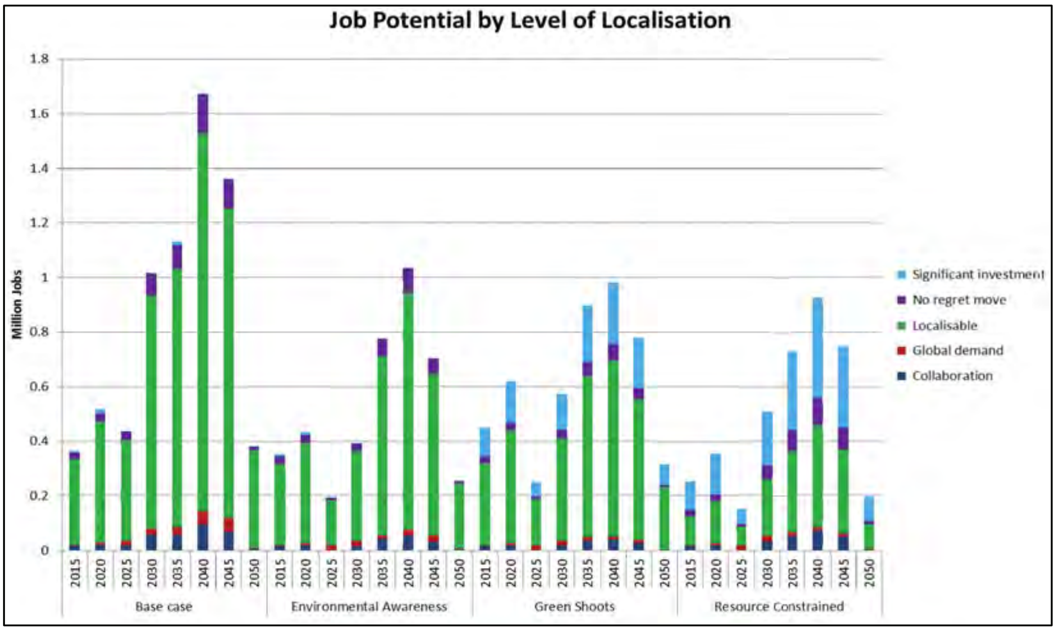
Source: DoE Analysis

Figure 0-11: Potential number of jobs in the energy sector by scenario

For a more detailed analysis, jobs were classified according to five levels of localisation in line with a McKinsey & Company report on localisation of energy technologies (McKinsey & Company, 2014). Each level within the classification requires greater investment than the previous level. These levels and their associated assumptions are as follows:

- **Localisable –** Assumes that the current policy framework is conducive for localisation, local supply of the required skills set is available and there is sufficient demand for raw material to justify local production
- **No regret move –** The current policy framework exists or could be developed and implemented within a fairly short timeframe
- **Significant investment required –** The current policy and regulatory framework could be developed and implemented within five years and some targeted investments would need to be made
- **Collaboration –** Regional co-operation and partnerships would need to be developed in order to create demand beyond South Africa's borders
- **Global demand required –** South Africa would need to be competitive in exporting the technologies and services to the global market.

The localisation potential for each of the scenarios is presented in Figure 0-12. The number of potential jobs in the energy sector is dependent on the circumstances assumed in the scenarios and the level of investment in the various energy technologies. In all scenarios and time intervals, 85% of the jobs are localisable without any additional large investments beyond those required for the construction and operation of the various technologies.

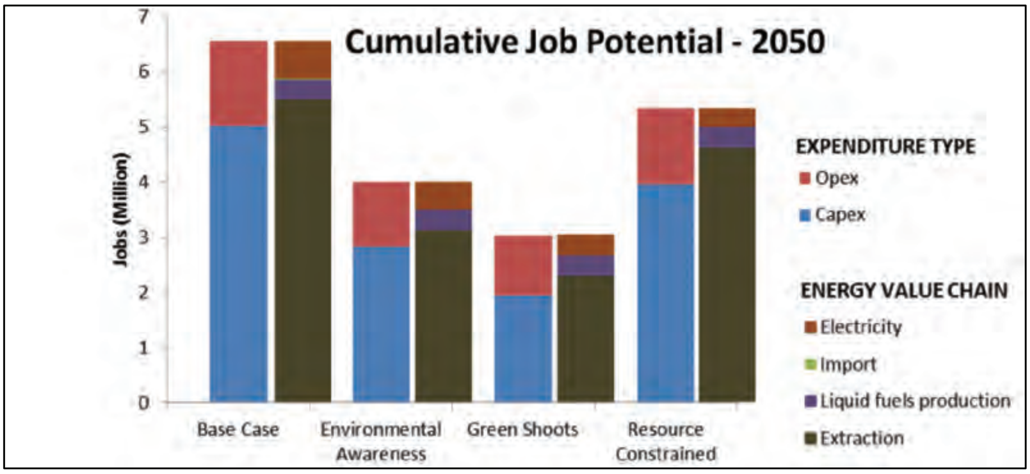


Source: DoE Analysis

Figure 0-12: Job potential in the energy sector by scenario level of localisation

Job potential by investment type (operational and capital expenditure) as well as segment of the energy value chain (extraction, liquid fuel production, electricity generation and imports) are illustrated in Figure 0-13.

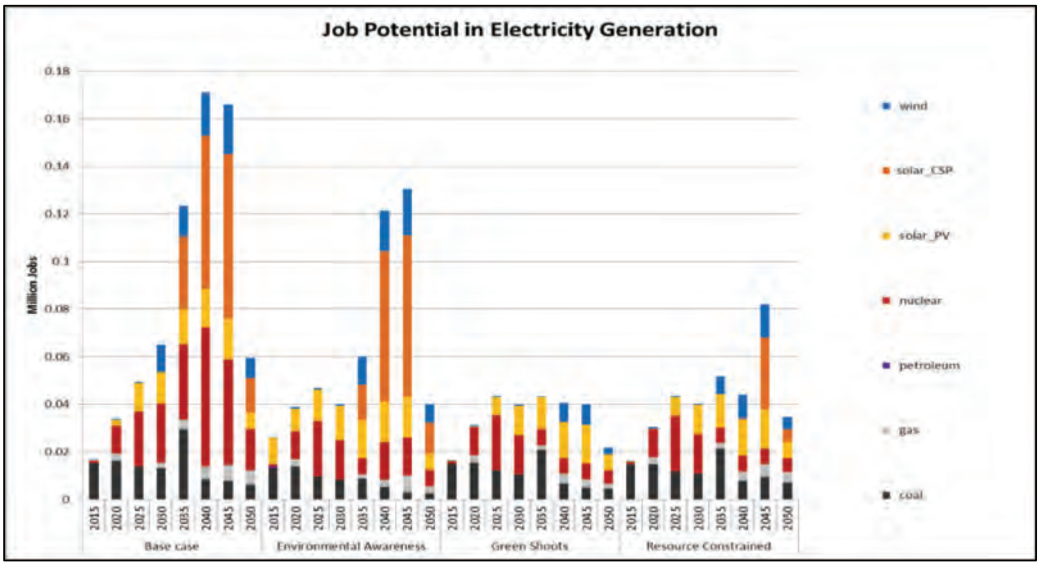
Expenditure Type: For all scenarios, more job potential exists as a result of the construction of energy technologies rather than the operation of these technologies. Although capital expenditure provides more jobs (required for construction of new capacity) than operational jobs, these are of a short-term nature and may therefore not be sustained without continually increasing capacity requirements. As the economy matures, less new capacity is needed, as is evident in the Green Shoots Scenario.



Source: DoE Analysis

Figure 0-13: Cumulative jobs in the energy sector by scenario

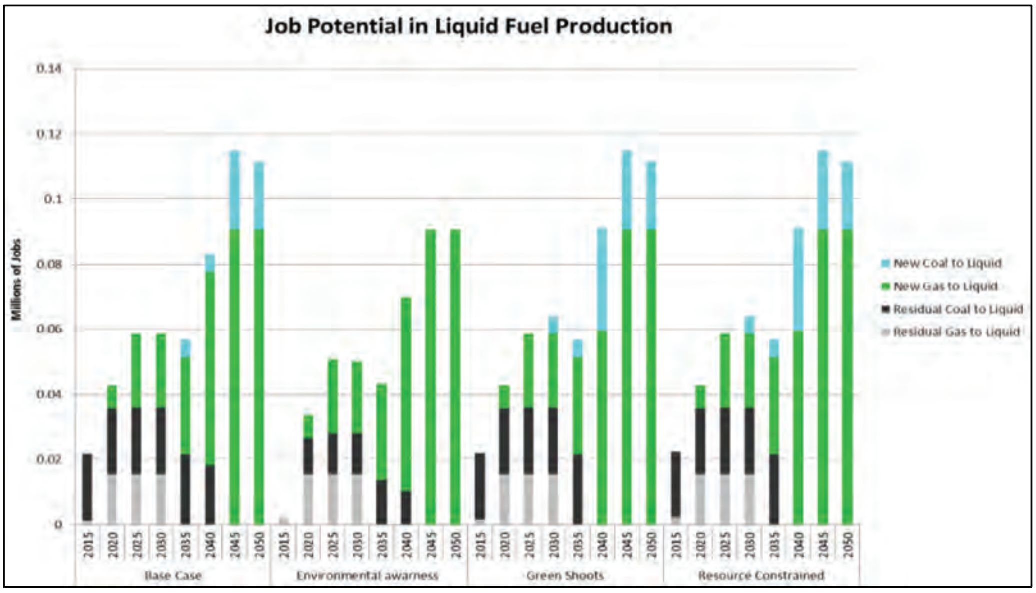
Energy Value Chain: Most of the potential jobs are in the extraction of energy commodities (shale gas and coal) followed by electricity generation. The jobs in electricity generation result mostly from solar technologies followed by nuclear technologies as shown in Figure 0-14. Jobs in imports and retail were not considered, however, retail jobs are directly related to the final consumption of fuels and will correspond with final energy demands in the scenarios.



Source: DoE Analysis

Figure 0-14: Job potential in electricity generation by scenario

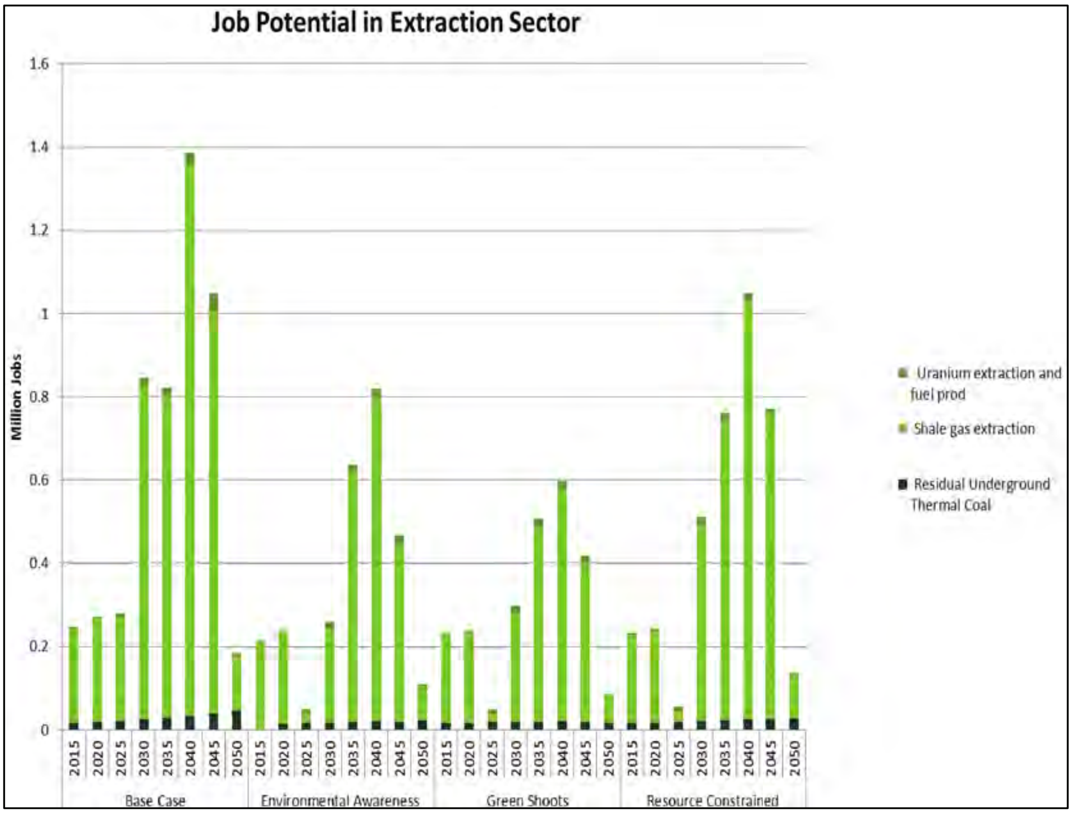
Job potential in the liquid fuels sector is shown in Figure 0-15. The creation of jobs as a result of the construction of new GTL plant is prominent in all scenarios. This is due to more GTL plant being constructed in the planning horizon.



Source: DoE Analysis

Figure 0-15: Job potential in liquid fuels production by scenario

The job potential related to the extraction of coal and shale gas, and the uranium fuel cycle are illustrated in Figure 0-16. Initial supply of natural gas is from imports only. It is assumed that shale gas extraction has a lead time of seven years and job potential from shale gas extraction results from shale gas coming online from 2022. In all scenarios the majority of jobs are related to the extraction of shale gas. In the Resource Constrained and Environmental Awareness scenarios, the assumed emission constraints and improvements in energy efficiency dampen the level of extraction. In the Green Shoots Scenario, coal and gas demand are lower due to the assumed GDP growth.



Source: DoE Analysis

Figure 0-16: Jobs in the energy extraction sub-sector by scenario[1]

6.4. Emissions

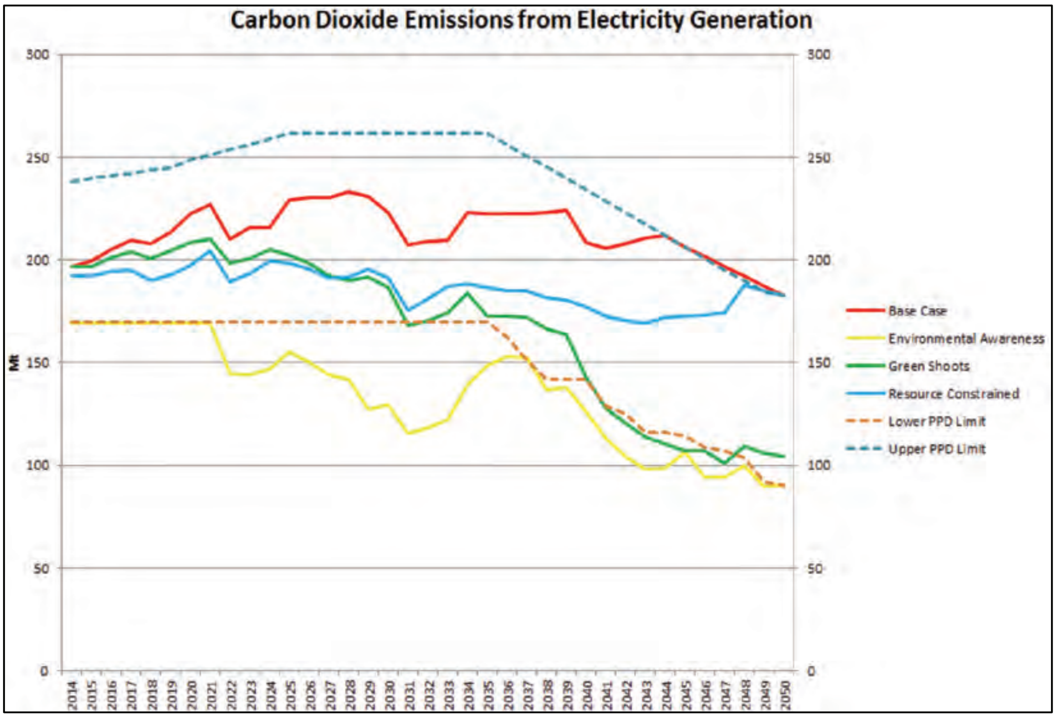
Emissions from the energy sector and the final use of energy are presented and compared in this section. Emissions are separated into carbon emissions and pollutant emissions.

6.4.1. Carbon emission

The National Climate Change Response White Paper (NCCRWP) defines targeted reductions in total emissions in terms of a 'Peak-Plateau-Decline' (PPD) emissions limit trajectory. CO_2 emission from electricity generation is presented in Figure 0-17. The PPD upper limit is applied to the Base Case, Green Shoots and Resource Constrained scenarios while the PPD lower limit is applied to the Environmental Awareness Scenario. The CO_2 emission profiles in all scenarios fall well within the specified emission limits and this is attributable to the inclusion of externality costs associated with carbon and other pollutants as part of the technology and fuel costs. It should be noted from Figure 6-14 that the PPD upper

[1] Jobs for shale gas extraction include construction of reticulation infrastructure

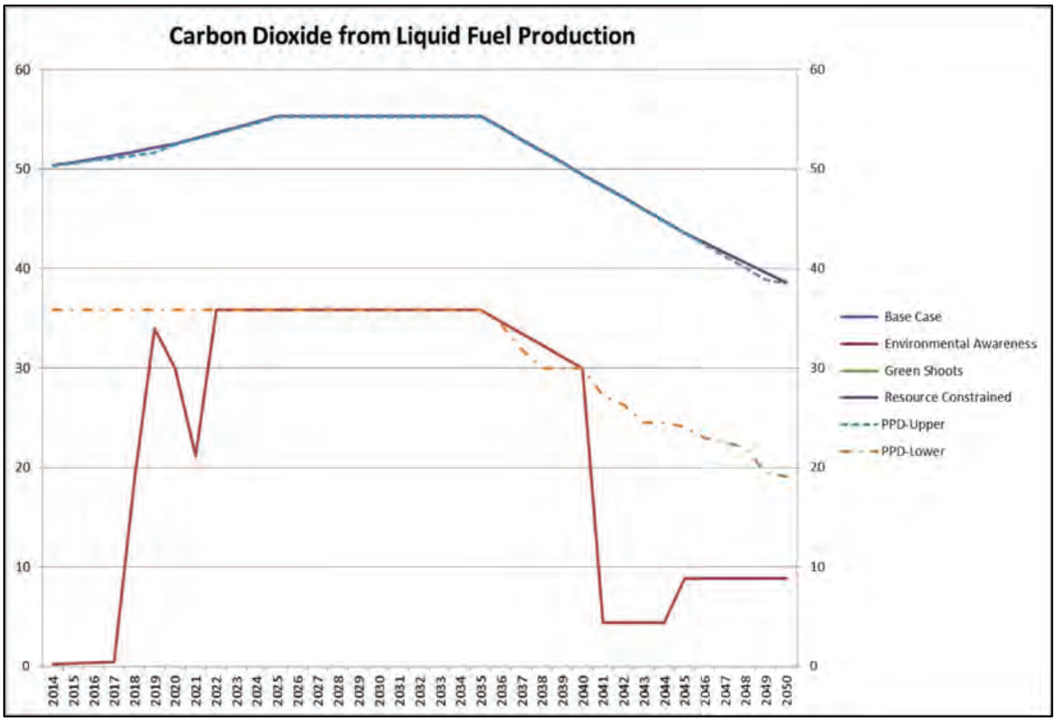
limit is binding on the Base Case only from 2044 onwards. All scenarios (with the exception of the Base Case and Resource Constrained scenarios), show decreases in emissions between 2021 and 2031 and a general decline after 2040. While the increase in CO_2 emissions is caused by either new coal capacity or life extension of older plant, in most cases retired coal plant is replaced by technologies which have lower or no emission factors or externality costs, resulting in a general decline in the emission trajectories.



Source: DoE Analysis

Figure 0-17: Carbon dioxide emission from electricity generation

CO_2 emission from liquid fuel production is shown in Figure 0-18. The Base Case, Green Shoots and Resource Constrained scenarios conform to the upper PPD emission limit. Towards the end of the modelling period there is a decrease in CO_2 emission in all scenarios, as a result of the importation of final refined petroleum products. In the Environmental Awareness Scenario CO_2 emission is below the lower PPD limit with a substantial decline from 2040. This is due to the high externality cost imposed on this scenario, resulting in no new CTL capacity being built.



Source: DoE Analysis

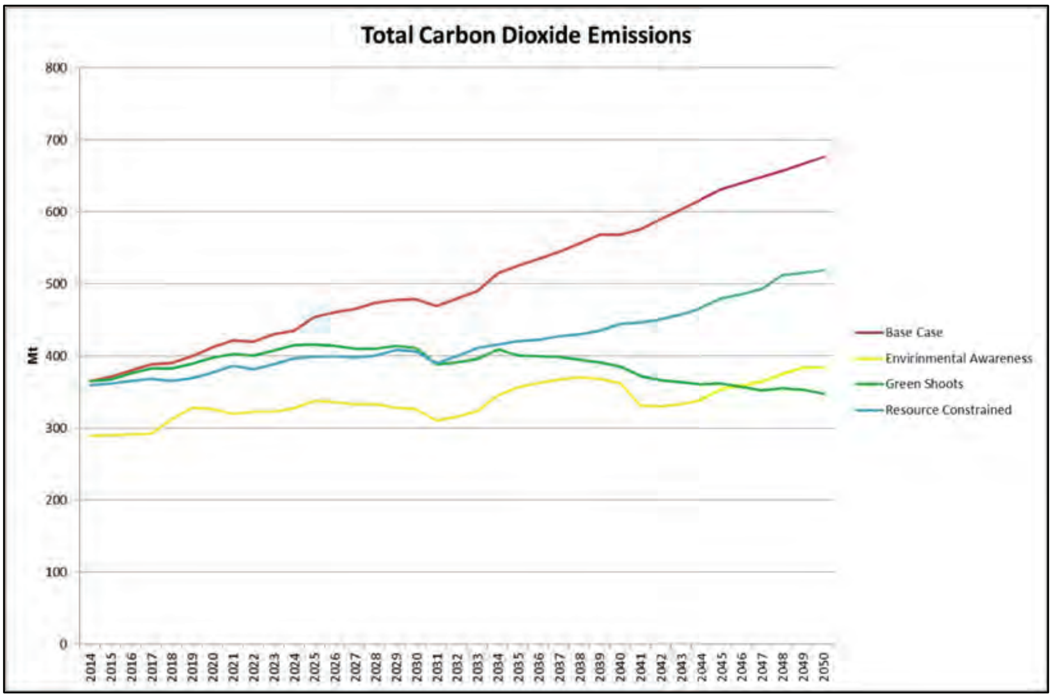
Figure 0-18: Carbon dioxide emissions from liquid fuel production

The total carbon dioxide emission from all sub-sectors, including electricity generation, liquid fuel production, transport and final end-use, is shown in Figure 0-19. The carbon emission limits placed on electricity generation and liquid fuel production are the equivalent to those discussed above. No emission limits were imposed on the extraction of energy commodities or on the final consumption of fuels but the emissions from these activities are included in the total CO_2 emissions presented, and externality costs are applied to them.

The Environmental Awareness Scenario is subject to a more stringent emission limit which is evident in the lower emission trajectory for this scenario. Lower emission is achieved through fuel switching and efficiency improvements on the demand side, in addition to a larger share of renewable energy technologies on the supply side.

Although the Green Shoots Scenario has a higher economic growth trajectory in the earlier years, its economic growth slows compared to the other scenarios in the longer term and energy efficiency improves, both of which result in a declining emission trajectory.

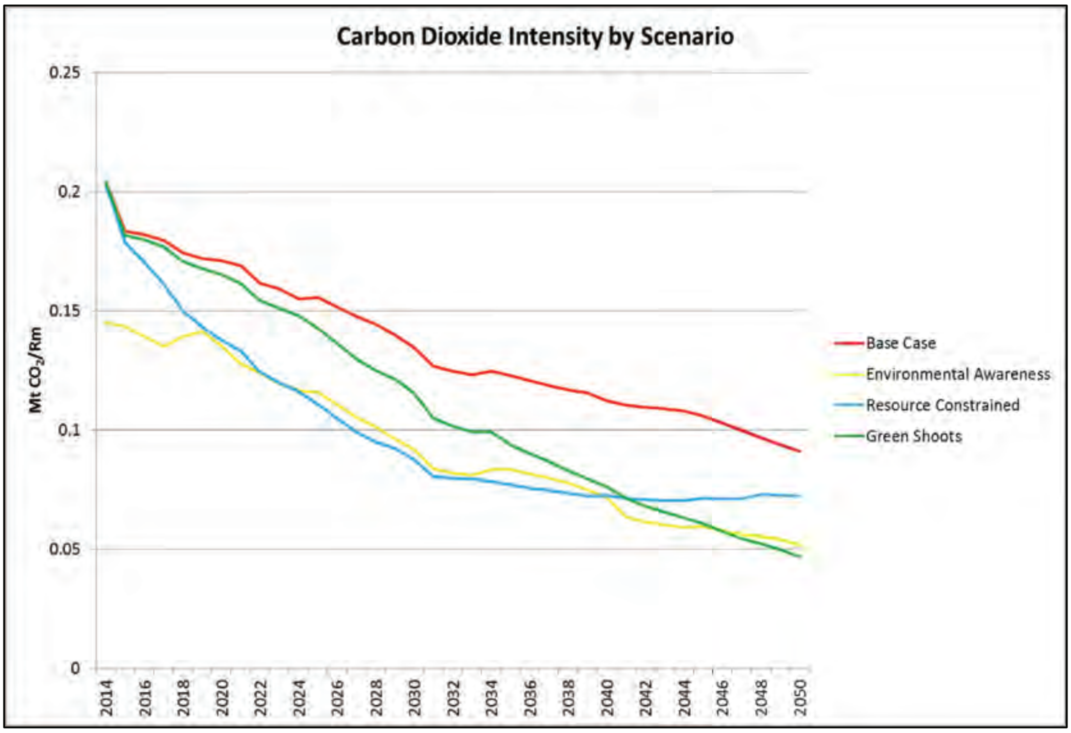
The Resource Constrained Scenario has an emission trajectory that lies between that of the Base Case and Environmental Awareness scenarios. This is due to a greater improvement in energy efficiency compared to the Base Case Scenario but lower costs and less stringent constraints compared to the Environmental Awareness Scenario.



Source: DoE Analysis

Figure 0-19: Total CO_2 emissions (energy supply and energy end-use)

The changing carbon dioxide intensities across the four scenarios are shown in Figure 0-20. These intensities are similar to the total emissions but the growth in GDP in all cases changes the path of the trajectories.



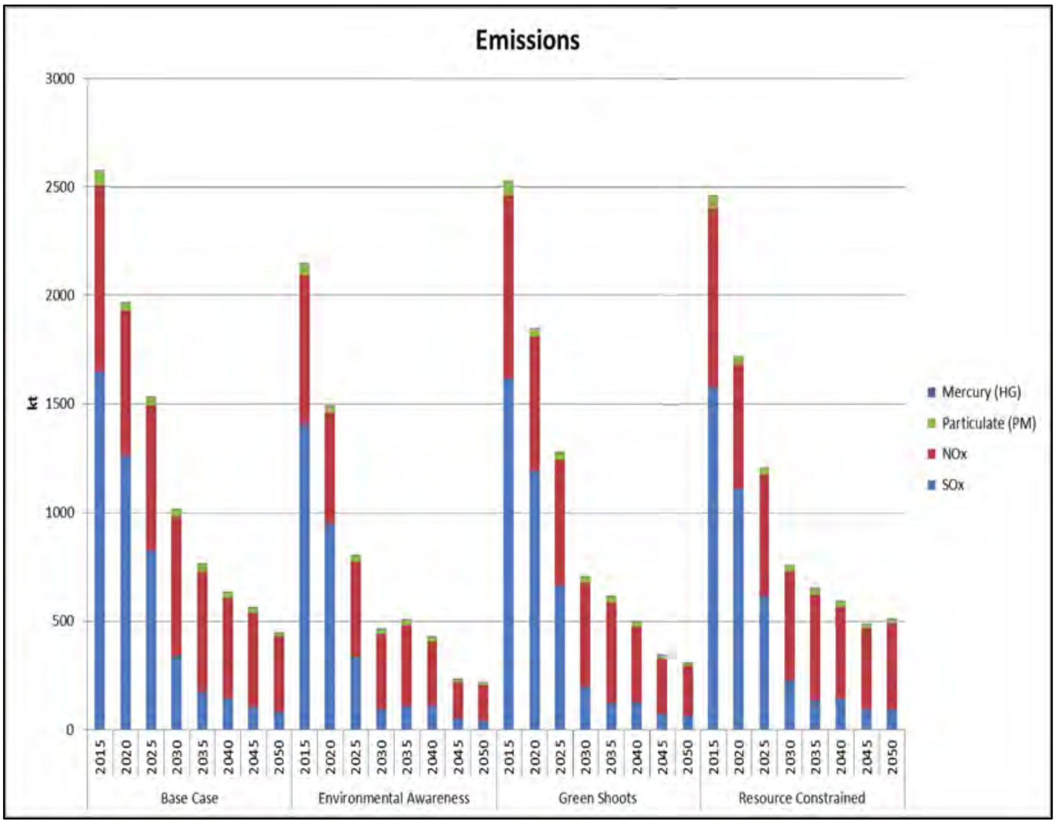
Source: DoE Analysis

Figure 0-20: CO_2 intensity per scenario

6.4.2. Pollutant emissions

Pollutant emissions of SO_x, NO_x, particulate matter (PM) and mercury (Hg) are presented in Figure 0-21. In all scenarios it is assumed that the necessary retrofits, required to meet environmental regulations, have been implemented. Financial and practical implications (in terms of cost and downtime of units) were not considered as part of the optimisation process within the IEP modelling process. Further detailed studies are required to determine the impact of possible combinations of retrofits, life extensions and early plant retirements.

All the pollutants show a substantial decline in all scenarios over the modelled period. This is mainly due to assumed compliance with the emissions regulations, and the use of flue gas desulphurisation and particulate filters.

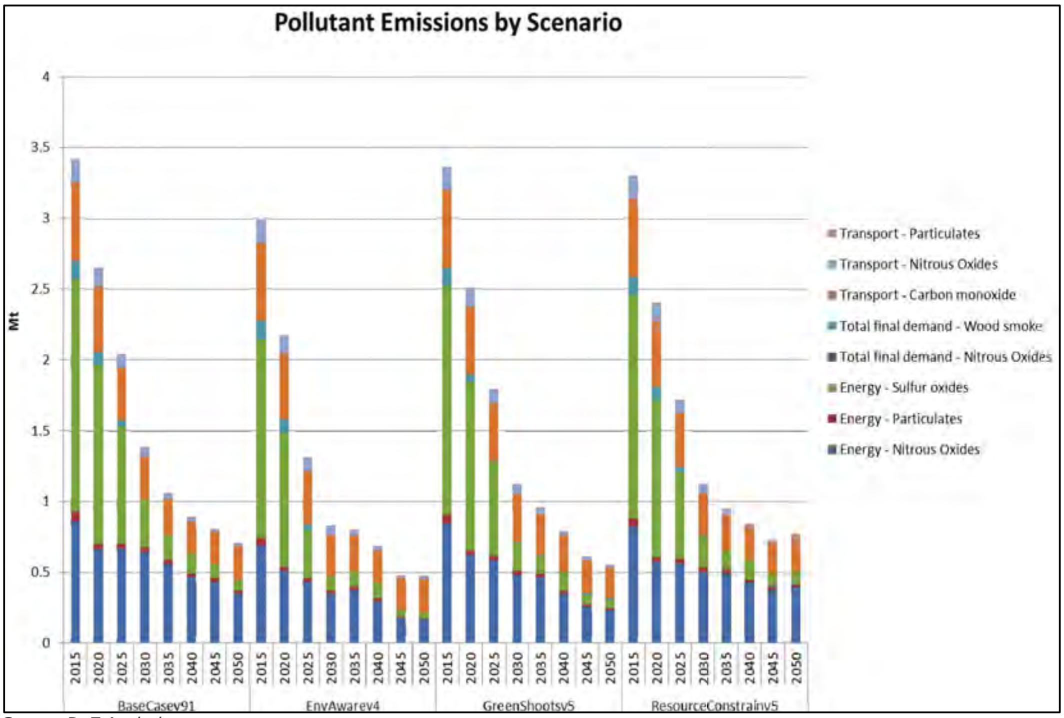


	Base Case				**Environmental Awareness**				**Green Shoots**				**Resource Constrained**			
	SOx (kt)	**NOx (kt)**	**PM (kt)**	**Hg (kt)**	**SOx (kt)**	**NOx (kt)**	**PM (kt)**	**Hg (kt)**	**SOx (kt)**	**NOx (kt)**	**PM (kt)**	**Hg (kt)**	**SOx (kt)**	**NOx (kt)**	**PM (kt)**	**Hg (kt)**
2015	1648	859	66	0.03	1406	688	54	0.03	1618	843	64	0.03	1577	821	61	0.03
2020	1265	662	38	0.03	950	510	30	0.02	1191	620	35	0.03	1111	574	34	0.03
2025	828	667	35	0.03	341	433	26	0.02	662	584	32	0.03	612	563	31	0.03
2030	342	639	34	0.03	95	346	21	0.02	195	481	28	0.02	228	501	28	0.02
2035	174	558	32	0.03	107	374	25	0.02	126	461	28	0.02	132	491	29	0.02
2040	145	463	25	0.02	111	297	19	0.01	125	349	22	0.02	140	426	24	0.02
2045	104	434	22	0.02	49	172	11	0.01	71	256	16	0.01	93	373	20	0.02
2050	79	350	18	0.02	40	166	9	0.01	61	233	14	0.01	92	397	19	0.02

Source: DoE Analysis

Figure 0-21: Total pollutant emissions from the electricity sector only

The emissions of the various pollutants and their sources are shown in Figure 0-22. Sulphur oxides and nitrous oxides from power generation constitute the greatest volume of pollutants, followed by carbon monoxide and nitrous oxides from the transport sector.

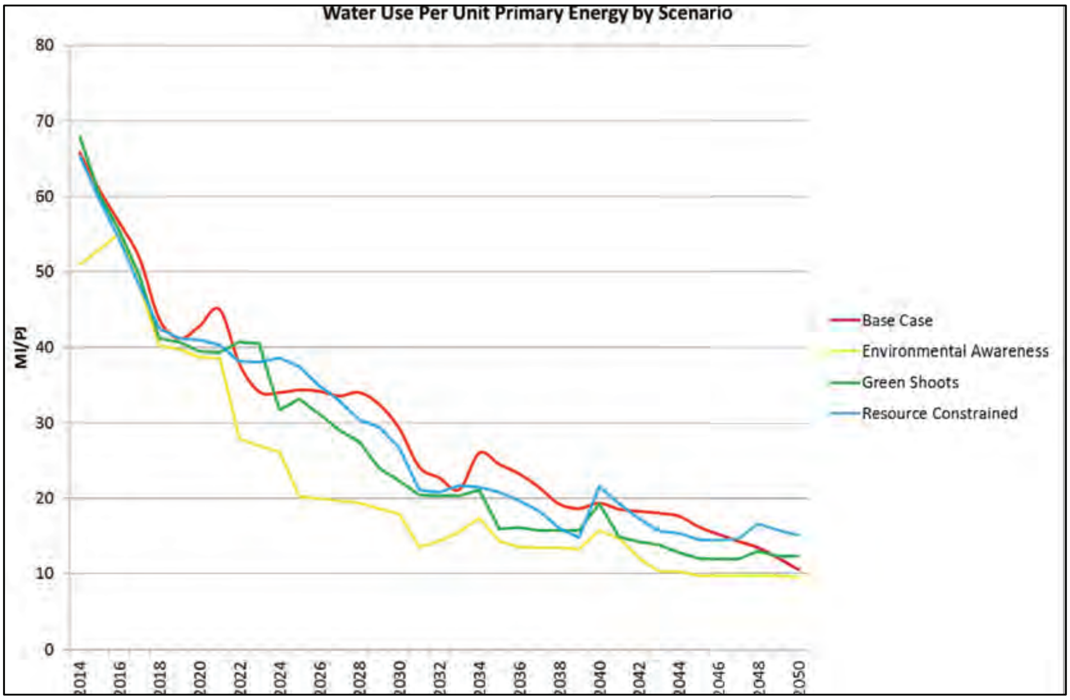


Source: DoE Analysis

Figure 0-22: Total pollutant emissions (energy supply and energy end-use) by scenario

6.5. Water consumption

Water consumption for the core IEP scenarios is shown in Figure 0-23. There is little variation between the Base Case, Green Shoots and Resource Constrained scenarios; however, they do all gradually decrease over time. The Environmental Awareness Scenario reflects significantly lower water usage as a result of the more stringent CO_2 emission limit which results in greater investment in technologies which are less water intensive. All future coal fired power stations are expected to be air cooled and will contribute to the reduction in water demand by the energy sector.

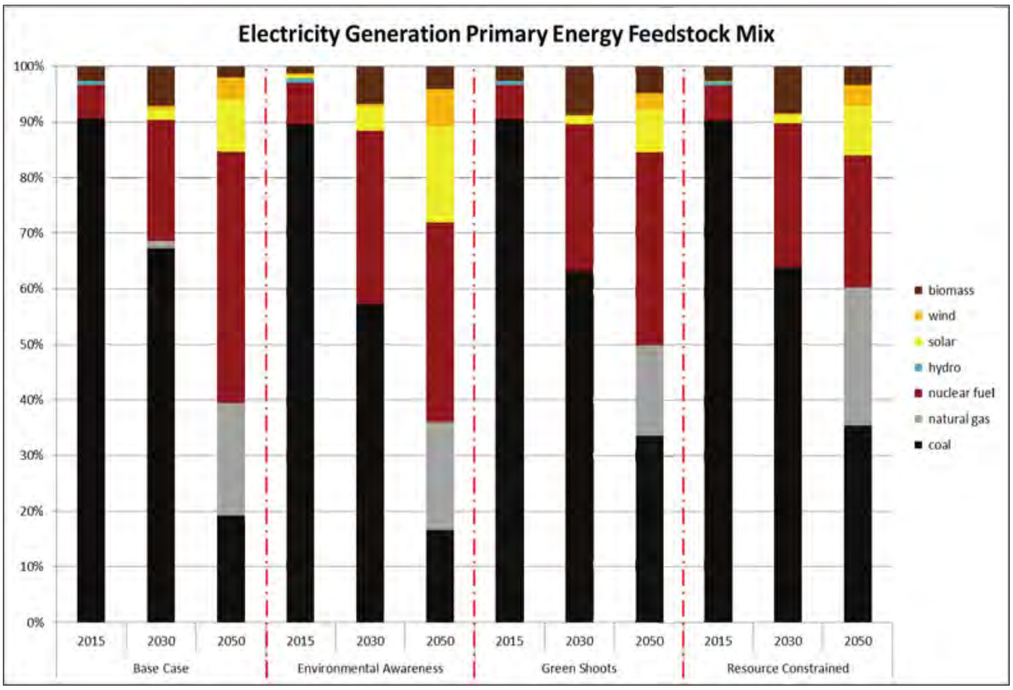


Source: DoE Analysis

Figure 0-23: Total water use in the primary energy sector

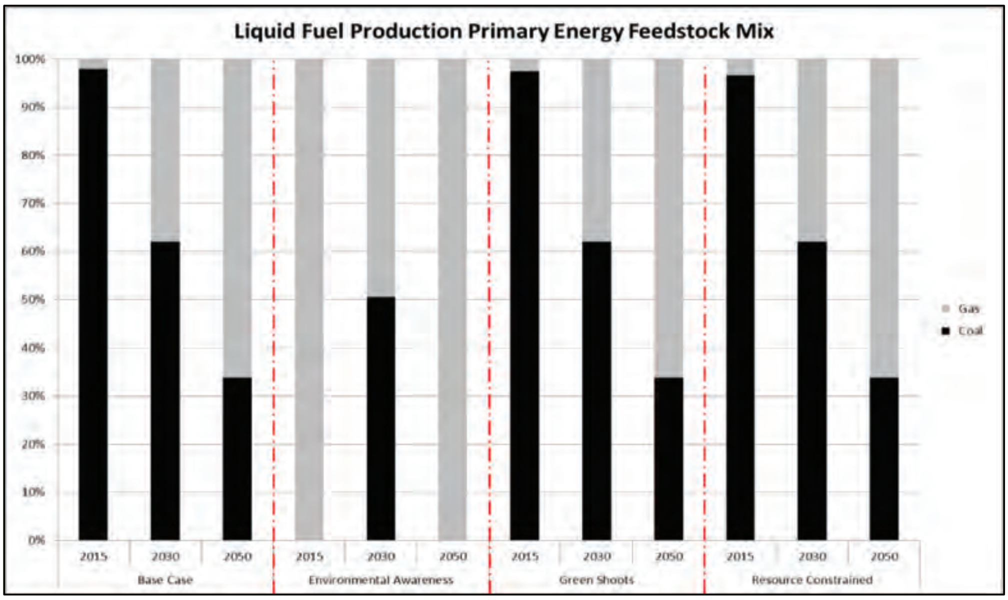
6.6. Primary energy mix (diversity)

Primary energy feedstock for electricity generation, liquid fuel production and final end-use are shown in Figure 0-24, Figure 0-25 and Figure 0-26. Coal and gas feature in all sectors. In the electricity generation sector, coal constitutes close to 90% of the primary energy mix in 2015 in all scenarios. The use of coal declines to below 35% of the primary energy mix by 2050 in the Green Shoots and Resource Constrained scenarios, and to below 20% of the primary energy mix in the Base Case and Environmental Awareness scenarios. Nuclear fuel constitutes over 20% of the primary energy mix from 2030 onwards in all scenarios. In terms of liquid fuels, the primary energy mix is dominated by coal and gas with gas becoming the more prominent energy carrier in the future. The primary energy mix in the final demand sub-sector comprises coal, gas and wood. Coal is most dominant in this sector with wood declining in use beyond 2030.



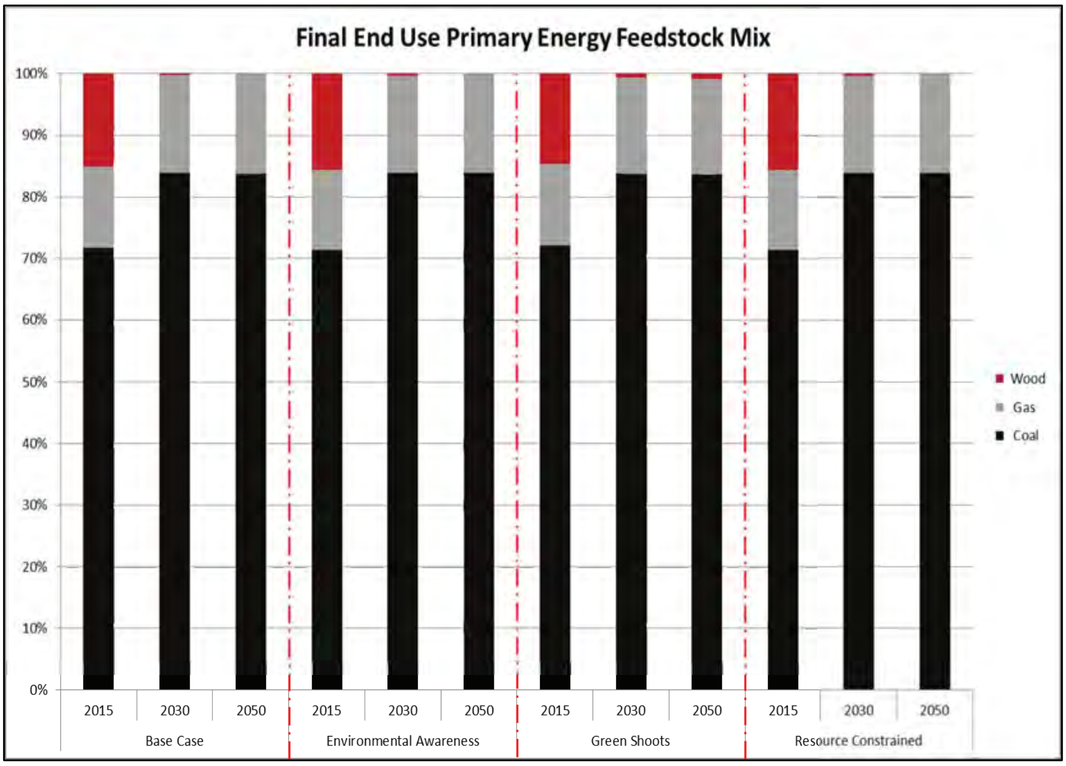
Source: DoE Analysis

Figure 0-24: Electricity generation primary energy feedstock mix



Source: DoE Analysis

Figure 0-25: Liquid fuel production primary energy feedstock mix

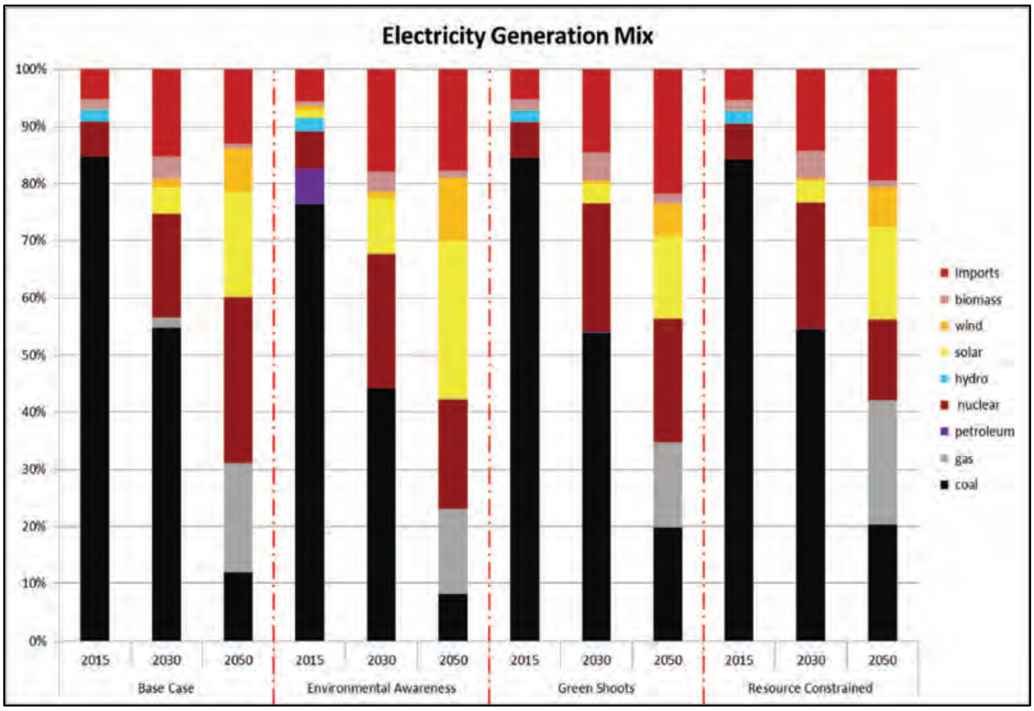


Source: DoE Analysis

Figure 0-26: Final end-use primary energy feedstock mix

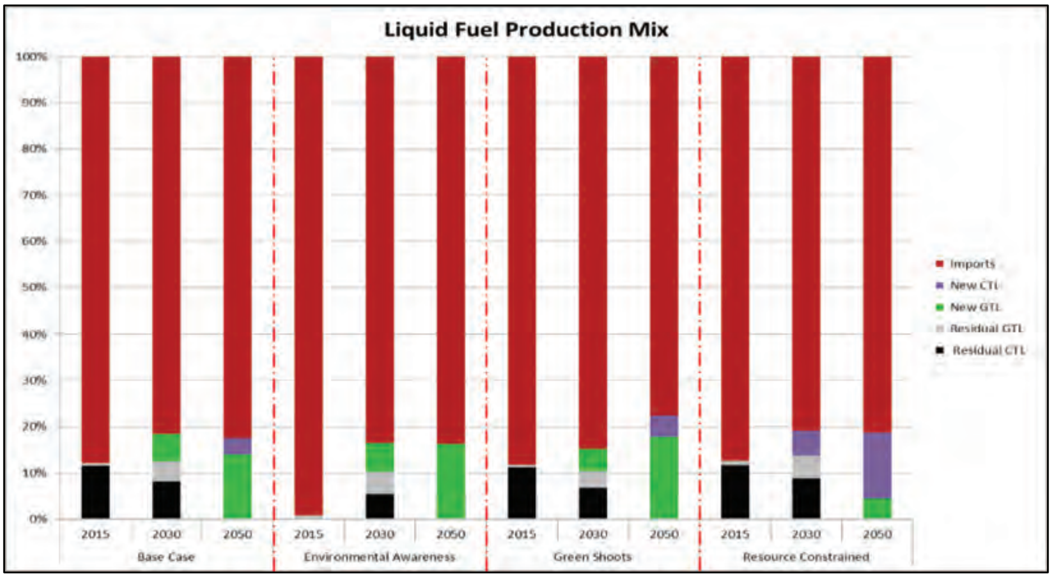
The changes in the energy mix for electricity generation and liquid fuel production for the IEP scenarios over the modelled period are shown in **Error! Reference source not found.** and Figure 0-28. Primary energy supply includes locally extracted resources, electricity generated from wind and solar, imports of refined petroleum products and imports of electricity (in this context only). In all scenarios the energy mix for electricity generation becomes more diverse over the period to 2050, with coal reducing its share from about 85% in 2015 to 15–20% in 2050 (depending on the scenario). Solar, wind, nuclear, gas and electricity imports increase their share. The Environmental Awareness and Green Shoots scenarios take on higher levels of renewable energy.

Imports form the bulk of the supply mix for liquid fuels in all scenarios and constitute at least 75% of the mix over the entire planning horizon for all scenarios. All scenarios show a slight decline in the importation of refined petroleum products as shale gas is used in gas to liquid production.



Source: DoE Analysis

Figure 0-27: Electricity generation mix

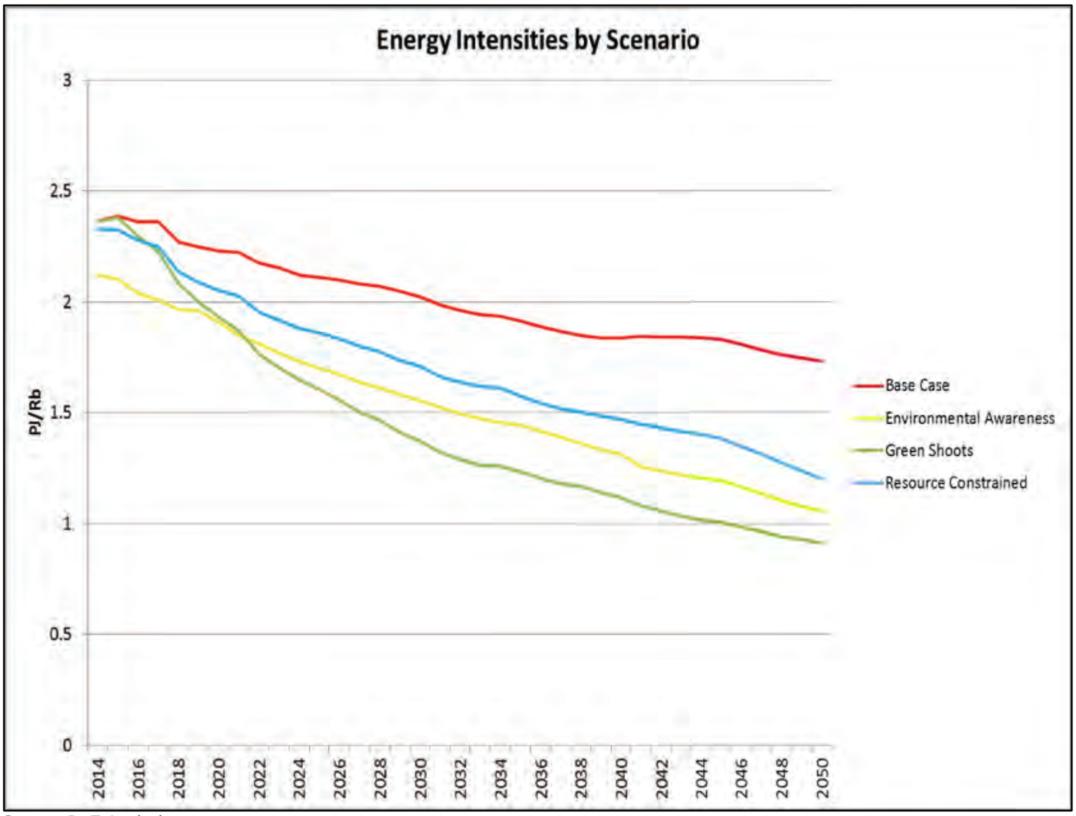


Source: DoE Analysis

Figure 0-28: Liquid fuel production mix

6.7. Energy intensity

Energy intensities over the modelled period decline for all scenarios as shown in Figure 0-29. This is due to improvements in energy efficiency and GDP growth relative to energy demand. The Green Shoots Scenario has the fastest improvement in energy intensity in the first decade of the modelling period due to the initially high growth in GDP. The remaining scenarios have the same GDP growth rates so the differences in the intensities are due to energy efficiency improvements and fuel switching.



Source: DoE Analysis

Figure 0-29: Energy intensities in the energy sector

6.8. Summary of scenarios against the eight objectives

Objective	High-level summary of scenario results
Ensure security of energy supply	The objective of optimisation modelling is to ensure that all demand is met. Within all scenarios, the projected demand is met and therefore the objective of ensuring security of supply (which is the underpinning objective) is assumed to have been met.
Minimise the cost of energy	While all scenarios seek to ensure that costs are minimised within the constraints and parameters of each scenario, the Base Case Scenario presents the least cost followed by the Environmental Awareness, Resource Constrained and Green Shoots scenarios respectively when total energy system costs are considered. The total costs are mostly comprised of imports of final petroleum products but when electricity system costs are explored in isolation this picture changes. • **Electricity Sector system costs:** The Green Shoots Scenario has the lowest total cost for electricity generation. This is followed by the Resource Constrained and Base Case scenarios while the Environmental Awareness Scenario has the highest cost. • **Liquid Fuel Supply (Combined production and imports):** When the total supply of liquid fuels is considered the resulting profiles are similar to those of total system costs.
Promote job creation and localisation potential	The potential number of jobs created within each of the scenarios changes year-on-year. Cumulatively, the Base Case Scenario presents the greatest job creation potential, followed by the Resource Constrained, Environmental Awareness and Green Shoots scenarios respectively. In all scenarios, approximately 85% of total jobs are localisable. • For electricity generation, most jobs result from solar technologies followed by nuclear and wind, with natural gas and coal making a smaller contribution. • For liquid fuel, most jobs result from new GTL plants and, to a smaller extent CTL plants, with no additional jobs resulting from new crude oil refining as no new crude oil refining capacity comes on line in the period.
Minimise negative environmental impacts	The Environmental Awareness Scenario, due to its stringent emission constraints, shows the lowest level of total emissions over the planning horizon. This is followed by the Green Shoots, Resource Constrained and Base Case scenarios. These trends are similar when emissions are considered cumulatively and individually by type.
Minimise water consumption	The results for water consumption across the four scenarios are similar to those of emissions with the Environmental Awareness Scenario showing the lowest level of water consumption and the Base Case showing the highest water consumption.
Diversify supply sources and primary energy carriers	All scenarios present a fairly diversified energy mix across the electricity sub-sector and the liquid fuel sub-sector. It is important to note that none of the scenarios include crude oil in the future, implying that the importation of refined petroleum products is the least cost option.

Objective	High-level summary of scenario results
Promote energy efficiency (reduce energy intensity of the economy)	The Green Shoots Scenario, which is characterised by a significant structural shift in the economy, presents the highest reduction in energy intensity. This is largely informed by the larger contribution by the tertiary sub-sector by comparison with other scenarios. This is followed by the Environmental Awareness, Resource Constrained and Base Case scenarios respectively.
Promote energy access	Energy access encompasses the ability to provide energy as well as the availability of that energy when required. The ability to provide electricity to all South African citizens is made possible by connecting new households to the grid where it is cost-effective to do so and by introducing off-grid technologies where it is not. Therefore an energy mix that includes technologies which are suitable for off-grid application presents the most potential to increase energy access. Presently solar energy technologies (e.g. rooftop solar PV panels and other solar home systems) show the greatest potential in this regard. The Base Case Scenario includes the largest share of renewable energy technologies, followed by the Environmental Awareness, Resource Constrained and Green Shoots scenarios respectively. It should be noted that in addition to the supply-side renewable energy technologies, the Base Case and Resource Constrained scenarios assume the introduction of 1 million solar water heaters by 2030, and the Environmental Awareness and Green Shoots scenarios include the introduction of 5 and 10 million solar water heaters respectively by 2030.

6.9. Sensitivity analysis

While the four main scenarios described in the previous sections have informed core analysis for the IEP, they include three assumptions which, if varied, could particularly affect the Base Case Scenario, namely:

- Shale gas is economically viable and abundant;
- New nuclear capacity in the amount of 9.6 GW is made available as planned; and
- One million solar water heaters are installed.

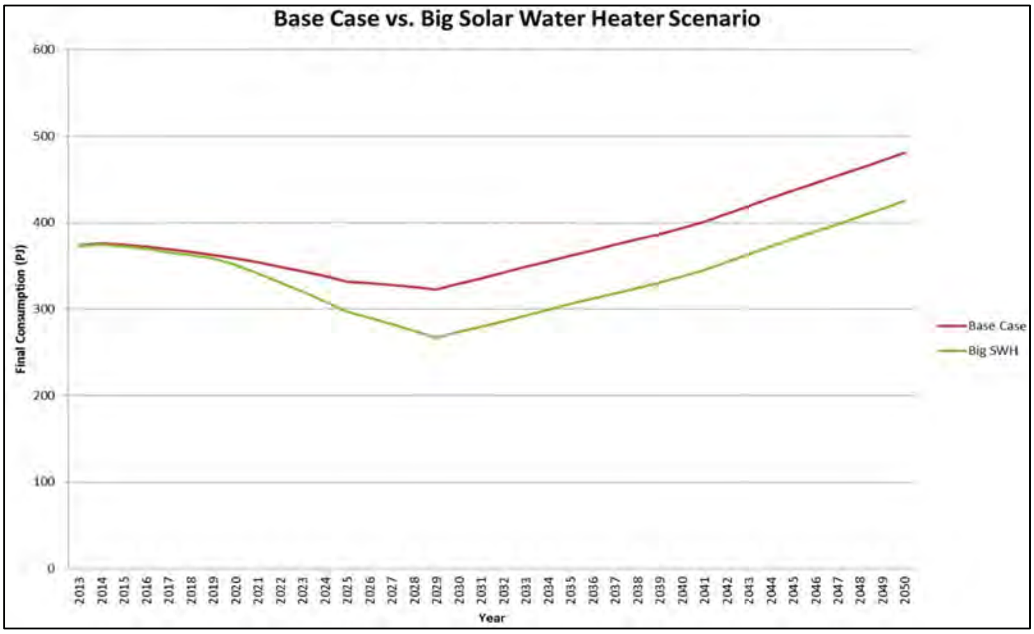
Three further sensitivity analyses were therefore conducted on the Base Case Scenario to inform model output. These are described below.

No Shale Gas Scenario: This scenario does not consider shale gas as a viable primary energy source. The objective of this scenario is to test the impact of a long-term energy future where the extraction of shale gas turns out to be less economically viable than is currently projected, due to the high uncertainty associated with the levels of recoverable shale gas.

Nuclear Relaxed Scenario: The Base Case Scenario currently assumes that the New Nuclear Build Programme to introduce 9.6 GW, which was announced by the President in the 2014 State of the Nation Address, will proceed as planned. The nuclear relaxed study allows the IEP process to explore flexibility in the building of new nuclear capacity in detail, by allowing nuclear build options to compete with other technologies to meet future energy needs.

Big Solar Water Heater Scenario: The one million Solar Water Heater (SWH) Programme is currently being implemented by government in an effort to reduce dependence on solid fuels in low income households as well as reduce the peak demand for electricity. The objective of this scenario is to test the impact of pursuing a more aggressive approach to the introduction of SWH in households as part of electricity Demand-side Management.

Total energy demand for the Base Case and the Big SWH scenarios is shown in Figure 0-30: . In the short term the penetration of SWH is slow and the energy demand for both scenarios is the same until 2019. From 2020, a more aggressive approach is adopted to ensure the installation of up to ten million SWH by 2030 to replace electrical water heaters. This has a marked impact, which is reflected in the sharp decline in energy consumption. After 2030, there is an increase in energy consumption due to the SWH programme being terminated in 2030.



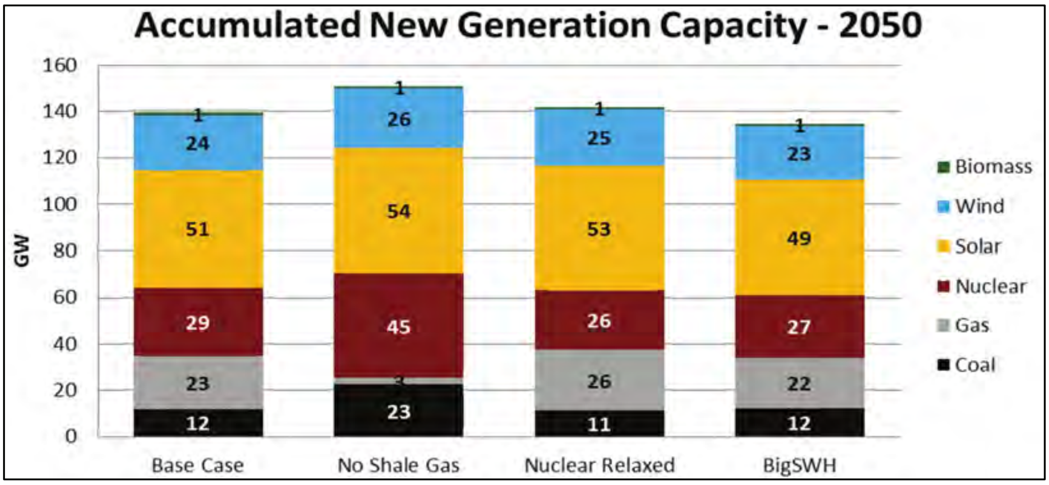
Source: DoE Analysis

Figure 0-30: Base Case and the Big Solar Water Heater Scenario

6.9.1. Accumulated new capacity

Accumulated new electricity generation capacity for the four scenarios is shown in Figure 0-31. Environmentally clean technologies are preferred in the selection, in keeping with the climate change mitigation strategy. New capacity using solar constitutes the highest percentage in all scenarios (50.5 GW in the Base Case Scenario, 53.8 GW in the No Shale Gas Scenario, 53 GW in the Nuclear Relaxed Scenario and 49.5 GW in the Solar Water Heater Scenario).

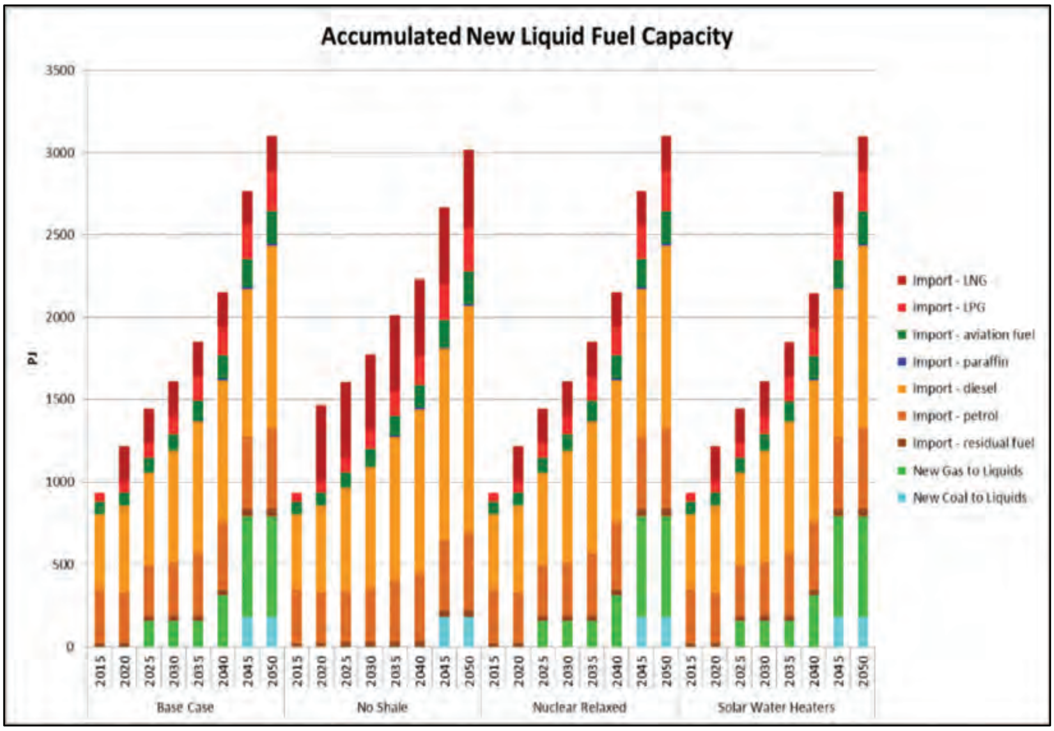
- In the Base Case Scenario, nuclear constitutes (29.5 GW), wind (23 GW), gas (22.7 GW), imports (15.5 GW) and coal (12 GW) of the new generation capacity mix.
- The Nuclear Relaxed Scenario includes gas (26.3 GW), nuclear (25.8 GW), wind (24.6 GW), imports (15.5 GW) and coal (11.1 GW). This scenario has the highest new capacity using gas. New capacity in terms of imports is very similar to that of the Base Case.
- In the No Shale Gas Scenario the elimination of gas as an option results in a large percentage of the new generation mix being nuclear (45.4 GW), followed by wind (25.6 GW), coal (22.5 GW) and imports (7.2 GW). The use of new coal technologies in this scenario is approximately double that of the other scenarios. Imports in this scenario are much lower than in the other scenarios.
- Accumulated new generation capacity in the Solar Water Heaters scenario comprises nuclear (26.9 GW), wind (23.1 GW), gas (21.7 GW), imports (15 GW) and coal (12.4 GW).



Source: DoE Analysis

Figure 0-31: Accumulated new electricity generation capacity by scenario

The accumulated new capacity for liquid fuels is shown in Figure 0-32. The bulk of new capacity in all scenarios is from imports (74% in the Base Case Scenario, 94% in the No Shale Gas Scenario, 74% in the Nuclear Relaxed Scenario and 74% in the Solar Water Heater Scenario). Diesel comprises the bulk of imports (36% in all scenarios except the No Shale Scenario where new capacity for liquid fuel imports is 45%). This is followed by petrol (21% in all scenarios). Aviation fuel, liquefied petroleum gas (LPG) and liquefied natural gas (LNG) constitute 21% of the accumulated new capacity from imports in all scenarios except the No Shale Gas Scenario. In the No Shale Gas Scenario, these products constitute 31% of imports due to a higher amount of LNG being imported. Accumulated new capacity for domestic liquid petroleum production is achieved by building new coal to liquid (CTL) and gas to liquid (GLT) plant. In the Base Case, Nuclear Relaxed and Solar Water Heater Scenarios, 792 PJ of accumulated new capacity, comprising 176 PJ of CTL capacity and 616 PJ of GTL capacity, is brought on line. In the No Shale Gas Scenario only 176 PJ of CTL capacity is brought on line due to shale gas not being a viable primary energy option.

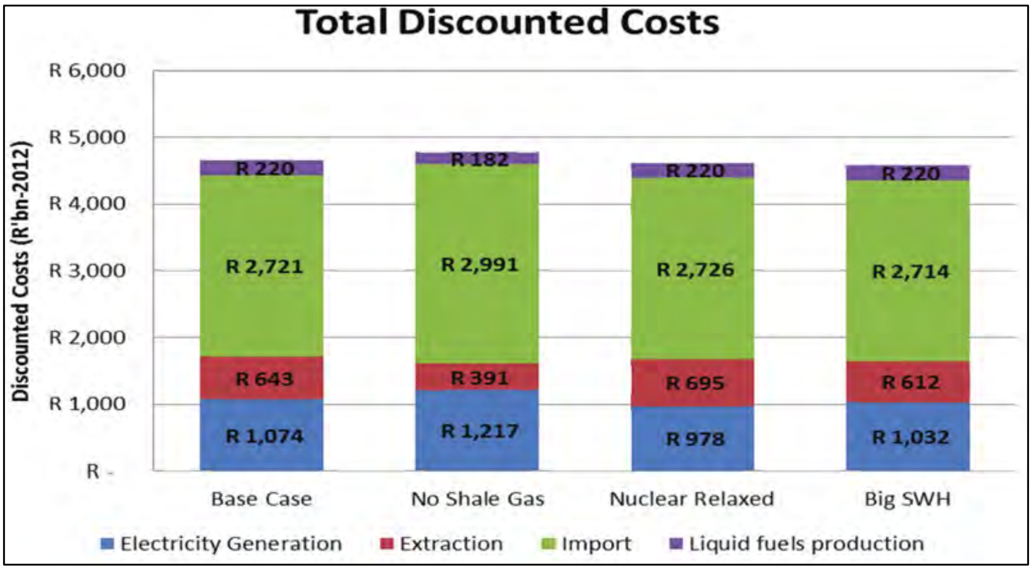


Source: DoE Analysis

Figure 0-32: Accumulated new liquid fuel capacity by scenario

6.9.2. Costs

The energy system costs are divided into cost components representing different parts of the energy value chain from primary energy supply (imports and extraction) to energy provided for final consumption. The cost components for the three sensitivity analyses are provided in Figure 0-33.



Source: DoE Analysis

Figure 0-33: Cost structure of the energy system for the period 2014-2050

The No Shale Gas Scenario is the most costly of all the scenarios. The elimination of shale gas as a primary energy option leads to higher imports of comparatively more expensive refined petroleum products, and a reduction in domestic fuel production. This is coupled with higher electricity generation costs as other alternatives to combined-cycle gas turbines (CCGTs) are needed to meet electricity demand. Elimination of gas as a primary energy option leads to lower extraction costs as expected. The price of shale gas is assumed to be lower than that of gas imports in the Base Case Scenario.

The Nuclear Relaxed and the Solar Water Heater scenarios are marginally less costly than the Base Case Scenario. In the Nuclear Relaxed Scenario, this is due to the optimisation of investment costs through the scheduling of new nuclear build capacity only when it is economical to do so. In the Solar Water Heater Scenario, the use of solar water heaters as a renewable energy technology results in a decrease in coal extraction costs.

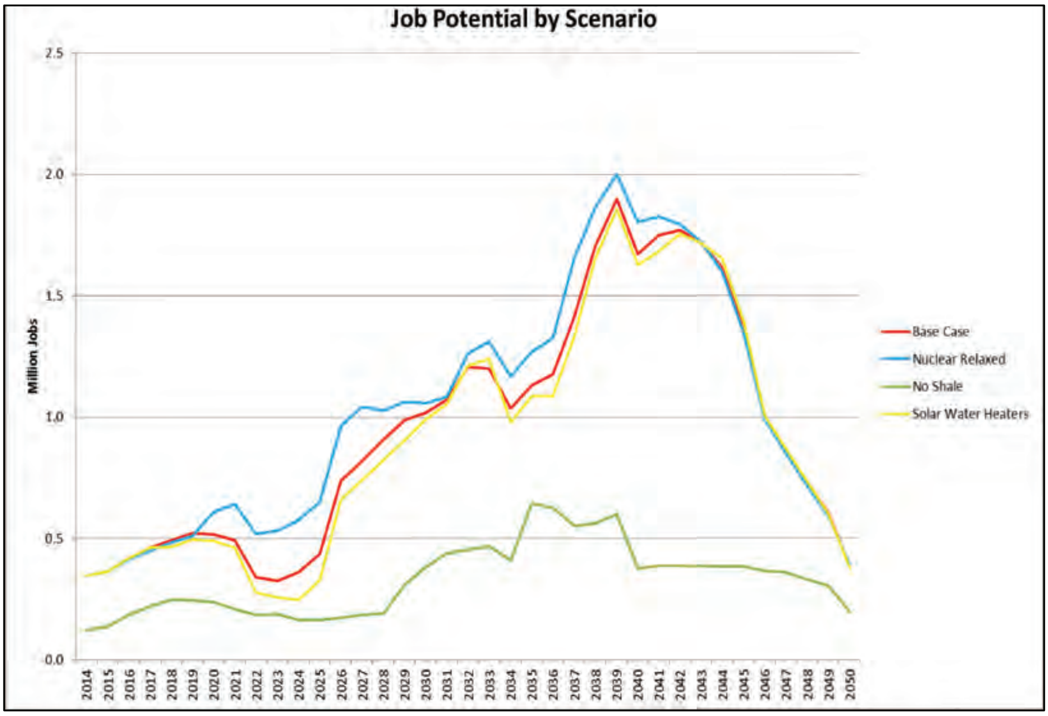
The Nuclear Relaxed Scenario has the highest externality cost due to the use of generation technologies with primary energy that have a high level of pollutants relative to nuclear energy. The No Shale Scenario has the lowest externality cost, due to the externalities associated with imports being lower.

6.9.3. Jobs

The total number of potential jobs annually in each of the sensitivity scenarios and the Base Case Scenario are shown in Figure 0-34.

The Nuclear Relaxed Scenario has the highest annual job potential from 2020 to 2043, due to more construction in this period.

The No Shale Gas Scenario has a significantly lower annual job potential due to the assumption that it is not economically viable to extract shale gas.

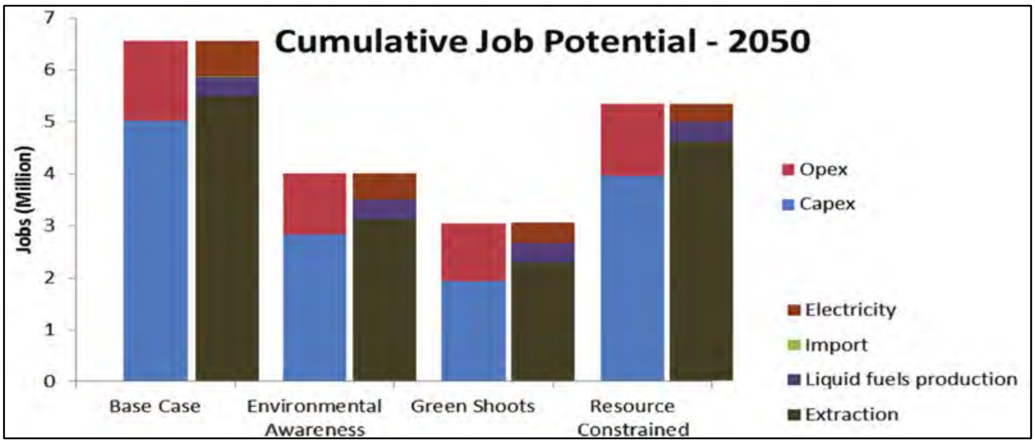


Source: DoE Analysis

Figure 0-34: Potential number of jobs in the energy sector by scenario

Job potential by investment type (operational and capital expenditure) as well as segment in the energy value chain (extraction, liquid fuel production, electricity generation and imports) are illustrated in Figure 0-35.

As in the four core scenarios, there is a higher potential for jobs in the construction of energy technologies compared to the operation of residual technologies. The reduced potential for jobs in the No Shale Gas Scenario results from no new capital investment in shale gas extraction or in the construction of new GTL refineries. As can be expected, the potential for jobs relating to extraction in the No Shale Gas Scenario is much lower as a result of shale gas not being explored.

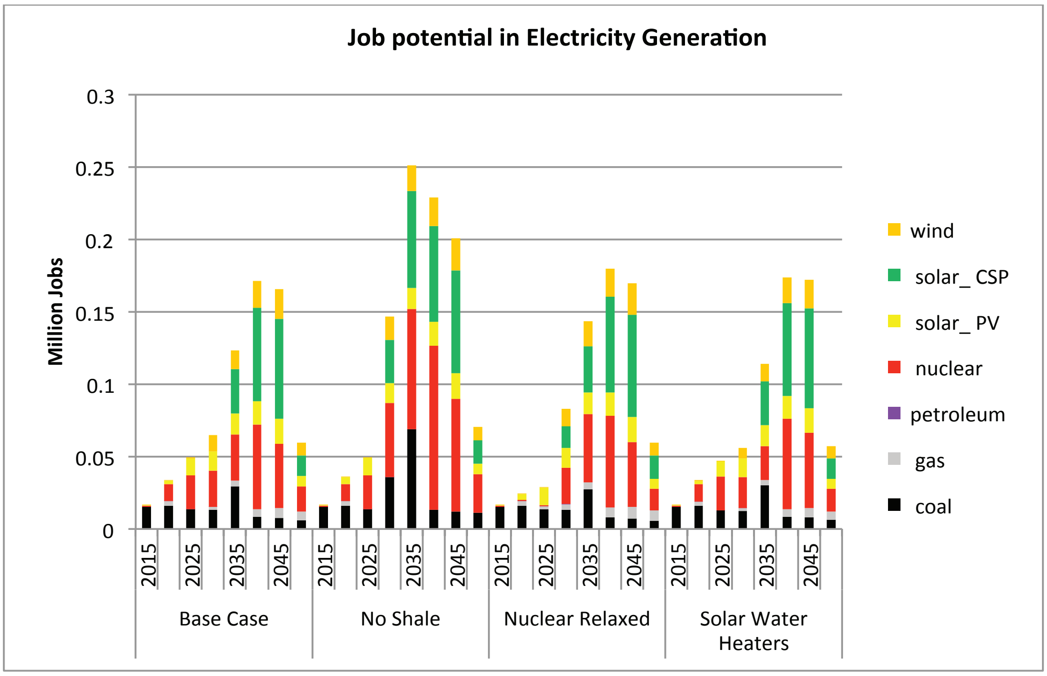


Source: DoE Analysis

Figure 0-35: Cumulative jobs in the energy sector by scenario

The job potential for the electricity generation sector for the scenarios is shown in Figure 0-36. The No Shale Gas Scenario has the highest job potential over the planning horizon. Most of the potential jobs in this scenario are in the nuclear, solar and coal sectors. In the other scenarios, the nuclear and solar sectors are dominant in creating jobs.

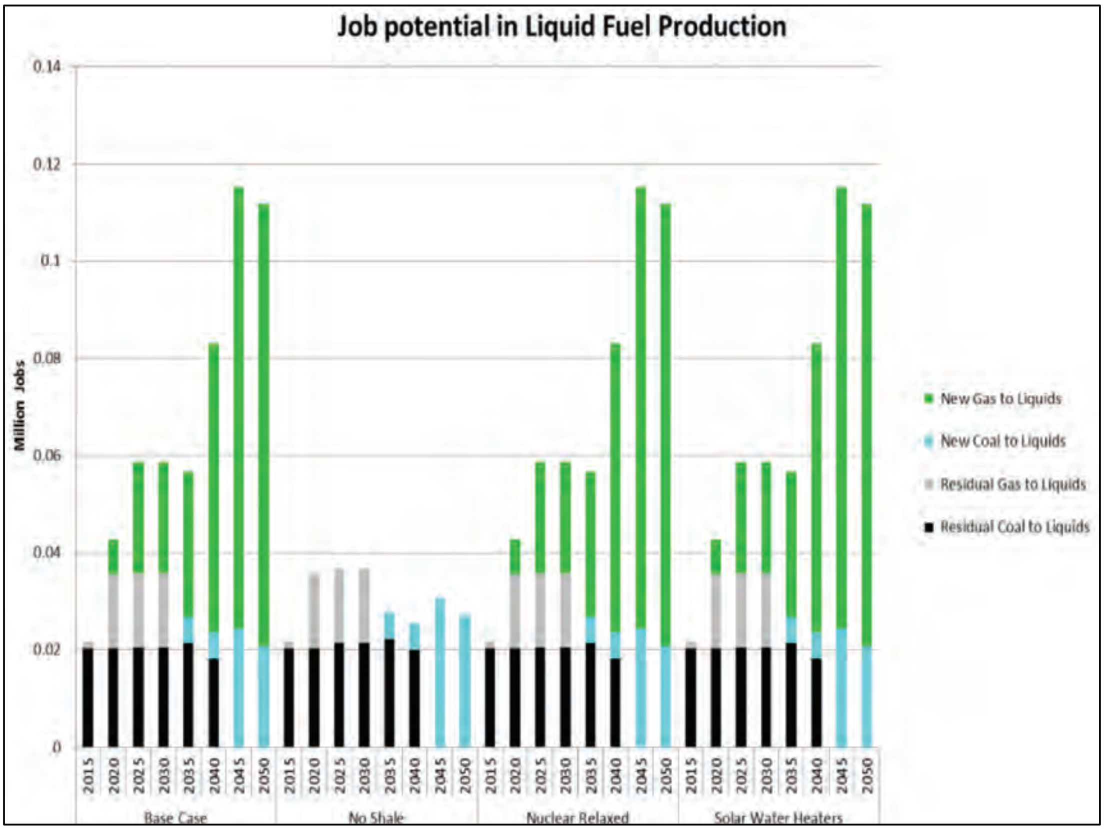
> *… As in the four core scenarios, there is a higher potential for jobs in the construction of energy technologies compared to the operation of residual technologies …*



Source: DoE Analysis

Figure 0-36: Jobs for electricity generation by scenario

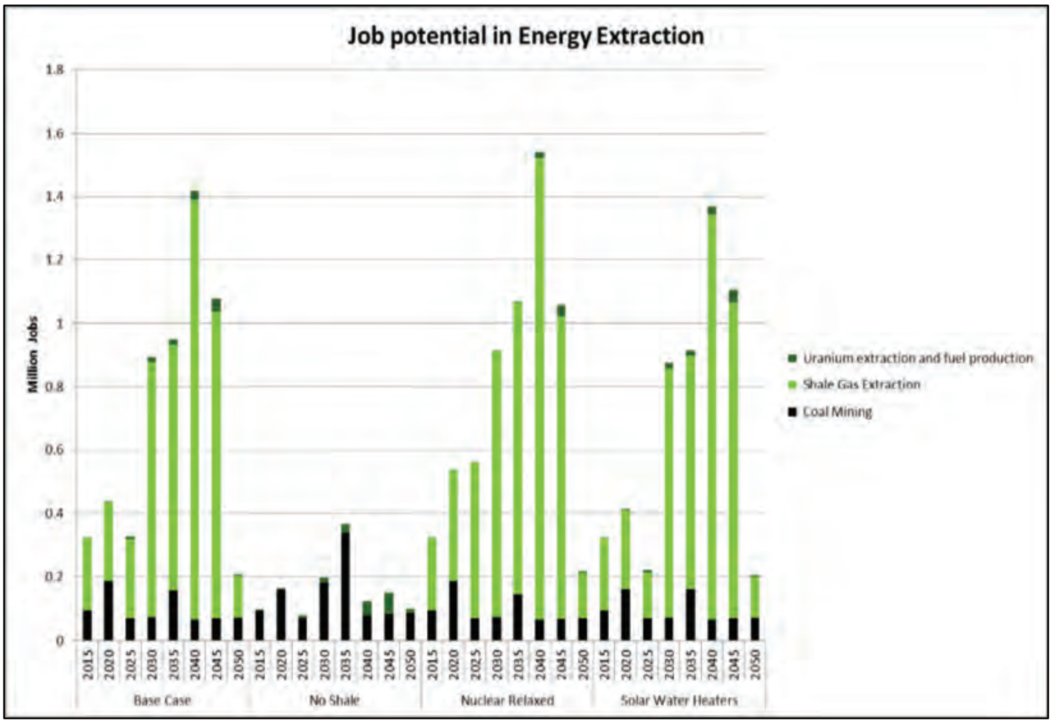
The job potential in liquid fuel production for the four scenarios is shown in Figure 0-37. The same numbers of jobs are created in the Base Case, Nuclear Relaxed and Solar Water Heater scenarios as flexibility in the New Nuclear Build Programme and electricity demand-side interventions have no impact on liquid fuel production capacity requirements. In these scenarios new CTL and GTL plant is constructed, leading to an increase in job potential for these scenarios. In the No Shale Gas Scenario, no new GTL plant is constructed due to economic constraints, with a resultant negative impact on the job potential for this scenario.



Source: DoE Analysis

Figure 0-37: Jobs for liquid fuel production by scenario

The job potential related to the extraction of coal and shale gas, and the uranium fuel cycle in the four scenarios is shown in Figure 0-38. The Nuclear Relaxed Scenario has the highest job potential. The No Shale Gas Scenario has the lowest job potential due to there being no extraction of shale gas in this scenario.



Source: DoE Analysis

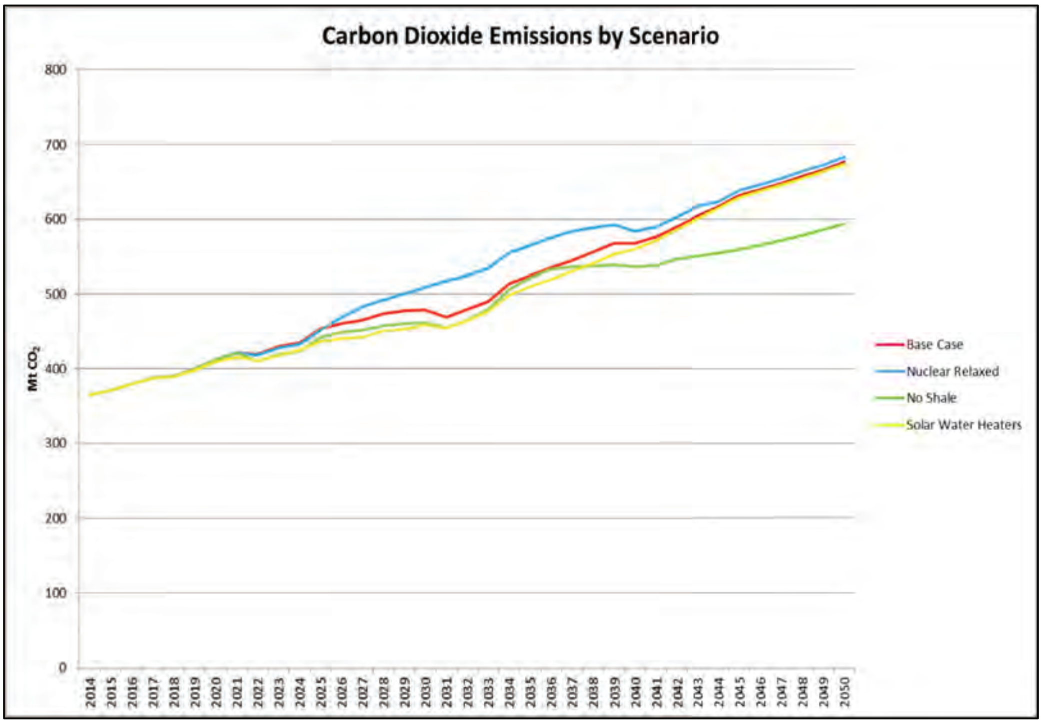
Figure 0-38: Jobs in the energy extraction sub-sector

6.9.4. Emissions

Emissions from the energy sub-sector are compared for the Base Case, Nuclear Relaxed, No Shale Gas and Solar Water Heater scenarios in this section. The emissions are separated into carbon emissions and pollutant emissions.

Carbon emissions

Carbon dioxide (CO_2) emissions for the energy sub-sector, transport sub-sector and final demand sub-sector are shown in Figure 0-39. The total CO_2 emitted until 2019 is approximately the same in all scenarios. Post 2019, the Solar Water Heater Scenario presents the lowest CO_2 emissions until 2030, in keeping with the Solar Water Heater Programme. Post 2021, the Nuclear Relaxed Scenario has the highest CO_2 emissions due to other polluting technologies replacing nuclear technology. The main contributors to the high emissions are the electricity generation sub-sector and the final demand sub-sector. Although the No Shale Gas Scenario presents the lowest CO_2 emissions over the planning horizon, this scenario has the highest emissions from the electricity generation sub-sector due to a higher percentage of coal fired power stations in the generation mix.



Source: DoE Analysis

Figure 0-39: Total CO_2 emissions (energy supply and energy end-use)

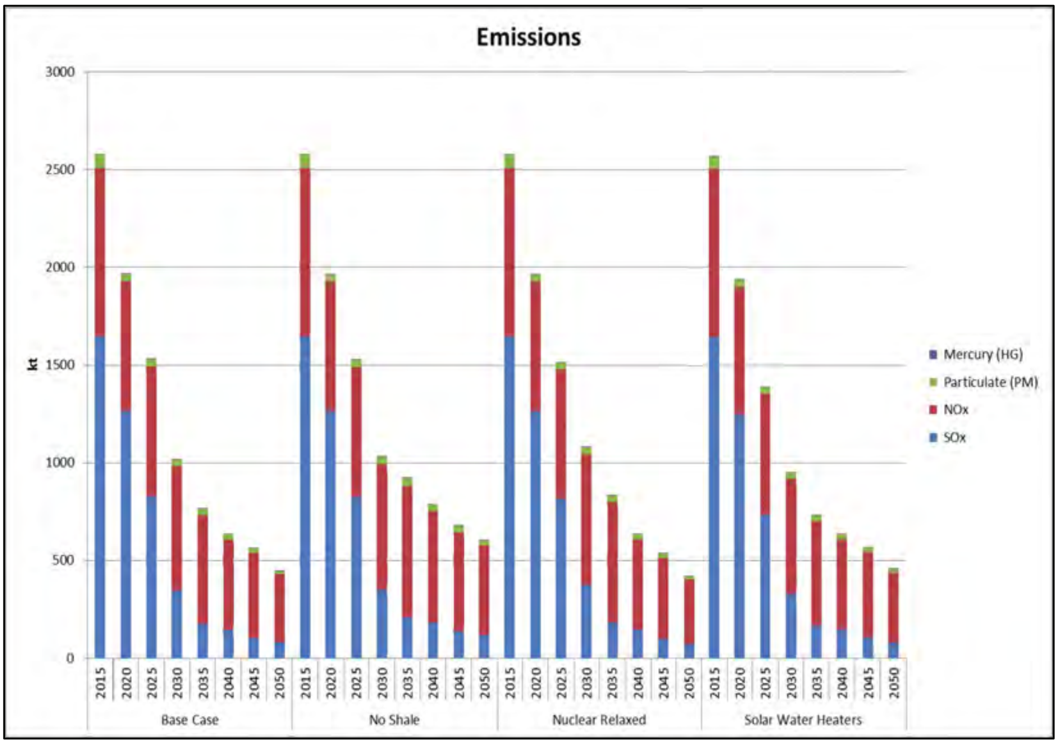
Pollutant emissions

Emissions of sulphur oxide (SO_x), nitrogen oxide (NO_x), particulate matter (PM) and mercury (Hg) are shown in Figure 0-40. There are significant reductions in SO_x, NO_x and PM in all scenarios as a result of the implementation of emission controls to comply with regulations for new and retrofitted power stations in accordance with Section 21 of the Air Quality Act. As in the core scenarios the reduction of these pollutants can be attributed firstly to PPD emission limits (with the Environmental Awareness Scenario attracting the more stringent PPD lower limit) set across all scenarios; secondly to costing of all externalities associated with NO_x, SO_x, PM, Hg; and finally to Flue-gas Desulphurisation (FGD) being compulsory in all new coal fired plant and life extensions to existing coal fired plant. This results in a preference for non-fossil fuelled electricity-generating technologies.

FGD has a considerable impact on the reduction of SO_x emissions as shown in Figure 0-40. The main driver of SO_x and Hg pollution is the content of these pollutants in the coal used in coal fired power stations and CTL plants.

PM in the electricity generation sub-sector is reduced by retrofitting fabric filters, as part of the life extension of existing power stations. Emissions of NO_x and PM are also produced in the transport sub-sector thereby contributing to the slower reduction in these emissions when compared to other pollutants. Post 2025 until 2032, NO_x emissions in the Nuclear Relaxed Scenario are higher than in the other scenarios, due to higher emissions from the electricity generation sub-sector. Post 2035, NO_x emissions in the No Shale Gas Scenario dominate due to the use of environmentally unclean electricity generation technologies.

PM and Hg emissions in the No Shale Gas Scenario are marginally higher than in the other scenarios, due to a higher percentage of coal fired power stations in this scenario.



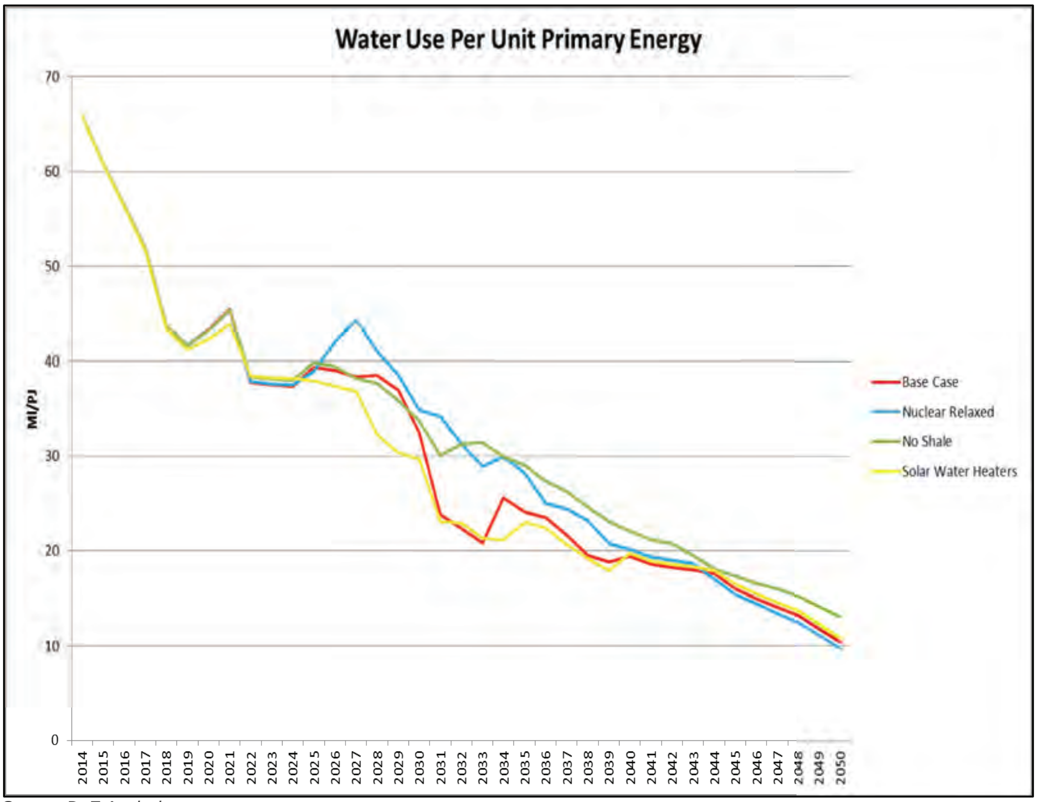
	Base Case				No Shale				Nuclear Relaxed				Solar Water Heaters			
	SO_x (kt)	NO_x (kt)	PM (kt)	Hg (kt)	SO_x (kt)	NO_x (kt)	PM (kt)	Hg (kt)	SO_x (kt)	NO_x (kt)	PM (kt)	Hg (kt)	SO_x (kt)	NO_x (kt)	PM (kt)	Hg (kt)
2015	1648	859	66	0.03	1648	859	66	0.03	1648	859	66	0.03	1644	857	66	0.03
2020	1265	662	38	0.03	1264	661	38	0.03	1264	661	38	0.03	1246	651	37	0.03
2025	828	667	35	0.03	825	665	35	0.03	816	661	35	0.03	734	618	33	0.03
2030	342	639	34	0.03	353	642	35	0.03	374	669	36	0.03	330	587	32	0.03
2035	174	558	32	0.03	208	673	39	0.03	184	613	33	0.03	168	531	31	0.03
2040	145	463	25	0.02	181	572	36	0.03	143	464	25	0.02	145	461	26	0.02
2045	104	434	22	0.02	135	510	32	0.03	98	415	21	0.02	106	439	23	0.02
2050	79	350	18	0.02	120	456	28	0.02	72	329	16	0.01	81	356	18	0.02

Source: DoE Analysis

Figure 0-40: Total emissions from the energy sub-sector

6.9.5. Water consumption

Water consumption across the four alternate scenarios is shown in Figure 0-41. Water consumption per unit of primary energy decreases across all scenarios over the planning horizon, because all future coal fired power stations will be air cooled rather than water cooled. A slight variation in water consumption occurs across all scenarios up to 2023. Post 2023 until 2032, the Nuclear Relaxed Scenario is the most water intensive, followed after 2032 by the No Shale Gas Scenario.

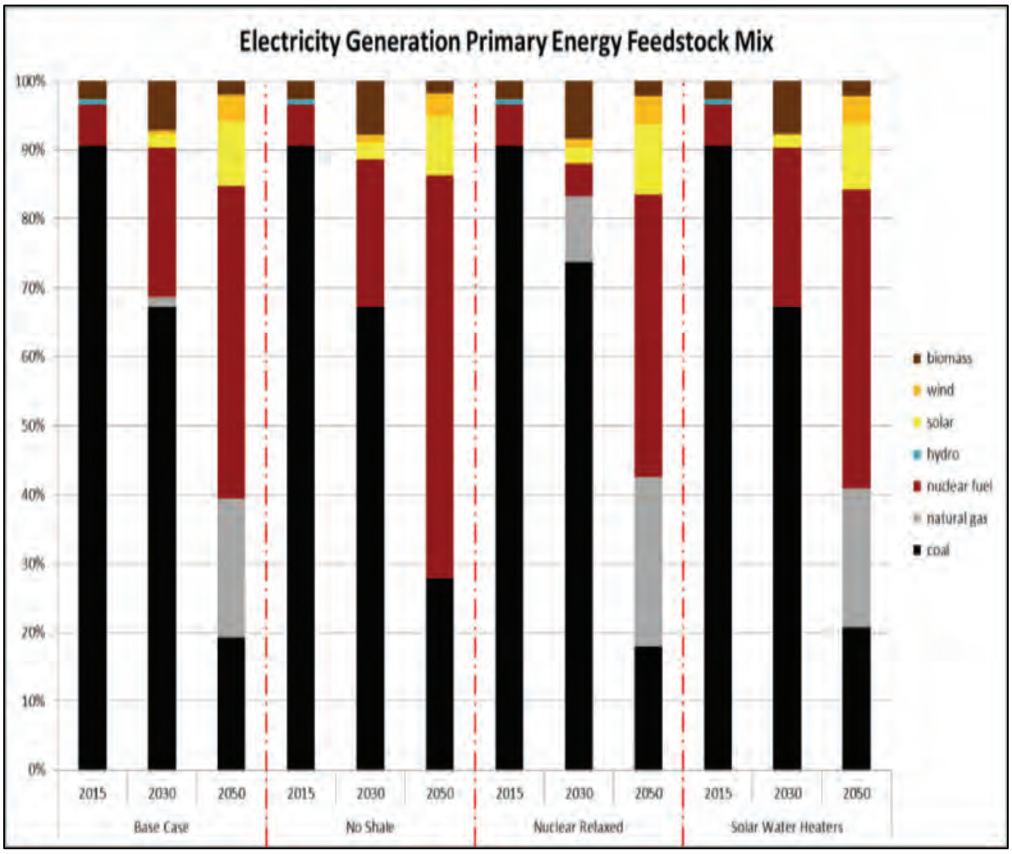


Source: DoE Analysis

Figure 0-41: Total water use in the primary energy sub-sector

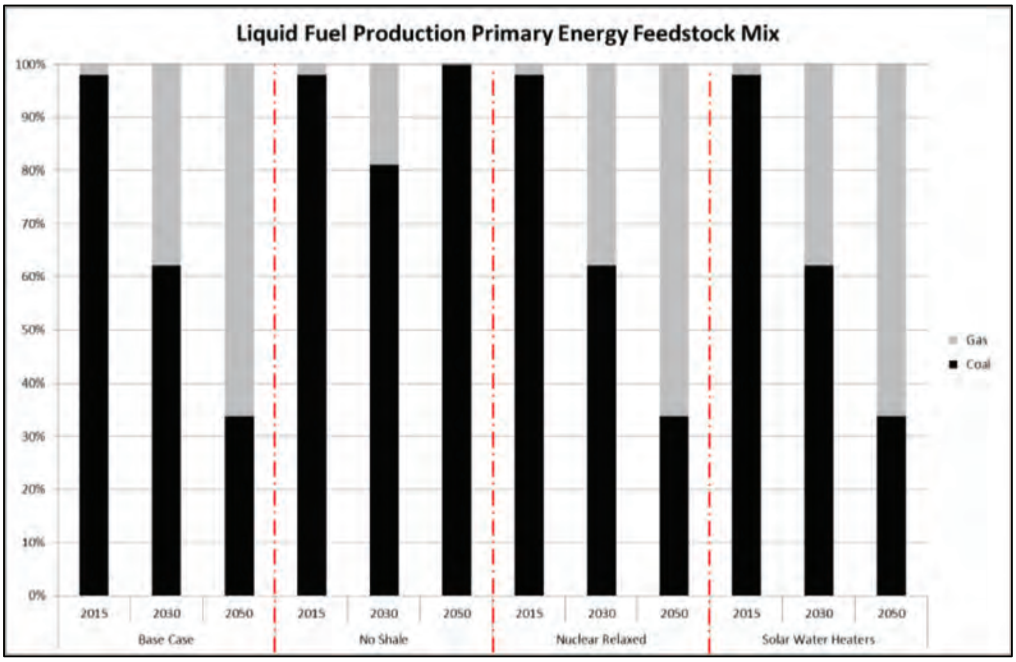
6.9.6. Primary energy mix (diversity)

Changes in the primary energy feedstock mix for electricity generation, liquid fuel production and final end-use are shown in Figure 0-42, Figure 0-43 and Figure 0-44. Coal and gas feature in all sectors except in the No Shale Gas Scenario. Coal constitutes close to 90% of the primary energy mix for electricity generation in 2015 in all scenarios. The use of coal declines to below 30% of the primary energy mix by 2050 in the No Shale Gas Scenario and below 21% in the other scenarios. Nuclear fuel features prominently in electricity generation from 2030, contributing over 40% of the generation mix by 2050. In the liquid fuel sub-sector, the primary energy mix is dominated by coal and gas in the Base Case, Nuclear Relaxed and Solar Water Heater scenarios, with gas becoming the more prominent energy carrier in the future. In the No Shale Gas Scenario, liquid fuel production is predominantly from coal with total production from coal by 2050. The primary energy mix in the final demand sub-sector comprises coal, gas and wood as in the core scenarios.



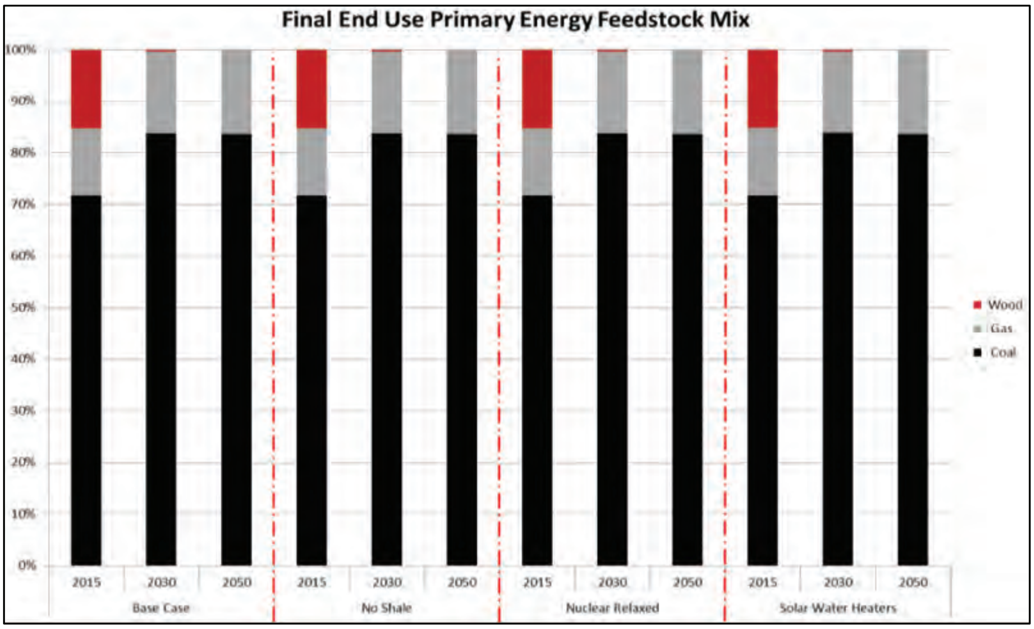
Source: DoE Analysis

Figure 0-42: Primary energy feedstock mix for electricity generation



Source: DoE Analysis

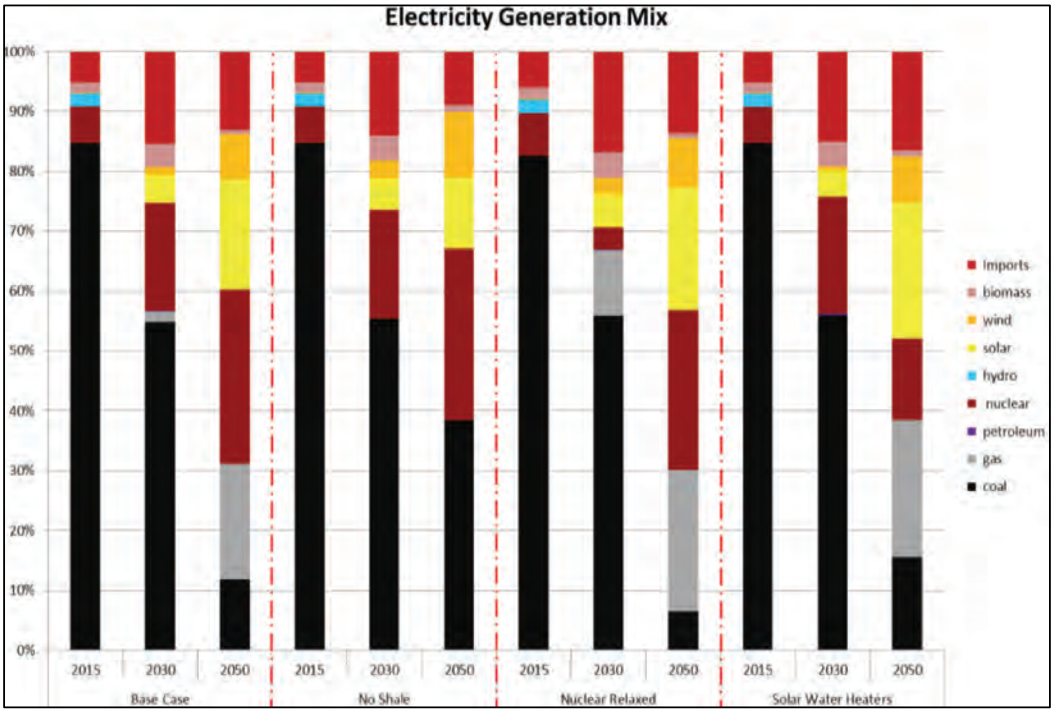
Figure 0-43: Primary energy feedstock mix for liquid fuel production



Source: DoE Analysis

Figure 0-44: Primary energy feedstock mix for final end-use

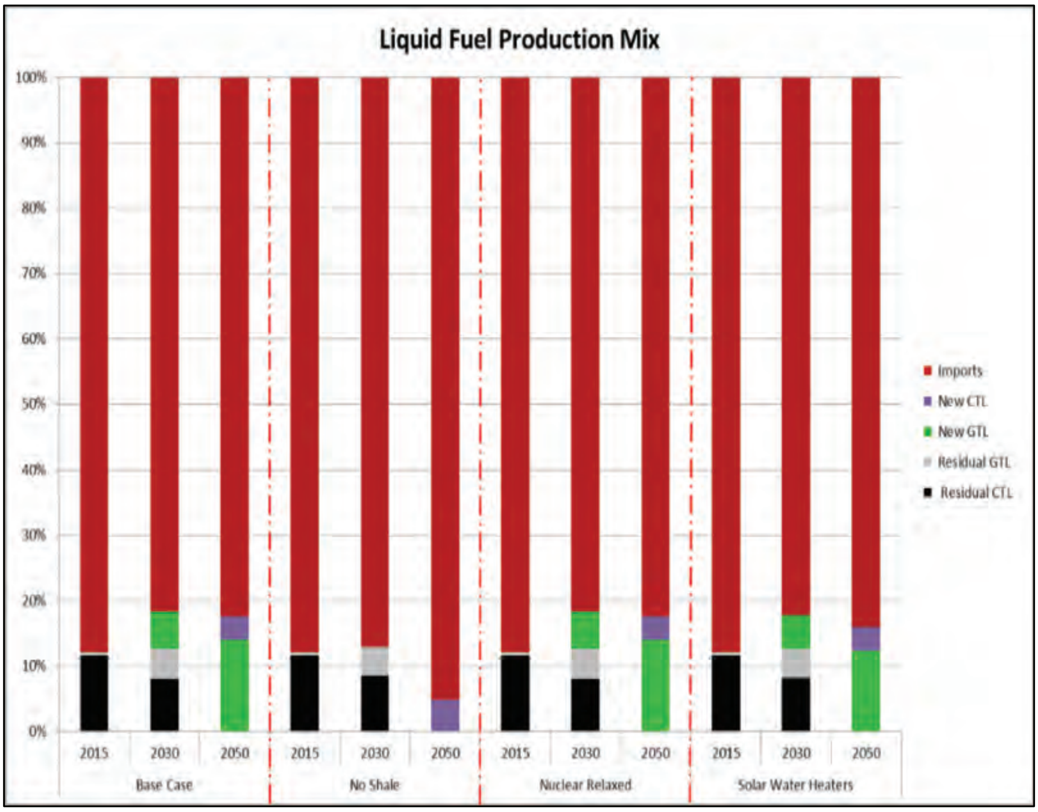
The change in the primary energy mix for electricity generation across the four scenarios is shown in Figure 0-45. Results for all scenarios are similar to the four core scenarios, with the energy mix becoming more diverse over the period to 2050, and the share of coal reducing from about 85% in 2015 to under 16% in 2050 in the Base Case, Nuclear Relaxed and Solar Water Heater scenarios. In the No Shale Gas Scenario, coal contributes to less than 25% of the energy mix by 2050. Nuclear and solar become more prominent sources of energy in the future in all scenarios.



Source: DoE Analysis

Figure 0-45: Electricity generation energy mix

The change in the energy mix for liquid fuel production across the four scenarios is shown in Figure 0-46. Results in all scenarios are similar to the four core scenarios with imports constituting the bulk (75%) of the supply mix over the entire planning horizon. The importation of petroleum products is higher in the No Shale Gas Scenario due to reduced domestic production of petroleum products based on the assumption that shale gas is not economical as a primary fuel option.

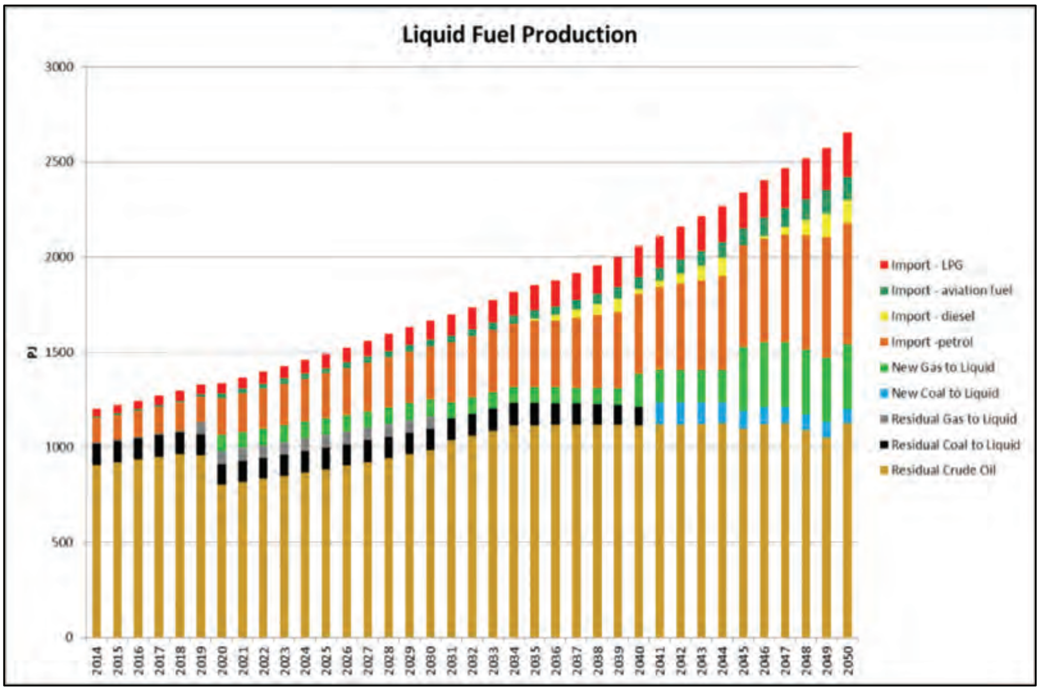


Source: DoE Analysis

Figure 0-46: Liquid fuel production energy mix

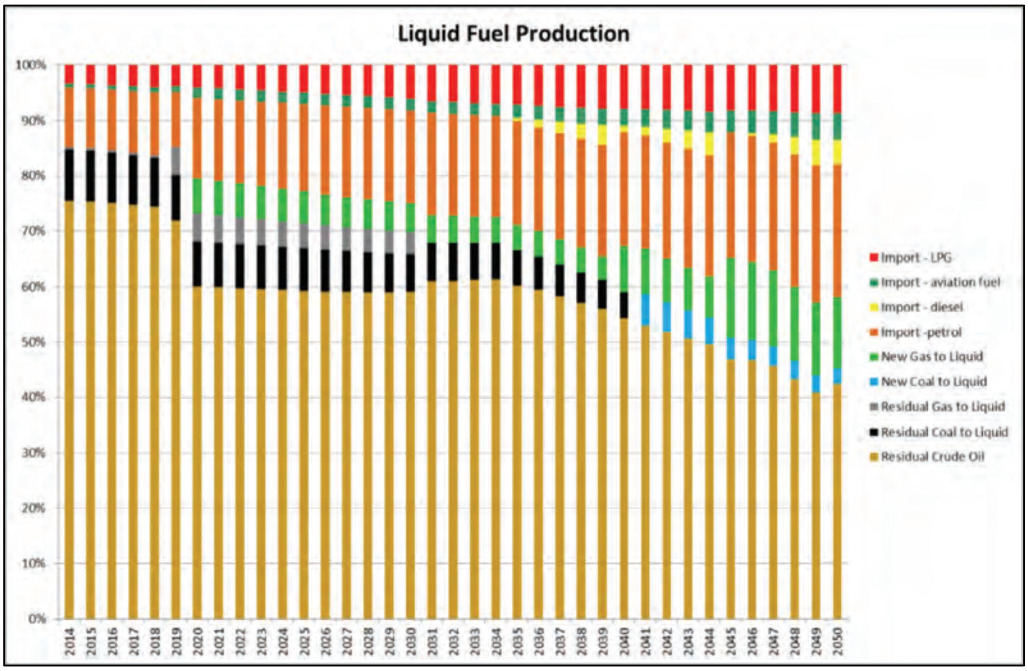
6.9.7. Liquid fuel imports

The sensitivity of domestic fuel production to refined petroleum product imports was investigated by constraining annual diesel imports. Figure 0-47 shows the annual liquid fuel production when diesel imports are limited to 864 PJ over the planning horizon. Residual oil refineries are the major producer of petroleum products, contributing to 85% of production in 2015 and decreasing to 42% by 2050. Production from new CTL and GTL make up 8% over the planning horizon, with increased production from 2040 onwards. Importation of refined petroleum products increases from 15% in 2015 to 42% by 2050. The percentage change in energy mix for liquid fuel production for the four scenarios is shown in Figure 0-48.



Source: DoE Analysis

Figure 0-47: Liquid fuel production energy mix – diesel import constrained



Source: DoE Analysis

Figure 0-48: Percentage change in liquid fuel production energy mix – diesel import constrained

Section 7: Electricity price path and macroeconomic impact analysis

Electricity price paths were calculated for the four core scenarios and the three sensitivity analyses. Assumptions were made regarding the proportion of new capacity to be built by the state-owned entity (SOE) and Independent Power Producers (IPPs), as indicated in Table 0-1. The percentage split between SOE-built and IPP-built capacity is based on the total required capacity rather than individual unit size.

Table 0-1: Assumed split of build by technology type

Technology type	SOE built	IPP built	Import built
Nuclear	100%		
Coal	70%	30%	
Gas – CCGT and OCGT	70%	30%	
CSP	70%	30%	
Solar PV		100%	
Wind		100%	
Landfill biomass		100%	
Imported hydro, coal and gas			100%

Figure 0-1 shows the assumed proportion of new capacity built by the SOE versus IPPs based on the above split.

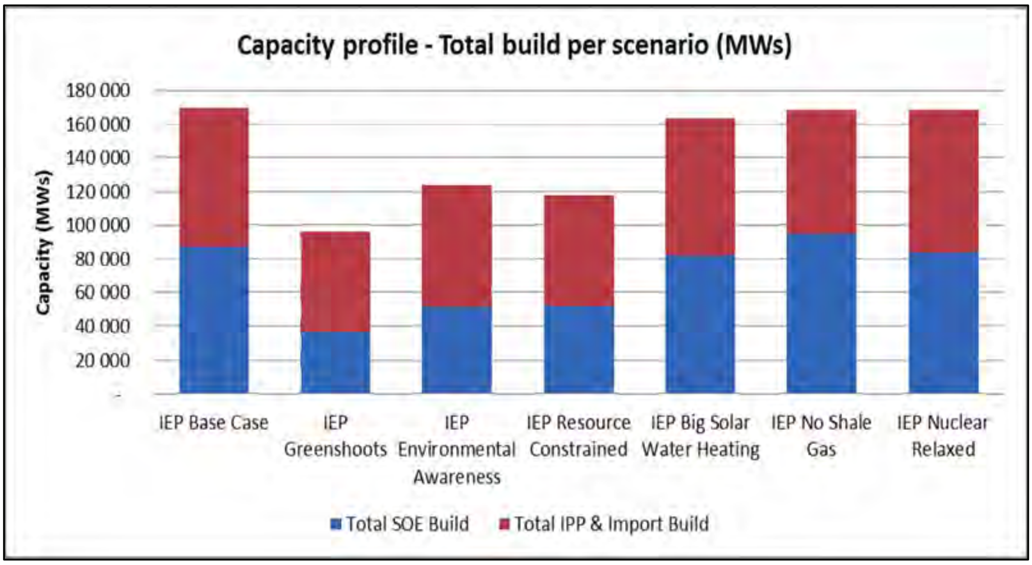


Figure 0-1: Proportion of build for new capacity per scenario

Figure 0-2 indicates the electricity price paths for all scenarios. The price path for the Environmental Awareness Scenario shows the greatest fluctuations as new investments are more flexible; the scenario shows the highest increase in electricity prices between 2018 and 2028, and again from 2043 onwards. It shows the second lowest prices between 2032 and 2040 following the Green Shoots Scenario. Overall the Environmental Awareness Scenario presents the highest average prices.

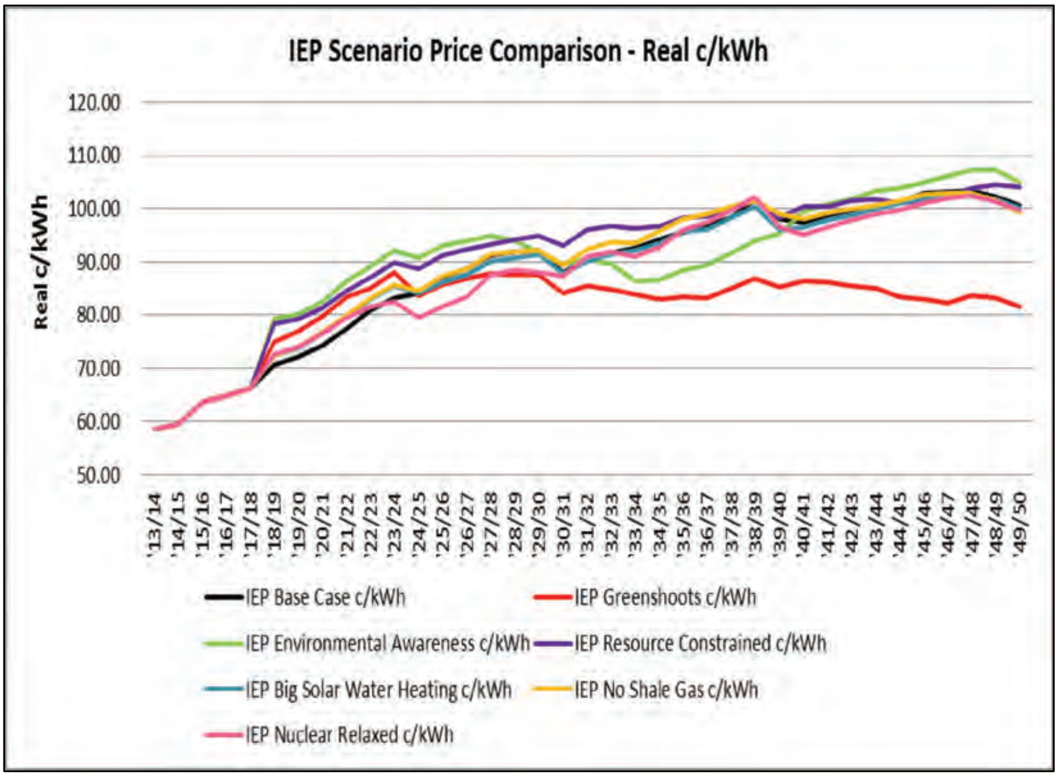
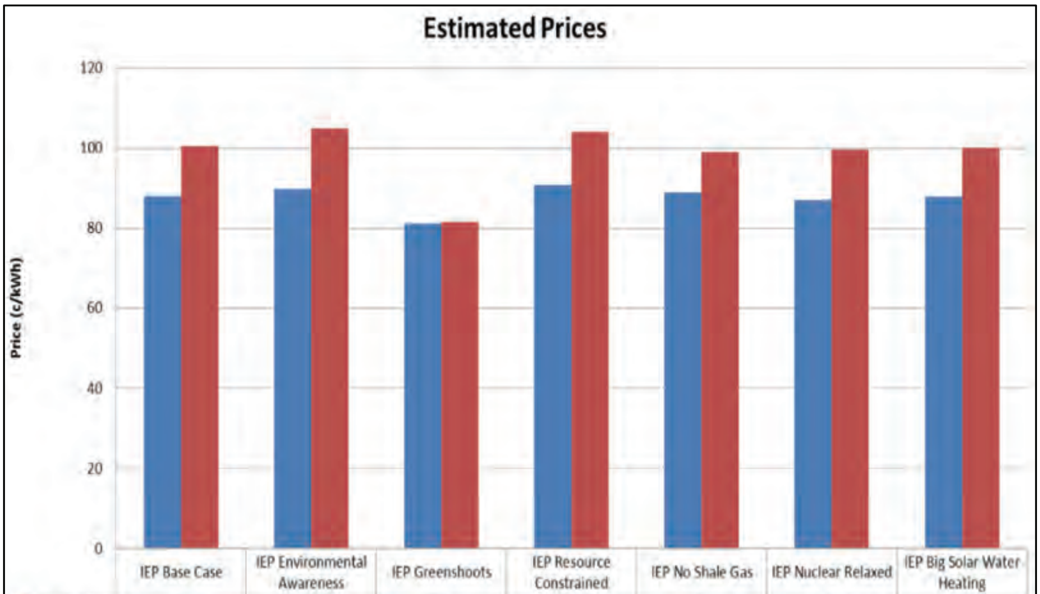


Figure 0-2: Electricity price path across all scenarios

> *… The Base Case Scenario presents higher average and peak prices as a result of the additional capacity required to meet the energy demand of an economy which is still fairly energy intensive …*

Figure 0-3 reflects the average and peak electricity prices for each scenario. Estimated electricity prices range from 80c/kWh to 105c/kWh, with the Green Shoots Scenario showing the lowest average and peak electricity price due to its reduced new capacity requirements.

The significant investments in demand-side interventions (i.e. aggressive implementation of the Solar Water Heater Programme and greater improvements in energy efficiency) result in a reduced demand overall for energy and hence lower investments in new electricity generation capacity in this scenario. The Base Case Scenario presents higher average and peak prices as a result of the additional capacity required to meet the energy demand of an economy which is still fairly energy intensive. The higher prices presented in the Environmental Awareness Scenario result from the higher externality costs for fossil fuels.



	IEP Base Case	IEP Environmental Awareness	IEP Greenshoots	IEP Resource Constrained	IEP No Shale Gas	IEP Nuclear Relaxed	IEP Big Solar Water Heating
Average Price	88.2	89.8	81.2	90.9	89	87.2	88
Highest Price	100.63	104.98	81.61	104.13	99.17	99.65	100.2

Figure 0-3: Average and highest electricity prices per scenario

Section 8: Conclusions and recommendations

The future energy landscape is one in which all eight objectives of the IEP are met.

8.1. Security of supply

Security of supply is ensured by timely decisions and investment in new energy infrastructure.

- For the electricity sector, cost reflective tariffs are applied by all generators to ensure that adequate funds are available to:
  - make the necessary investments in new capacity that may be required; and
  - make allocations for required maintenance.
- For the liquid fuel sector, security of supply should be ensured by diversifying, to move away from imported fuel sources. Local production capacity should be considered as a strategy to increase security of supply, however this option must be weighed up against the associated costs.

… The future energy landscape is one in which all eight objectives of the IEP are met …

8.2. Cost of energy

- New electricity generators should be brought on line through a competitive bidding process, where the ability to generate electricity at low cost is a key criteria.
- The implementation of new nuclear capacity should be conducted in a manner that has the least cost impact on the energy system. The implementation of the 9.6 GW New Nuclear Build Programme, as espoused in the IRP2010, should be reviewed such that the scale and pace of the programme has a less severe impact on electricity tariffs than an expedited programme.
- South Africa is a price taker and the price of petroleum products is influenced by global crude oil prices. Where possible, maximum (i.e. capped) retail prices should continue to be implemented for fuels such as LPG and natural gas to encourage the switch away from electricity.

8.3. Diversified energy mix

A diversified energy mix, wherein reliance on a single or a few primary energy sources is reduced, needs to be pursued. For electricity generation, the technology mix should take into consideration the roles that different technologies play in providing baseload and peaking power.

8.3.1. Coal

- Coal will continue to play a role in providing energy in the future, however this will be limited to electricity generation, because alternative and more economically viable options such as gas and crude oil exist for the production of liquid fuels. Coal is suitable for providing baseload power and will continue to do so in the foreseeable future. It will, however, be displaced substantially over time by a diverse mix of energy carriers including solar, wind, nuclear and gas. These alternatives reduce GHG emissions and other pollutants, help to improve security of supply and in most cases lower the cost of providing energy when externality costs are accounted for.
- Coal will, however, play an increased role should gas prices prove not to be competitive (either in the form of economically recoverable shale gas or imported gas).
- Coal-to-liquid plants are not viable in an environment of stringent emission constraints or when externality costs are taken into consideration. New investments are not envisaged and this is unlikely to change in the future.
- Investments should be made in research targeted at clean-coal technologies, including carbon capture and storage and underground coal gasification. Such research will ensure that South Africa develops mechanisms to exploit this indigenous resource responsibly in the long term.

… . For electricity generation, the technology mix should take into consideration the roles that different technologies play in providing baseload and peaking power …

8.3.2. Nuclear

- In efforts to mitigate climate change while ensuring a steady source of electricity supply, nuclear will need to play a more prominent role in the provision of baseload power in the energy mix.
- The sensitivity analysis for the Nuclear Relaxed Scenario (which realises 25 GW of new nuclear capacity by 2050) indicates that the timing and pacing for additional generation capacity from nuclear can be revised, such that the first unit starts generating power from 2030, without causing a further negative impact on the adequacy of electricity supply before that period because other options can be deployed faster.
- The No Shale Gas sensitivity analysis (which assumes no economically recoverable shale gas) sees 45 GW of new capacity from nuclear by 2050. The availability of competitively priced gas will determine the magnitude of nuclear required in the energy mix.
- Given the long lead times associated with the development of nuclear projects, it is recommended that preparatory work on the New Nuclear Build Programme continue to take place and that the decision be prioritised as to the vendor/s with whom South Africa will partner.

… In efforts to mitigate climate change while ensuring a steady source of electricity supply, nuclear will need to play a more prominent role in the provision of baseload power in the energy mix …

8.3.3. Natural gas

- Conventional and unconventional natural gas should play a more prominent role in South Africa's future energy mix both in the electricity sector and in the liquid fuel sector. Natural gas is a cleaner energy source than coal; it can be used as a primary energy source for power generation and for liquid fuel production and directly in end-use applications such as thermal.
- Gas-fired Combined Cycle Gas Turbines (CCGTs) present the most significant potential for developing the gas market in South Africa. The advantages of CCGT power plants include:
  - Relatively short construction and commissioning lead times;
  - Low capital costs per unit of capacity;

- Increased efficiency using simple and proven technology;
- Operational flexibility as they can be ramped up or down to suit the system demand on an hourly or daily basis. They are therefore suitable to meet unexpected spikes in electricity demand and also for complementing intermittent generation from renewable energy plants.
- When situated at the coast they have several benefits, including:
  - The ability to use sea water as a cooling medium;
  - Providing an additional source of power close to source in high usage areas;
  - If supplied through an LNG terminal, the LNG terminal can be expanded to supply other industries.

- Gas as feedstock to GTL is a viable option should gas prices allow for this or should local exploration activity yield recoverable gas resources.
- Switching from electricity to gas as a fuel source should be prioritised. Direct use of natural gas in industrial processes could be the starting point for the development of a gas market in South Africa in the medium to long term as this presents the most significant potential and could assist in providing energy requirements in support of the re-industrialisation policy.
- Compressed Natural Gas (CNG) is already being used on a small scale in the transport sector by minibuses and buses. The CNG market could be expanded in the long term and could help to reduce the demand for the import of liquid fuels in the sector.
- Regional co-operation with gas-rich countries such as Mozambique, Tanzania and Angola should be strengthened. Agreements with neighbouring countries should be pursued for the purpose of joint development and exploitation in countries that have abundant resources. South Africa, through its state-owned entities and other local players in the sector should co-invest in the development of gas projects in these countries.
- The No Shale Gas Scenario includes more coal, nuclear and renewable technologies in the energy mix and also reflects significantly higher total energy system costs. Recoverable shale gas could thus become a game changer for the South African energy landscape if it is exploited in a responsible and transparent manner. The perceived environmental risks of extracting 'tight' gas such as shale gas are considered to be significant, requiring substantial amounts of water and presenting a challenge in water-scarce areas. There are also concerns regarding the possible contamination of ground water, which may result from improper disposal of fluids during the hydraulic fracturing process. Amendments to the Minerals and Petroleum Resources Development Act (MPRDA) are currently being finalised and will set the

legislative framework for the extraction of shale gas. Regulations which define the manner in which extraction must be done have been finalised and will become operational once the amendment to the MPRDA has been enacted.

- The availability of indigenous shale gas at affordable prices makes the case for GTL, GTP and the direct application of gas for thermal needs feasible. Exploration to determine the extent of locally recoverable resources therefore needs to be expedited.
- South Africa should consider appropriate alliances and possible joint ventures to further the development of coal bed methane opportunities in other countries such as Botswana and Zimbabwe.

8.3.4. Crude oil and imports of final liquid fuels

- The low contribution of crude oil in the energy mix across all scenarios has been informed by assumptions regarding its availability; lower priced gas (mainly comprising natural gas); and no externality costs imposed on imported refined product.
- However, should the levels of economically recoverable shale gas be insignificant, new crude oil refineries will be needed in the medium to long term.
- If externality costs are imposed in the price of imported fuels, the cost of imported fuels increases which in turn has a negative impact on the balance of payments.
- Therefore in order to ensure security of supply and to reduce the negative impact on the balance of payments due to imports of refined product, new refinery capacity will be essential. New refinery capacity should meet the new fuel specifications.

8.3.5. Solar

- Solar should play a much more significant role in the electricity generation mix than it has done historically, and constitutes the greatest share of primary energy (in terms of total installed capacity) by 2050. The contribution of solar in the energy mix comprises both CSP and solar PV. Solar PV includes large scale installations for power generation which supply to the grid and individual, off-grid solar home systems and rooftop panels.
- Several interventions which could enhance the future solar energy landscape are recommended as follows:
  - Large scale CSP projects with proven thermal storage technologies and hybridisation/industrial steam application projects should be incentivised in the short to medium term. In the long term the existing incentives could be extended

to promote locally developed CSP technology storage solutions and large scale solar fuel projects.

- A thorough solar resource assessment for South Africa should continue to be undertaken in the Northern Cape Province and extended to other provinces deemed to have high solar radiation levels.
- Investments should be made to upgrade the grid in order to accommodate increasing solar and other renewable energy contributions.

8.3.6. Wind

- In addition to solar, wind energy should continue to play a role in the generation of electricity. Allocations to ensure the development of wind energy projects aligned with the IRP2010 should continue to be pursued.

8.3.7. Renewable Energy Independent Power Producer (REIPP) Procurement Programme

- To ensure the ongoing deployment of renewable energy technologies, the REIPP Procurement Programme should be extended and new capacity should be allocated through additional bidding windows.
- Experience and insights gained from the current procurement process should be used to streamline and simplify the process.
- The implementation of REIPP projects in subsequent cycles of the programme should be aligned with the spatial priorities of provincial and local government structures in the regions that are selected for implementation, in line with the Spatial Development Frameworks. This will ensure that there is long-term, sustainable infrastructure investment in the areas where REIPP projects are located. Such infrastructure includes bulk infrastructure and associated social infrastructure (e.g. education and health systems). This alignment will further assist in supporting the sustainable development objectives of provincial and local government by benefiting local communities.
- The Department of Environmental Affairs has commissioned the CSIR to undertake a Strategic Environmental Assessment aimed at facilitating the efficient and effective rollout of wind and solar PV energy in South Africa. The assessment covers the infrastructure projects identified by the Presidential Infrastructure Coordinating Commission, and aims to identify strategic development areas for renewables with the intention of integrating environmental considerations with social and economic benefits in those areas at implementation level. (CSIR, 2015).

- To this effect Renewable Energy Development Zones (REDZs) have been identified and describe geographical areas:
  - In which clusters (several projects) of wind and solar PV development will have the lowest negative impact on the environment while yielding the highest possible social and economic benefit to the country;
  - That are widely agreed to have strategic importance for wind and solar PV development;
  - Where the environmental and other authorisation processes have been aligned and streamlined based on scoping level pre-assessments and clear development requirements; and
  - Where proactive and socialised investment can be made to provide time-efficient infrastructure access.
- The Strategic Environmental Assessment been implemented in the Western Cape, Northern Cape, and KwaZulu-Natal. The assessment should be extended to all provinces where there is potential for renewable energy.

… the REIPP Procurement Programme should be extended and new capacity should be allocated through additional bidding windows …

8.3.8. Biomass

- Cogeneration is the simultaneous production of electrical and thermal energy from a single fuel source and is sometimes also termed combined heat and power (CHP). These systems are characterised according to the sequence of energy types generated. Topping cycle systems produce electricity first, and then recover the excess thermal energy for heating or cooling applications. Topping cycle cogeneration is widely used and is the most popular method of cogeneration (Sanedi, 2013). In contrast, bottoming cycle systems utilise a process where waste heat from an existing process is used to produce electricity. Bottoming cycle systems are mainly deployed in industries that require a large amount of process steam (e.g. cement and petrochemical plants) (Sanedi, 2013).
- Biomass (inclusive of bagasse and wood waste) plays an important role in the provision of electricity close to the demand location through cogeneration. Given the current electricity supply challenges, cogeneration options should be pursued in order to address electricity capacity constraints in the short to medium term.

- The optimal use of waste energy in cogeneration results in an increase in the overall efficiency of the heat and power production processes. The fuel intake for the combined process is less than that required for the individual heat and power production processes. Other advantages of on-site cogeneration include a positive contribution to the reduction of greenhouse gas (GHG) emissions, due to a reduced dependence on grid supply. Reduced dependence on the grid also helps alleviate capacity constraints and transmission losses. In the case of feed-in to the national grid, cogeneration can assist in increasing generation capacity on the network.
- To date only a few cogeneration plants have been constructed in South Africa. These include amongst others, a biomass cogeneration plant at an abattoir in Jan Kempdorp in the Northern Cape, a gas turbine tri-generation plant at MTN in Johannesburg, cogeneration from natural gas at Sasol Synfuels, and cogeneration from calcium carbide furnace waste gas at SA Calcium Carbide. The overall efficiency of the biomass cogeneration plant is 84.6%, with savings of 247 MWh/year in electrical energy and 991 MWh/year in diesel heating energy. The annual reduction in emissions is 2000 t CO_2-equ. The total energy savings of the gas turbine tri-generation plant at MTN is 26 GWh/year and the annual reduction in emissions is 2000 t CO_2-equ. Annual reduction in emissions for the Sasol Synfuels plant is in excess of 1 Mt CO_2-equ (Sanedi, 2013).
- The sugar industry in South Africa has demonstrated commitment to expanding cogeneration capability. Sugar cane is a renewable energy source, and the production of electrical energy from sugar cane fibre is receiving increased attention due to the positive spin offs in terms of security of supply and greenhouse gas (GHG) emission reductions.
- The South African sugar industry produces an average of 2.2 Mt of sugar per annum (South African Sugar Association, 2015). Sugar cane is supplied to 14 mills where it is processed into sugar (South African Sugar Association, 2015). Bagasse and molasses are produced in the process. Bagasse is the fibrous biomass that remains after sugar cane stalks are crushed to extract the juice. According to Tongaat Hulett Sugar, every 100 tons of sugar cane harvested and milled produces 10 tons of sugar and 28 tons of bagasse (Tongaat Hulett Sugar, 2015). Some of the sugar mills are undertaking cogeneration of electricity from bagasse but mainly for their own consumption and a small amount is exported into the national grid.
- The South African sugar industry generates about 5.9 Mt of bagasse per annum. The power output per ton of sugar cane in the South African industry is approximately 30 kWh (Mbohwa, 2013). The industry produces a total of 742 GWh of electrical energy per year, most of which is consumed by the industry itself. A great deal of potential

exists to increase the energy output of the industry by adopting more efficient cogeneration technologies and this should be pursued and supported through the cogeneration programme, which is currently being implemented by the DoE.

… New energy infrastructure investments that optimise the creation of jobs within the energy sector should be favoured …

8.3.9. Hydrogen and fuel cells

Opportunities related to hydrogen technologies can help to establish South Africa's place in the fuel cell sector both locally and globally. A sizeable pilot demonstration will maximise the opportunities for local adoption as well as incorporation of local technology content in said systems in the foreseeable future.

- **Stand-alone 1-20 kW power systems**
  Substantial opportunity exists in the electrification of municipalities and operations that are too far from the nearest grid point to be included in short- and medium-term grid expansion plans.

  Fuel cell systems can also be used in residential and commercial buildings, as back-up power or in energy efficiency demand-side management (EEDSM) initiatives to shift load and reduce pressure on the generating capacity.

- **Storage for Renewable Energy (P2G technology)**
  Hydrogen is an ideal medium to 'store' excess electricity during off-peak times by producing hydrogen through electrolysis using the excess electricity and then using the stored hydrogen to produce electricity via fuel cells during peak/required times. This is specifically relevant to the new renewable energy being introduced on the national grid, where wind and PV power, which is not dispatchable, poses integration and stability challenges.

- **Combined Heat and Power (CHP) units**
  Smaller 1–2 kW fuel cell systems can be used in residential buildings as back-up power or prime power in EEDSM initiatives to shift load and reduce pressure on the generating capacity. This creates substantial opportunity for off-grid applications, and should be considered for inclusion in long-term grid expansion plans.

- **Back-up Power and Prime Power Units**
  Portable/stationary power is a niche market, where proton-exchange membrane (PEM) fuel cells and hydrogen storage technology are likely to compete commercially with alternative solutions in the near-term (next five years). This is particularly true for remote areas, where there is no road infrastructure, making transportation of fuel costly. Uninterrupted Power Supply (UPS) for telecommunication systems is a rapidly growing market, particularly in regions where there is a rapid growth of mobile phone users (Asia and Africa). South Africa seems very well positioned to be part of the telecom infrastructure development in the southern parts of Africa. Hence, there has been a special focus in HySA Systems on 1–5 kW class UPS/prime power for telecom and rural applications and for African conditions.

- **Hydrogen Fuelled Vehicles – Rail transport**
  Hydrogen powered rail transport systems have been developed and are being tested at various locations worldwide. An ideal (but not the only) application in South Africa would be on the Sishen-Saldanha iron ore railway line. As a long-term solution, implementing hydrogen-powered locomotives will assist to expand capacity on the line and will reduce reliance on diesel fuel and alleviate pressure on electrical supply on the line as well as potential transmission and distribution line upgrades. This railway line is close to a number of new solar installations and could potentially tap into hydrogen resources produced using renewable energy.

8.4. Job creation and localisation potential

New energy infrastructure investments that optimise the creation of jobs within the energy sector should be favoured. More importantly, these jobs should be sustainable, either due to their relevance throughout the operating life of a plant or as a result of the continuous deployment of a particular technology. In addition, the ability to ensure that local skills exist and are utilised or can be easily developed should be a key criterion.

- To find a combination of technologies that both makes sense for the economy and is cohesive within the energy ecosystem, a systems approach to a solution needs to be considered.

- **Overall costs:** No matter how many jobs a technology can create, if the cost of creating those jobs is too high (e.g., results in a significant increase in energy prices), then the gains through direct employment in energy generation are counter-productive.
- **Skills and capabilities:** Temporary construction jobs have minimal long-term impact compared to permanent employment, however the build programme can be planned to account for these spikes in temporary employment.
- **Industrialisation potential:** Technologies that have the potential to deliver jobs in other parts of the South African economy could make a bigger contribution to overall development objectives than a technology that creates jobs in just one sector.
- **Maximising localisation potential:** By focusing on a few demand and supply levers, South Africa should be able to increase the localisation potential of certain technologies.
- **Broader macroeconomic impact:** Focusing only on job creation potential in a particular sector or technology may mean that fewer resources are available for other more productive activities, potentially reducing the economy's long-term productivity, and hence growth prospects, therefore broader macroeconomic considerations need to be taken into account.

- The number of jobs that a single technology can potentially generate is therefore only one consideration amongst others that should inform long-term energy policy making.
- **Nuclear:** The McKinsey study shows that while nuclear plant construction generates the highest number of total job years per GW installed, the localisation of these jobs would require significant investment and South Africa would need to be globally competitive in order to create sufficient demand to warrant local manufacturing. This challenge is minimised when the construction of nuclear plants takes the form of an extended fleet programme, implemented over an extended period rather than as a standalone, once-off project.
- Other technologies, notably coal, concentrated solar power (CSP) and onshore wind, have a much higher immediate localisation potential of total jobs at 5 GW. Total jobs generated by the extraction technologies have very high localisation potential (over 80% of the total jobs can be localised at 5 GW).
- **Coal** also has significant job creation potential, both during construction and throughout the operating life of the power plants. In addition, coal-fired power plants require sustained mining activity to keep up the supply of coal, which in turn increases the number of associated supplier jobs. However the impact of carbon

emissions on the climate and environment is an inhibiting factor and once externality costs are taken into account coal no longer becomes an affordable option.

- **Natural gas** as an energy source has the potential to create jobs in many fields, from extraction (in the case of shale gas) to the generating of power in CCGT plants and the liquefaction process in GTL plants. Besides the fact that affordable, locally produced gas could replace current imports of petroleum, it has the potential to make South Africa more competitive and would boost domestic growth (and hence job creation) in industries that can make direct use of natural gas. These include process heating in the manufacturing sector (e.g. cement, fertiliser, methanol/ethanol, glass, paper and pulp, plastics, steel and aluminium) and as a feedstock (e.g. plastic polymers, glass sheets).
- **CSP** creates the most jobs in terms of capital investment and operating expenditure. The technology is still, however, relatively expensive and without storage does not provide a stable source of baseload power. In addition, depending on where CSP plants are located, there could be a requirement for significant investment in additional transmission lines to densely populated areas. As a result, installing CSP alone, or for that matter any technology with these same constraints, would not be cost effective for South Africa's economy.
- **Solar PV** technologies present the greatest opportunity for localisation. To this effect several developments should be supported:
  - Establish solar component manufacturing policy framework and supplier park infrastructure to support industry in a similar manner to the way in which the automotive component industry has been supported by the Automotive Industry Development Centre.
  - Expand the offerings of the South African Renewable Energy Technology Centre at the Cape Peninsula University of Technology, to include national train-the-trainer skills development programmes for solar sector component manufacture, system maintenance, installation, and system service skills.
  - Promote joint-ventures with global solar component manufacturers to attract existing know-how and value chains to South Africa – beyond that of the local market. Use export potential to the rest of the continent as an attraction.
  - Promulgate and enforce SABS quality standards, and potentially add tariffs to de-incentivise imports of solar technology components that can be manufactured locally.
  - Assess the optimal levels of local content for each solar technology from a macroeconomic perspective – inclusive of potential export demand to sub-Saharan African markets.

… South Africa has committed to reducing its Green House Gas emissions by 34% below its "business as usual" growth trajectory by 2020, and by 42% by 2042…

- The diffusion of distributed generation in the energy supply sector will promote localisation, technology transfer and job creation. It is therefore imperative that joint ventures with international partners be created to enable skills transfer and value chains to South Africa. It is also important that a manufacturing framework be developed to ensure that norms and standards are adhered to in the manufacturing process of distributed generation components and subsystems.

8.5. Environmental considerations

- South Africa has committed to reducing its Green House Gas emissions by 34% below its "business as usual" growth trajectory by 2020, and by 42% by 2042. The NCCRWP defines these targeted reductions in total emissions as the 'Peak-Plateau-Decline' (PPD) emissions limit trajectory. Although presenting a higher externality cost and the most stringent emission reduction limits, the Environmental Awareness Scenario presents significantly lower total systems costs than the Base Case. This indicates that pursuing lower emission targets is not necessarily more costly when all other factors have been considered. It is therefore proposed that the lower PPD emission limit trajectory be factored into future energy sector targets. The work currently being undertaken by the Department of Environmental Affairs to translate the total targets into sectoral targets should continue to be pursued.
- The deployment of technologies that utilise primary energy carriers with high carbon content and other pollutants should be reduced over time. Regulatory measures such as the carbon tax should be implemented to discourage future investments in these technologies, while carbon offsets and other innovative incentives such as Renewable Energy Certificates and Energy Efficiency Certificates should be explored and implemented.
- The introduction of cleaner fuel specifications (Clean Fuels 2) will improve vehicle efficiency and thus fuel consumption, which will ultimately reduce dependence on imported crude oil. Requirements for new refining capacity will be reduced and the quality of the environment will improve through the resultant reduction in pollution from vehicles.

8.6. Water usage

- The Environmental Awareness Scenario presents the lowest total water requirement of all the core scenarios. For electricity generation, implementation of new technologies such a dry-cooling in coal fired power stations and the location of nuclear plants along the coast should continue to be pursued as these assumptions have contributed to the low emissions trajectory as well as significant reductions in water consumption.

8.7. Demand-side interventions

Various demand-side levers can be considered to reduce the energy intensity of the economy. Improvements in end-use technology and fuel-switching are some of the alternatives. Different mechanisms for implementation apply to different sectors.

8.7.1. Agricultural Sector

Since 1993 the demand for energy in the agricultural sector has grown due to the change in the economic structure. There are key government policies such as the Biofuels Industrial Strategy of the Republic of South Africa and the New Growth Path which emphasise the growth of the agro-processing and agricultural sectors to support job growth in South Africa. Lastly the expected increase in temperature in South Africa will have an impact on the amount of electricity needed for irrigation within the sector, as the water requirements are likely to increase. The following initiatives will play a crucial role going forward:

- Increasing investment in technologies which promote the more efficient use of electricity for pumps in the agricultural sector is essential. Currently irrigation is responsible for 8% of total energy demand within the sector and improvements in pumps would go a long way towards saving energy.
- One of the main objectives of the Biofuel Industrial Strategy is the alleviation of poverty and the creating of jobs, especially in disadvantaged communities. During the implementation phase, effort should be taken to ensure that emerging farmers are prioritised to play a key role in meeting the targets identified. Training on energy efficiency should be integrated into training programmes for emerging farmers working as a part of the subsidy programme.

- Government should develop and implement a package of specifically designed policies and energy savings measures to promote energy efficiency. This should include promotion of high-quality and relevant information on proven practice for energy efficiency that is appropriate for emerging farmers.

8.7.2. Commercial Sector

Energy consumption in the commercial sector (i.e. both public and private buildings) has continued to increase at a rapid rate and this has become an urgent challenge for the country. This rapid increase in energy consumption by the commercial sector has been observed in many countries around the world, resulting in a special declaration at the G8 Summit, held at the United Kingdom in 2005, calling for improvement in energy efficiency. Due to the challenges of energy inefficiency in the sector, the following recommendations are made:

- The development of databases on energy consumption by both public and commercial buildings and efficiency indices for the evaluation and development of relevant policy measures such as the Energy Efficiency Strategy. The database may also be used to allocate energy efficiency targets and/or incentives for specific buildings.
- The provision of information and the granting of incentives in the sector to promote energy conservation.
- A campaign to clarify the benefits resulting from the dissemination of energy conservation technologies and the implementation of energy conserving policies. This will require specific models to verify the effectiveness of energy conservation measures.

There is significant scope for the use of alternative sources of energy, other than electricity, in the commercial sector.

… There is significant scope for the use of alternative sources of energy, other than electricity, in the commercial sector …

- Use of LPG for space heating and cooking should be advocated. Mechanisms should be put in place to ensure the deployment of LPG.

- Heat pumps should be installed in public and commercial buildings to provide for hot water requirements.

8.7.3. Industrial Sector

The South African manufacturing sub-sector is highly energy intensive and depends heavily on energy resources to provide fuel, power and steam for the conversion of raw materials into usable products. The efficiency of energy use, together with the cost and availability of energy, therefore have a substantial impact on the competitiveness and economic health of South African manufacturers. When comparing the Base Case Scenario to the other scenarios the penetration of new technology has a large impact on the future energy requirements of the industrial sector, but the high cost of investment is often communicated as a barrier to the uptake of new technologies. Affordable clean energy strategies and effective energy policies will be top priorities for manufacturers and will serve as important differentiators for highly competitive countries and companies.

- Before purchasing new efficient equipment in order to reduce overall cost, companies should implement energy system efficiency improvements which would contribute not only to the bottom line but also to improved reliability and control. Pay back periods for system optimisation projects are typically short – from a few months to three years – and involve commercially available products and accepted engineering practices. South Africa has local programmes in place where practical assistance is given to companies to implement energy system optimisation within plants (e.g. the National Cleaner Production Centre).
- Systematic energy management is one of the most effective approaches to improving energy efficiency in industries, because it equips companies with information and highlights new opportunities for improvement (IEA, 2012). An energy management system is a collection of procedures and practices to ensure the systematic tracking, analysis and planning of energy use in industry. The implementation of energy management programmes to support the monitoring of National Energy Efficiency Targets is critical to monitoring progress towards future targets.

- Currently almost 67% of energy use in the sector is for process heating, most of which is supplied by coal and to a lesser extent electricity. The industrial sector therefore presents the most significant opportunity for switching to alternative sources of energy such as natural gas. Natural gas provides a cleaner source of energy than coal and is more efficient for thermal use. The iron and steel sub-sector as well as the mining sub-sector constitute the most significant portion of demand and could be the starting point. Sectors where natural gas could be used for both energy end-use and as a feedstock to produce final product (e.g. plastics; paper and pulp; methanol and ethanol; and fertiliser) also present an opportunity for fuel switching.

… The use of rooftop PV solar panels, heat pumps and other initiatives to reduce the reliance on electricity for thermal use in households should be pursued …

8.7.4. Residential Sector

The residential sector presents different challenges for end-users across different income levels.

- For higher income households, the most significant challenge is to reduce reliance on electricity, especially for thermal application.
  - Fuel switching from electricity to other fuel sources such as LPG for thermal needs should continue to be pursued.
  - More than 65% of household energy end-use goes towards cooking and space heating. This presents a significant opportunity for switching from electricity, and investments in new housing infrastructure should be coupled with investments in piping infrastructure for gas reticulation.
  - The use of rooftop PV solar panels, heat pumps and other initiatives to reduce the reliance on electricity for thermal use in households should be pursued.
  - Projected increases in future household income will have an impact on the future ownership of appliances. Energy efficiency regulations for electrical appliances are therefore critical to ensure that the intensity of household energy consumption continues to decline in the long term.

- For low income households, the most significant challenge is to provide access to modern forms of energy and to minimise the use of solid fuel sources such as coal, wood, dung and other biomass:
  - Since household income has the greatest impact on the fuel switching potential of households from solid fuels to cleaner fuels such as LPG and electricity, subsidies for LPG in remote areas should be considered. Settlements close to industrial development zones present an opportunity for cross-subsidisation of LPG for low income households by industrial users at specific locations and various pricing structures and models should be considered.
  - Existing programmes such as the one million Solar Water Heating Programme and the Integrated National Electrification Programme (INEP) have the most impact on reducing the use of solid fuels and unsafe fuels for water heating and lighting and should continue to be pursued.
  - The Universal Electrification Strategy seeks to introduce off-grid electricity solutions to the remotest parts of the country and therefore to address energy poverty where households have no access to electricity, or where households can only afford modest quantities of electricity. Implementation of the strategy should be prioritised as part of the INEP.
  - The long-term, persistent use of solid and unsafe fuels within South African households indicates the need for an integrated household energy strategy, which should amongst other factors:
    - Outline an aggressive implementation plan to move households to cleaner forms of energy in order to minimise the negative impacts which are mostly borne by women and children in low income households.
    - Outline interventions to address issues of safety associated with a range of commonly used fuel types in the households.
    - Build on and bring together all programmes and objectives related to household energy and consider demand and supply options in an integrated manner for all household fuels.
    - Develop a long-term vision that clearly articulates the objectives for household energy transitions in the short, medium and long term.

… Energy for transport is expected to grow by between 50% and 100% over the next 36 years based on vehicle fleet structure and the resulting fuel demand for the various scenarios …

8.7.5. Transport Sector

- Energy for transport is expected to grow by between 50% and 100% over the next 36 years based on vehicle fleet structure and the resulting fuel demand for the various scenarios. The factor with the most significant impact on fuel demand is vehicle energy efficiency (or fuel economy) as evident when comparing the Base Case Scenario with any of the other scenarios. This suggests the important role of vehicle energy efficiency within energy policy in order to manage liquid fuel demand. Vehicle efficiency improvements are equivalent to providing virtual refineries but fuel quality improvements are needed to enable these more efficient vehicles.
- Vehicle efficiency and technology switching play an important role in managing transport fuel demands but they require cleaner fuels. Clean fuels therefore should be implemented as these will reduce the dependence on imported crude, reduce required refining capacity and improve quality of the environment.
- Further policies, in addition to vehicle carbon taxes and efficiency labelling, will be needed to ensure more efficient vehicle technologies are adopted. These could include policies such as corporate average fuel consumption targets and subsidies for more efficient vehicles.
- Two of the NATMAP 2050 goals are to minimise the impact of transport on the environment and reduce the carbon-footprint; and to provide energy-efficient transport, using energy sources that are sustainable in the long term. Energy policy should be supportive of this transport policy as it has the positive effect of managing demand of energy.
- For **passenger transport** the simultaneous implementation of the following policy drives should be pursued:
  - Avoidance of travelling
  - Encouraging a shift from motorised to non-motorised and green transport, especially for short distances
  - Improving the efficiency of vehicles and existing systems.
- For short distance and inner city travelling, investment should be made in buses with dedicated bus lanes as has already been implemented in some major cities.
- For long distance travelling, investment should be made in modernising the passenger rail system in order to encourage the shift from small private passenger vehicles. Measures to ensure safety and security of passengers at stations and on trains should be put in place. Adequate ticketing and marshalling systems should be deployed to minimise incidents of non-payment.

- A fiscal system that rewards the purchase of the most efficient vehicles while penalising the use of carbon intensive vehicles, similar to the carbon tax on new vehicles, should be implemented. The carbon tax alone, which is a once-off penalisation of carbon intensive vehicles, may not have the desired impact as users of such technologies may use them more extensively having already paid the tax.
- Additional variable pricing schemes, where electronic tolling systems can be used as a mechanism to either reward or penalise vehicles, should be considered.
- **Freight road transport** has high external costs and is the source of substantial physical damage to road infrastructure. It is therefore recommended that policies be developed and measures implemented to shift freight from road to rail by introducing the following:
  - Investment in freight transport infrastructure
  - High toll prices for heavy duty vehicles
  - Improved logistics systems through intelligent transport systems.

… Combined with smart technology and metering, distributed generation can form an essential part of the smart grid …

8.7.6. Other considerations

- The International Energy Agency (IEA) developed 25 Energy Efficiency Policy Recommendations (IEA: 2011). These recommendations are categorised into those that are cross-sectoral, as well as those that can be implemented in specific sectors. The IEA recommendations, in addition to those mentioned in the sections above, should be considered during the third review of the National Energy Efficiency Strategy.
- Reliable, timely and detailed data on energy end-uses, markets, technologies and efficiency opportunities in all sectors will contribute to the development of effective energy efficiency strategies and policies. The DoE should continue participating in international forums and reference international data collection methodologies (such as the IEA annual energy efficiency data template) to determine what data to collect and methods for the measurements and monitoring of energy efficiency.

8.8. Energy access

- According to the National Energy Regulator of South Arica (NERSA), distributed generation is defined as the installation of and operation of electric power generation units connected to the distribution network or connected to the network on the customer side of the meter (NERSA, 2015). Distributed generation also refers to small- and medium-scale technologies that generate electricity and heat close to the location of use, either operating independently or connected to the grid (Scarola, 2011). In contrast to the large-scale sources of power generation, distributed generation can refer to diverse energy systems that rely on renewable energy sources that are not centrally controlled by the system operator.
- Combined with smart technology and metering, distributed generation can form an essential part of the smart grid that is capable of bi-directional flow of electricity from centrally controlled power plants and distributed generators. Such grids allow for the consumption of energy from, and injection of energy into, the power grid. While these technologies may require significant investment in the short term, they do have several advantages over centrally dispatched generation. These include, shorter construction times, smaller space requirements, and fewer and cheaper bulk infrastructure requirements.
- Distributed generators are generally located closer to the demand location, thus increasing reliability and efficiency and reducing transmission and distribution losses.
- The most common technologies for distributed generation include micro-turbines, fuel cells, storage devices, photovoltaics, concentrated solar power (CSP), wind turbines, hydroelectric power, hybrid power and microgrids. These technologies have the added advantage of not emitting greenhouses gases or other pollutants during operation.
- Distributed generation systems can range in size, from several kW to over 100 MW. Small distribution generation systems are typically less than 20 kW and are designed for on-site use at the residential level. Power injection into the grid becomes an option with medium and large distributed generation systems.
- Off-grid or stand-alone systems are a viable technology to increase electricity access to isolated communities, which are generally located far from the national electricity grid and are economically unattractive to the national electrification programme which prioritises the allocation of mass resources. With the maturation of various small scale renewable energy technologies, distributed generation is a viable and cost effective alternative for electrification of such communities.

- The most widespread use of solar energy has been in the heating of water for domestic use and the provision of electricity to off grid communities in rural areas. Solar energy has also contributed to the provision of electricity for medical facilities, schools and other community establishments. The inclusion of PV in the generation mix enhances security of supply and provides a cost effective alternate source of energy.
- With the escalating price of retail electricity, PV rooftop installations have become a viable option for residential and commercial electricity consumers. It is expected that these consumers will embark on installing small-scale distributed generation to meet some or all of their electricity requirements. It is therefore imperative that national and local government entities formulate regulations and incentives for such installations.
- Several factors have been identified which if effectively implemented could promote further development of the solar industry:
  - The spatial distribution of PV across the country should be optimally configured so as to maximise availability and predictability of the aggregated output.
  - Incentive schemes for a wide-spread roll-out of off-grid PV systems should be implemented.
  - National incentive and regulatory schemes to promote deployment of SWH systems, particularly high pressure systems, should be expanded.
  - Support should be provided for training in the installation and maintenance of roof top PV and SWH systems.
  - Further investigation should be conducted to assess the business case for PV/diesel based micro/island grids to connect remote areas to electricity as an alternative to expansion of the main grid.
  - The potential for PV/diesel/battery augmentation to alleviate grid constraints in those areas that are already grid connected should be explored.
  - A programme should be implemented to retrofit government buildings – in particular to promote SWH system uptake and the use of solar thermal technology for cooling/heating.
- Funding should continue to be provided to ensure the implementation of the INEP and the Universal Electrification Strategy.
- Funding should also be allocated for the development of an Integrated Household Energy Strategy which will ensure that households which are not connected or cannot afford electricity have access to safe alternative fuels and appliances.

8.9. Research and development

Research and development is recommended in the following areas:

- Explore solar augmentation (concentrated solar heat) for existing coal-fired power stations to reduce daily coal demand, and therefore supply chain pressure and the risks of a failing coal supply chain (e.g. wet coal)
- Investigate the possibilities of (and requirements for) mass producing PV products in South Africa
- Explore innovations that can aid in the reduction of the cost of CSP
- Investigate the heating needs of industry and the use of solar thermal technology to meet part of this demand
- Explore solar/gas hybridisation to reduce gas demand and investigate the optimal energy mix for flexible gas and solar power plants
- Explore PV and solar thermal solutions for use in the mining industry and other energy intensive industrial sectors (e.g. cement)
- Target more funding at longer-term research focus areas in clean coal technologies such as CCS and UCG as these will be essential in ensuring that South Africa continues to exploit its indigenous minerals responsibly and sustainably
- Exploration to determine the extent of recoverable shale gas should be pursued and this needs to be supported by an enabling legal and regulatory framework.

8.10. Other considerations

8.10.1. Data collection

- Ongoing data collection to support evidence-based policy development and planning has long been recognised as a critical enabling factor. Organisations such SANEDI should play a significant role by partnering with the Department to collect data on energy technologies and conduct studies which provide information on the development and characteristics of future energy technologies. Such studies should include:
  - An impact analysis of the effect of different policy interventions on the development of technology
  - An impact analysis on the energy efficiency savings potential of different technologies
  - More in-depth analysis on the cost curves, scrap curves and residual capacities of various technologies.

… The energy sector of the future should be one wherein energy security is not interpreted in a narrow sense, but is defined in broad terms to take into account broader national aspirations and sustainability…

8.10.2. Development of capacity within the Energy Sector

- Collaboration with energy research institutes is essential in order to develop much needed human capacity in the sector
- While sponsorships through bursaries are currently provided to students, an internship programme which enables graduates to spend a year working with an energy company or in the energy services division of a company should be developed
- As part of addressing the challenge presented by the dearth of data (mentioned above), a formal qualification in energy statistics should be developed in conjunction with tertiary institutions and relevant international organisations such as the IEA, International Energy Forum and the United Nations Statistics Division. This would make energy statistics an attractive field, specifically for the younger generation. Moreover, it would boost capacity in the field of energy data collection, management and statistics, which is currently experiencing a global 'brain drain' due to most of the experts reaching retirement age.

8.10.3. Co-ordinated policy development and planning

The policy and planning functions within the DoE need to be clearly defined. The roles of the various plans developed, namely the Integrated Energy Plan, Integrated Resource Plan, the Liquid Fuel Roadmap and the Gas Utilisation Masterplan need to be well defined. The Integrated Energy Plan should provide the overall energy sector landscape of the country; should identify policy and regulatory vacuums and make recommendations; should guide the energy mix across all energy sub-sectors; and should propose capacities and indicative timing of new infrastructure development. The sector-specific plans should provide in-depth information on infrastructural matters, such as assessing the potential location for new plants, testing capacity adequacy etc., and directives to guide the implementation thereof.

8.10.4. The role of government agencies established by the Minister of Energy

The split of the Department of Minerals and Energy into the Departments of Mineral Resources and Energy created ambiguity in the reporting lines and accountability with regard to cross-cutting energy and minerals issues. The strategic role of government agencies established by the Minister of Energy needs to be enhanced and the mandate of the various entities needs to be strengthened. Where relevant, enabling or supporting legislation should be developed or reviewed in order to ensure that the governance frameworks that enable these entities to operate optimally are in place.

8.10.5. Integrated planning across all spheres of government (provincial and local government)

- The linkages and feedback loops between national, provincial and local government energy planning should be strengthened.
- The DoE has identified the need to have representation from local government in its governance structures through SALGA. SALGA should continue to participate and provide feedback through relevant local government structures.
- Likewise, representation of the DoE is essential in the provincial and local government structures. Co-ordination with provincial and local government structures should be facilitated through the DoE's Regional Offices.

The energy planning process has sought to paint a picture of the envisaged energy sector landscape of the country. While the plan has focused on long-term energy options, short-term challenges remain and are addressed through different structures and programmes.

The energy sector of the future should be one wherein energy security is not interpreted in a narrow sense, but is defined in broad terms to take into account broader national aspirations and sustainability. It is a future in which energy security is commonly interpreted as ***"ensuring that diverse energy resources, in sustainable quantities and at affordable prices, are available in support of economic growth and poverty alleviation, taking into account environmental management requirements and interactions among economic sectors".***

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