DEPARTMENT OF ENERGY

DRAFT 2012 INTEGRATED ENERGY PLANNING REPORT

ANNEXURE A – TECHNICAL REPORT

PART 1: DEMAND MODELLING REPORT

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1. Introduction

The South African energy economy can be grouped into five broad energy demand sectors: agriculture; commerce and public services; industry (including mining); residential; and transport. The share of total final energy consumed by each sector is shown below in Figure 1-1. In South Africa, most energy is consumed by the industrial and mining sectors (~41%), followed by the transport sector (~27%), households (~20%), commerce (~8%) and agriculture (~3%). A small quantity of energy is converted into other products such as chemicals (these are referred to as "Non-energy end use" in Figure 1-1).

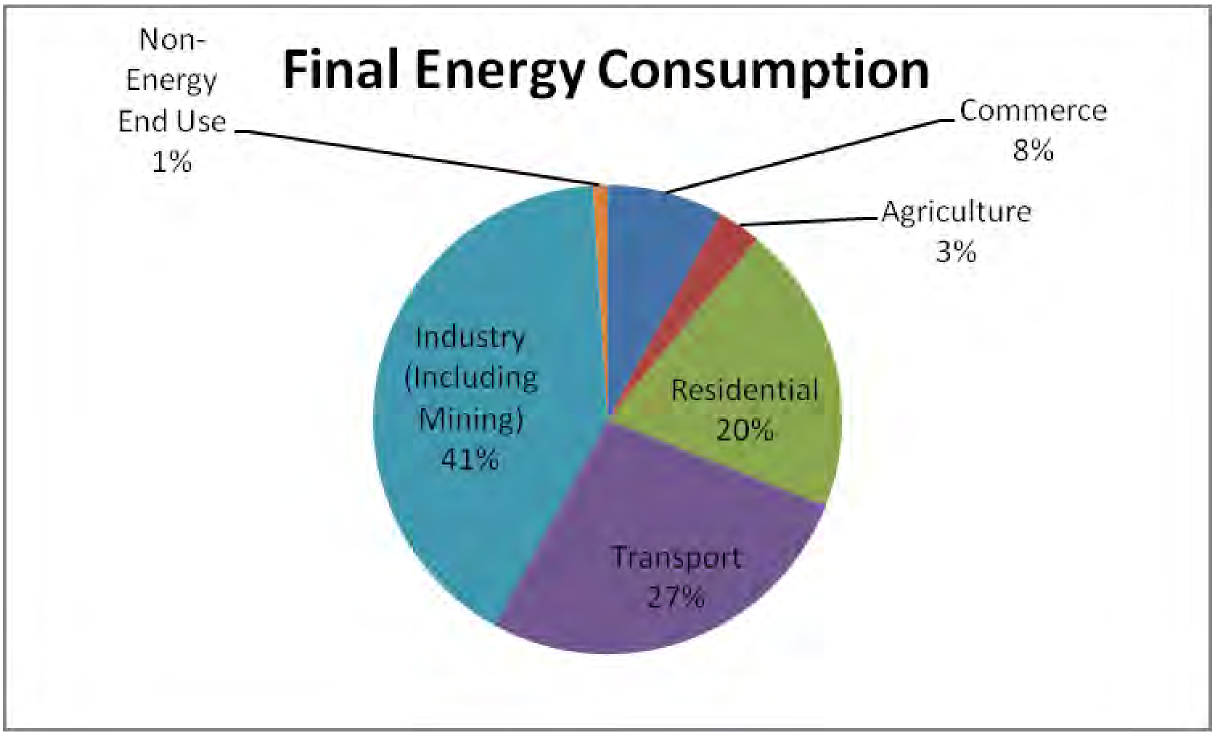

Figure 1-1: Final Energy Consumption (Source: DoE, 2009)

This document describes the demand modelling approach; provides key inputs and assumptions; and discusses the demand projections for the various sectors considered during the energy planning process.

1.1 Scope

The economy of a country can be described broadly through three main categories, namely: primary, secondary and tertiary sectors. The primary sector makes 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 provision of services. The economic grouping is based on the economic activities of the various sectors, and is therefore effective in quantifying and analysing the economic value-add of each of the sectors. However, in

order to effectively quantify energy consumption within each of the economic sectors, a grouping aligned to energy end-use becomes more constructive. While energy demand can be closely linked to economic activity, this approach also becomes effective in quantifying energy demand in those sectors whose productivity may not always have a high level of correlation with energy demand (for example energy consumed in offices and public buildings).

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

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

2. Demand Modelling Approach

The two traditional approaches which are used in projecting demand for energy are econometric and end-use accounting. A brief description of each approach is as follows:

- Econometric models are based on economic theory and try to validate the economic rules empirically using time series data.
- End-use accounting demand models attempt to establish accounting coherence using a detailed engineering representation of the energy system.
- Combined or hybrid models attempt to reduce the methodological divergence between the econometric and engineering models by combining the features of the two techniques.

The aim of econometric analysis is to establish a quantitative relationship between the dependent variable and the independent variable by statistical analysis of historical data. By using the projected values of the independent variable, the derived relationship is then used to determine the future value of the dependent variable.

While the end-use energy accounting demand models allow a detailed sectoral representation of the different uses of energy and hence produce more realistic projections, when compared with econometric models, these models are highly data dependent and require significant and low-level data which is not often readily available (Battacharyya et. al, 2009).

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 (agriculture, commerce, industry, mining, residential and transport), due to paucity of energy consumption data at an energy end-use level, demand projections were conducted for the energy demand sectors as follows:

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

2.1 Activity Variables

Within energy demand modelling, the independent variable is represented by an activity variable which often is an indicator or measure of economic activity or output within the various economic sectors. While the ideal activity variable is the level of production or output within the various sectors, the final choice of activity variable was informed by the availability of the relevant data. Table 2-1 below provides a mapping of economic sectors to energy demand sectors, with the key activity variables used within the respective sectors in the last column.

Table 2-1: Activity Variables

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

3. Modelling Assumptions

3.1 Key Drivers of Energy Demand

How much and what kind of energy service is demanded depends on various factors such as: climate, size of dwellings, number of people per dwelling, floor area of service sector buildings per unit of service sector output; share of energy-intensive products in manufacturing output; tonne-km of transported goods per GDP; average distance travelled per capita; and the share of different modes of transport activities, amongst other factors (IEA, 2012). These factors are themselves influenced by exogenous elements which are briefly discussed in the following sub-sections. While each of these elements can be further analysed, the intention is to provide a very high-level overview of each.

3.1.1 Population Dynamics

Population growth affects the quantity of energy consumed, while the general standard of living of a population determines the composition of the energy services demanded. Other demographic factors such as the average age of the population, affect both the level and pattern of energy use. Older people, for example, tend to travel less for work and leisure. The rapid growth of cities and towns in the developing world is often accompanied by a decline in the growth of the rural population. The rate of urbanisation therefore remains an important determinant of energy demand, as city and town dwellers in the developing world tend to have higher incomes and better access to energy services than people dwelling in rural areas. Strong buying power and the resultant increase in ownership of household goods and appliances tend to propel the increase in energy consumption.

The chart below shows the urbanisation pattern in world since 1950 indicating that even in Africa more people will be living in urban areas in 2050 than was the case 100 years earlier.

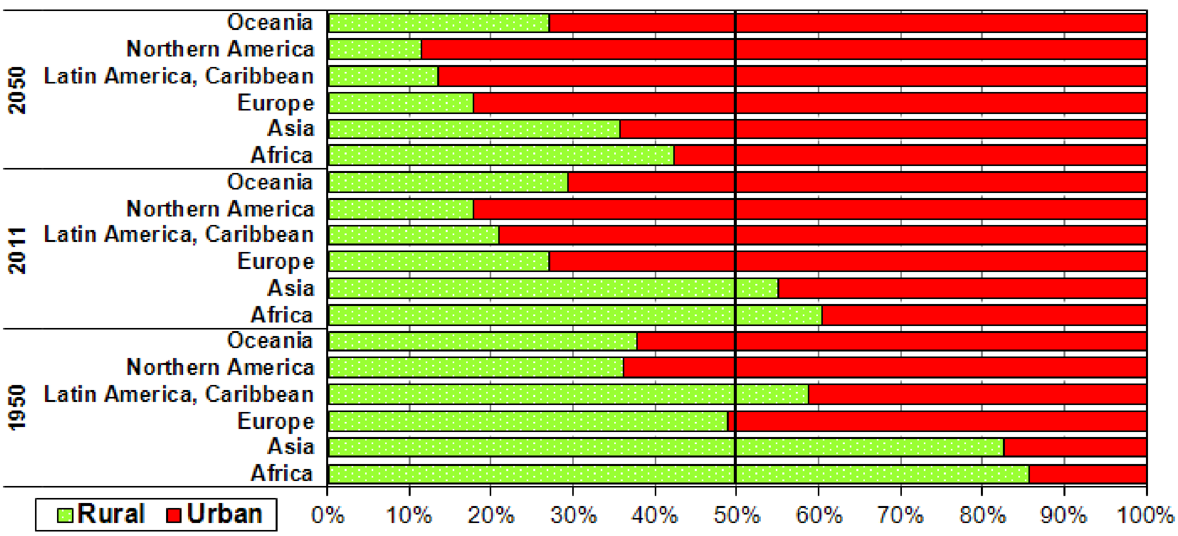

Figure 3-1: Proportion of Urban and Rural Population by Development Regions 1950, 2011 and 2050 (Source: United Nations, 2011)

3.1.2 Economic Growth

Economic growth is by far the most significant indicator of the overall demand for energy services, with energy consumption having a positive correlation to economic activity although typically at a lower rate.

Economic activities in the primary sector tend to be more energy intensive compared to those in the secondary and tertiary or services sectors, with the tertiary sector being the least energy intensive. The structure of the economy and changes thereof have an impact on the energy-intensity of the economy and therefore on final energy demand.

Mobility (for both the movement of people and goods) is a key component of economic growth and transportation demand therefore tends to increase substantially with economic growth.

3.1.3 Energy Efficiency

Improved energy efficiency has an impact on energy demand and has been the main reason why final energy use has been decoupled from economic growth in most economies.

Energy efficiency improvements are however often fuelled by other factors, for example, high energy prices may provide an incentive for the use of more energy efficiency equipment and appliances, or even switching to alternative energy sources.

Technological developments and the adoption of technologies that are more efficient, methods and processes can have significant impacts on reducing total energy consumption. Better use of different energy sources – i.e. using the most appropriate forms of energy for the intended application or energy end-use, results in overall reduction in energy intensity.

Non-price factors which have an impact on energy efficiency are often introduced through appropriate policy and standards which generally promote the adaptation of more efficient equipment, appliances and methods.

3.1.4 Energy Prices

Energy prices have an impact on final energy demand and in particular on the choice of fuel used to provide a particular energy service. However while the impact of energy prices (especially in a developing economy such a South Africa) is a factor influencing final energy demand, determining the impact of increases in energy prices is difficult to quantify and it is itself a changing variable highly influenced by many other factors.

The choice of primary energy source and energy technology used to provide secondary energy both have a high bearing on the final price of energy. However, additional factors such as the pricing of

CO_2 emissions into the final energy price come to play and affect investment decisions in the energy sector by altering the relative costs of competing fuels.

3.1.5 Climate

Local climate and weather patterns have a significant impact not only on the quantity of energy demanded, but also on the form of energy demanded. With the onset of climate change, energy consumption patterns are likely to be highly impacted.

3.2 Macroeconomic and Demographics Assumptions

While the previous section outlines some of the key drivers for energy demand not all the possible factors that influence energy demand have been considered. This section provides the assumptions on the key demand drivers which were considered. Efforts to include more explanatory variables in the demand projections in order to enhance the demand projections are on-going.

3.2.1 Gross Domestic Product and Gross Value-Added per Sector

The Gross Domestic Product (GDP) is one of the primary indicators of a countries economic performance and has been widely used as a proxy to estimate energy demand. Historical GDP figures were obtained from Statistics South Africa, while projections of the domestic average potential economic growth for the country were provided by the National Treasury. The projections of domestic average potential economic growth provided by National Treasury were then used to derive the estimated average potential growth or value-added for the primary, secondary and tertiary sectors.

As mentioned above, the primary sector of the economy is the sector of an economy making direct use of natural resources and includes agriculture, forestry and fishing, mining, and extraction of oil and gas. The secondary sector includes those industries or sub-sectors responsible for producing manufactured and other processed goods, while the tertiary sector includes all economic sectors which provide various services. As illustrated in Figure 3-3 below, over the last 30 years the contribution of the primary and secondary sector towards total GDP has declined while that of the tertiary sector has continued to grow. This trend is projected to continue into the future.

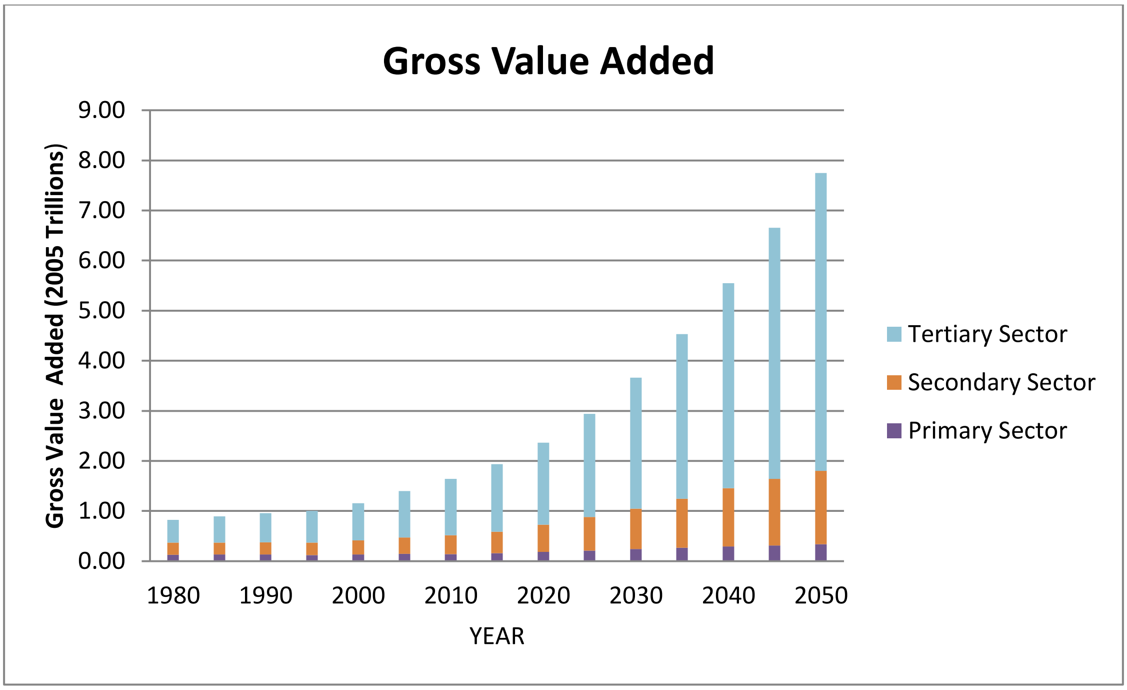

Figure 3-2: Gross Value Added (Source: Historical Data (1980-2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

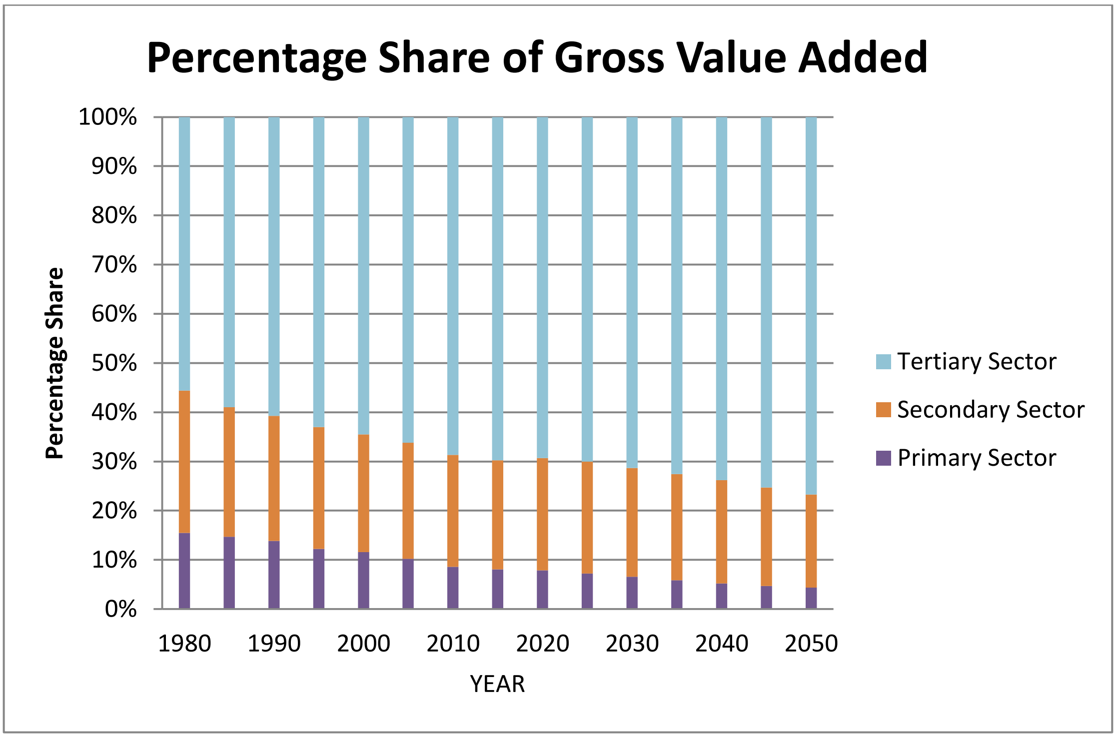

Figure 3-3: Percentage Share of Gross Value Added (Source: Historical Data (1980-2010), Statistics South Africa; Projected Values (2010-2050), Model Output,)

The electricity demand for industrial, commercial and agricultural sector was derived directly from the GDP growth figures provided by National Treasury. In contrast the projected gross value added for the secondary sector was used to estimate future fossil fuel demand for in the industrial sector,

while projected gross value added for the tertiary sector was used to derive future fossil fuel demand for the commercial sector.

3.2.2 Gross Value Add – Agricultural Sector

Historical values for gross value added for the agricultural sector were obtained from Statistics South Africa while projected values were estimated based on the historical contribution of the agricultural sector to GDP. The projected values were used to derive total final fossil fuel demand for the agricultural sector and are shown in Figure 3-4.

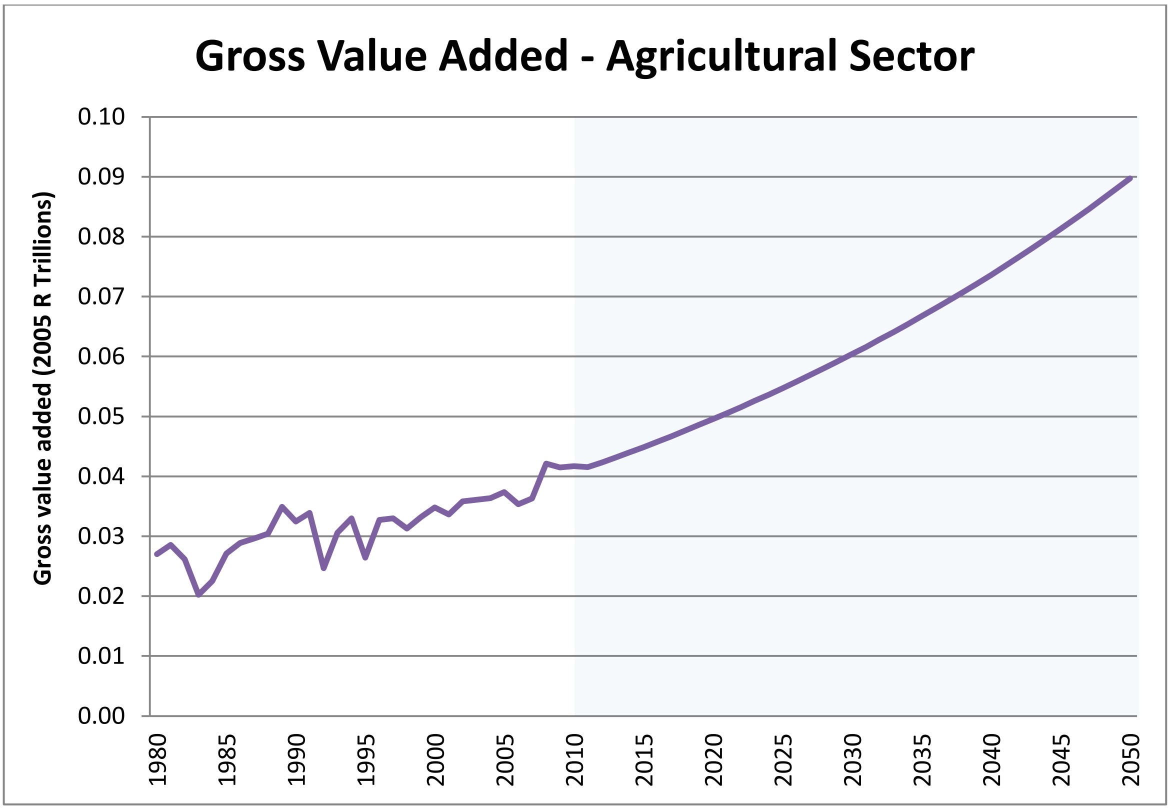

Figure 3-4: Gross Value Added in the Agricultural Sector (Source: Historical Data (1980- 2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

3.2.3 Iron Ore Production

Iron and steel (representing almost 95% of all metals used per year globally) are the world's most commonly used metals, with iron ore as the key component. World production of iron ore averages around two billion metric tons of raw ore annually. In 2010, South Africa produced 55 million metric tons ranking seventh in the world and being responsible for just over 2% of the world's production, of iron ore.

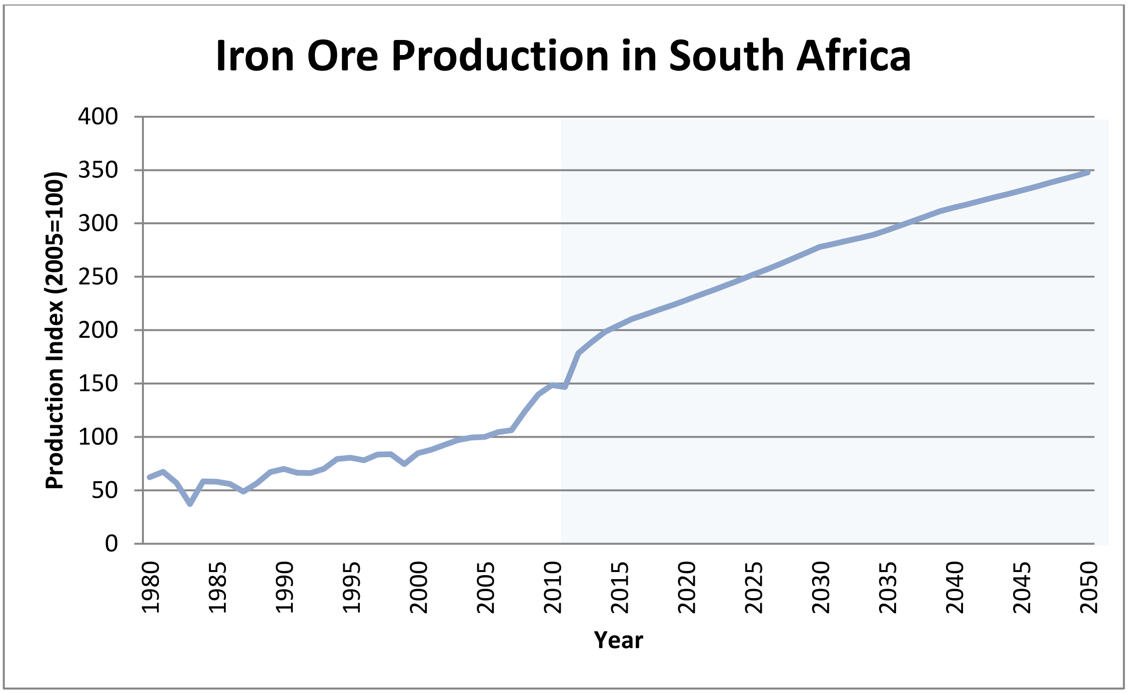

Figure 3-5: Iron Ore Production in South Africa (Source: Historical (1980-2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

As illustrated in Figure 3-5 above from 1980 to 2010 iron ore production in South Africa has more than tripled and going into the future iron production is expected to continue increasing albeit at a slower rate. The projected iron ore production in South Africa was used to estimate future fossil fuel demand in the iron and steel sector.

3.2.4 Per Capita GDP

Per capita GDP - calculated as the total GDP divided by the total population - has been commonly used as an indicator of standard of living. Although not a measure of personal income, a higher per capita GDP is generally interpreted as an indication of a higher standard of living as compared to a lower value. In 2010, South Africa's per capita GDP was R53 238. The projected GDP per capita has been used to estimate future demand for passenger transportation for South Africa.

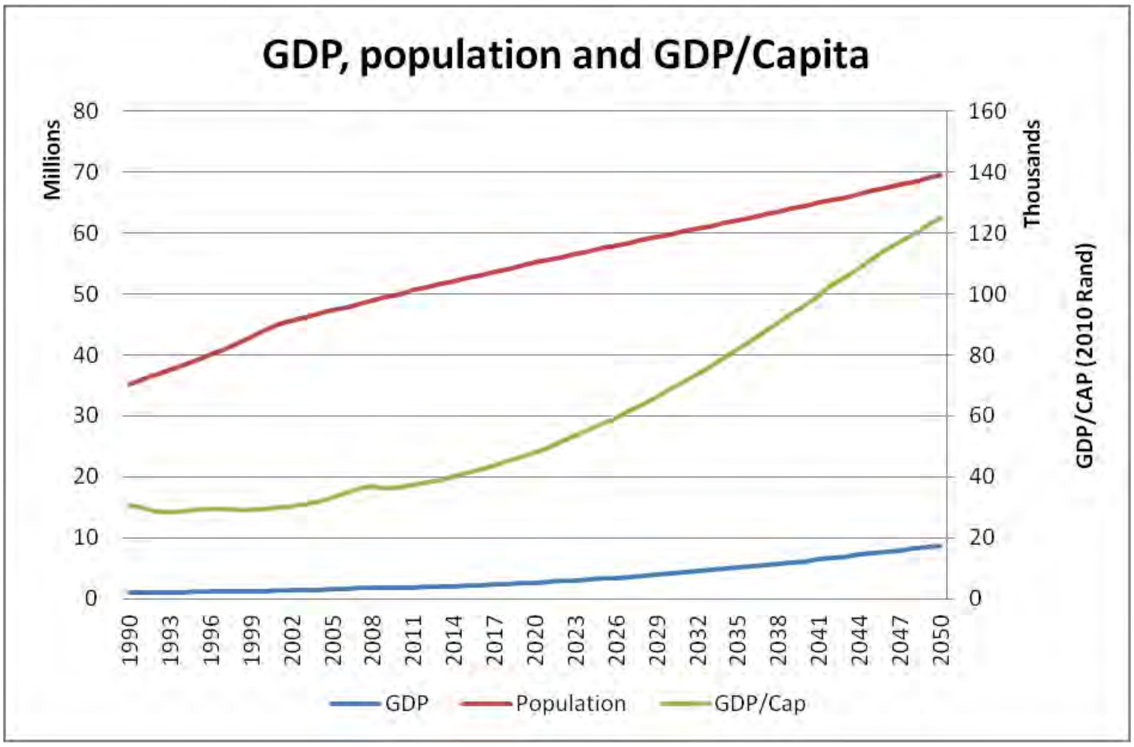

Figure 3-6: GDP per Capita (Source: Historical Data (1980- 2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

3.2.5 Number of Persons per Household

The number, size and structure of households in South Africa have undergone a dramatic change since 1996. While the total number of households in South Africa has increased from an estimated 9, 059, 571 in 1996 to 14, 756, 000 in 2011, the average household size has declined from about 4.48 in 1996 to 3.4 in 2011. Similar trends are seen in other developing countries as they transition into a developed country over time. The average number of persons per household, together with the estimated population growth in the future, was used to derive the estimated number of households.

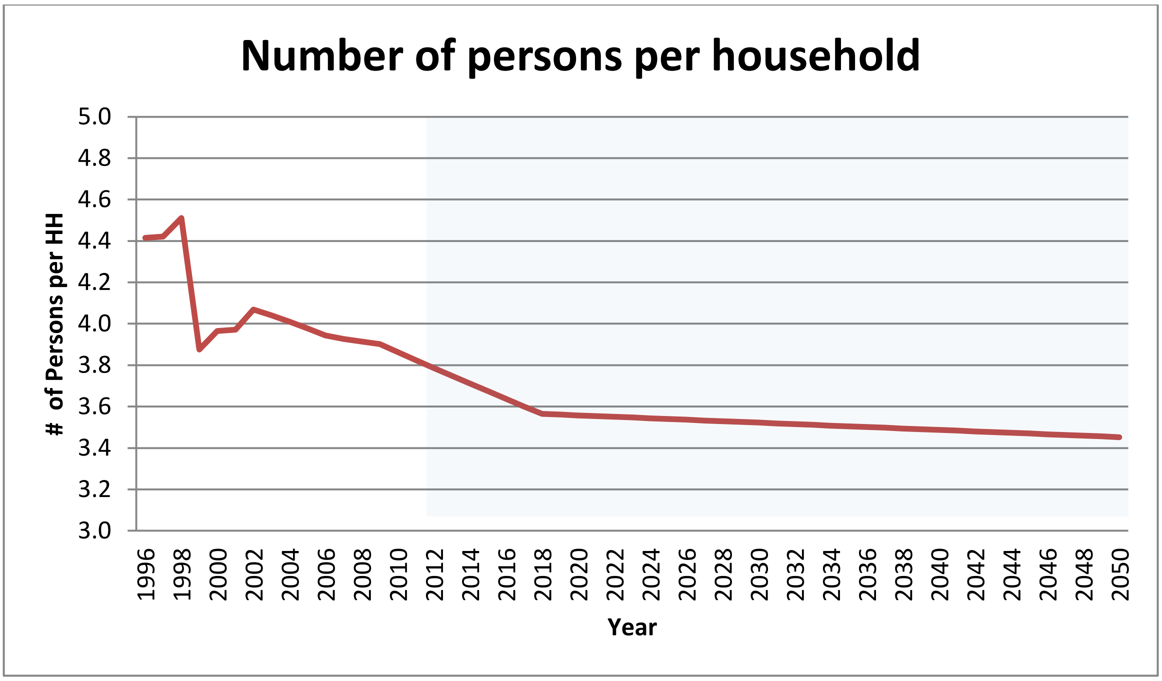

Figure 3-7: Number of persons per household (Source: Historical (1995- 2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

3.2.6 Percentage of Households with grid connection

Universal access to modern forms of clean energy is a strategic objective of the Department of Energy. Electrification is a cornerstone of social upliftment and has been proven to positively contribute to South Africa's developmental goals. More than 5.6 million grid connections have been made between 1994 and 2012 as a result of Government's National Integrated Electrification Programme (INEP) managed by the Department of Energy. In the period from 2002 to 2013, a little over 65 000 households were supplied with non-grid technologies such as solar home systems as part of the non-grid electrification programme. According to the General Household Survey 2011, the percentage of households connected to the grid has increased relatively consistently from a little over 76% in 2002 to just fewer than 83% in 2011 (Statistics South Africa, 2012).

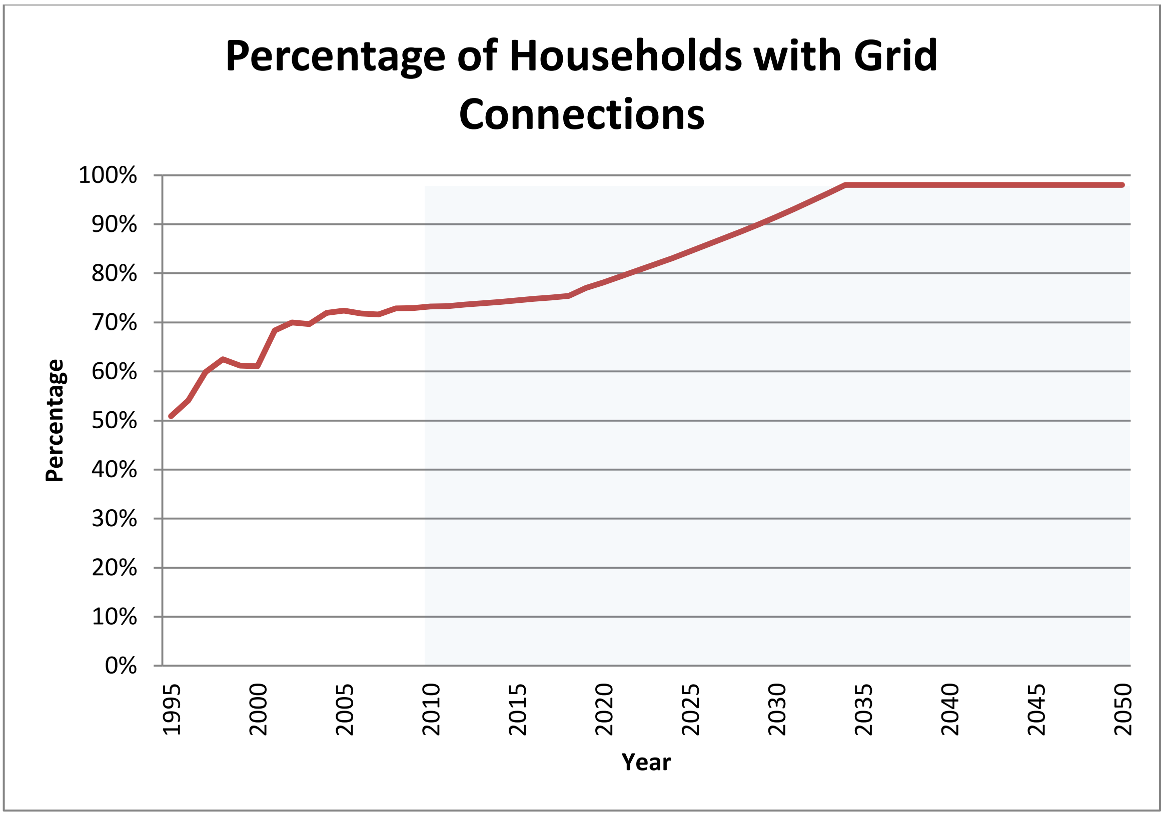

Figure 3-8: Percentage of household with grid connections (Source: Historical (1995 - 2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

The percentage of households connected to the grid is expected to grow up to an estimated 98% by 2033. The percentage of households is not expected to quite reach 100% due to technical constraints and the associated infrastructure costs. However universal access to electricity can be accomplished through the implementation of off-grid solutions and non-grid solar home systems.

3.2.7 Number of Households

A combination of population growth and changes in the average household size (i.e. number of people living in a single household) determines the total number of households in the future. In the recent General Household Survey of 2011 South Africa has 14 756 000 households with Gauteng containing the largest number of households followed by KwaZulu Natal, Eastern Cape and Western Cape (Statistics South Africa, 2012b). Northern Cape, the least populous province, has the smallest number of households. Residents of Gauteng, North West and Western Cape were the most likely to live in informal dwellings, while Limpopo households were least likely to inhabit informal dwellings. As energy demand in the residential sector is best estimated for households rather than individuals, the projected number of households was used to estimate future final energy demand for the residential sector. Furthermore, the projected number of households connected to the grid provides a basis for estimating future electricity demand; while the projected number of households

not connected to the grid provides a basis for estimating demand for other energy carriers other than electricity in households.

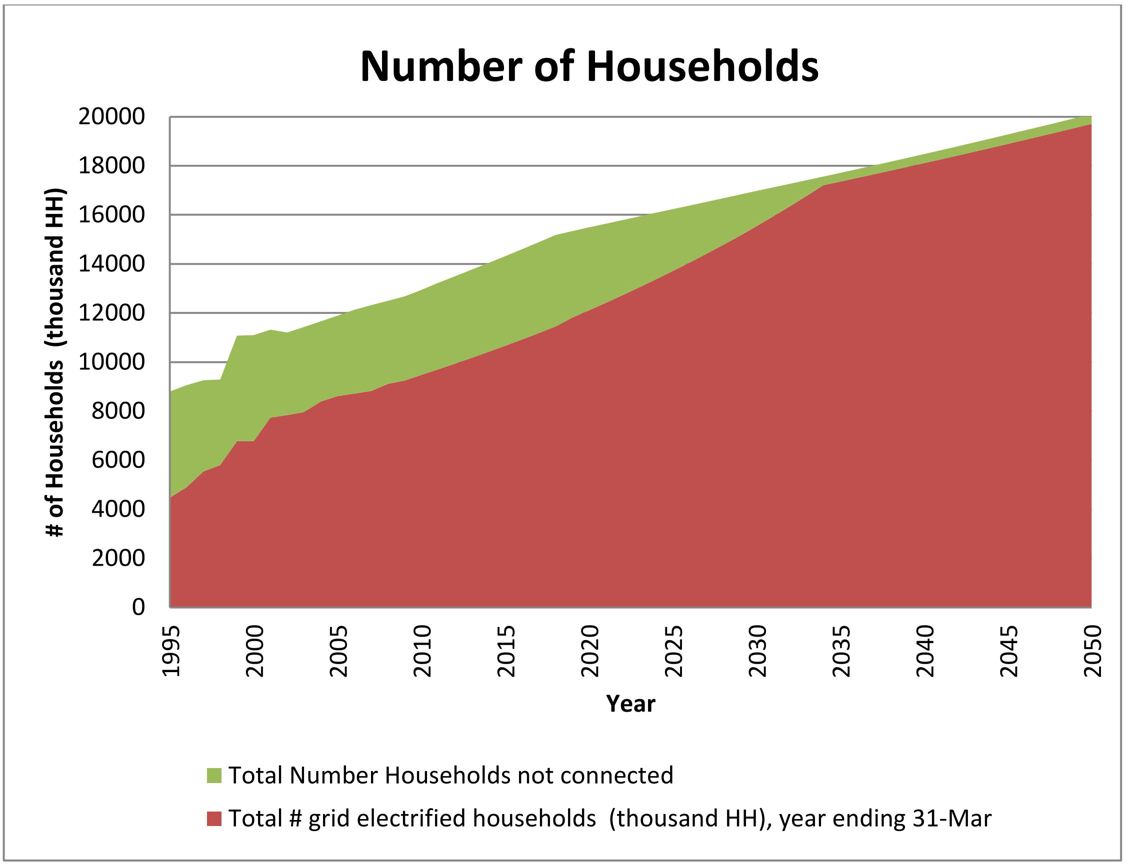

Figure 3-9: Number of households (Source: Historical (1995- 2010), Statistics South Africa; Projected Values (2010-2050), Model Output)

3.3 Main Sources of Historical Data

The main data sources are as outlined in the table below:

Table 3-1: Main Sources of Historical Data

	DATA SET	SOURCE
Macroeconomic data	Gross Domestic Product and Gross Value Added	Statistics South Africa, 2012c
Energy Consumption Data	Electricity, Coal, Diesel, Natural Gas, LPGas, Residual Fuel Oil, Illuminating Paraffin	Department of Energy, 2009
	Residential coal consumption	Department of Energy, 2012a
Energy end-use data	Electricity end use all sectors	Eskom IDM, 2012
	Coal, Natural Gas end use for industrial sector and agricultural sector	Institute for Energy Studies, 1992
	Coal, Illuminating Paraffin, Diesel, Residual Fuel Oil, LPGas end use for residential and commercial sector	Energy Research Centre, 2013
	Diesel, Coal end use for mining	US Department of Energy, 2007

Demographic data	Total number of households and total population	Statistics South Africa,1998, 2003, 2007,2012a,2012b, 2012d
	Electrification rates for households	Statistics South Africa, 1998, 2003,2007, 2012a

4. Industrial Demand Projections

South Africa is a highly energy intensive economy. According to the 2012 Energy Sustainability Index developed by the World Energy Council, the energy intensity of South Africa is 0.05 million BTU per USD. The Industrial sector which comprises of mining, iron and steel, chemicals, non-ferrous metals, non-metallic minerals, pulp and paper, food and tobacco, and other manufacturing consumes ~41% of the final energy demand in the country. The largest of these is iron and steel which consumes ~27% of the total energy used by the industry sector. Mining consumes ~26% of the energy used in industry. Key drivers for potential changes in energy demand trends in the industrial sector will include structural changes within the economy as South Africa moves towards a low carbon economy and the tertiary sector grows; an increased focus on climate change and emissions associated with energy end-use; increases in energy prices and adoption of less energy-intensive technologies and practices.

4.1 Chemical Sector

The South African chemical industry is dominated by local companies which developed from the industry's historical base in explosives for the mining industry, followed by the development of nitrogen based fertilizers and sulphuric acid. The chemical sector of South Africa is an integral component of the economy, converting various raw materials (e.g. petroleum, natural gas, minerals, coal, air and water) into more than 70,000 diverse products. In South Africa the chemical sector is a key component of the country's industrial base with a contribution of R318 million to the GDP in 2011, which is about 21% of total manufacturing sales (Statistics South Africa, 2012c). As shown in Figure 4-1 close to 68% of total energy requirements in the chemical sector were met using fossil fuels with coal accounting for the majority.

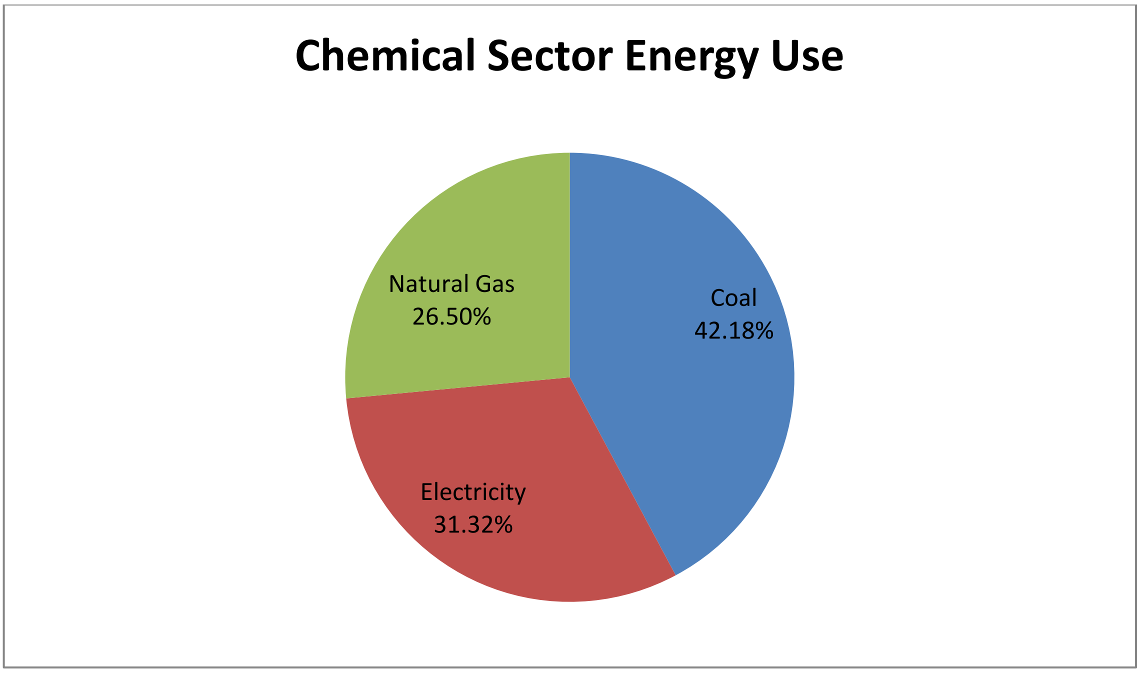

Figure 4-1: Chemical Sector Energy Use (Source: DoE, 2009)

4.1.1 Energy End Use

Figure 4-2 below shows end use attributed to both fossil fuels and electricity. From an energy perspective the main step chemical manufacturing involves combining feedstock to achieve specific chemical reactions followed by separating out the desired product. For example within the pharmaceutical industry the primary step produces the active ingredient which is followed by secondary processing to turn the active drugs into products suitable for administration (Kema, 2012). Energy is consumed in chemicals manufacture to provide process heating, industrial cooling to power motor-driven systems and for other purposes. The chemical industry is diverse ranging from plastics to pharmaceuticals hence energy usage within individual sub sectors is closely tied to product configurations as well as whether or not fuels are used as a raw material (feedstock). For example, inorganic chemicals are produced from a variety of feedstock with methane for the fertilizer industry, air for the production of main industrial gases, and minerals for the production of acids and bases (Kema, 2012). Hence the proportion of energy attributed to different end use is an average for the chemicals industry and may not reflect sub-sector differences.

As shown in Figure 4-2 technologies which process heat particularly used for fluid heating represent the bulk of energy use in chemicals manufacture at approximately 88%. These include steam systems, fired systems such as furnaces and reboilers. Motor systems which include motor driven units such as pumps, conveyor belts, compressors, fans, and mixers as well as grinders and other material handling or process equipment rank second with just over 7% of total energy end use.

Energy use attributed to running an office (other electrical equipment, lighting, water heating, HVAC) contribute a small fraction at just under 1%.

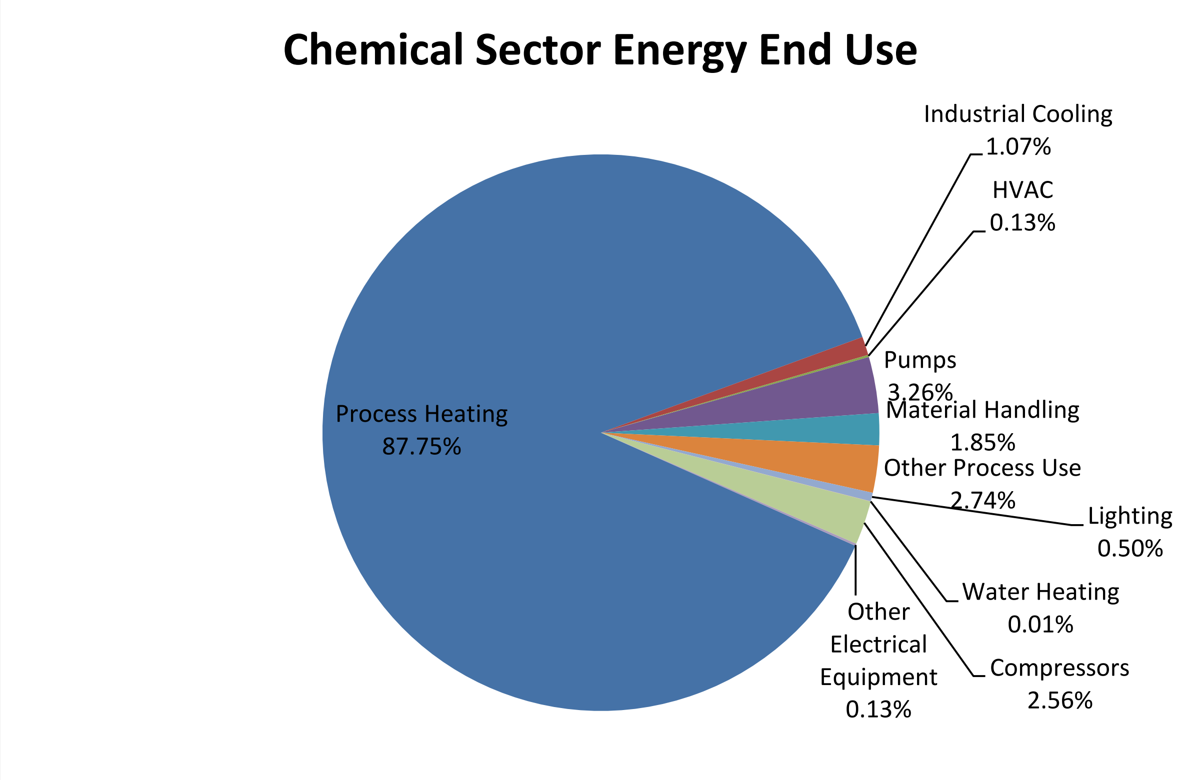

Figure 4-2: Chemical Sector Energy End Use (Source: DoE Analysis)

4.1.2 Electricity End Use

While the use of fossil fuels is assumed to primarily go towards process heating (which includes direct fuel for boilers) the use of electricity within the chemical sector is diverse and is outlined in detail in Figure 4-3. Motor systems (compressors, pumps, material handling) comprise approximately 60% of electricity use within the chemical sector. Pumps can be used in the transference of fluids across the processing plant while compressors are used for refrigeration purposes as well as pressurised air for control systems such as pneumatic valves. Other process use which encompasses just over 21% of total electricity end use may include electricity used for electro-chemical processes which involves energy used in systems that convert raw inputs to products through an electrochemical reaction. Given that motor systems comprise the largest electric end use within the chemical industry, exploring related efficiency measures presents the best opportunity for reducing demand as well as reducing operating costs associated with energy.

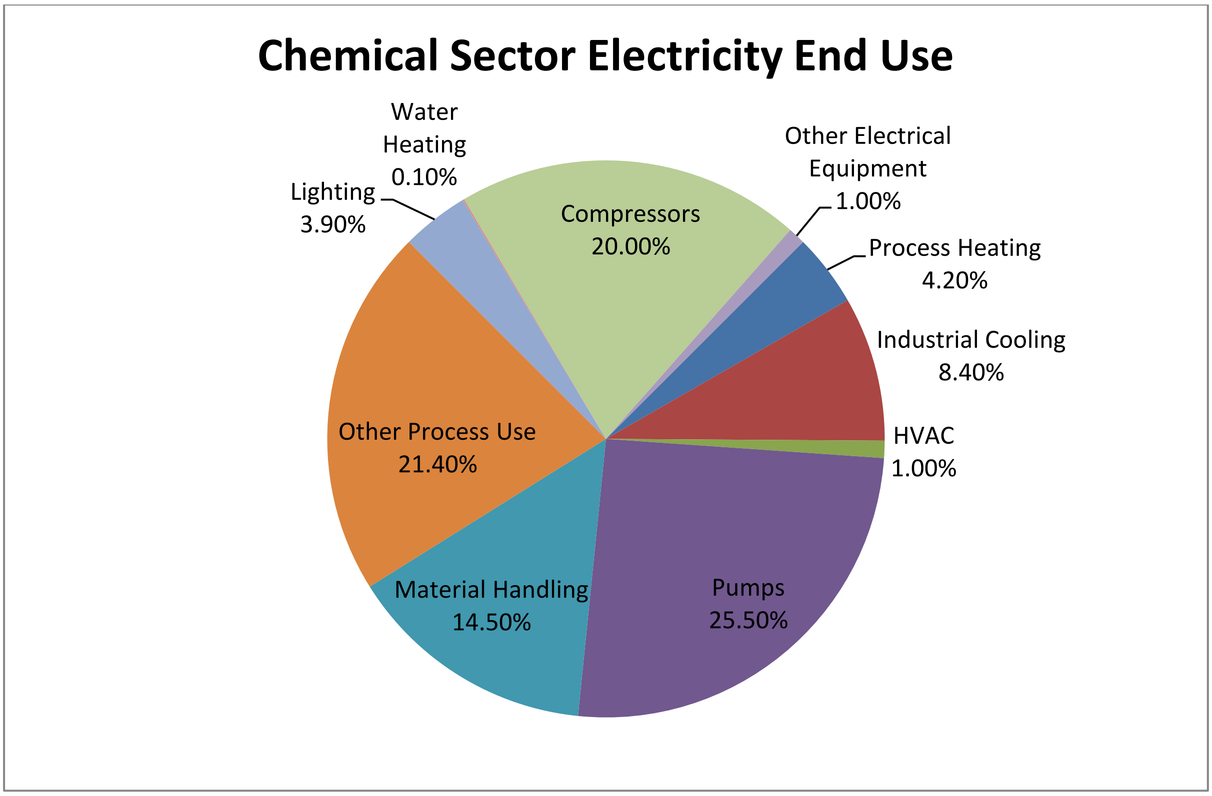

Figure 4-3: Chemical Sector Electricity End Use (Source: Eskom IDM)

4.1.3 Projected Demand

Chemical products are critical components of consumer goods and are found in everything from automobiles to plastics and electronics. The historical demand for fossil fuel consumption in the chemical, nonferrous and other manufacturing sector was analysed against value-added within the secondary sector. The future demand for energy within the chemical sector was then projected using the relationship between the historical values. The fuel mix represents the share of various fuels such as coal, oil, natural gas, heat, and electricity that make up the final energy use. Historically the fuel mix for the chemical sector has been dominated by fossil fuels. Overall total energy consumption in the chemical sector increases despite the decline in coal consumption. The decline in coal consumption in the chemical sector is a recent trend seen in the last few years.

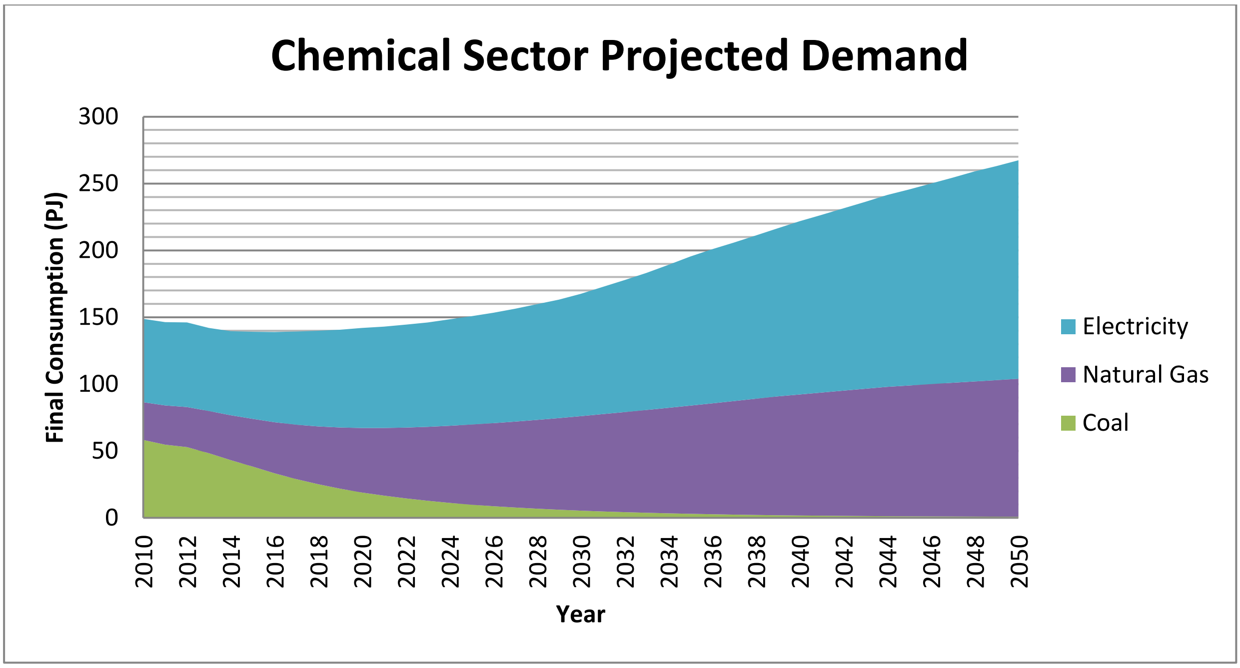

Figure 4-4: Chemical Sector Projected Demand (Source: Model Output)

The largest growth in demand is experienced in natural gas consumption which grows from 2010 to 2050 and fills the gap left by the decline in coal. Over the same time period electricity consumption grows albeit slower than natural gas.

4.2 Iron and Steel Sector

Steel is an integral part of the South African infrastructure providing the foundation for consumption (bridges, buildings) transportation systems (railroads, cars, trucks) and utility systems (municipal waste systems, power systems). It is also the material of choice for such diverse applications as military equipment, food storage, appliances and tools. Manufacturers and end users of low intensity steel products consume approximately 85% of South African steel. As shown in Figure 4-5 the bulk of steel products are consumed in the construction sector at 40% followed by the automotive sector at 11%.

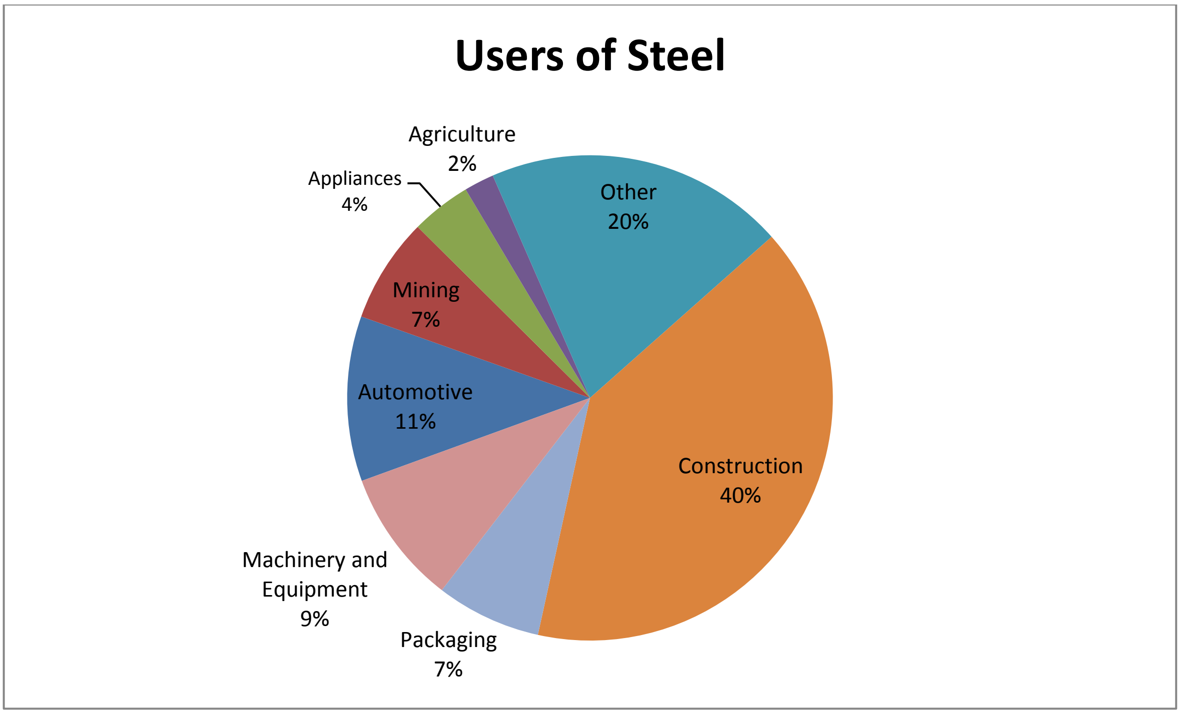

Figure 4-5: Users of Steel (Source: Kumba Iron Ore and Anglo American, 2011)

Globally there are three routes for producing final steel products (IPCC, 2007). The first route is the integrated steel mill which uses a blast furnace to produce molten iron from iron ore, coal, coke and fluxing agents (IPCC, 2007). A basic oxygen furnace is then used to convert the molten iron ore, along with up to 30% steel scrap and alloys into refined steel. The second route is the mini mill whereby recycled scrap is melted in electric arc furnaces and further processed into final products (IPCC, 2007). The market for providing scrap substitutes for companies using the electric arc furnace route and the South African scrap industry is very well developed. In addition to satisfying local demand (2.8 mt in 2008) local companies exported scrap amounting to 0.1mt in 2008 (Kumba Iron Ore and Anglo American, 2011). Though both processes are energy intensive, integrated steelmaking requires greater amounts of energy per ton of product than the mini mill route. As certain steel qualities require the use of virgin materials, and as there are constraints on the supply of economically available steel scrap, both integrated steelmaking and mini mill steelmaking are required and are not direct substitutes for one another. The third route involves using natural gas to produce direct reduced iron (DRI) (IPCC, 2007). In 2010, iron production in South Africa was split between blast furnaces (58%), direct reduced iron production (18%), electric furnaces (15%) and other Corex (9%) (South African Iron and Steel Institute, 2012). Given the dominance of blast furnaces and direct reduced iron production energy consumption in the iron and steel sector is dominated by fossil fuels with ~60% of energy needs being met by coal and ~12% being met by natural gas. As seen the Figure 4-6 the balance of ~28% is met by electricity and this is due to the electric arc furnaces used within the industry.

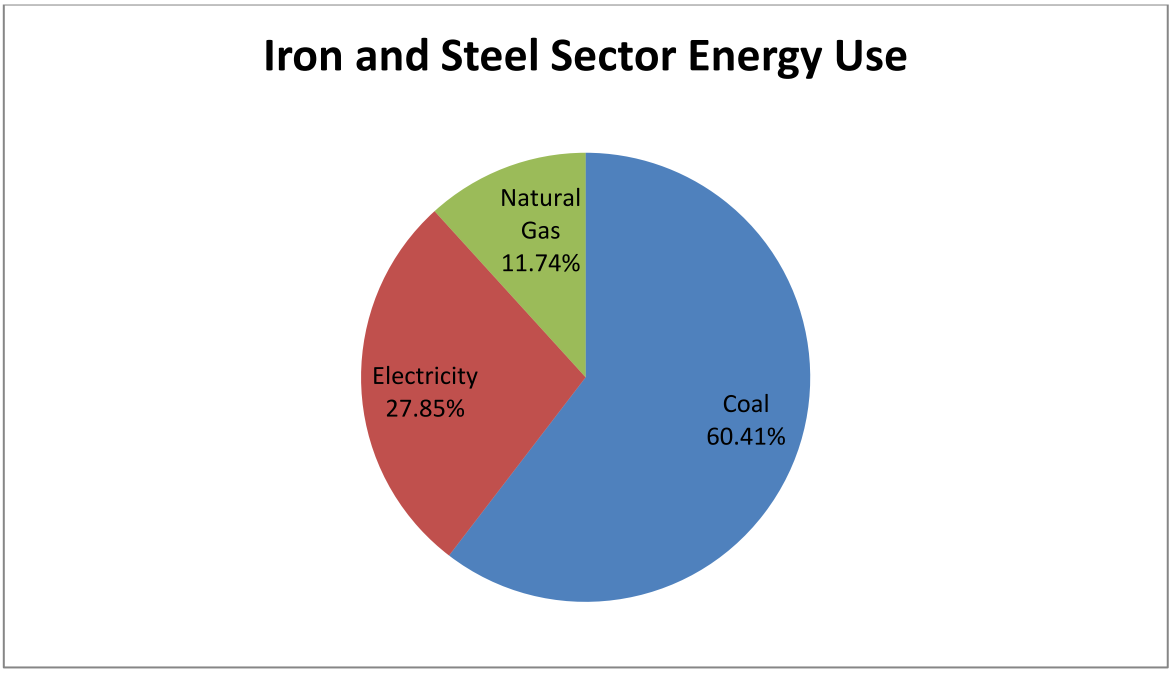

Figure 4-6: Iron and Steel Sector Energy Use (Source: DoE, 2009)

4.2.1 Energy End Use

Energy is consumed in the manufacture of iron and steel to supply process heating (reduction of ferrous oxide, melting, reheating), to power motor-driven systems such as rolling mills, and for various other purposes. A breakdown of energy end-use is shown in Figure 4-7. Process heating for blast furnaces, electric arc furnaces represents the bulk of energy use at just below 90%. Motor systems, which include motor driven units such as compressors (1.09%),pumps (0.66%), conveyors and materials handling equipment(0.97%) account for a total of 2.7%. Facilities support which accounts for HVAC and lighting for offices as well as water heating at institutional facilities is accountable for a little over 1% of total end use.

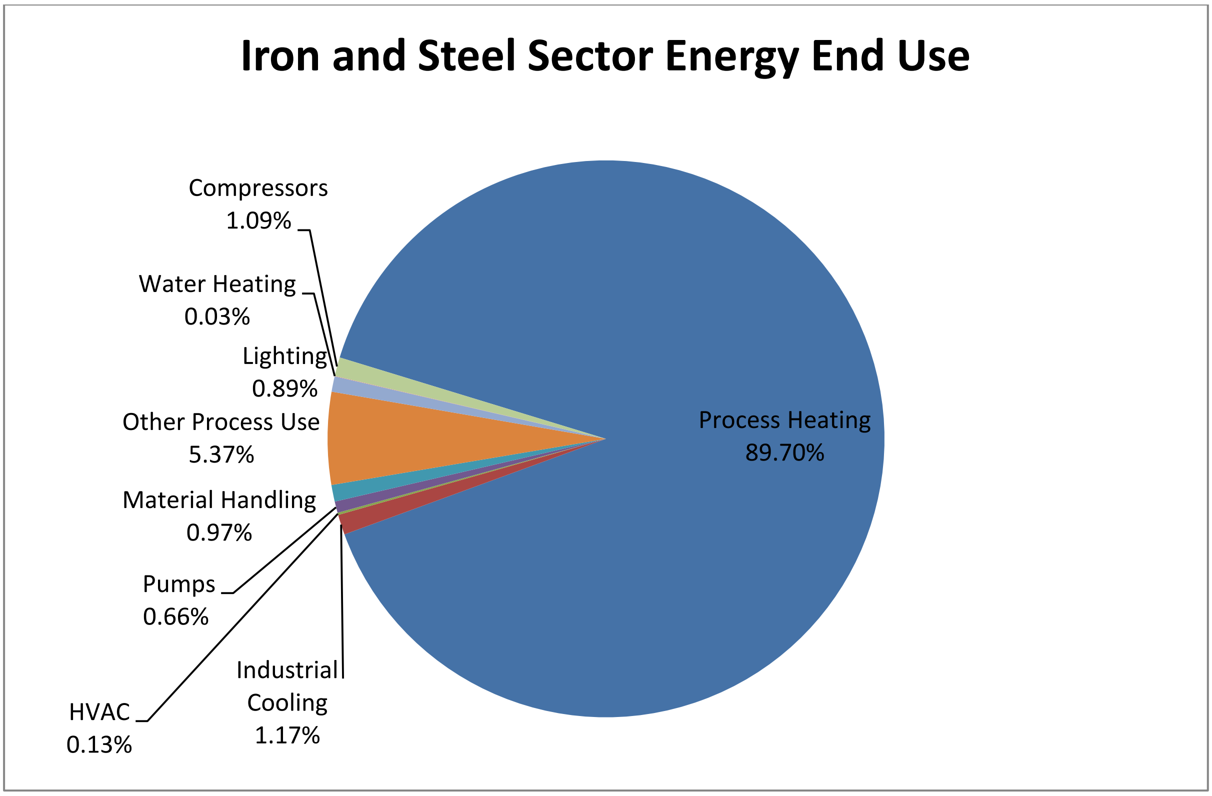

Figure 4-7: Iron and Steel Sector Energy End Use (Source: DoE Analysis)

4.2.2 Electricity End Use

Unlike other industrial sub sectors electricity end use within the iron and steel sector is dominated by process heat due to the use of electric arc furnaces to process scrap metal. In 2010, 43% of steel produced in South Africa used electric arc furnace with the remaining 57% using basic oxygen furnace (South African Iron and Steel Institute, 2012).

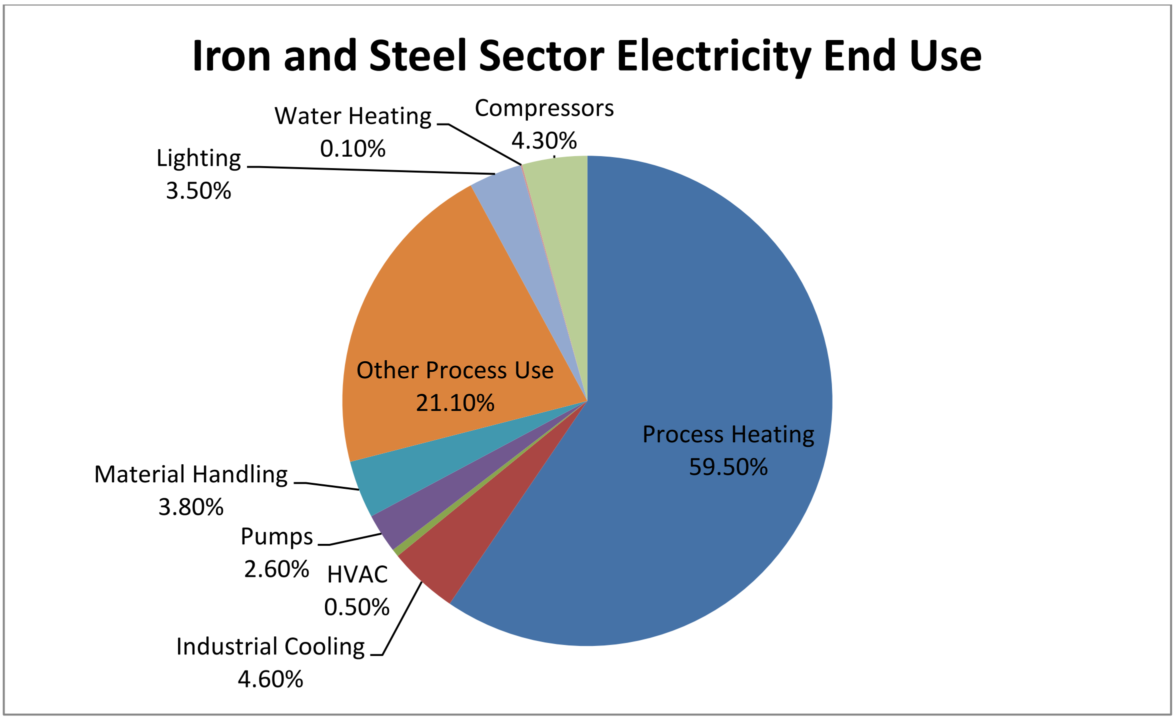

Figure 4-8: Iron and Steel Sector Electricity End Use (Source: Eskom IDM)

Given the share of process heating for both total energy (89.7%) and electricity (59.55%) opportunities for reducing energy consumption within the iron and steel sector can focus on improving technologies that use energy for process heating. In Figure 4-9 below specific savings potential for the iron and steel sector of South Africa is communicated to be 3.8 EJ/year which is below the world average of 4.4 EJ/year.

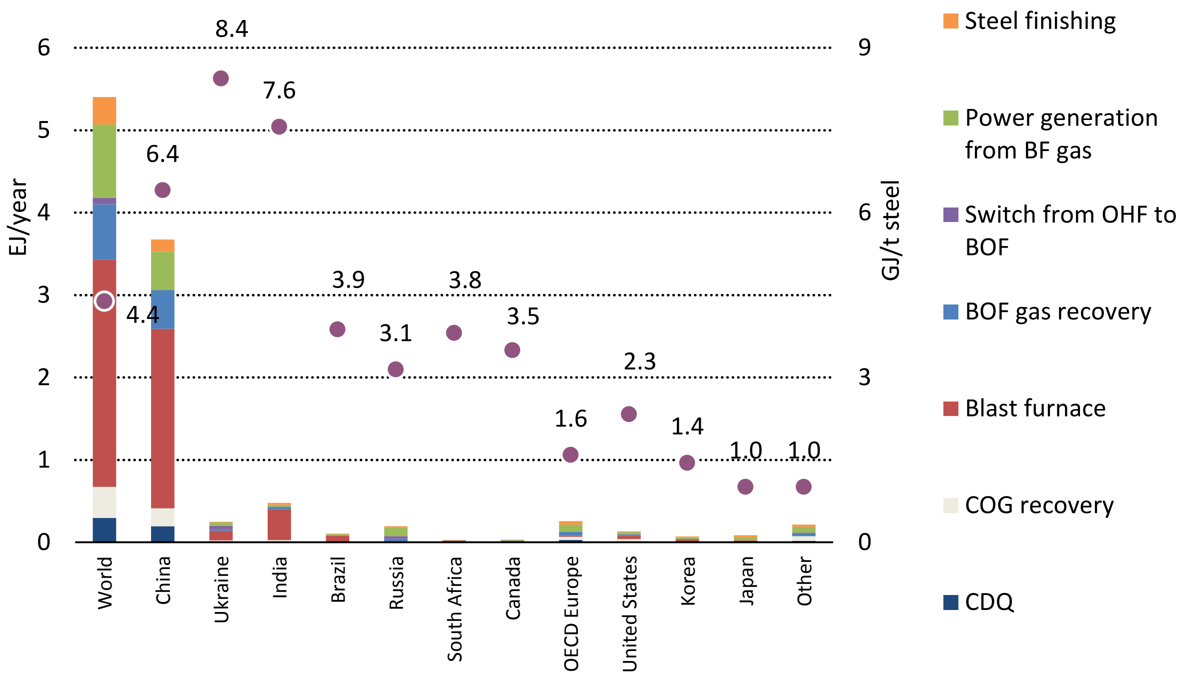

Figure 4-9: Current Energy Savings Potential for Iron and Steel Based on Best Available Technologies (Source: IEA, 2012b)

4.2.3 Projected Demand

The fuel mix for iron and steel continues to be dominated by fossil fuels with a slight increase in the share of natural gas from 14% to 22% from 2010 to 2050. Electricity consumption within the iron and steel is still necessary as electric arc furnaces provide process heating for blending scrap steel with pig iron produced from blast furnaces.

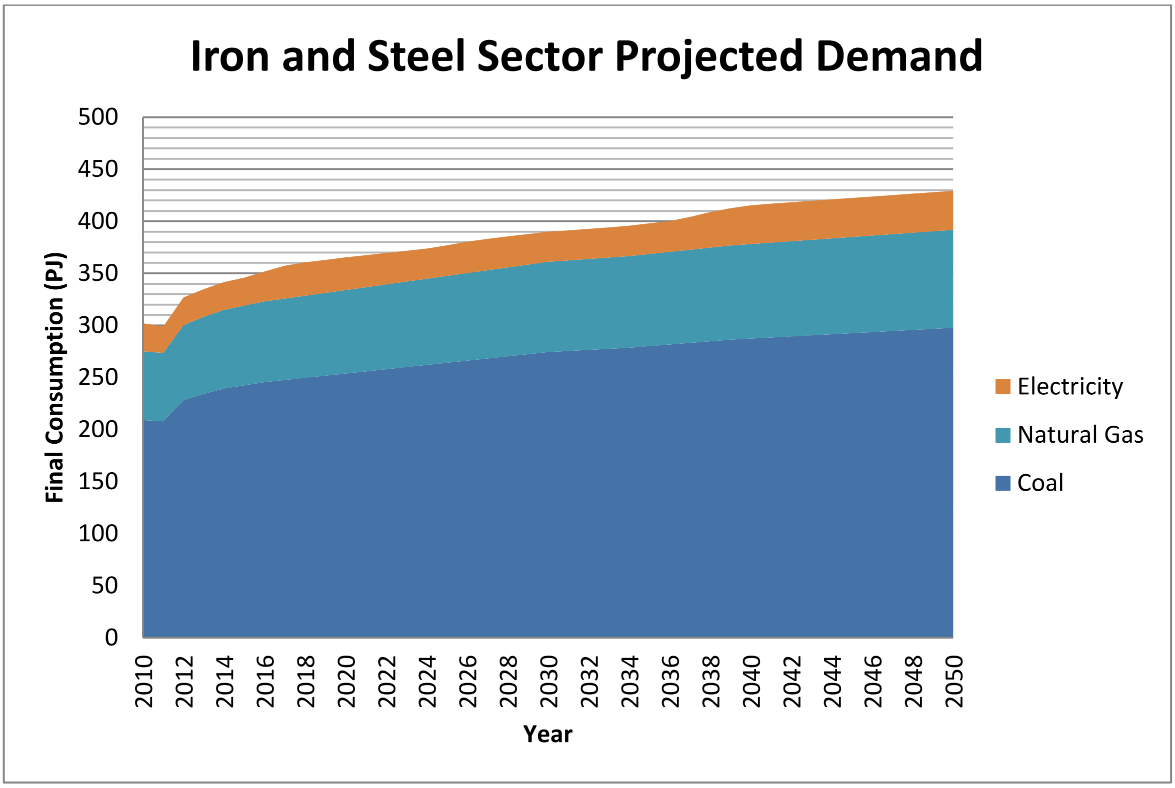

Figure 4-10: Iron and Steel Sector Projected Demand (Source: Model Output)

4.3 Nonferrous Metals Sector

South Africa's nonferrous metal industry is comprised of aluminium and other metals including copper, brass, lead, zinc and tin. Aluminium is a strong, light and durable metal that is resistant to corrosion, a good reflector and conductor of electricity and heat. The main uses of aluminium are in the building and construction sectors, in containers and packaging, for electrical application, in road, air and seagoing transport and industrial machinery and equipment. Due to its favourable properties and the environmental benefits the demand for aluminium has increased significantly over the past decade.

In 2007 South Africa was the ninth largest primary aluminium producer responsible for 2.4% of global production (United States Geological Survey, 2009). South Africa does not have economically exploitable deposits of bauxite thus all bauxite is imported primarily from Australia. The domestic primary production of aluminium is a remnant of a history of access to inexpensive electricity.

Upstream aluminium production which includes aluminium produced through recycling is cost effective as it takes 95% less energy than is used in producing primary aluminium from bauxite (IEA, 2009). Production of primary aluminium in South Africa is controlled entirely by BHP Billiton, one of the world's largest diversified resource companies. BHP Billiton has majority ownership of two aluminium smelters in South Africa, Hillside Aluminium and Bayside Aluminium, both in Richard's Bay. Even though the nonferrous sector is an energy intensive industrial sector, as seen in Figure 4-11 in comparison to other regions in the world Africa's usage of electricity per tonne of aluminium produced is below than that in other continents.

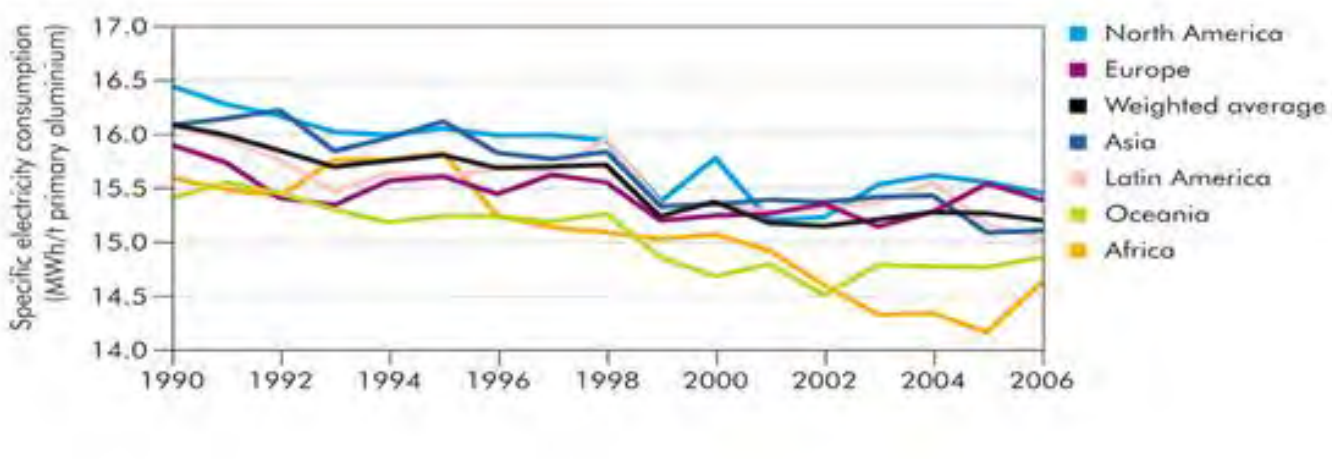

Figure 4-11: Regional Specific Power Consumption in Aluminium Smelting (Source: IAI, 2008)

4.3.1 Energy End Use

Unlike the iron and steel and chemical sectors the profile of end use for total energy end use and electricity end use for the nonferrous sector are very similar. This is due to the fact that the share of electricity in the fuel mix in the nonferrous sector is well over 90%.

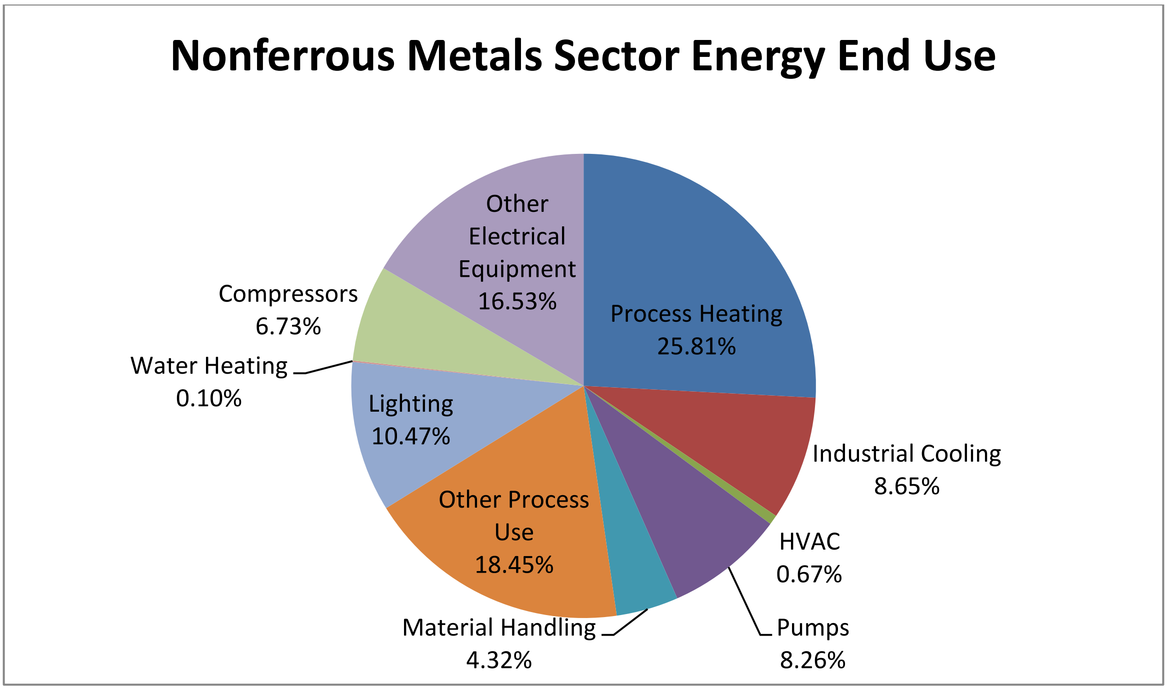

Figure 4-12: Nonferrous Metals Sector Energy End Use (Source: DoE Analysis)

4.3.2 Electricity End Use

As shown in Figure 4-13 process heat used by smelters comprise the largest use of electricity in the nonferrous sector at 22.8%. Motor systems (compressors (7.0%), pumps (8.6%)), materials handling (4.5%)) provide the second largest component of total electricity end use totalling 20.1%.

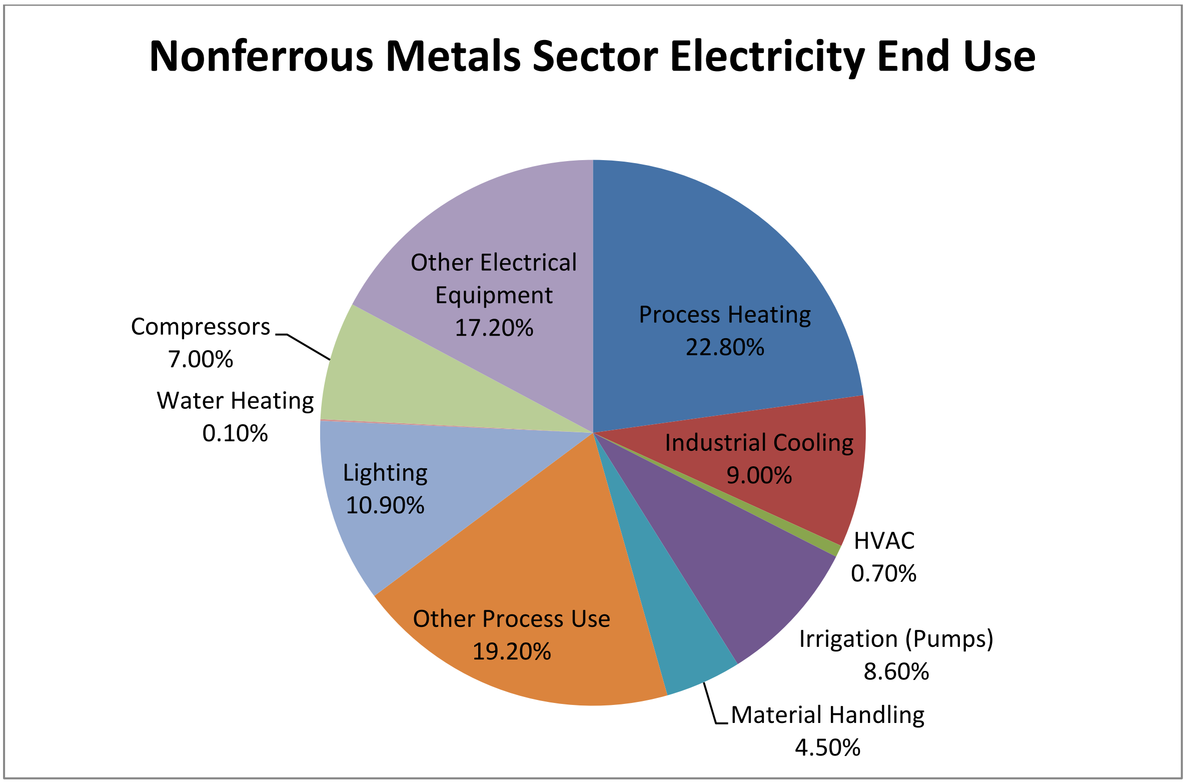

Figure 4-13: Nonferrous Metals Sector Electricity End Use (Source: Eskom IDM)

4.3.3 Projected Demand

In 2008 electricity provided close to 98% of the total energy requirements of the nonferrous sector. There is a marginal increase in the energy consumption of the nonferrous sector from 2010 to 2050 with electricity still responsible for the majority of demand.

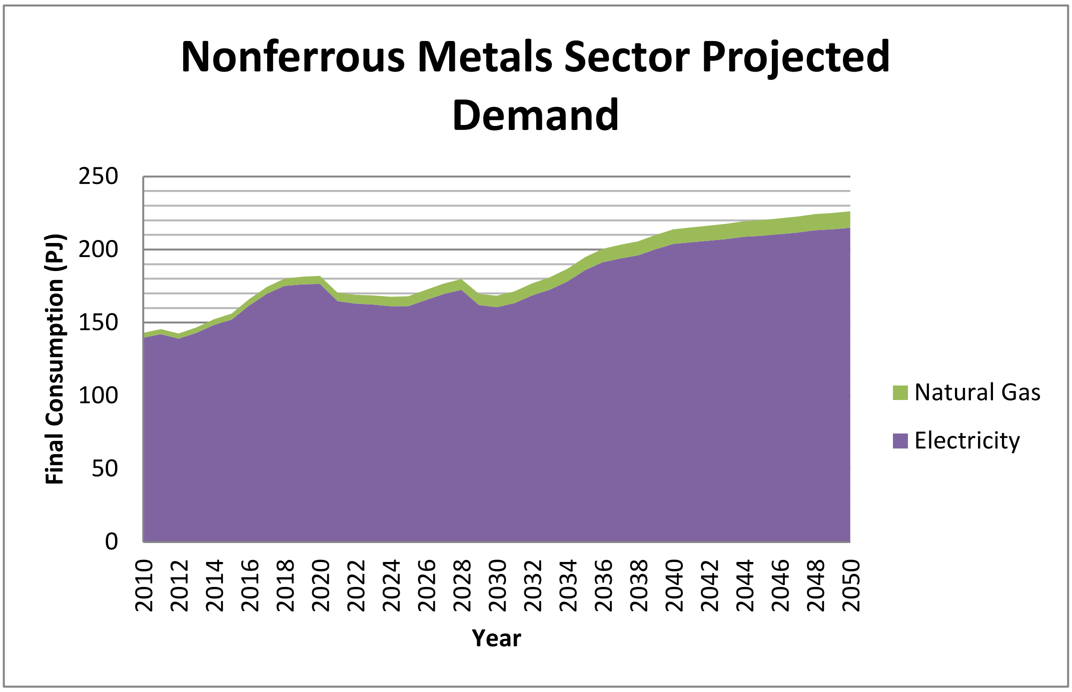

Figure 4-14: Nonferrous Metals Sector Projected Demand (Source: Model Output)

4.4 Rest of Manufacturing

Due to constraints on data availability the remaining manufacturing sectors were grouped together into the rest of manufacturing. As detailed in table 2.1 this includes non-metallic minerals, food and tobacco, paper and pulp, construction, machinery, textiles and leather, wood and wood products and transport equipment. The fuel mix is dominated by coal with ~49% of final consumption followed by electricity at ~38% with the balance coming from natural gas and petroleum products.

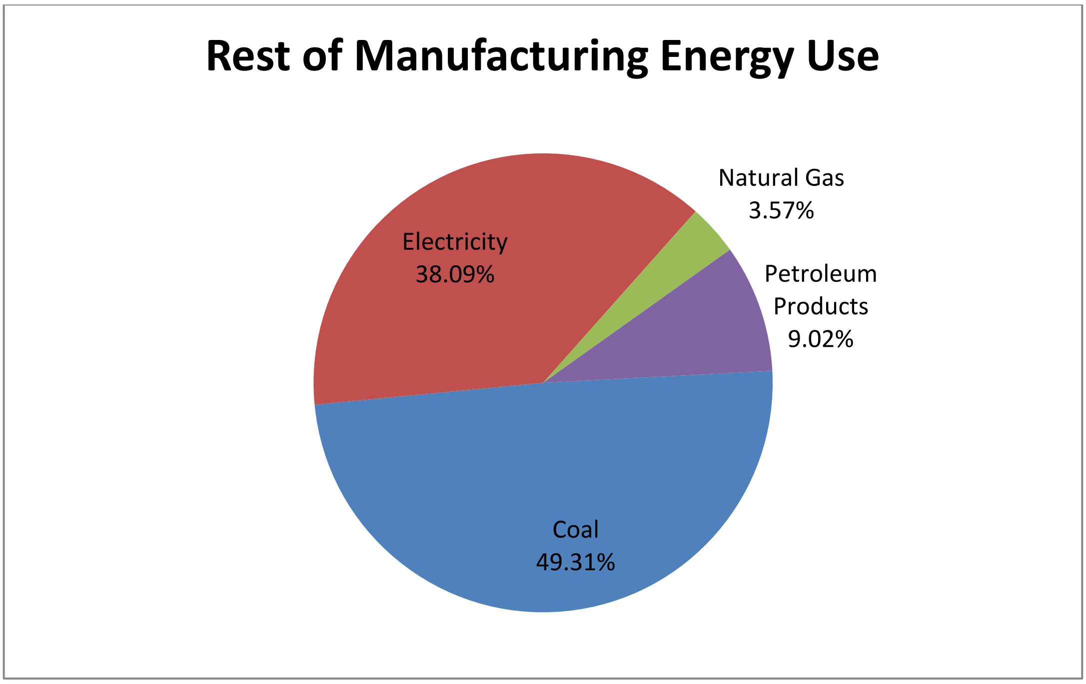

Figure 4-15: Rest of Manufacturing Energy Use (Source: DoE, 2009)

4.4.1 Energy End Use

The energy end use breakdown is indicative of averages across many sectors which combine both energy intensive subsectors such as non-metallic minerals with less intensive sectors such as textiles and leather. The majority of energy end use in the rest of manufacturing sector goes toward process heating. For instance the production of cement clinker from limestone and chalk is the main energy consuming process in the cement industry which is a subsector of non-metallic minerals. Fuels are burned to produce intense heat at levels of 1500^{0}C to transform raw feedstock into clinker. Other non-metallic mineral subsectors use process heating for instance when sand, limestone and other ingredients are melted together in a furnace to create molten glass which is then formed into a final product.

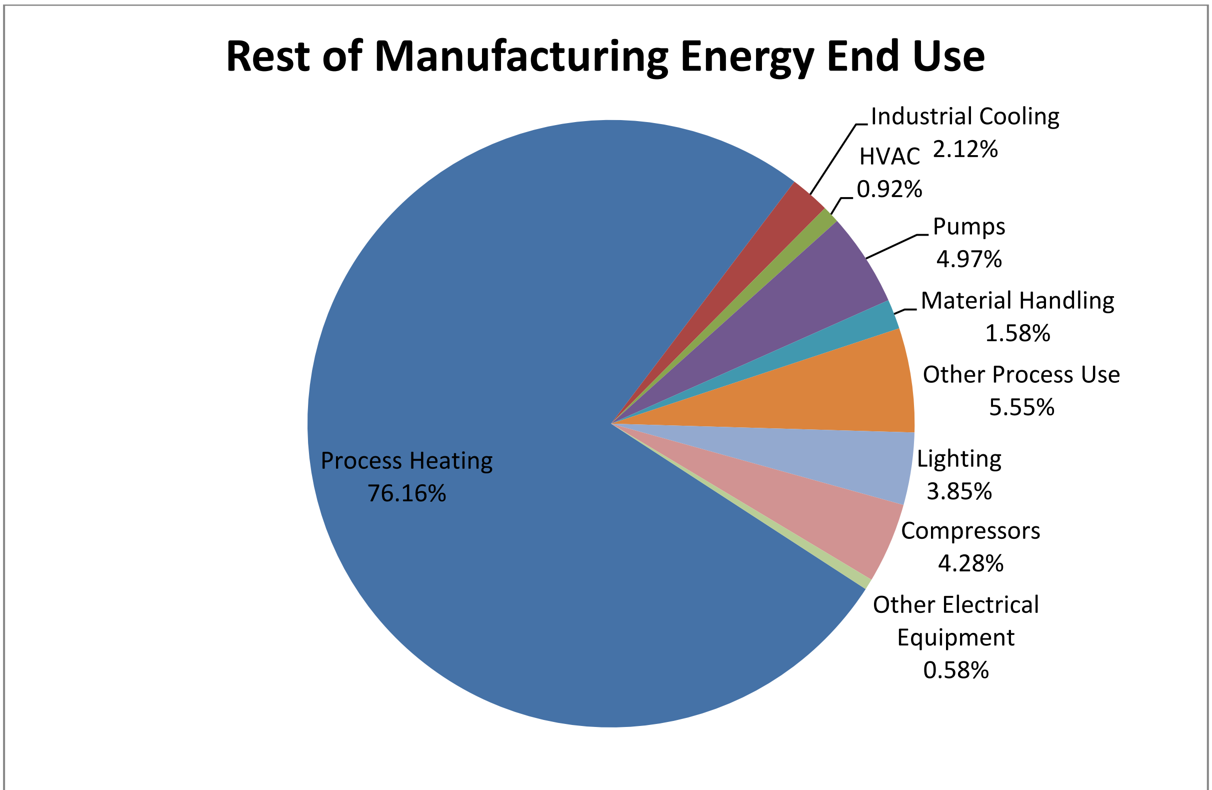

Figure 4-16: Rest of Manufacturing Energy End Use (Source: DoE Analysis)

4.4.2 Electricity End Use

As illustrated in Figure 4-17 the use of electricity in the rest of manufacturing is very diverse with the majority going towards process heating. Industrial cooling is important in the food and tobacco industry where food needs to be stored at optimal temperatures before being used further downstream in the services sector. Unlike the iron and steel, nonferrous metals and chemical sector lighting, HVAC and other electrical equipment feature more strongly with lighting encompassing 10% of electricity demand, HVAC just over 2% and other electrical equipment just over 1%.

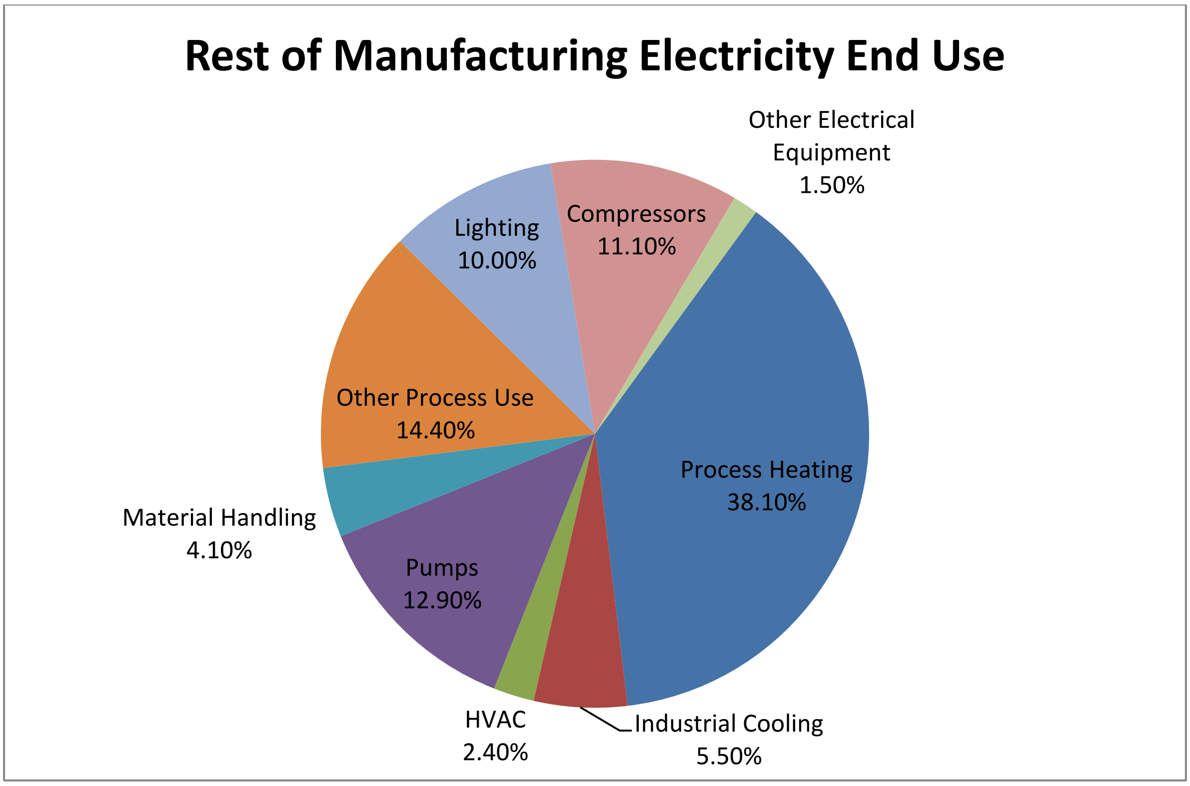

Figure 4-17: Rest of Manufacturing Electricity End Use (Source: Eskom IDM)

4.4.3 Projected Demand

Overall total demand for energy for the rest of manufacturing grows. Despite the growth in coal consumption its share of the fuel mix declines from ~54% to just below 35% from 2010 to 2050. During the same time period the average annual growth rate of natural gas outstrips the overall growth in energy consumption while its share of the fuel mix increasing from ~8% to ~42%.

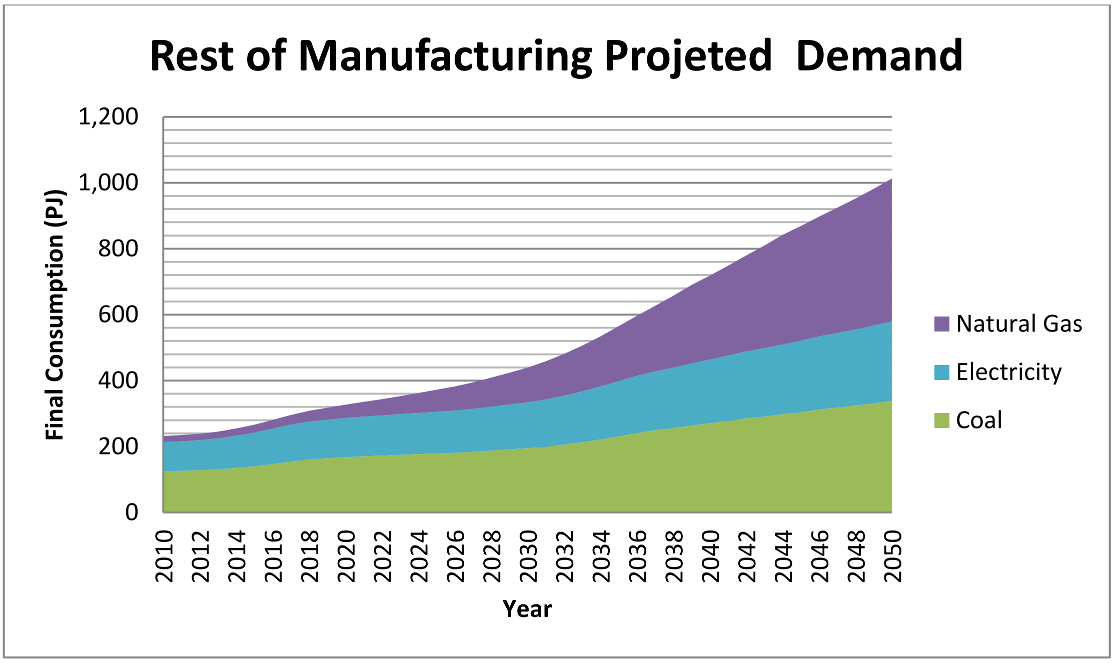

Figure 4-18: Rest of Manufacturing Projected Demand (Source: Model Output)

4.5 Mining Sector

South Africa is one of the world's leading mining and mineral-processing countries. In 2011, the mining sector accounted for 8.8% of GDP directly on a nominal basis. The contribution is closer to 18% if indirect multiplier and induced effects of mining are included (Chamber of Mines, 2012). Major energy sources for the South African mining industry are petroleum products, electricity and coal. As shown in Figure 4-19 in 2008 electricity accounted for ~ 67% of total demand, followed by coal at ~30%, with petroleum products and natural gas supplying the balance.

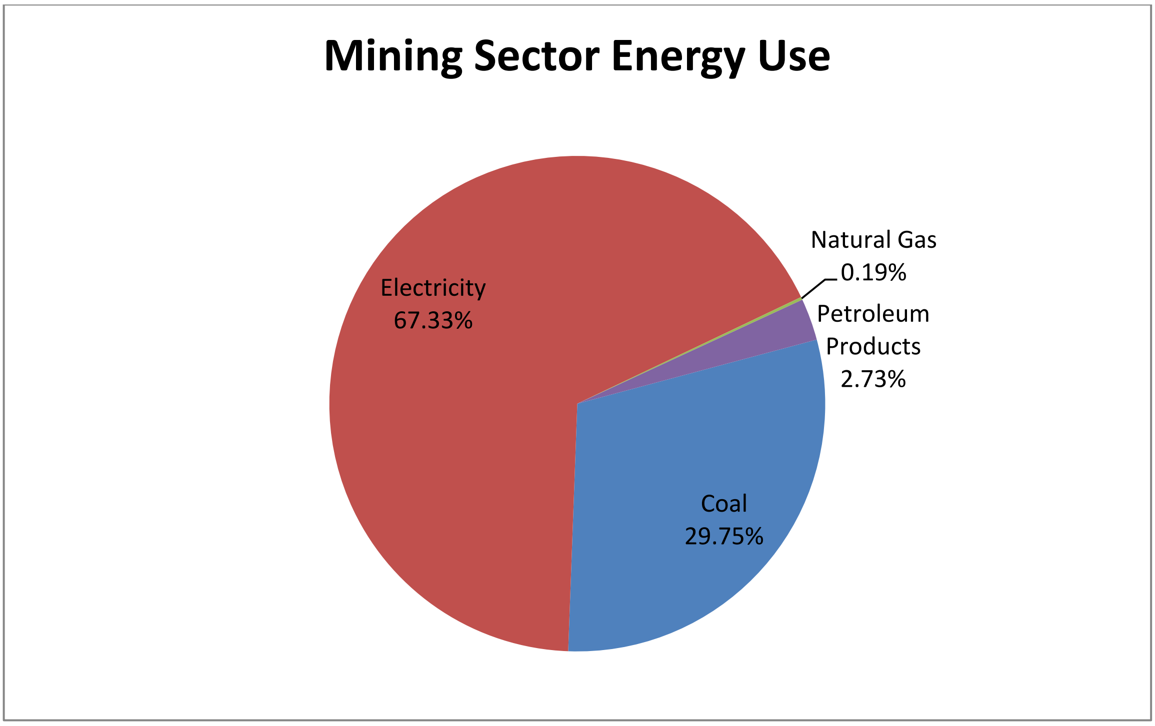

Figure 4-19: Mining Sector Energy Use (Source: DoE, 2009)

4.5.1 Energy End Use

Activities which make up the mining process can be categorised into the three main stages of extraction, materials handling and beneficiation (US Department of Energy, 2007). Extraction involves blasting and drilling to physically remove material from the mine. Materials handling includes the movement of ore and waste away from the mine to a mill or disposal area which is followed by beneficiation which occurs away from the mine at a processing plant.

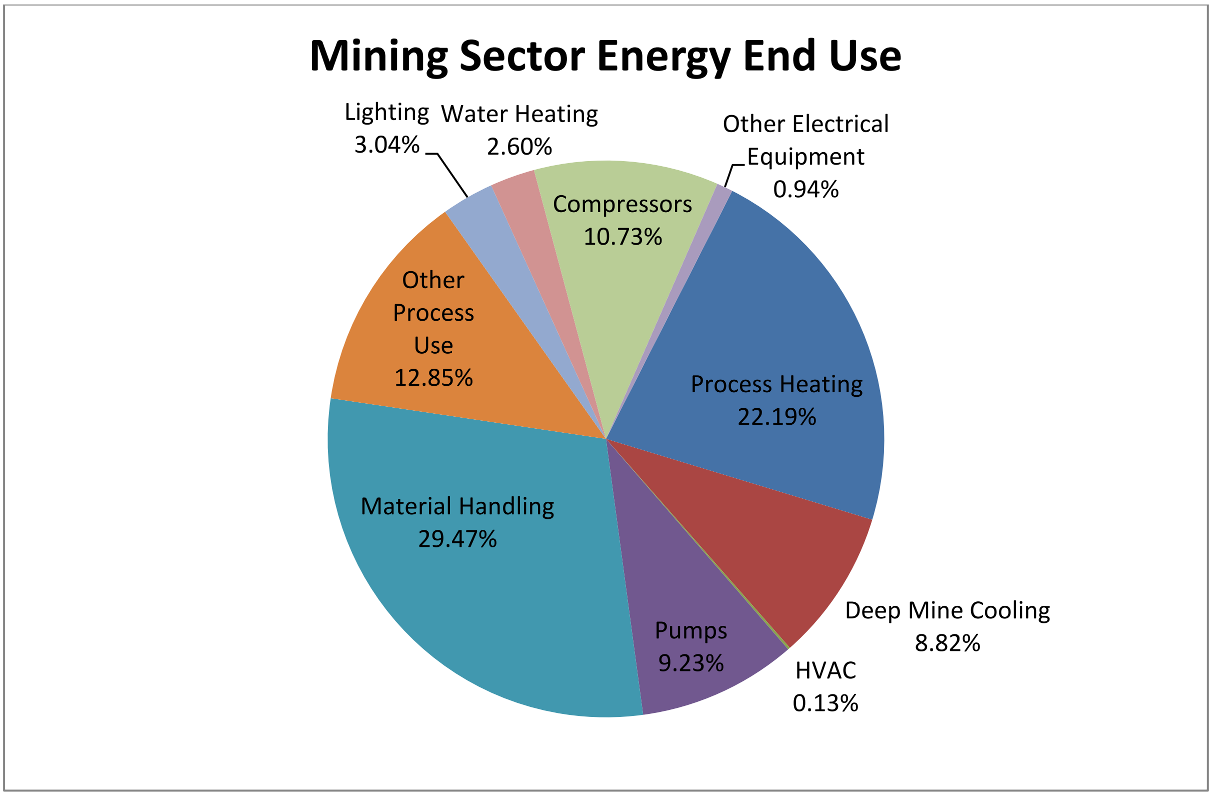

Figure 4-20: Mining Sector Energy End Use (Source: DoE Analysis)

In the first stage energy is used in drilling, digging, ventilation and dewatering. As shown in Figure 4-20 drills which use electricity indirectly from compressed air represent 10.73% of total energy use. Deep mine cooling and ventilation which is a process for bringing fresh air to the underground mines while removing stale or contaminated air as well as cooling work areas in deep underground mines accounts for 8.82%. Pumps at 9.23% are critical to de-watering deep underground mines as well as to pump water into flotation tanks in platinum processing and coal washing facilities.

Material handling accounts for 25.65% of total energy end use and encompasses both diesel and electric equipment. In general, diesel fuel is used by rubber tire or track vehicles that deliver material in batches while electricity powers continuous delivery systems such as conveyor belts or slurry lines.

Other process use which accounts for 12.85% of total energy end use occurs within the third stage of beneficiation. Activities such as crushing, grinding and separations, while processing operations include roasting, smelting and refining to produce the final mined product.

Within the industrial and mining sector water heating is defined as water heated for use in institutional living quarters which is defined as space provided by a business or organisation for long-term housing of individuals whose reason for shared residence is their association. In comparison to the previous industrial sectors analysed above where the share of water heating was negligible (Iron

and Steel (0.03%), Chemicals (0.01%), Nonferrous Metals (0.10%)) water heating within mining comprises 2.6% of the energy consumed. This is due to the fact that unlike the manufacturing sector employees of mines may live onsite at the facility.

4.5.2 Electricity End Use

The extraction of precious metals or minerals involves either surface or underground mining. Factors which impact upon the method chosen are the nature and location of the deposit, the size, depth and grade of the deposit (US Department of Energy, 2007). Underground mining is used when mineralisation is deep beneath the surface and/or when ore grade or quality is sufficient to justify more targeted mining. About 46.5 % of the country's coal mining is underground and 53.5 % is produced from open-cast mining methods (GCIS, 2008). 95% of South Africa's gold mines are underground operations reaching depths of over 3.8 km (Mbendi, 2013). Underground mining is more energy intensive than surface mining due to the extra requirement for materials handling, deep mining cooling and water pumping. When comparing the percentage share of electricity used in gold and platinum mining for deep mine cooling and ventilation against coal and the rest of mining, 14.9% of electricity in gold and platinum goes towards deep mine cooling while only 8.8% of electricity goes towards the same end use in coal and the rest of mining.

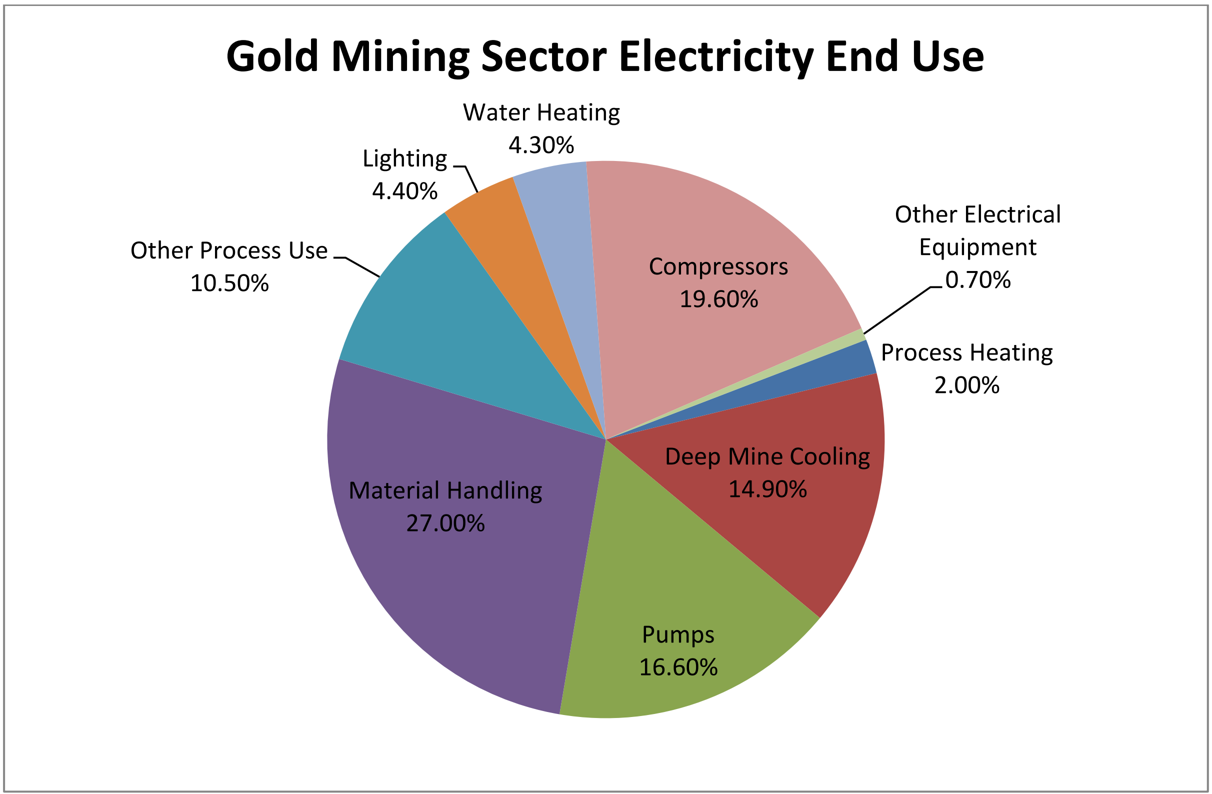

Figure 4-21: Gold Mining Sector Electricity End Use (Source: Eskom IDM)

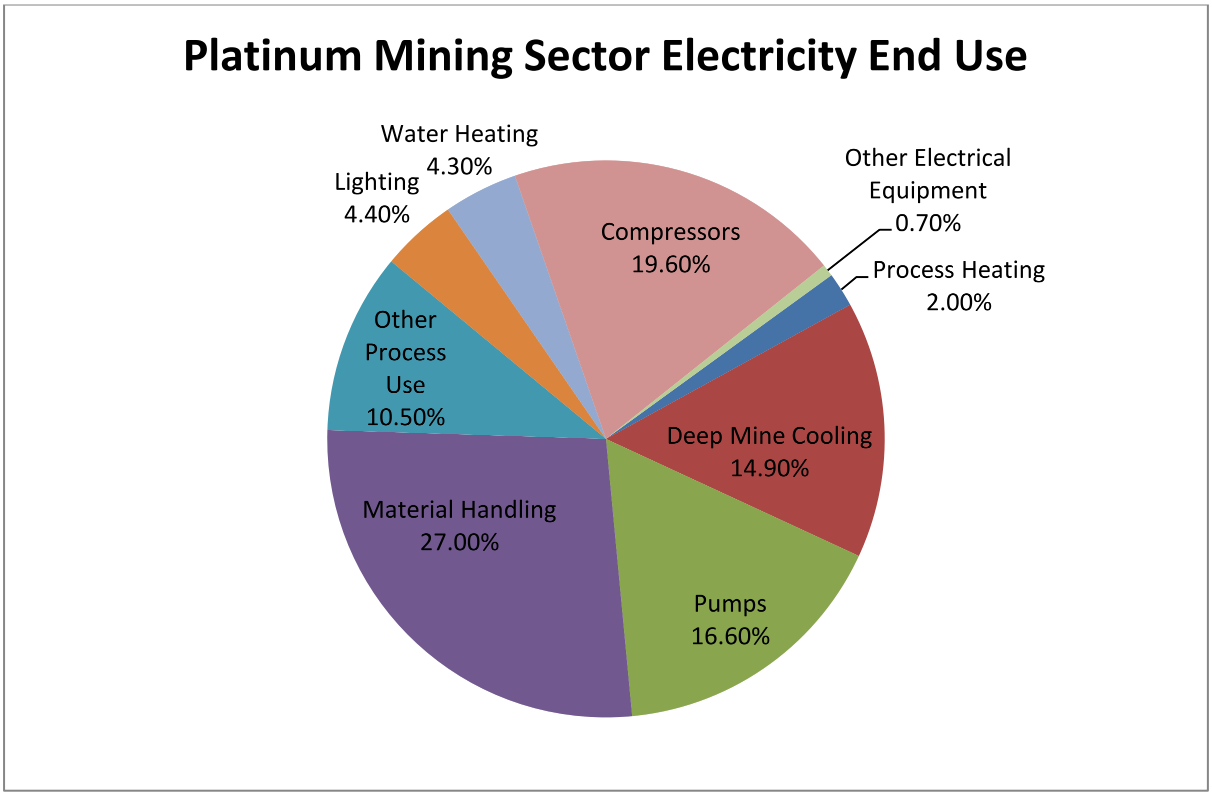

Figure 4-22: Platinum Mining Sector Electricity End Use (Source: Eskom IDM)

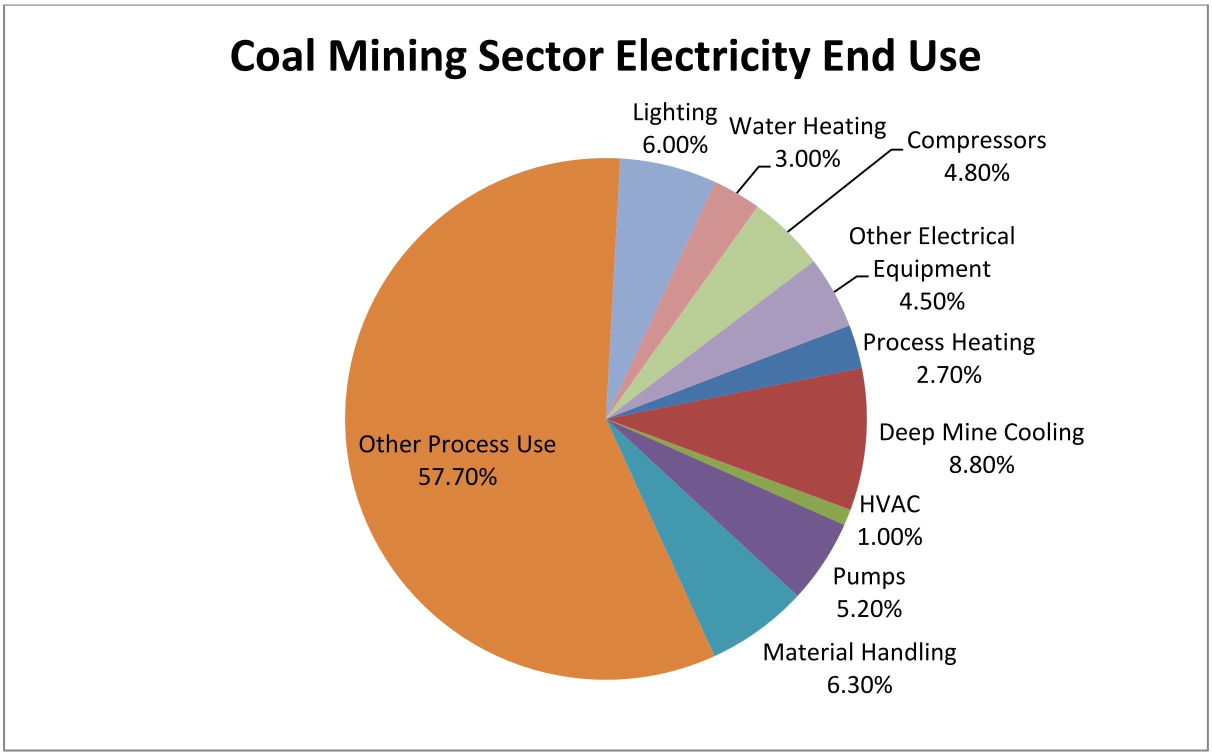

Figure 4-23: Coal Mining Sector Electricity End Use (Source: Eskom IDM)

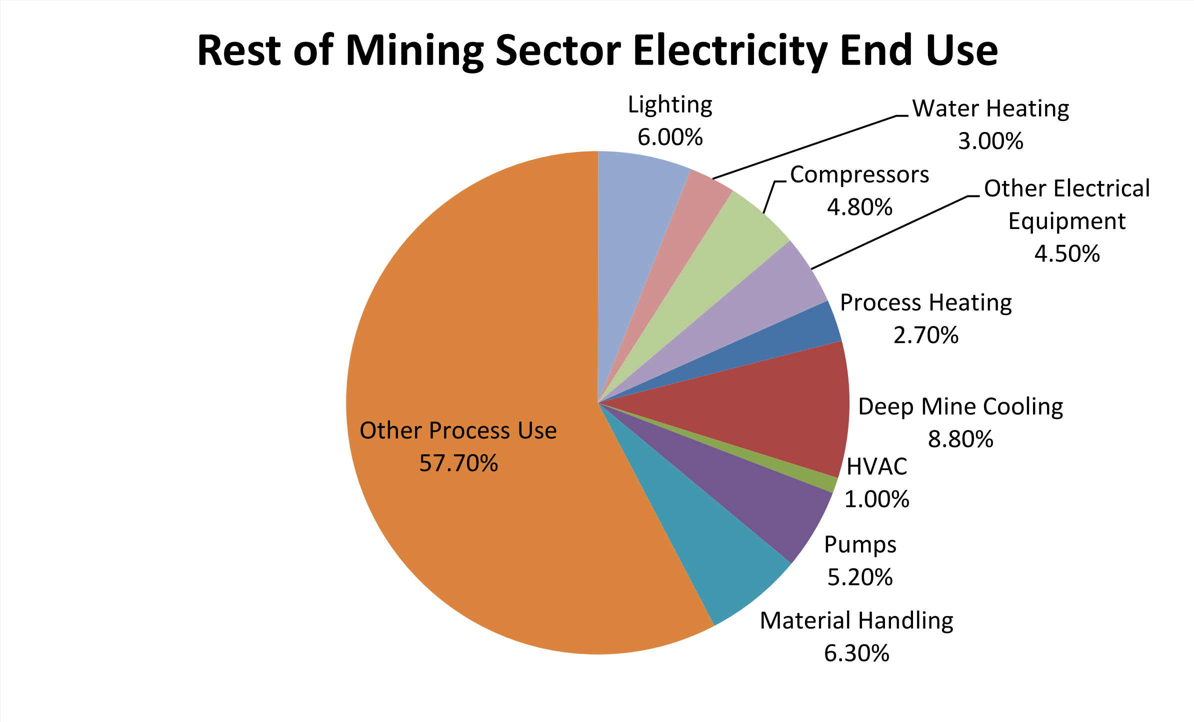

Figure 4-24: Rest of Mining Sector Electricity End Use (Source: Eskom IDM)

4.5.3 Projected Demand

Energy requirements vary considerably for each commodity and depend upon the type of ore being mined, whether it is underground or surface, whether it is beneficiated or processed, and the extent to which it must be beneficiated or processed. For example, energy requirements in underground gold mining are significantly on a per-ton basis than underground coal mining where the resource can be obtained in larger quantities. From 2010 to 2018 the energy consumption in the mining sector grows steeply but post 2018 growth in energy consumption stagnates.

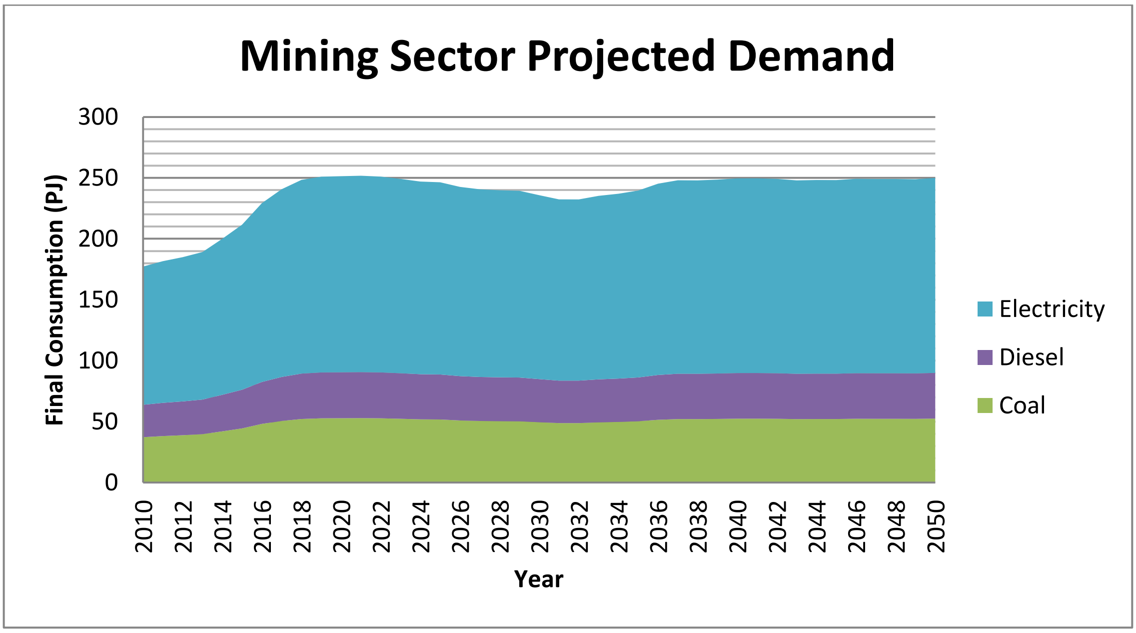

Figure 4-25: Mining Sector Projected Demand (Source: Model Output)

Electricity continues to dominate the fuel mix being responsible for the majority of energy use within the mining sector up to 2050. With regards to electricity gold mining's share of total electricity declines while electricity consumption in platinum mining fills in the gap.

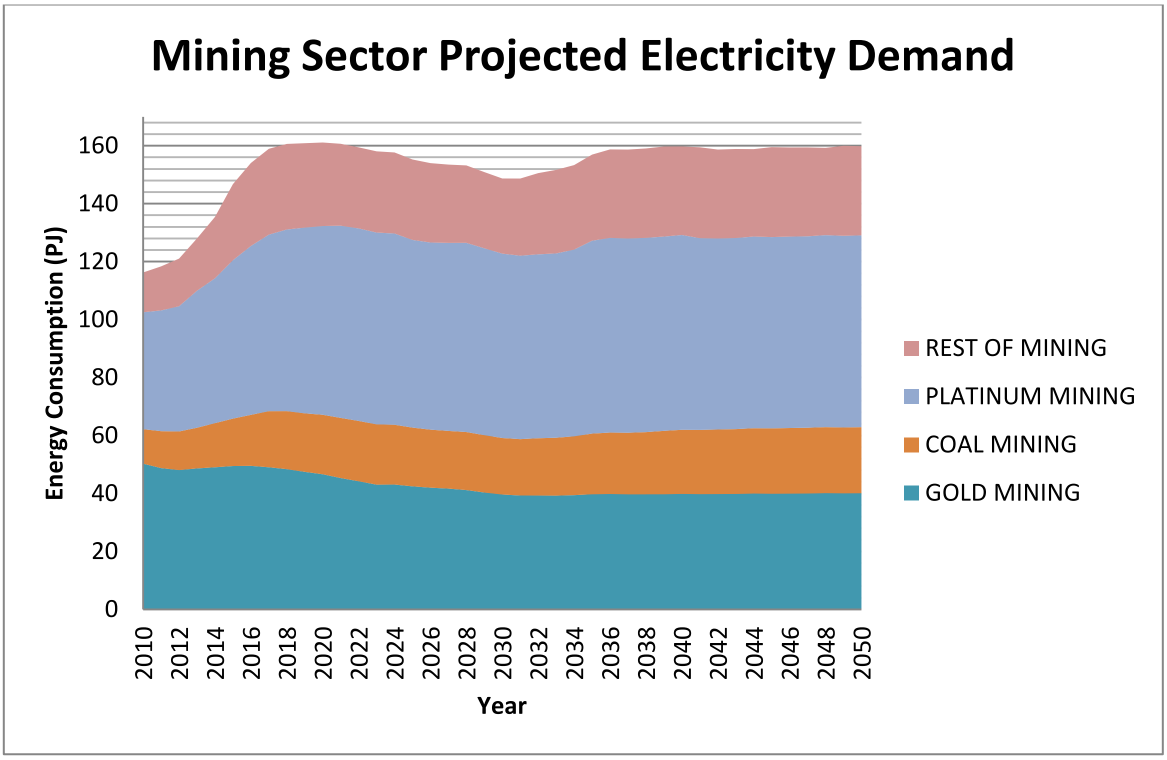

Figure 4-26: Mining Sector Projected Electricity Demand (Source: Model Output)

4.6 Industrial Sector

4.6.1 Projected Demand

The growth in energy demand for the industrial sector more than doubles from 2010 through to 2050. In 2010 the share of total energy demand within the industrial sector is allocated to iron and steel with 24%, Chemicals 14%, Nonferrous Metals 14%, rest of manufacturing 29% and Mining 18%. In 2030 the share of individual subsectors to total energy demand shifts slightly with iron and steel accounting for 28%, Chemicals 12%, Nonferrous Metals 12%, Rest of manufacturing 31% and Mining 17%. Further on in 2050 the share of individual subsectors changes with iron and steel with 20%, Chemicals 12%, Nonferrous Metals 10%, Rest of manufacturing 46% and Mining 11%. The reduction in the share of total demand from the mining sector is expected due to the fact that while production of mining sector is increasing overall there are sharp declines seen in gold sector. For instance in 2007, gold mining accounted for close to 47% of the electricity demand within the mining subsector and from 2007 to 2050 the electricity demand for gold mining declines by 28%.

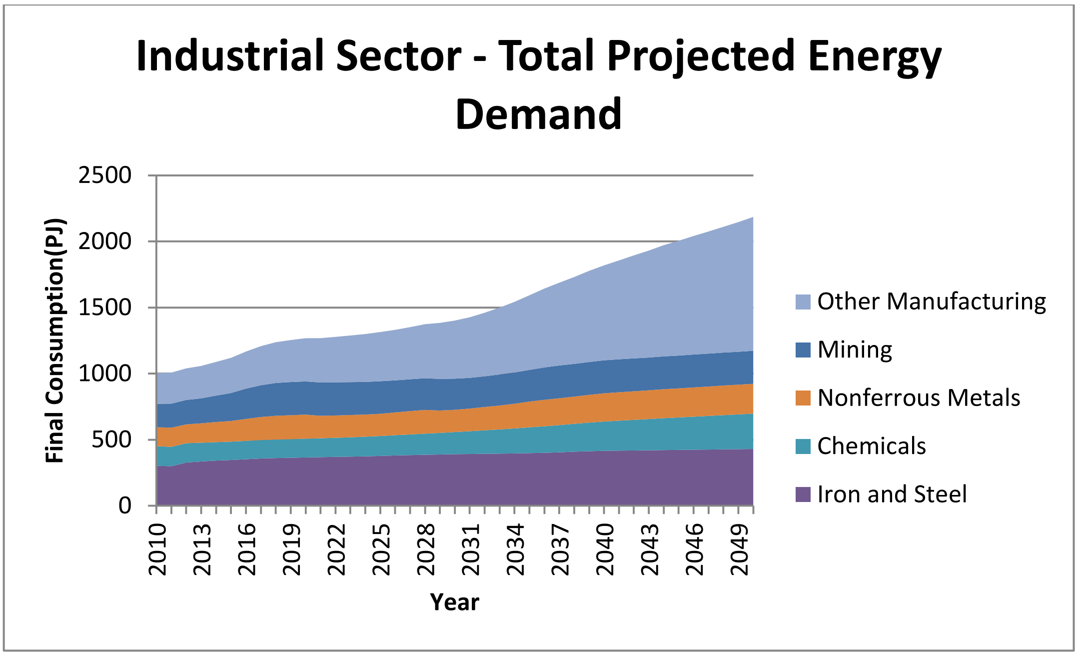

Figure 4-27: Industrial Sector-Total Projected Energy Demand (Source: Model Output)

4.6.2 Industrial Sector Energy Intensity

Since 1990 global industrial energy intensity has fallen at an average annual rate of 1.7% (UNIDO, 2011). There are a number of factors which can impact upon industrial energy intensity such as technological or structural change. Technological change occurs through changes in the product mix of each manufacturing sector, adoption of more energy efficiency technologies, optimisation of production systems and application of energy efficient organisational practices. Structural changes can reflect changes in the contribution of each sub sector, including shifts from or towards energy intensive industries. According to recent studies from 1995 to 2004 technological change accounted for a slightly larger share of the decline in industrial energy intensity globally, but since 2005 structural changes have had an increasing impact on energy intensity (UNIDO, 2011).

Although energy use has been rising, industrial energy intensity has been declining in all regions and in countries at all levels of development, implying a gradual change in the relationship between industrial energy use and economic growth, though with considerable variation across regions and industries. The reduction in industrial energy intensity results by part from government policy. Another important part is an outcome of technological progress, industrial restructuring and changes in fuel mix and production-oriented initiatives. And while globally 1990-2008 saw an absolute decoupling of manufacturing value added (MVA) growth from industrial energy intensity (a decrease in industrial energy intensity greater than the increase in MVA), industrial energy consumption still grew rapidly (UNIDO, 2011). The decline in industrial energy intensity tends to follow a three stage trend which is described as follows:

- Total industrial energy intensity tends to be high at early and intermediate stages of industrialisation, when energy intensive materials processing industries dominated, technical energy efficiency is poor and low quality fuels (such as coal) predominate.
- Industrial energy intensity decreases at later stages or industrialisation, as the structure of industry shifts from energy-intensive raw material processing to less energy-intensive processes from “brown” process industries to greener industries- and technical energy efficiency and the quality of the fuel mix improve.
- Industrial energy intensity declines substantially at the most advanced stages of industrialisation, with further technological improvements, structural change, production shifts towards more skill-intensive industries and increasing use of high quality fuels (gas and electricity).

There is considerable regional variation in energy intensity for the industrial sector. For example, industry uses on average 4.7 times more energy to produce a unit of MVA in developing Europe than in Latin America and the Caribbean (UNIDO, 2011). This is due mostly to the vintage of industrial facilities. There have been continual improvements in nearly every aspect of industrial activities, so countries with newer industries tend to have newer, more efficient facilities (IEA, 2007). Many non-OECD European countries have inherited inefficient, coal based, energy intensive industries that operate at a small fraction of their output capacity.

Of the ~22% decline in global industrial energy intensity over 1995-2008, 56% was due to changes in industrial structure. A study by the United Nations Industrial Development Organization (UNIDO, 2011) found that there had been a major reduction in the share of energy –intensive process sectors in global manufacturing value added and a large increase in the share of the machinery sector (from plant equipment to consumer electronics and electrical appliances) - from around 29% in 1995 to 44% in 2008 (UNIDO, 2011). It has been further found that changes in demand patterns as standards of living improve account for much of the shift in the structure of industry. Long term studies show that as disposable income grows, so does the demand for certain products. At lower incomes, demand is greatest for basic infrastructure- housing, roads and other services. This requires energy-intensive inputs like steel rods, aluminium castings, and copper lead wires. As incomes grow, people want higher quality products, a wider choice of goods and new products that upgrade an existing service (e.g. electronic reader in place of a book) (Schafer 2005 in UNIDO 2011). The manufacturing sector energy intensity was calculated by dividing the energy consumption of manufacturing subsectors of iron and steel, nonferrous metals, chemicals and rest of manufacturing

by the gross value added of the manufacturing sector. The specific energy intensity of the manufacturing sector declines from 2010 to 2050.

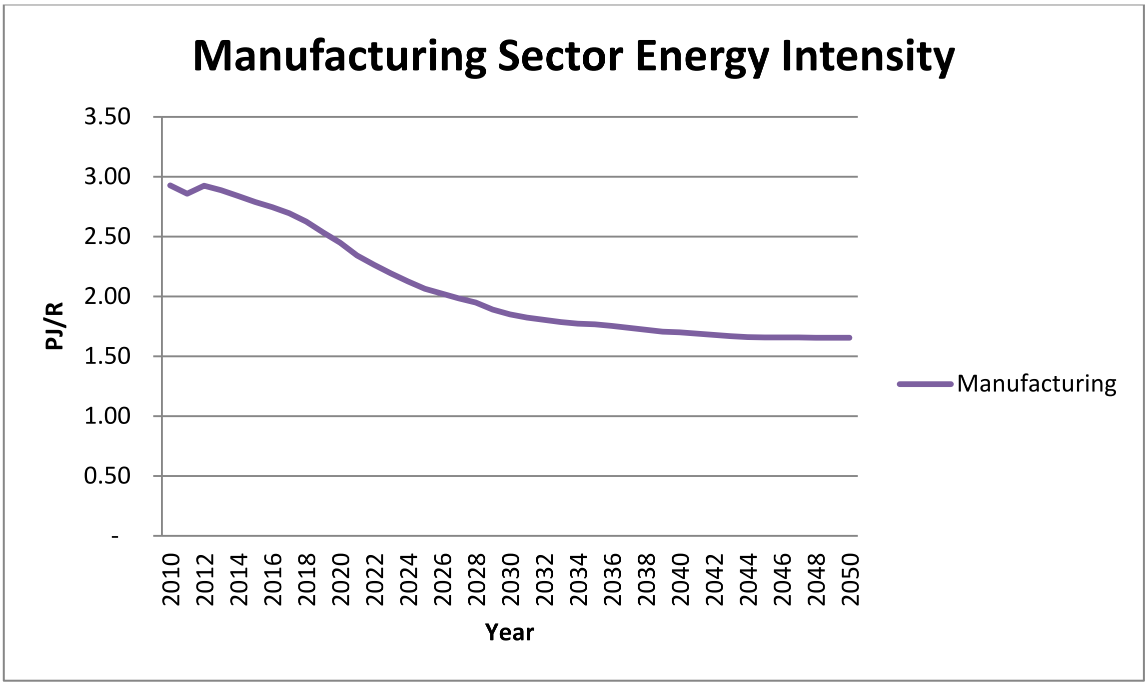

Figure 4-28: Manufacturing Sector Energy Intensity (Source: DoE Analysis)

The specific energy intensity of the mining was calculated by dividing the total energy consumption of the mining sector by the mining index. The decline in specific energy intensity in the mining sector is due to the decline in electricity used in gold mining. Electricity dominates energy use within the mining sector and the share of electricity used for gold mining declines markedly over from 2010 to 2050.

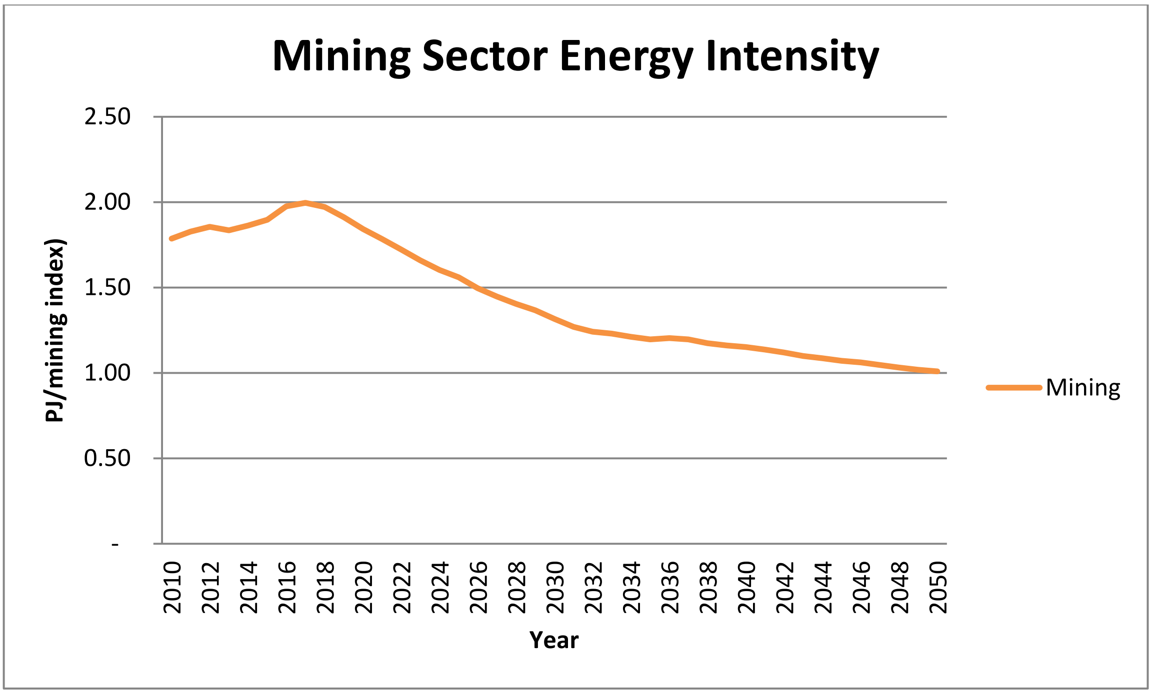

Figure 4-29: Mining Sector Energy Intensity (Source: DoE Analysis)

4.6.3 Energy Efficiency Opportunities in the Industrial Sector

Cutting edge technologies for industrial energy efficiency can reduce the widespread environmental impact of industrial energy use. These include cross cutting and industry wide technologies (such as cogeneration, energy recovery and efficient motors and steam systems), inter-industry opportunities (such as water heat or by-products by other industries), and process specific technologies. Further on industrial energy intensity can be reduced through technological progress and system changes that improve technical energy efficiency- changes that increase output using the same amount of energy or that deliver the same output using less energy. These changes include replacing old technologies, adopting energy-saving technologies (preferably best available technologies), improving processes and optimising systems, and employing energy management practices. They also include using more high-quality energy such as gas and electricity; innovative product designs; and changing the output mix. These improvements, especially those related to new technologies and processes, vary in complexity-from simple add-ons to complex system change.

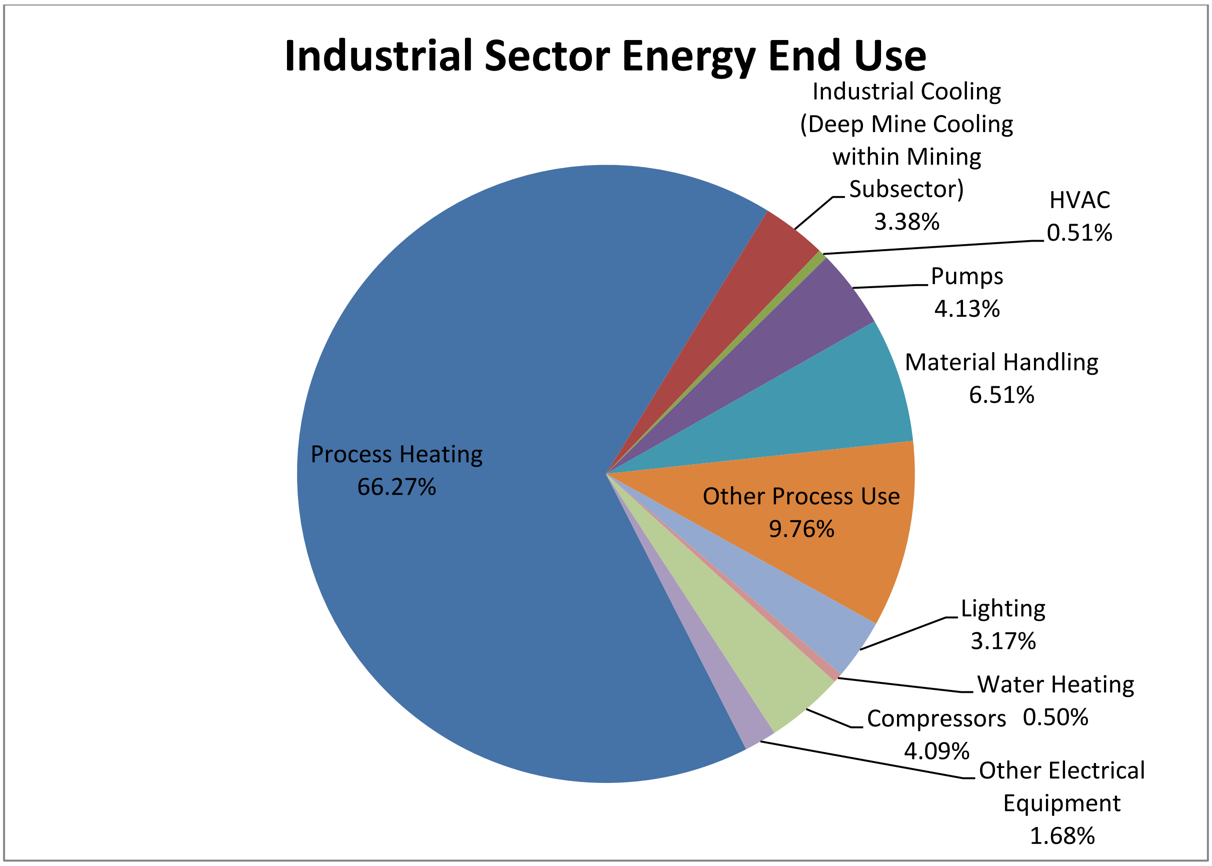

Figure 4-30: Industrial Sector Energy End Use (Source: DoE Analysis)

As show in Figure 4-30 the majority of energy used within the industrial sector is for process heating. In energy intensive industrial sub sectors such as iron and steel and chemicals process heating comprises 90% and 88% respectively. The use of energy for motor driven systems which are accounted for under pumps, compressors and material handling contribute the second largest share of total energy use at 14.73%. Industrial cooling which is designated as deep mine cooling within the mining subsector is the third largest share. In the mining subsector deep mine cooling and ventilation is used for bringing fresh air to the underground mines while removing stale or contaminated air. Other process use has been used in cases in which the exact end use is not well defined and cannot be attributed to a specific purpose.

While the use of fossils fuels within the industrial sector is primarily used for process heating the end use of electricity for individual end use is very diverse. In the table 4.6.1 a breakdown of electricity end use within the industrial sector is outlined.

Table 4.6.1: Electricity End Use: Industry

End Use	Chemicals	Iron and Steel	Non-ferrous Metals	Other Manufac turing	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

Most notable is that outside the use of electricity for process heating in iron and steel (59.5%) the majority of electricity end use within the individual manufacturing sectors goes towards motor systems (compressors, material handling, pumps). Within the manufacturing subsectors, the chemical sector ranks first with 61% of total electricity end use going towards motor systems, followed by nonferrous at 37.3% and rest of manufacturing at 29.6%. Worldwide motor-driven equipment accounts for approximately 60% of manufacturing final electricity use (UNIDO, 2010). Despite the fact that improvements in the use of motor systems within industry can contribute to substantial reductions in electricity consumption this potential is largely unrealised (IEA 2007).

A system is a set of connected unit operations or pieces of equipment that perform a service together. There is growing evidence that systems optimisation and systems solutions hold the greatest potential for energy efficiency gains (UNIDO, 2010). Globally, the energy consuming systems with the highest potential energy savings are motors, compressor and steam systems. Motor systems, consisting of drives, pumps and fans, are a largely untapped, cost-effective source of industrial energy efficiency savings that could be realised with existing technologies.

Lastly most industrial energy efficiency improvements achieved are by changing how energy is managed rather than by installing new technologies. Energy management systems include the technical systems, management programmes and trained staff needed to conduct energy audits, gather energy data, maintain sub-metering systems, analyse and compare consumption data to

trends and benchmarks, correct for influencing factors (IEA, 2012a). Governments can encourage companies to establish an energy management system by providing information on best practices, issuing standards, providing training in compliance and recognising or certifying firms that meet the standards.

5. Residential Demand Projections

Access to energy services using cleaner forms of energy has been identified as critical to both social and economic development such that increased access to energy services has been identified as essential to achieving all of the Millennium Development Goals (Modi et al., 2006). For instance cooking with firewood and dung is associated with a significantly higher disease burden than modern energy carriers, due to indoor pollution. Using modern forms of energy such as LPGas for cooking lowers smoke exposure thus reducing the disease burden from smoke, lowering child mortality rates, and improving maternal health. In other circumstances access to electricity for lighting can enhance a student's ability to study after hours with proper illumination thus improving education levels. In 2008 household energy use was split between electricity, coal, petroleum products and biomass with the majority coming from biomass.

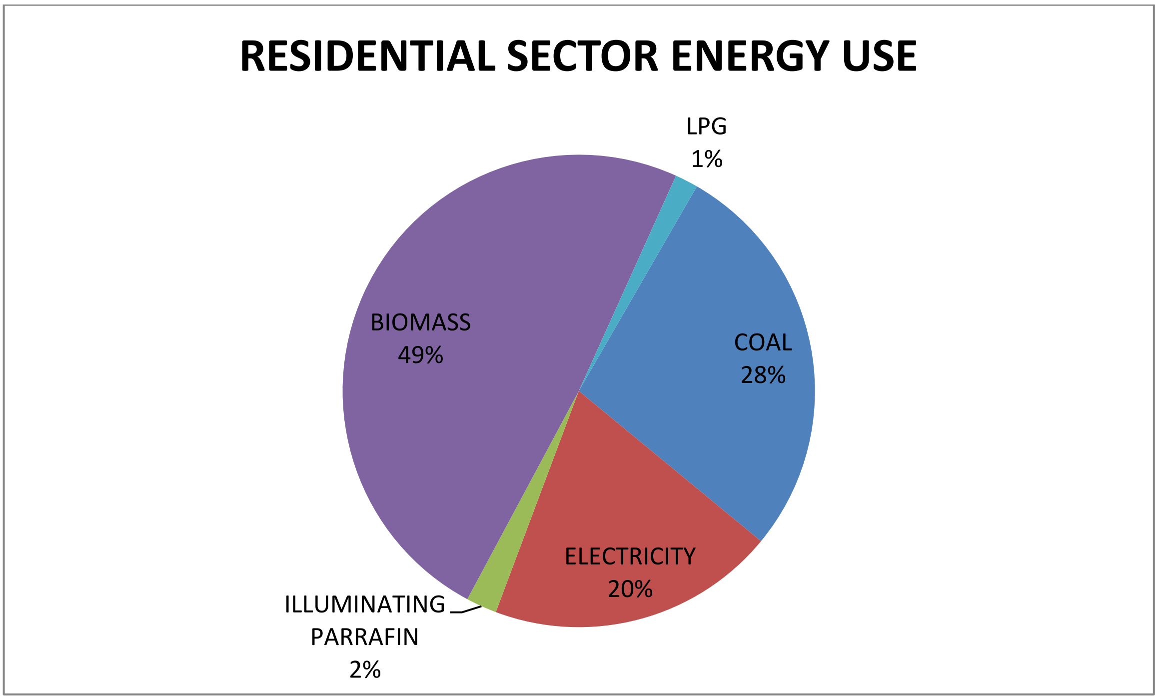

Figure 5-1: Residential Sector Energy Use (Source: DoE, 2009)

5.1 Energy Ladder and Multiple Fuel Use

An energy ladder shows the improvement of energy use corresponding to an increase in household income. The assumption is that as income increases, the energy sources used to meet household energy needs would be cleaner and more efficient, but more expensive. Socioeconomic status largely influences the extent of multiple fuel use. Indigent households are more likely to use wood and coal for thermal household tasks and accompany these fuels with paraffin for lighting. Slightly higher on the energy ladder are households who use paraffin for cooking and heating and use

electricity for lighting purposes. Highest on the ladder are households who use electricity exclusively as their main energy source (Masera et. al 2000).

5.1.1 Multiple Fuel Use Cooking

Climbing up the energy ladder tends to occur gradually as most low income households use a combination of fuels to meet their cooking needs. In Figure 5-2 below the overlaps are shown in detail for very low income, low income, middle income and high income households.

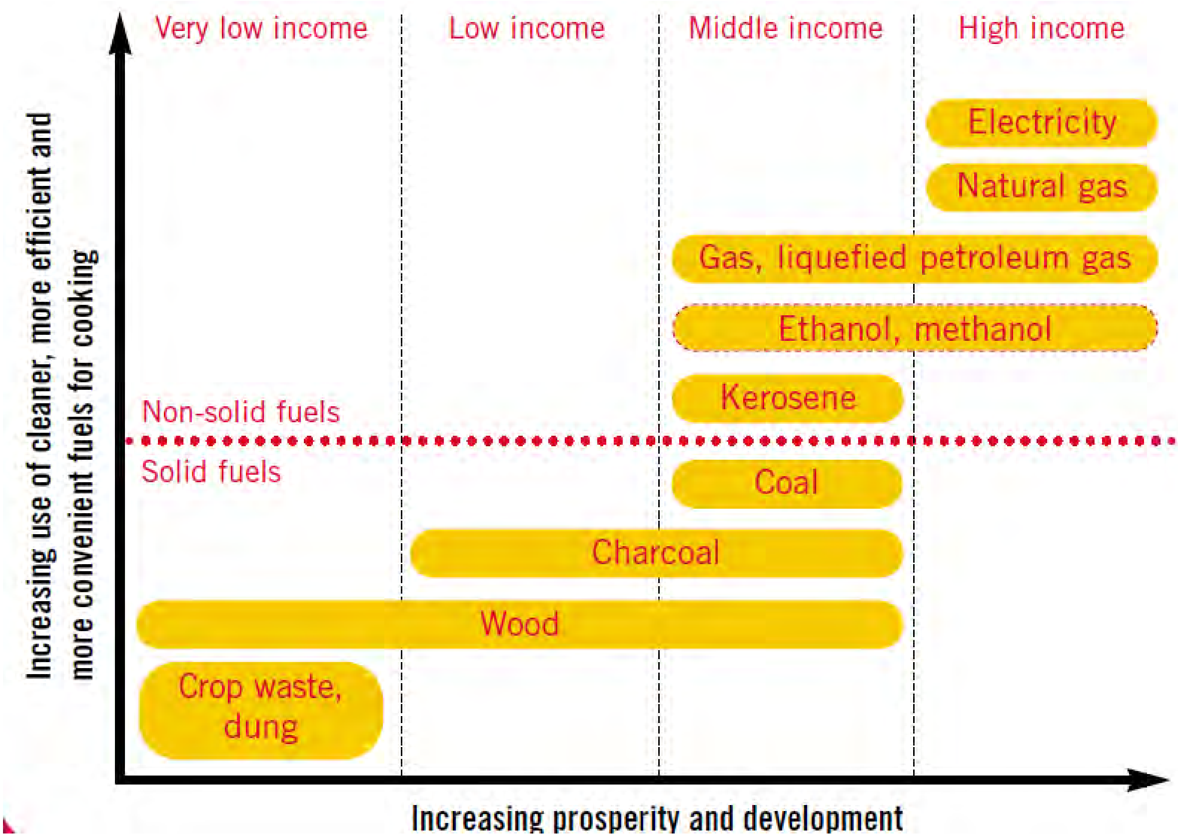

Figure 5-2: Energy Ladder for Cooking (Source: World Health Organization, 2006)

The United Nations Development Programme (UNDP) explicitly defines energy poverty as the "inability to cook with modern cooking fuels and the lack of a bare minimum of electric lighting to read or for other households and productive activities at sunset" (Gaye, 2007). In 2011, 52% of South African households reported the use of one fuel for cooking and of the households that reported the use of one fuel 42% used electricity only (Department of Energy, 2012a). Thus at a national level 48% of all households use multiple fuels to meet energy needs for cooking. There are large discrepancies which exist with the socioeconomic status and location of a household having an impact on the prevalence towards multiple fuel use. Low income households are more likely to use multiple fuels for cooking with 59% of households within this category being affected.

5.1.2 Multiple Fuel Use Space Heating

In 2011, 55% of South African households used one energy carrier to meet space heating needs with 27% using multiple fuels and 18% use no energy by relying on warm clothes and blankets. Electrified households were most likely to depend solely on electricity with 38% relying on electricity while in contrast 38% of non-electrified households rely solely on firewood (Department of Energy, 2012a).

5.1.3 Multiple Fuel Use Lighting

One measure of energy poverty at the level of the poorest is lack of a bare minimum of electric lighting to read or for other household and productive activities after dark. As outlined in the Free Basic Electricity Policy indigent households are given 50kWh per month of electricity which support basic lighting and cooking as well as minimal use of radio and television. Multiple fuel use for lighting still persists in South Africa with 46% of households reporting single use of an energy carrier; Out of the households which use one energy source for lighting 40% report electricity as the sole carrier followed by candles at 5% and illuminating paraffin at 1% (Department of Energy, 2012a). With regards to households which use multiple fuels 29% of electrified households use electricity and candles due to interruption of service caused by technical reasons or cut off for reasons such as prepaid vouchers running out or non-payment.

5.2 Household Trends in Biomass Use

Biomass usage in South Africa is primarily for thermal purposes such as space heating, water heating and cooking. Trends in biomass usage vary substantially by location with more than 74% of rural households in South Africa indicating recent use of biomass versus 17% of urban informal and 11% of urban formal households (Department of Energy, 2012a). At the provincial level 70% of households in Limpopo have recently reported the use of firewood whereas only 8% and 14% of households in Gauteng and Western Cape respectively have recently used firewood (Department of Energy, 2012a). An analysis of time series data from the Census 1996, 2001 and 2011 show a steady decline in the percentage of households that use wood for cooking by at least a half. With regards to space heating from 1996 to 2001 there was a sharp decrease in the percentage of households using wood for space heating but the percentage of households using wood for space heating has shown a slower decline between the 2001 and 2011 Census from approximately 6% to 2%.

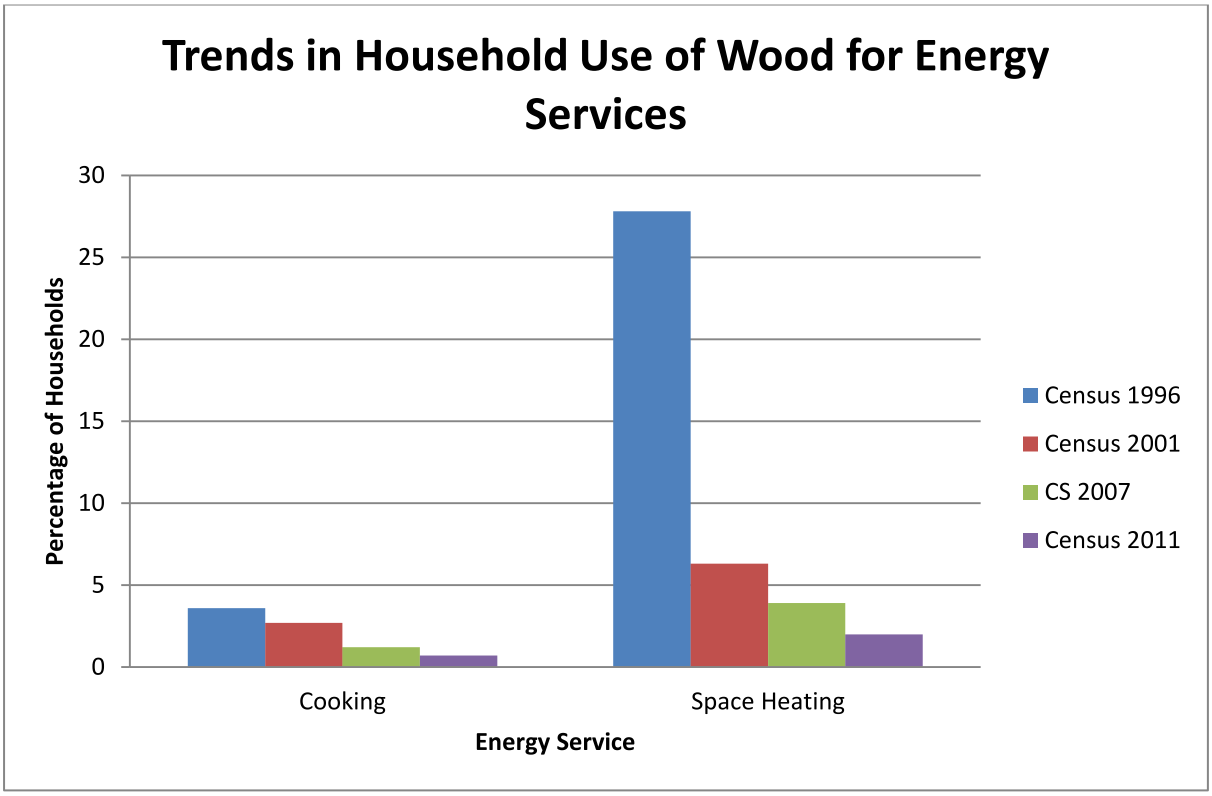

Figure 5-3: Trends in Household Use of Wood for Energy Services (Source: Statistics South Africa, 1998, 2003, 2007, 2012a)

5.3 Household Trends in Coal Use

Only 7% of households in South Africa reported the use of coal in 2011 (Department of Energy, 2012a). While the percentage of households that use coal across most provinces is close to the national average there is a notable difference in Mpumalanga which features 26% of households within the province using coal to meet energy needs (Department of Energy, 2012a). The prevalence of coal use in Mpumalanga is as a result of the close proximity of town such as Ermelo, Witbank and Secunda to major coal fields (Department of Energy, 2012a). As shown in Figure 5-4, since 1996 there has been a steep decline in the use of coal for space heating but in 2011 a larger percentage of households use coal for space heating than cooking.

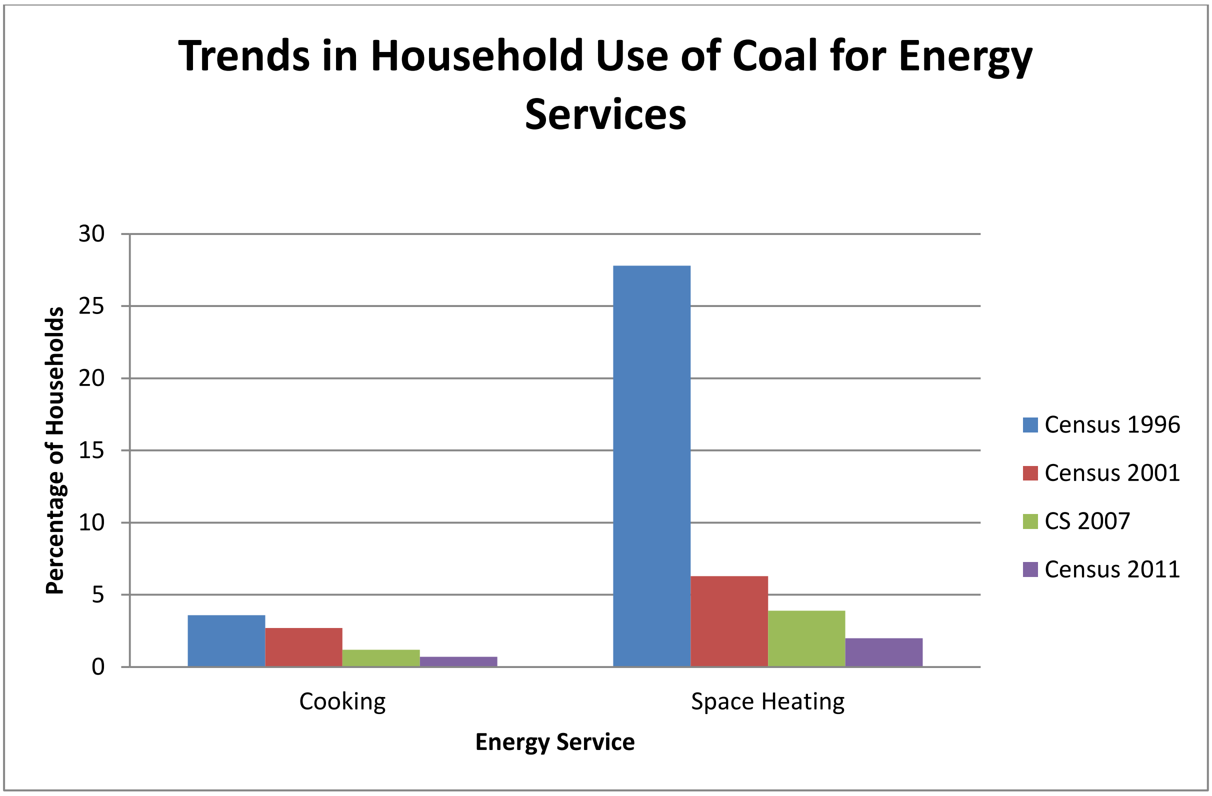

Figure 5-4: Trends in Household Use of Coal for Energy Services (Source: Statistics South Africa, 1998, 2003, 2007, 2012a)

The inefficient burning of solid fuels on an open fire or coal stove creates a dangerous mix of pollutants primarily carbon monoxide and small particles, but also many other health-damaging chemicals. When coal is used, additional contaminants such as sulphur, arsenic and fluorine may also be present in the air. As shown in Figure 5-4 the use of coal for cooking has declined in South Africa from just over 3% of households to just below 1% of households between 1996 and 2011.

5.4 Household Trends in Illuminating Paraffin Use

Illuminating paraffin is versatile and as such households use the fuel both for lighting and thermal purposes with the largest share (38%) going towards cooking. Since 1996 the percentage of households using illuminating paraffin for cooking, lighting and space heating has declined with the greatest decline seen in households that use illuminating paraffin for cooking. The decline in illuminating paraffin can be attributed to increased electrification rates as most households switch from illuminating paraffin to electricity once electrified.

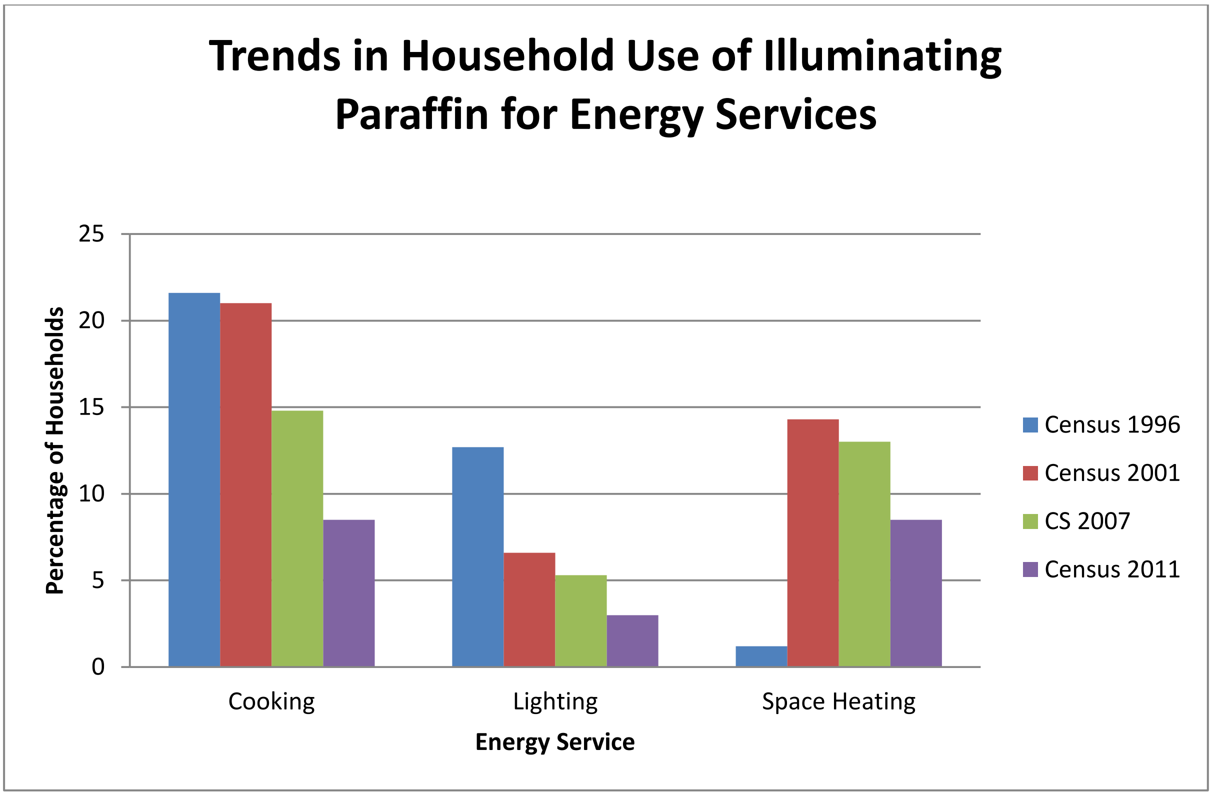

Figure 5-5: Trends in Household Use of Illuminating Paraffin for Energy Services (Source: Statistics South Africa, 1998, 2003, 2007, 2012a)

5.5 Household Trends in Electricity Use

In contrast to illuminating paraffin, coal and biomass the percentage of households that use electricity for space heating, cooking and lighting has increased from 1996 to 2011. The greatest increase in electricity end usage has been for lighting with close to 85% of households using electricity for lighting in the 2011 census compared to less than 60% in 1996. The increase in the percentage of households that use electricity for space heating since 1996 to 2011 has been fairly modest - this could be attributed to behavioural patterns identified in a recent study which shows that 18% of households choose to forgo electricity or other energy carriers to keep warm and rely mainly on blankets or warm clothing (Department of Energy, 2012a).

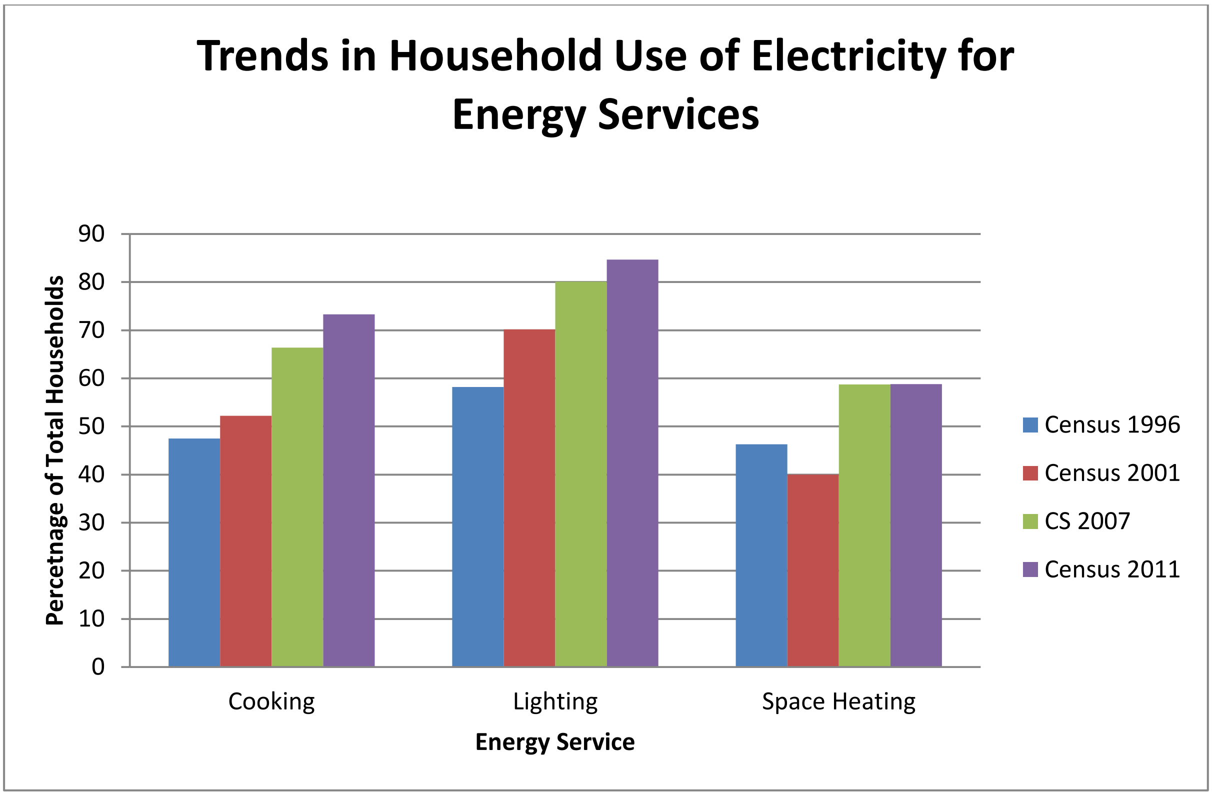

Figure 5-6: Trends in Household Use of Electricity for Energy Services (Source: Statistics South Africa, 1998, 2003, 2007, 2012a)

The increase in the percentage of households that use electricity for various energy services is directly impacted upon by the national electrification programme of Government which has ensured that 85% of households in South Africa have access to electricity.

5.6 Projected Demand

While historical trends in the use of biomass was expanded upon earlier in this section demand projections for biomass were not conducted due to the lack of a consistent time series for biomass consumption in South Africa. Trends which can be inferred from household energy usage statistics from Statistics South Africa illustrated in Figure 5-3 show that the use of biomass by households should continue to decrease into the future. The ability to effectively quantify the extent and rate of decline should be informed by recent and relevant studies on biomass usage in the residential sector which can be the focus of future research studies. Despite the decrease in the percentage of households that depend on biomass to meet household energy needs, households that continue to rely on biomass will face cumulative negative social and environmental consequences. Low income households and rural households may continue to spend a large proportion of income on the purchase of biomass or can devote up to a quarter of household labour collecting firewood, and will then suffer the life-endangering pollution that results from inefficient combustion.

As shown in Figure 5-7 below, the increase in energy demand is driven by an increase in the number of households, higher ownership rates for existing energy consuming devices and increasing demand for new types of energy services. The consumption of fossil fuels declines significantly with the transition from coal and illuminating paraffin to more modern fuels of LPGas and electricity. Historical trends in the decline in coal consumption in households continue as cleaner forms of energy become available for space heating and cooking.

While the historical energy balances were used to inform the projections for most energy carriers a recent study on energy consumption in South African households was used to derive the residential coal consumption in the starting year of the demand projections. Before going into more detail it is important to note that with regards to electricity, wood, illuminating paraffin and LPGas that household consumption trends between 1999 and 2009 mirror those shown in Statistics South Africa studies which were independently conducted. The only deviation between energy consumption trends for the Department of Energy data (DoE, 2012b) and Statistics South Africa residential data (Statistics South Africa 1998, Statistics South Africa 2003, Statistics South Africa 2007, Statistics South Africa 2012a) was for coal. The percentage of households which use coal to provide the demand for energy services has steadily declined from 1996 to 2011 while over the same period there is an increase in coal consumption for the residential sector in the energy balances published by the Department of Energy. Hence a different approach was taken to complete the projection for coal consumption in the residential sector.

A recent study on energy related behaviour and perceptions in South Africa provided information on household expenditure in coal for 2011 (DoE, 2012a). The residential coal consumption for 2011 was derived from household expenditure data for coal and the coal price for the domestics and merchants category in published data for the Department of Mineral Resources. In line with trends shown in Figure 5-4 an assumption was made that the coal consumption in the residential sector would continue to decline into the future by 2% on an annual basis. Despite the fact that the use of coal is known to have a negative impact on health, households will continue to use coal to meet household’s energy needs due to the continuing convenience associated with living close to coal fields as well as the prevalence of low income households to use multiple fuels to meet energy service needs.

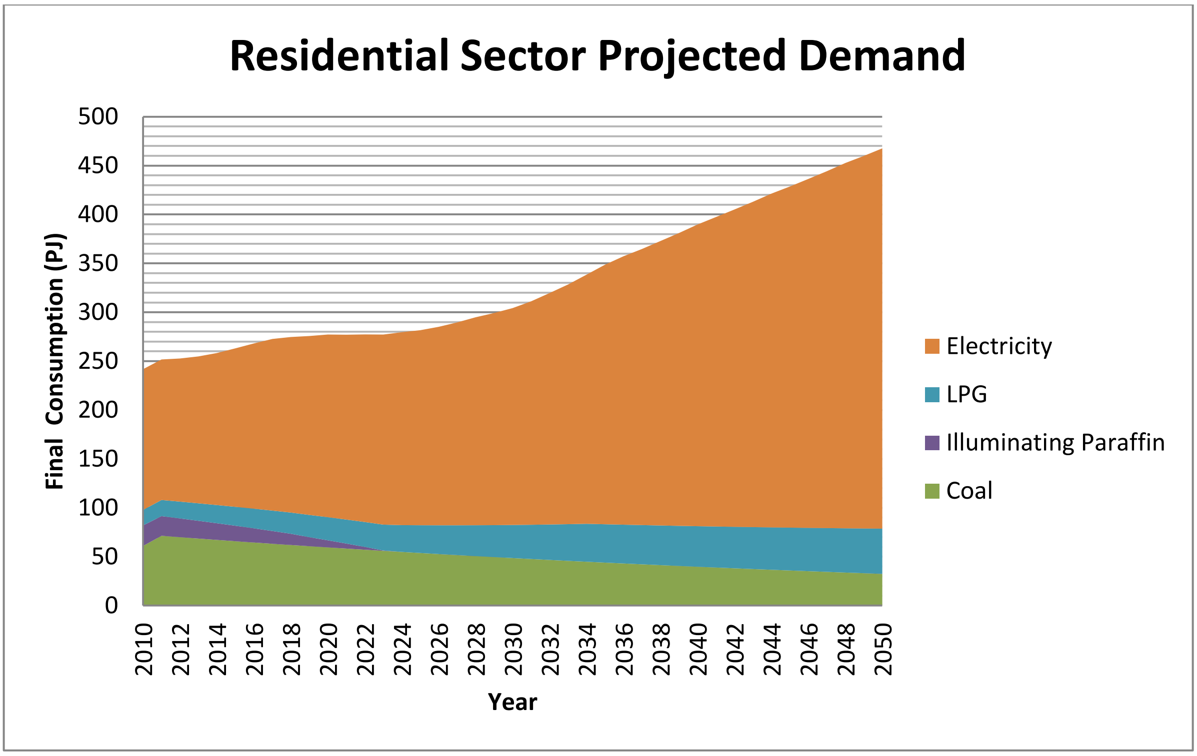

Figure 5-7: Residential Sector Projected Demand 2010-2050 (Source Model Output)

Overall the use of petroleum products increases from 2010 to 2050 but illuminating paraffin decreases. Similar trends have been seen from 1996 to 2011 and are expected to continue given that increases in the share of households with access to electricity will move away from the use of illuminating paraffin for lighting to electricity. The use of LPGas in the residential sector increases with its share of the final consumption energy mix (excluding biomass) moving from just above 6% to just below 9%.

Energy poverty at the household level is defined as a household which is negatively affected by very low consumption of energy, use of dirty or polluting fuels, and excessive time spent collecting fuel to meet basic needs. It is inversely related to access to modern energy services, although improving access is only one factor in efforts to reduce energy poverty. Given the proven success of Government's electrification programme as well as the firm commitment to continue efforts to ensure universal access to cleaner forms of energy it is reasonable to expect that electricity demand will continue to increase. Electricity's share of the total energy mix (excluding biomass) grows from approximately 60% to about 83% by 2050. The increase in electricity usage can also be attributed to increased ownership of electrical appliances.

5.7 Residential Sector Energy Intensity

The Human Development Index represents a combination of several indices and it is used by the United Nations to rank countries according to human development. The HDI combines data for

standard of living represented by GDP per capita, longevity and educational attainment. As shown in Figure 5-8 below there is a correlation between the Human Development Index and annual per capita electricity consumption.

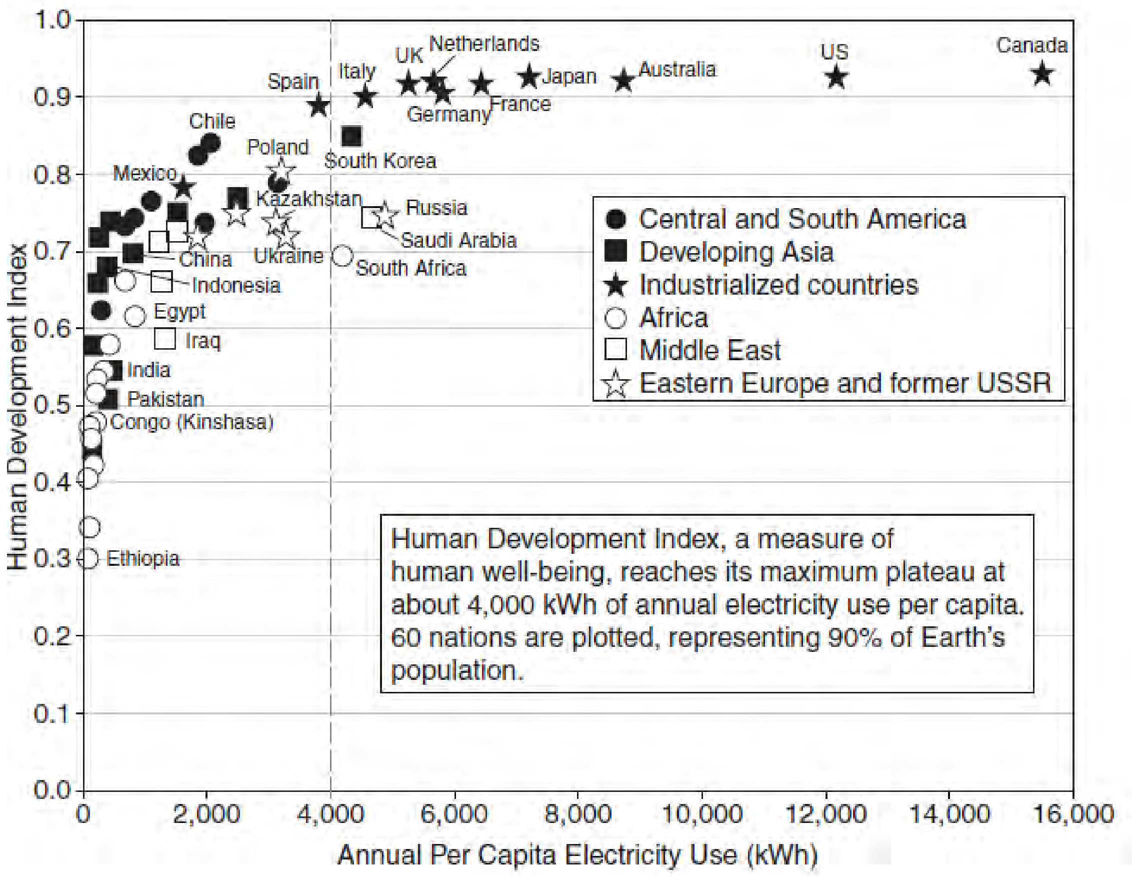

Figure 5-8: The United Nations' Human Development Index and Electricity Use (Source: Pasternak, 2000)

Analysis conducted using data from 1997 shows that 4000 kWh/capita seems to be threshold that corresponds to a Human Development Index (HDI) of 0.9.

Specific energy consumption is defined as the energy consumption per unit of output or scale. In the residential sector, specific energy consumption is often measured as total residential energy consumption per household or total residential energy consumption per capita. As outlined in Figure 5-9 the energy use per household declines from 2010 to 2030 due to the reduction in the use of coal for thermal end uses such as cooking and water heating to an increase in cleaner fuels such as LPGas and electricity. The expected improvement of the energy efficiency of individual appliances over time that should lead to a decrease in energy consumption is expected to be offset by an increase in the ownership of white goods such as washing machines, clothes dryers, dishwashers, refrigerators and separate freezers. This is in contrast to well-developed economies where

household ownership of electrical appliances and white goods has reached an upper saturation level and the improvement in energy efficiencies of electrical appliances is still expected to have a direct and immediate impact on the energy use per household. Thus, the increase in energy use per household post 2030 can be attributed to the increased ownership of household appliances that use electricity and is as such a reasonable expectation in South Africa where the market penetration of electrical appliances is not at the level of more developed economies.

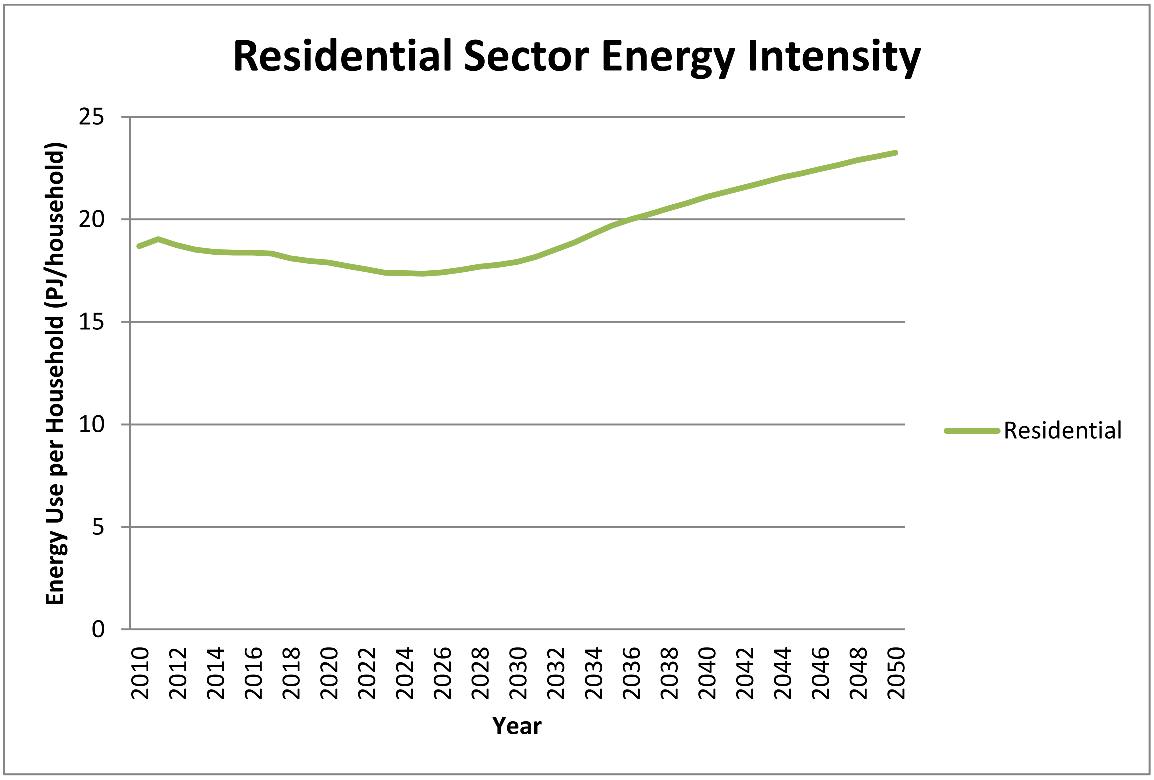

Figure 5-9: Residential Sector Energy Intensity (Source: DoE Analysis)

The increase in energy intensity can also be attributed to the decline in the number of persons per households. Similar trends have been seen in other countries where the increase in the energy consumption per household is driven by a decline in the number of persons per household, as there are some forms of fixed energy consumption that are associated with each household despite the number of people that occupy the home.

5.8 Energy Efficiency Opportunities in the Residential Sector

Energy efficiency is quoted as being the "hidden fuel" which provides a win-win situation for reducing emissions while improving access to cleaner forms of energy. A recently released publication by the IEA (IEA, 2013b) has identified four measures which can be implemented by countries to reduce emissions in the short term without having a negative impact on economic development. At the top of the list is the wider adoption of energy efficiency measures in industry,

buildings and transport. Amongst other factors identified key energy efficiency measures which are relevant to the residential sector and are defined as follows:

- More efficient heating and cooking systems in the residential and commercial buildings through minimum energy performance standards for new equipment, and technology switching as through greater use of heat recovery and better use of automation and control systems.
- More efficient appliances and lighting in residential and commercial buildings (IEA, 2013b).

Cooking is considered as an essential energy service. Given the highly intensive energy requirements of cooking coupled with the use of inefficient fuels such as firewood and coal the largest share of energy in the residential sector goes towards cooking (~39%). As seen in the Figure 5-10 below end use for other thermal purposes such as space heating and water heating take up the next largest share of total energy at ~28% and ~21% respectively.

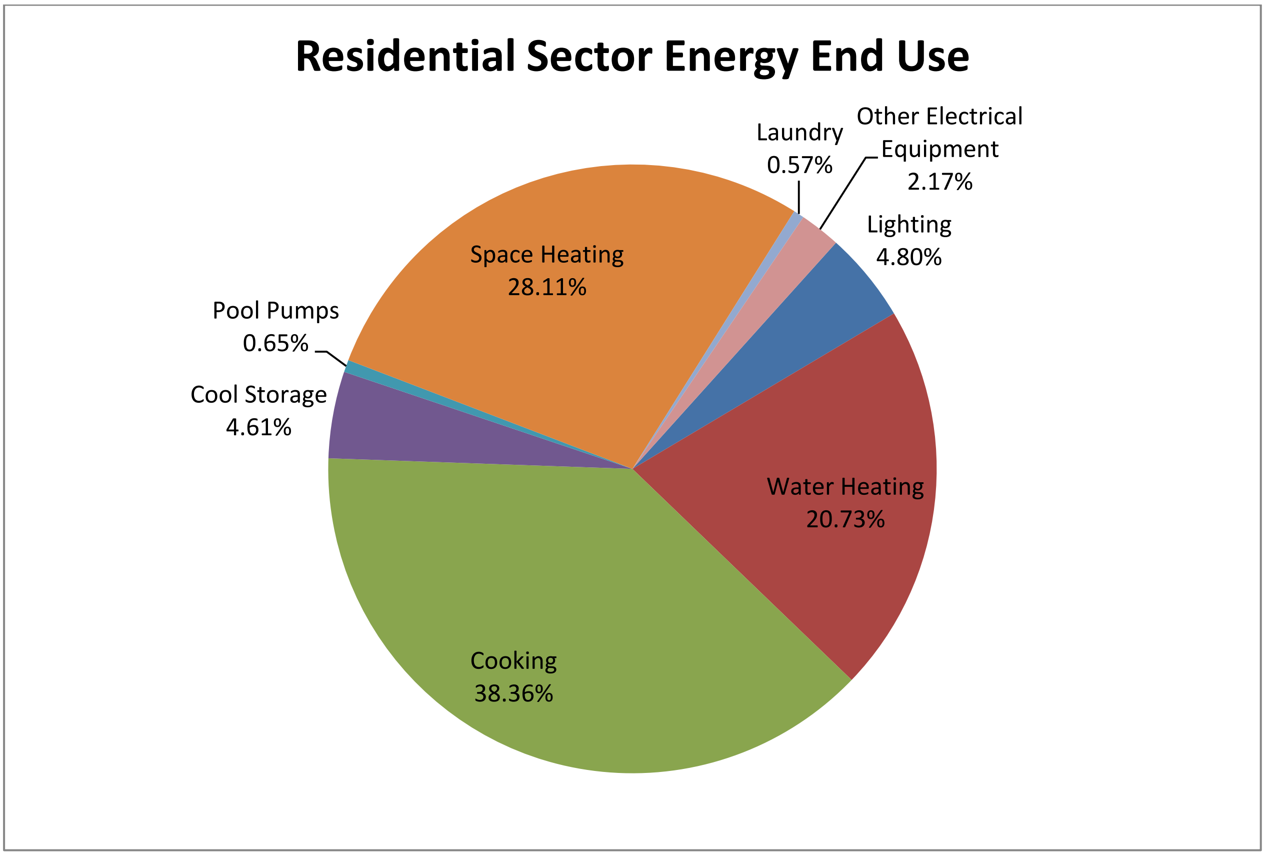

Figure 5-10: Residential Sector Energy End Use (Source: DoE Analysis)

As shown in Figure 5-11 the end use of electricity for lighting and appliances features more strongly in contrast to end use across all energy carriers with more than half the share of electricity going towards end uses which are not for thermal purposes. Worldwide electricity demand in the building

sector is dominated by lighting and appliances with 37% of electricity demand within the building sector going towards lighting and appliances within OECD countries and 26% in non-OECD countries (IEA, 2013a). Due to the relatively short lifespan of appliances and lighting minimum energy performance standards can be effective to implement change relatively quickly and are used widely in many countries. With regards to electricity consumption in the residential sector lighting accounts for approximately 17% of household end use. As shown in Figure 5-11, white goods such as stoves, refrigerator/freezers and laundry account for approximately 10%, 17% and 2% respectively. The balance of non-thermal end use is made up of pool pumps and other electrical appliances which include cell phones, computers, laptops and printers.

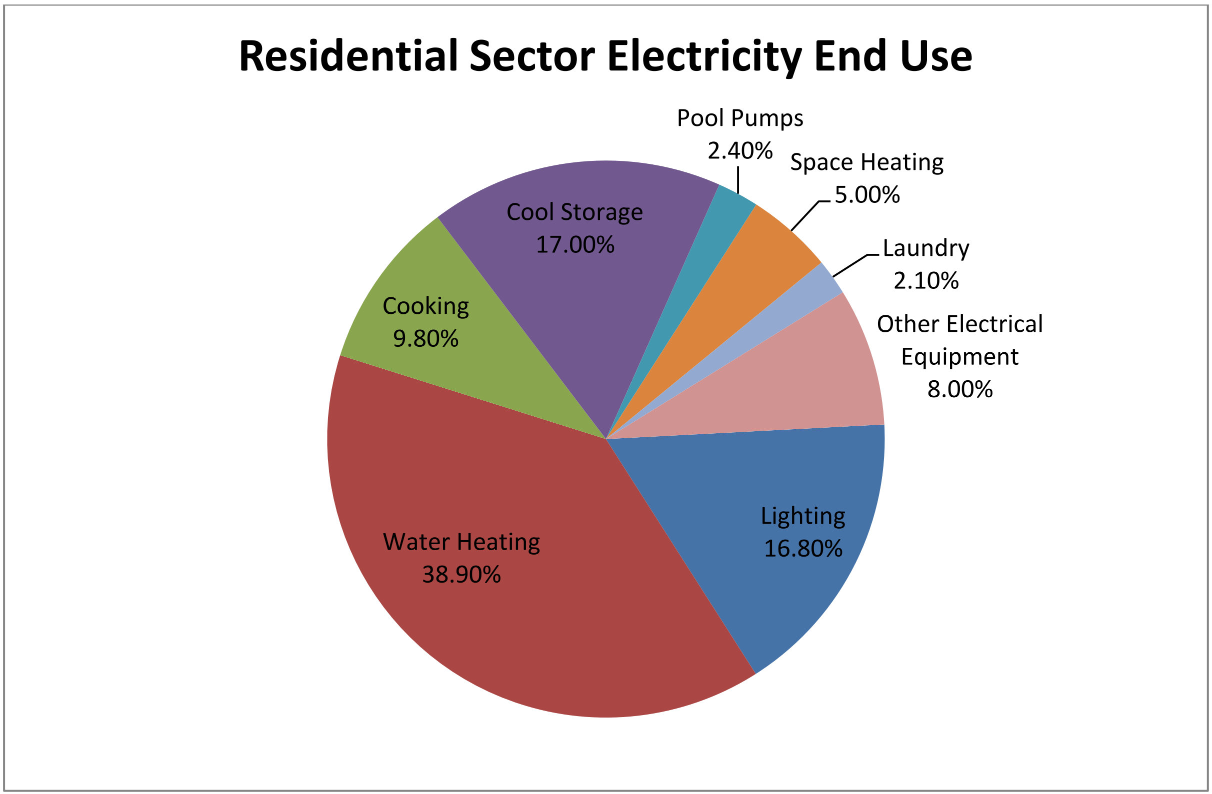

Figure 5-11: Residential Sector Electricity End Use (Source: Eskom IDM)

Government initiatives such as the 1 million solar water heater programme and more ambitious targets of 5 million solar water heaters as outlined the Industrial Policy Action Plan will go a long way to impacting upon the use of electricity in the residential sector given that the largest share of electricity in the residential sector goes toward water heating at approximately 39%.

6. Commercial Demand Projections

The commercial sector comprises of the following economic sub-sectors: finance, real estate and business services; general government services; personal services; storage and communication; and wholesale, retail, motor trade and accommodation. The commercial sector therefore largely comprises of the tertiary or services group of industries, but specifically excludes the transport sector. In this analysis the commercial sector therefore describes all industries within the tertiary sector excluding transportation of passengers and freight. The basis for the exclusion is that transportation demand requires a separate and focused analysis for energy consumption. However in describing the characteristics of the tertiary sector, transportation of goods and passengers are implicitly included. The commercial sector is considerably more heterogeneous than residential buildings, encompassing hospitals, schools, offices, houses of worship, lodging and the retail sector with its big box stores, strip malls, fast food and sit down restaurants. Each of these commercial sub-sectors is unique in its market structure, energy use, energy intensity and in the set of decision makers involved in design and construction projects.

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 now the largest sector of the economy in the Western world, and is also the fastest-growing sector. As a result of a wealth of mineral resources and favourable agricultural conditions, South Africa's economy has historically been rooted in the primary sectors. However, over the past four decades, the economy has been characterised by a structural shift in output. Since the early 1990s, economic growth has been driven mainly by the tertiary sector and more recently South Africa is moving towards becoming a knowledge-based economy, with a greater focus on technology, e-commerce and financial and other services. Some of the fastest growing tertiary industries over the last couple of years include transport and financial services, with most value-add having occurred in information and communications technology; communications; retail as well as finance and business services.

The fuel mix for the commercial sector for 2008 is depicted in Figure 6-1. Unlike the manufacturing sector petroleum products such as residual fuel oil and LPGas feature more strongly being responsible for ~17% of total consumption. Electricity and coal account for almost equal shares of energy consumption in the commercial sector at approximately 40%.

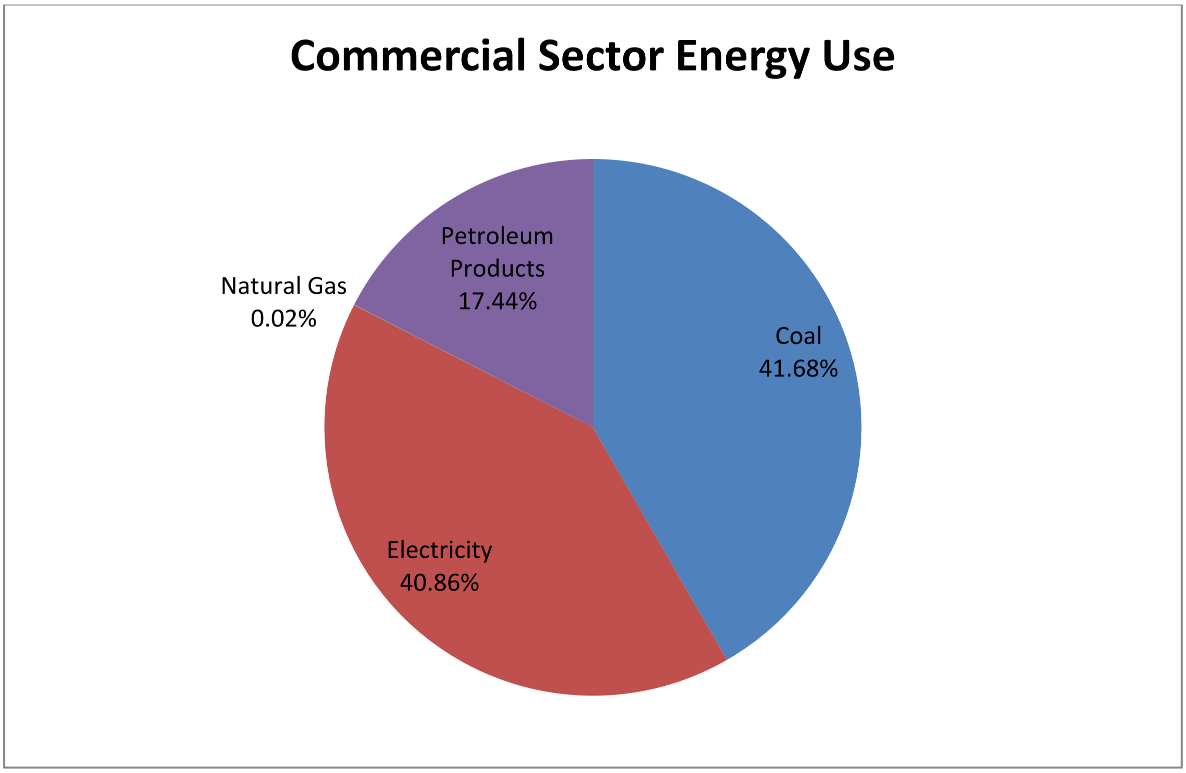

Figure 6-1: Commercial Sector Energy Use (Source: DoE, 2009)

6.1 Projected Demand

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

As economies develop, the commercial and public sector usually grows faster than other sectors and this has been true for South Africa. Continued expansion of the tertiary sector will see continued increases in the demand for energy, and more specifically electricity. The projected demand for the commercial sector is depicted in Figure 6-2. Similar to the residential sector the coal consumption in the commercial sector for the beginning of 2010 deviates markedly from the total consumption reported in the 2008 energy balance. This deviation was due to issues which were identified with respect to the time series data for coal consumption in the commercial sector and hence the projected demand is based on the assumption that coal usage within the commercial sector will decline at an average annual rate of 2% from 2010 to 2050. The fuel mix in the commercial sector continues to be dominated by electricity despite a slight decline in the total share of energy use in the commercial sector from ~77% to ~74%. The share in LPGas increases marginally from ~3% to

~4% over the same time period while the share of residual fuel oil which is mostly used in boilers increases from ~18% to ~22%.

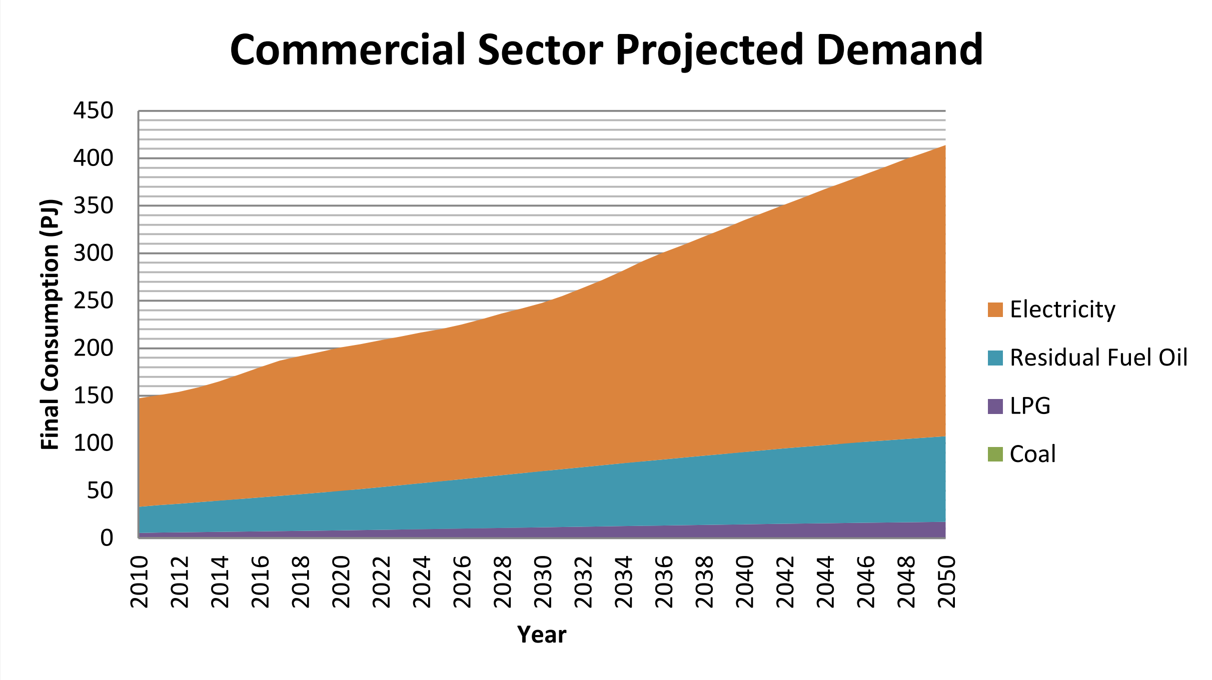

Figure 6-2: Commercial Sector Projected Demand 2010-2050 (Source: Model Output)

6.2 Commercial Sector Energy Intensity

With the on-going improvement in equipment efficiency and building shells, the growth in energy consumption is slower that the growth of value added in the tertiary sector Also the decline in solid fuels such as coal for heating within commercial buildings to more modern energy carriers such as electricity and petroleum products, has a positive impact on the energy intensity of the commercial sector.

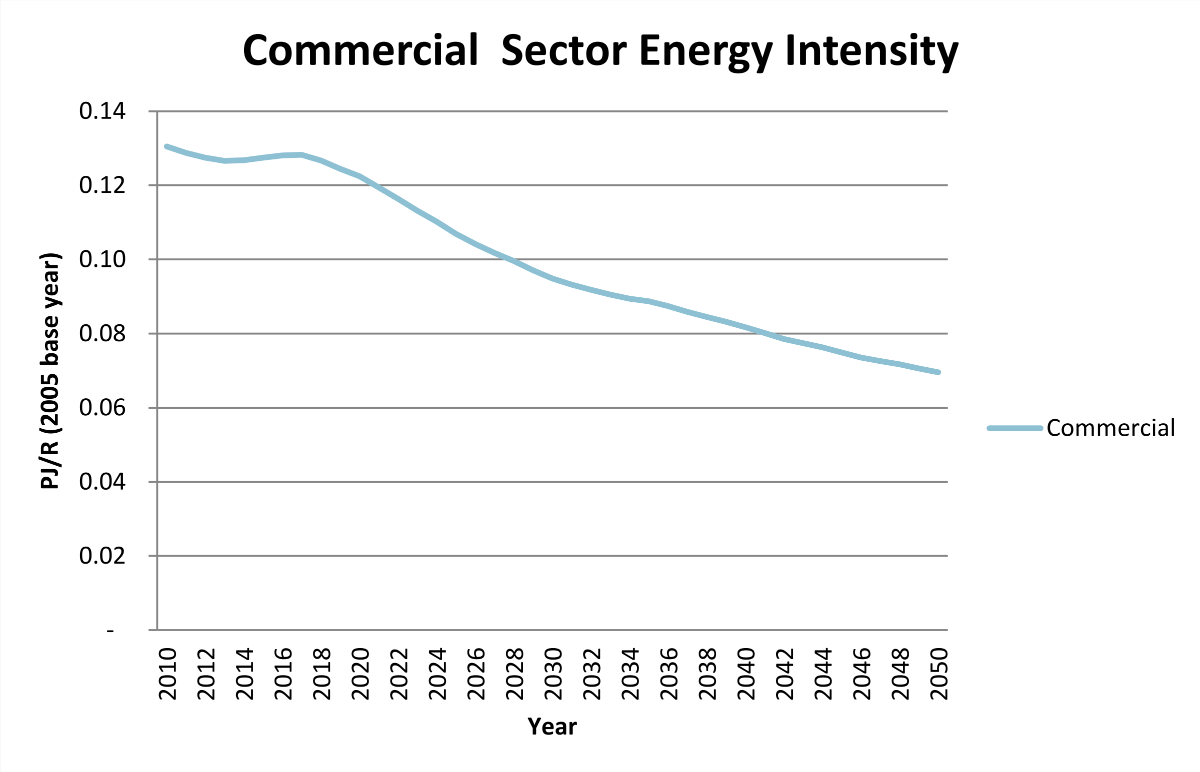

Figure 6-3: Commercial Sector Energy Intensity (Source: DoE Analysis)

6.3 Energy Efficiency Opportunities in the Commercial Sector

How energy is used in a commercial building has a large effect on energy efficiency strategies. The wide range of building types is one factor contributing to the complexity of end use in the commercial sector. The graphs shown in Figure 6-4 and Figure 6-5 below are indicative of average end use profile across the entire sector. In 2005, the majority of floor space in the commercial sector was comprised of offices at around 34% of total area followed by retail outlets which take up the second largest percentage (Haws & Hughes, 2007). The most important energy end use across the stock of commercial buildings is HVAC accounting for close to 34% of energy use. Water heating and cooking are next in importance, each close to 20% of the total. The remaining energy is consumed by lighting; cool storage as well as other miscellaneous uses.

The largest single influence on building energy consumption is the design of the building. New building envelope designs have been shown to reduce energy consumption through optimisation of thermal mass for local climate; optimal insulation; glazing; correct orientation; and building shape. However some barriers to improved thermal design include increased initial cost, split incentives (the developer often does not have to pay for the energy bill), and lack of training of architects and consulting engineers in efficient building practices (IEA, 2013b). 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 the heating and cooling of office buildings, office equipment and lighting. Water heating is slowly starting to see a shift to alternative energy sources such as solar and more energy efficient heat pumps. To this effect, the government has also introduced various legal and policy instruments aimed at improving efficiency. These include the National Building Regulations which include specifications and standards for the energy efficiency of new buildings as well as standards for the labelling of the efficiency of appliances. Various incentives schemes have also been introduced which are aimed at encouraging more energy efficient practices and behaviour from all industries including those that fall within the commercial sector.

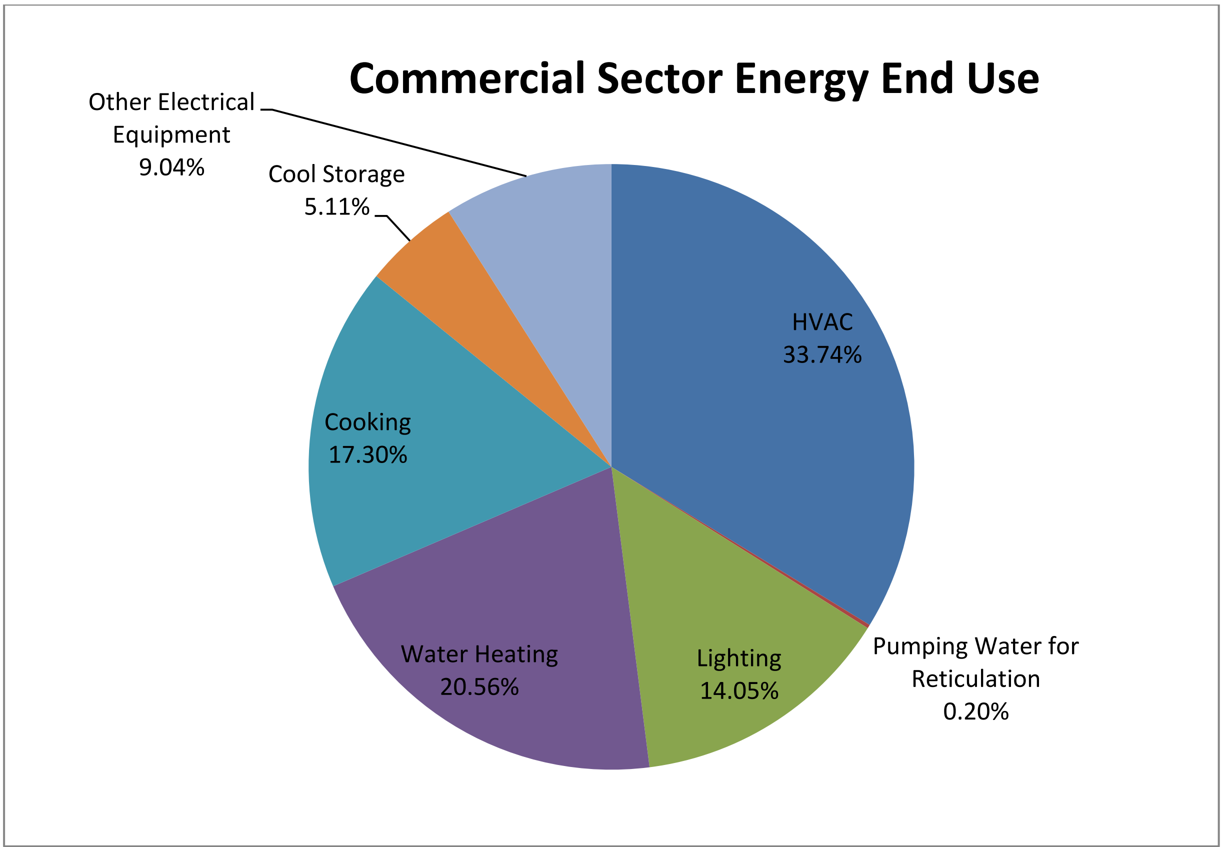

Figure 6-4: Commercial Sector Energy End Use (Source: DoE Analysis)

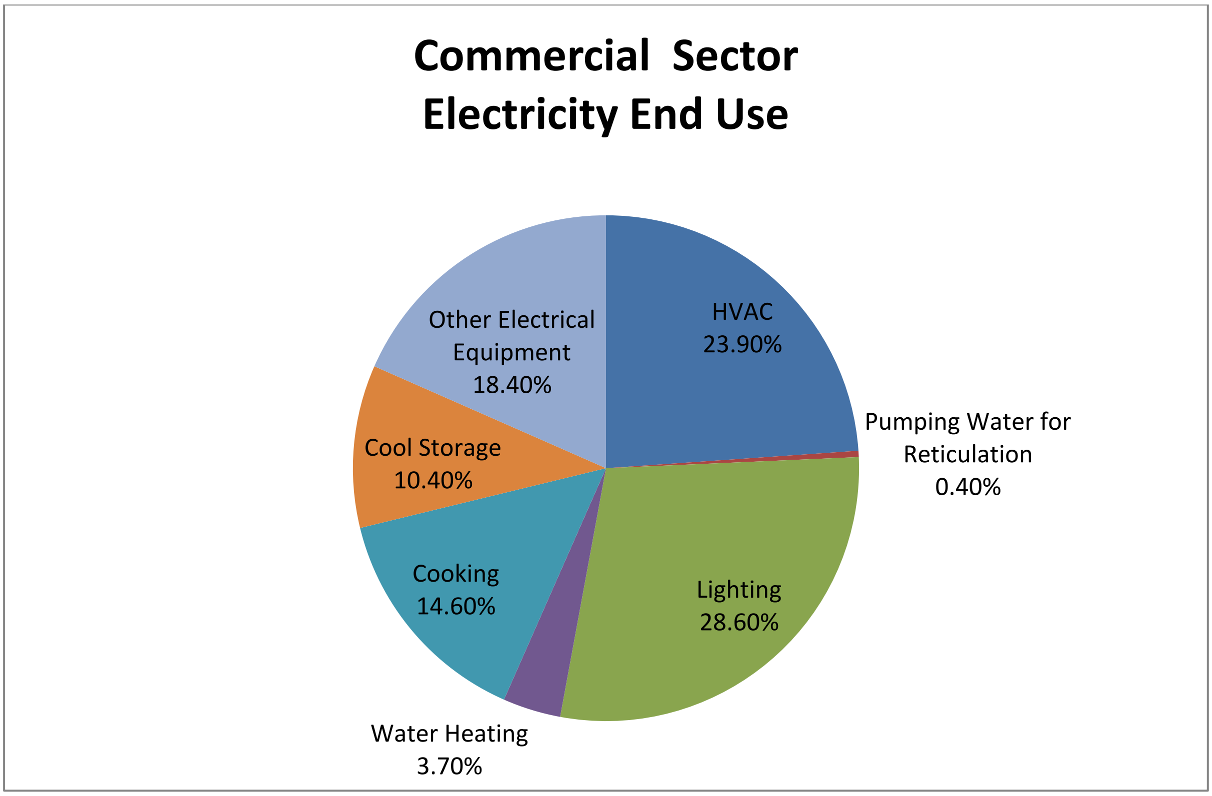

Figure 6-5: Commercial Sector Electricity End Use (Source: Eskom IDM)

7. Agricultural Demand Projections

South Africa has a dual agricultural economy which comprises a well-developed commercial sector and a predominately subsistence-oriented sector in the rural areas. Primary commercial agriculture contributes about 3% to South Africa's gross domestic product (GDP) and about 7% to 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 (GCIS, 2012).

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

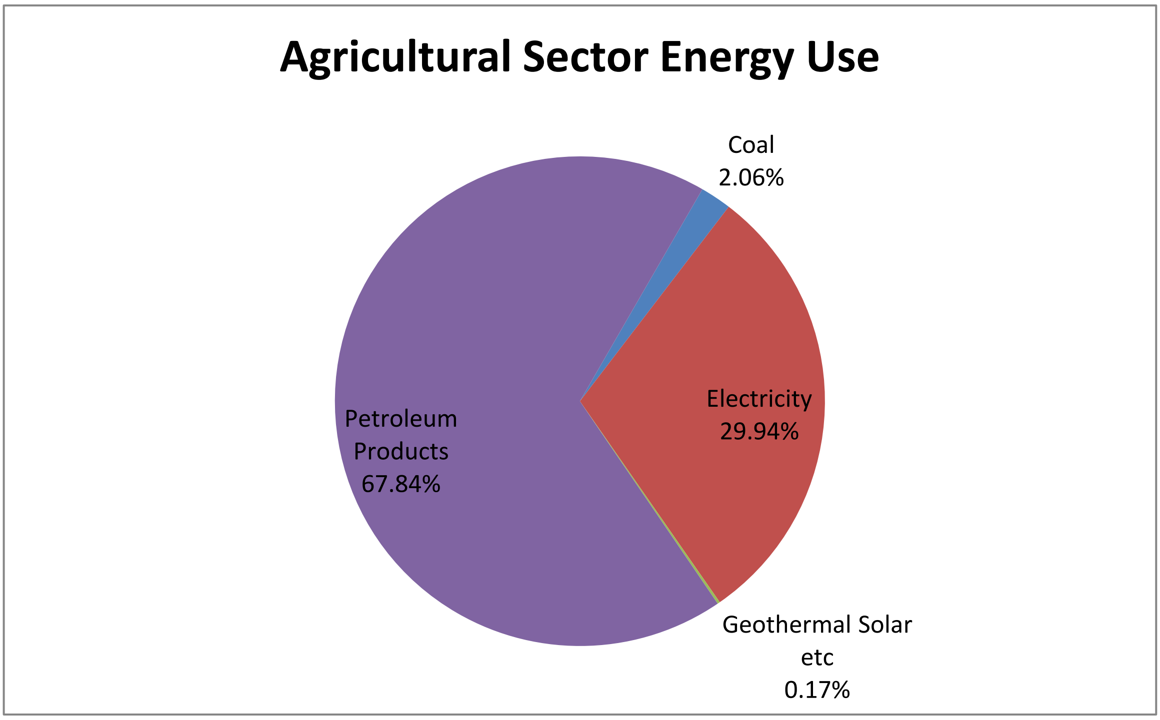

Figure 7-1: Agricultural Sector Energy Use (Source: DoE, 2009)

7.1 Projected Demand

Despite the relative importance of the agricultural sector to economic activity and employment, agricultural energy use is very small in comparison to the industrial and the commercial sector. In 2010 the majority of energy needs within in the agricultural sector are met from diesel and this continues to persist with diesel being responsible for the largest share of total energy consumption in the future. Overall total energy consumption increases with a modest increase in electricity demand coupled with a decline in coal over the same time period.

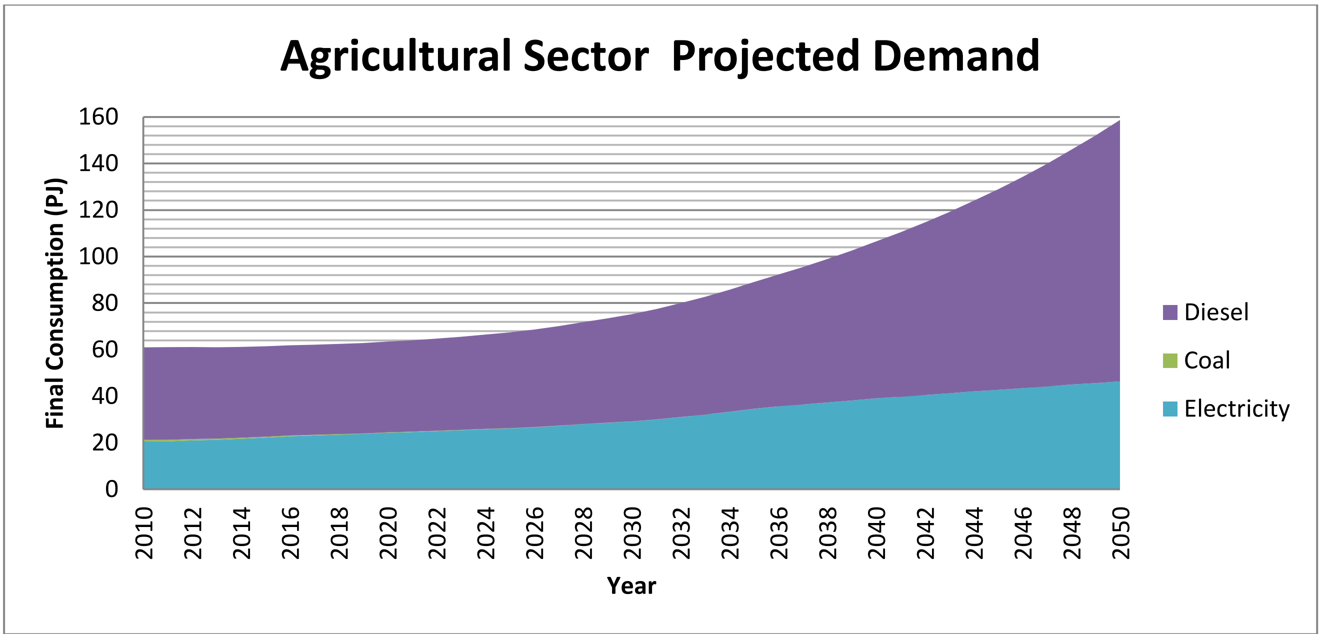

Figure 7-2: Agricultural Sector Projected Demand 2010-2050 (Source: Model Output)

7.2 Agricultural Sector Energy Intensity

For agriculture, the three-stage evolution can be considered as follows:

- Basic human work for tilling, harvesting and processing, together with rain-fed irrigation, none of which involve an input from an external fuel source;
- Then the use of animal work to provide various energy inputs;
- Finally, the application of renewable energy technologies such as wind pumps, solar dryers and water wheels, together with modern renewable and fossil fuel base technologies for motive and stationary power applications, and for processing agricultural products (FAO, 2013)

In the agricultural sector energy intensity changes over the three stages identified above. In the first and second stage, where agriculture is more traditional, human and animal power plays a significant role, energy intensity is lower since productivity is also low. In the initial phase of the third stage the

modernisation of agriculture, energy intensity increases because of increased energy investment to develop the infrastructure, application of chemical fertilizer and the introduction of machines. In the later phase of the third stage, energy intensity decreases due to increased efficiency of agricultural productivity through modern technology and efficient utilisation of various forms of energy (Khosruzzaman et.al, 2010).

South Africa has 2.76 million hectares of cultivated land, of which nearly 10.45 million hectares (82%) is used for commercial farming purposes. A total of 0.79 million hectares (only 6.19%) is permanently under cultivation and more than 10.83 million hectares (85%) is rain-fed (Agriseta, 2010). The formal sector which is comprised of well-established commercial farms is complemented by an informal or emergent sector. Within the commercial sector there are large established farming businesses and smaller ones that struggle to survive and within the less formal sector there are emergent farmers striving to achieve commercial success. The emerging farmer is neither an established commercial farmer nor subsistence in nature and is the focus of many of the government's efforts to achieve transformation within the sector as a whole. For instance the Department of Agriculture Forestry and Fisheries has promoted mechanisation through tractor distribution programmes in support of the Mechnanisation Policy for Household Food Security which targets households in rural areas with access to land with the potential to produce food (Department of Agriculture, Forestry and Fisheries, 2013). Other initiatives such as the Comprehensive Agricultural Support Programme has also supported farmers with access to equipment in an effort to increase agricultural production as mechanisation is key to moving from the first and second stage of agricultural production to the third stage (Department of Agriculture, Forestry and Fisheries, 2013).

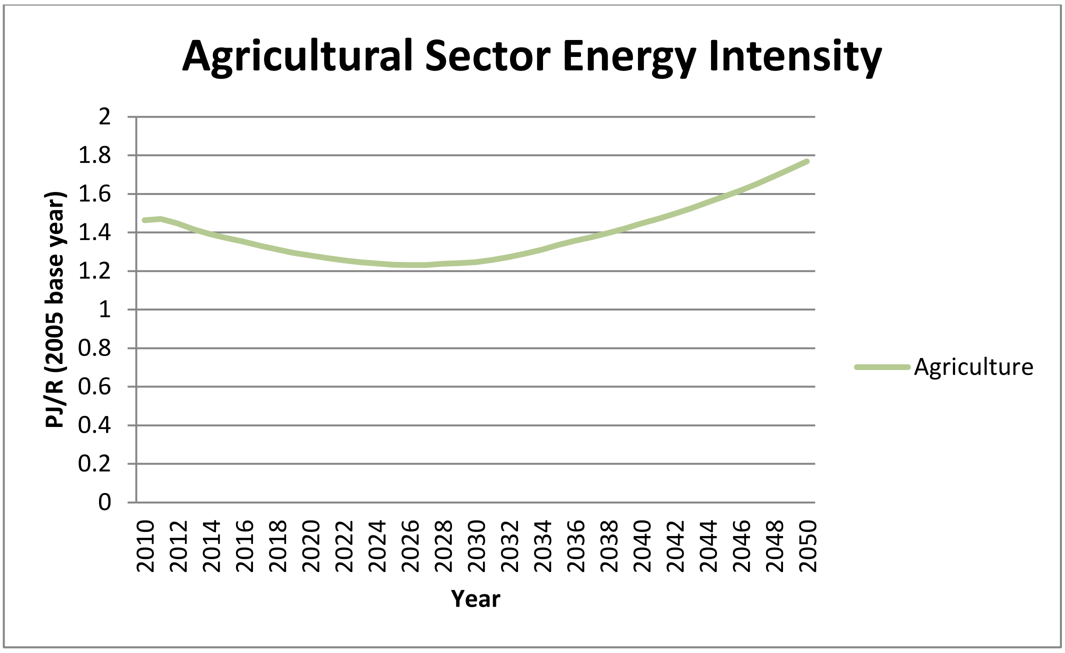

Figure 7-3: Agricultural Sector Energy Intensity (Source: DoE Analysis)

As shown in Figure 7-3 the energy intensity of the agricultural sector decreases from 2010 to 2034 but increases afterward from 2035 to 2050. Decreases in energy intensity from 2010 to 2034 can be attributed to the reduction in coal. Increases in agricultural intensity post 2034 can be attributed to the increase in the diesel demand as well as the increased usage of farm equipment by emergent farmers that look to expand agricultural production by moving from the first and second stage to the third stage of production.

7.3 Energy Efficiency Opportunities in the Agricultural Sector

The agricultural sector has at its core the production process for foodstuff (e.g. grains, fruits and vegetables, meat, fish, poultry, and milk), and non-food vegetable products of economic value (e.g. tobacco). However the sector also comprises or has close links with processes that take place before and after this core production process, such as fertilizer production, post-harvest processing, and transport of foodstuff. Farmers have many expenses, including chemicals like fertilizers and pesticides, farm labour, and seed, as well as energy expenses like lighting and diesel fuel for farm equipment. By lowering farm expenditure for energy through improved energy efficiency, the chance that a farm can become profitable will increase. Opportunities for improvements in energy efficiency should focus on the end uses within the agricultural sector which have the most impact on energy consumption. The majority of energy in the agricultural sector goes toward traction (~66%) followed by irrigation (~8%). With regards to electricity the largest share is used for irrigation (~28%) followed by water heating (~22%). As most of the energy consumed in the agricultural sector goes towards traction efforts to reduce energy consumption in the agricultural sector should focus on

increasing the efficiency of tractors or minimising the need for traction through low tillage agriculture in cases when it is appropriate.

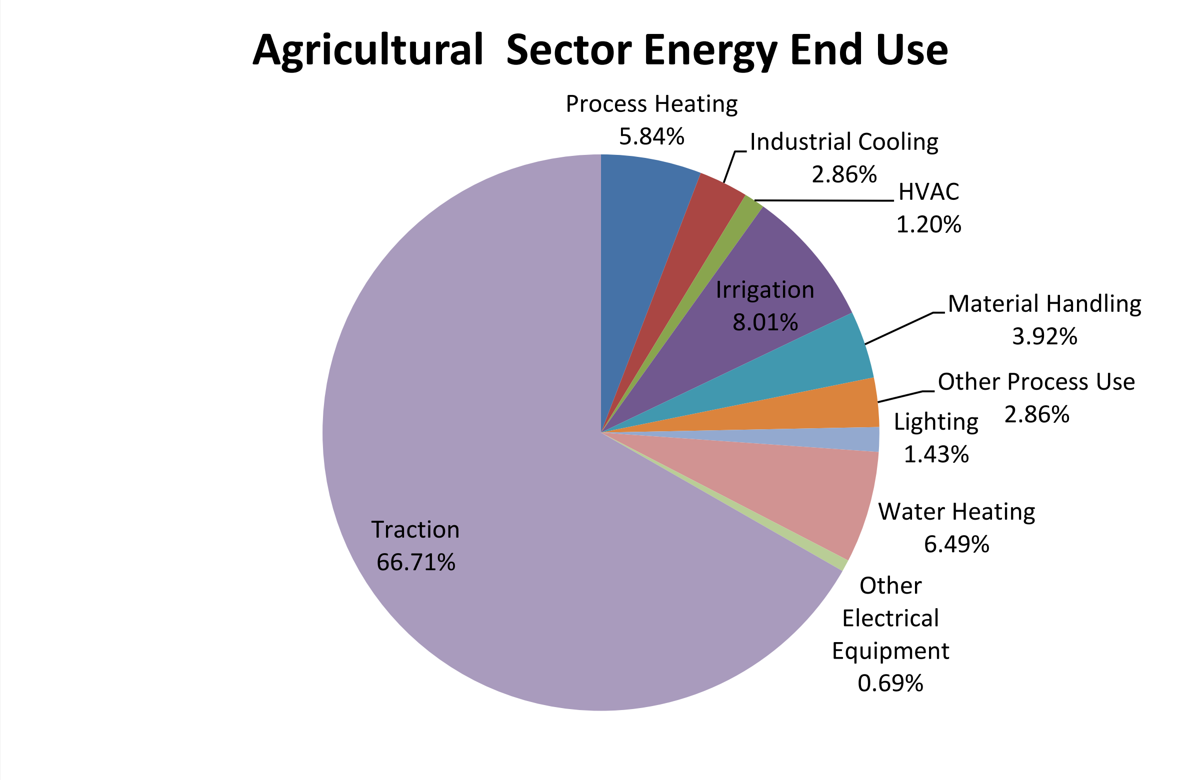

Figure 7-4: Agricultural Sector Energy End Use (Source: DoE Analysis)

Reduction in energy used for irrigation while providing the desired service is possible through the use of more efficient pump sets and water frugal farming methods. To improve the efficiency of irrigation pumps farmers can use foot valves that have low-flow resistance; replace undersized pipes and reduce number of elbows and other fittings that cause frictional losses; use high efficiency pumps; select pumps better matched to the required lift characteristics. As various agricultural products are subjected to drying or cold storage before they are sent to market, 10% of electricity used in the agricultural sector is used for industrial cooling. The efficiency of these processes used for industrial cooling can generally be improved through use of better equipment and proper maintenance. Reducing post-harvest food and grain losses through improved storage methods impervious to pests and rodents, the need for crop production can be reduced hence saving the energy that would have been used in that production.

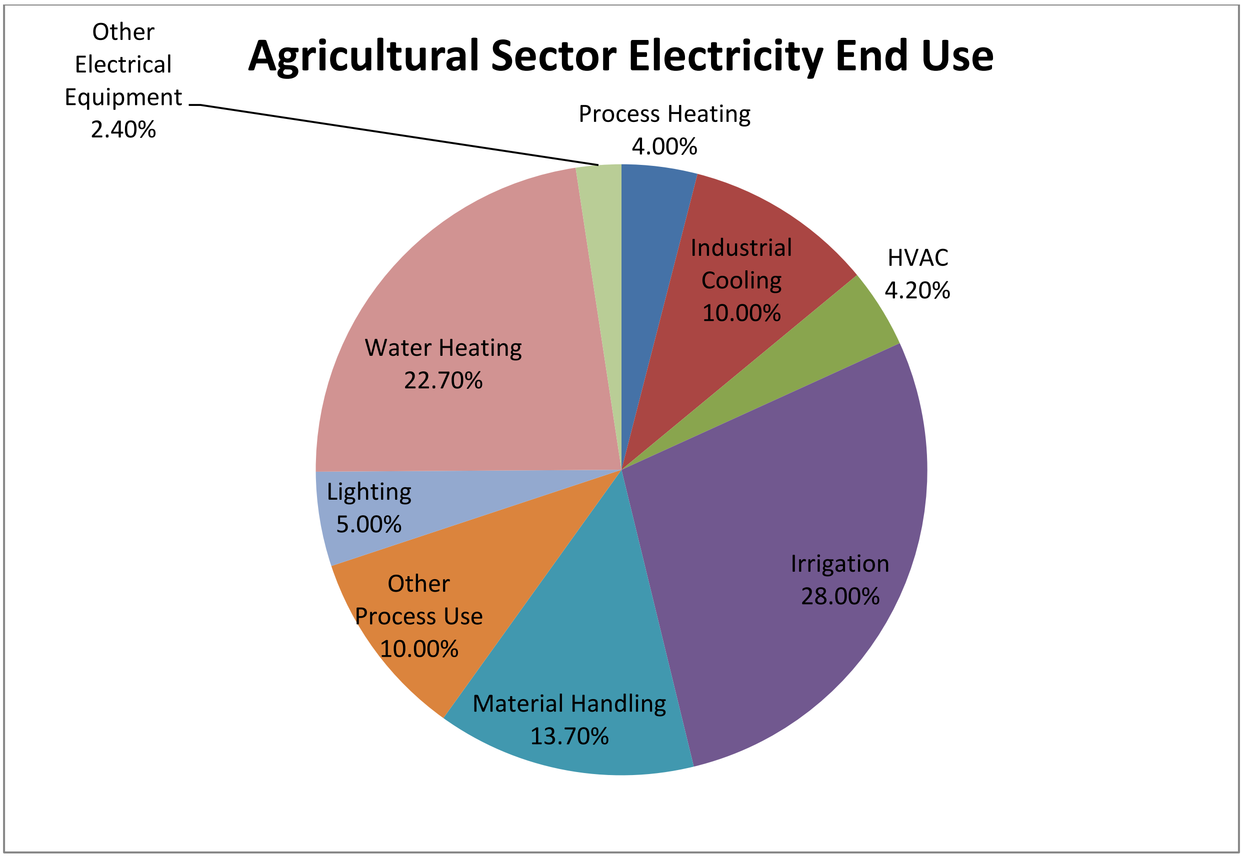

Figure 7-5: Agricultural Sector Electricity End Use (Source: Eskom IDM)

8. Transport Demand Projections

Transport uses a significant amount of the total final energy consumed in South Africa which results in high greenhouse gas emissions in comparison to many other countries. This is largely driven by the use of coal to produce liquid fuels for the transport sector.

There are multiple options in providing transport services from the primary resources of energy available to the country, the types of energy transformation to prepare transport fuels, the choice of vehicle type and mode of transport chosen by the end consumer. The optimum provision of transport services needs to consider all these possibilities in terms of their total costs (including externalities caused by such factors as GHG emissions and pollution) and benefits across the whole value chain.

The detailed assumptions on transport demand technologies are provided in ANNEXURE B: Inputs and Assumptions for the Optimisation Model. This section presents the output from the transport demand projections (i.e. transportation demand). It should be noted that this does not provide the demand for the vehicle technology or consequent demand for transport energy carriers. The latter is dependent on the optimisation model which is informed by the constraints of specific test cases and the least cost options within the constraints. The results for the total energy use for the transport sector in the base case and the various test cases is provided in ANNEXURE A: Part 2: Optimisation Modelling Report.

8.1 Scope and procedure of transport demand analysis

The scope of the analysis for the transport demand modelling was constrained by available data and limited to road transport including private passenger, public passenger and road freight. Air transport was considered by projecting demand for aviation fuels, but no aircraft technologies were considered. Private passenger vehicle types were disaggregated into cars and sport utility vehicles (SUVs) of petrol and diesel fuel types for the existing fleet. Future vehicle types include hybrids and electric vehicles. Public passenger vehicles were divided into busses (diesel only) and minibus taxis (both petrol and diesel). Freight vehicles were disaggregated into three classes, heavy, medium and light duty. Traction by rail is excluded as it is considered under electricity demand.

The modelling procedure to analyse the transport demand involves determining transport demand, person kilometres and ton kilometres travelled for passenger and freight transport respectively, based on correlations between transport demand and macroeconomic indicators taking into account typical vehicle usage, occupancy, and loading and projecting these correlations to 2050.

8.2 Drivers of transport demand

The relationship between transport services and macroeconomic indicators, used to project future demand for transport services, are discussed in this section. The decay of the residual vehicle fleet and projections of future fleet requirements, passenger kilometre and freight kilometre demand are detailed. Finally the required service demand to be met by new vehicles is presented.

Demand for transport services are assumed to be driven by economic activity represented by GDP for freight and public transport and GDP per capita for private passenger transport. The assumptions on GDP and GDP per capita are provided in previous sections in this document.

8.3 Existing vehicle fleet capacity

Investments in transportation technologies are informed by the difference between future transport demand and the capacity of the current vehicle fleet. Overtime the existing vehicle fleet decays due to age and deterioration. However, the existing vehicle fleet could to a certain extent meet a substantial portion of future transportation demand if demand-side interventions such as efficient driving, increasing passenger vehicle occupancy rates, increased usage of public transportation, amongst others, are introduced.

Normalised calibrated curves for the rate at which vehicle are scrapped were obtained from ERC (2012). These curves together with information about the current vehicles fleet are used to determine the absolute number of vehicles of a certain vintage remaining in the projected future. The scrapping of the various vehicle types in the vehicle fleet into the future is shown in Figure 8-1 (petrol cars are shown on the right vertical axis the remaining vehicles use the left vertical axis). The total remaining passenger fleet over the modelling period is shown in Figure 8-2 and the total remaining freight fleet is shown in Figure 8-3.

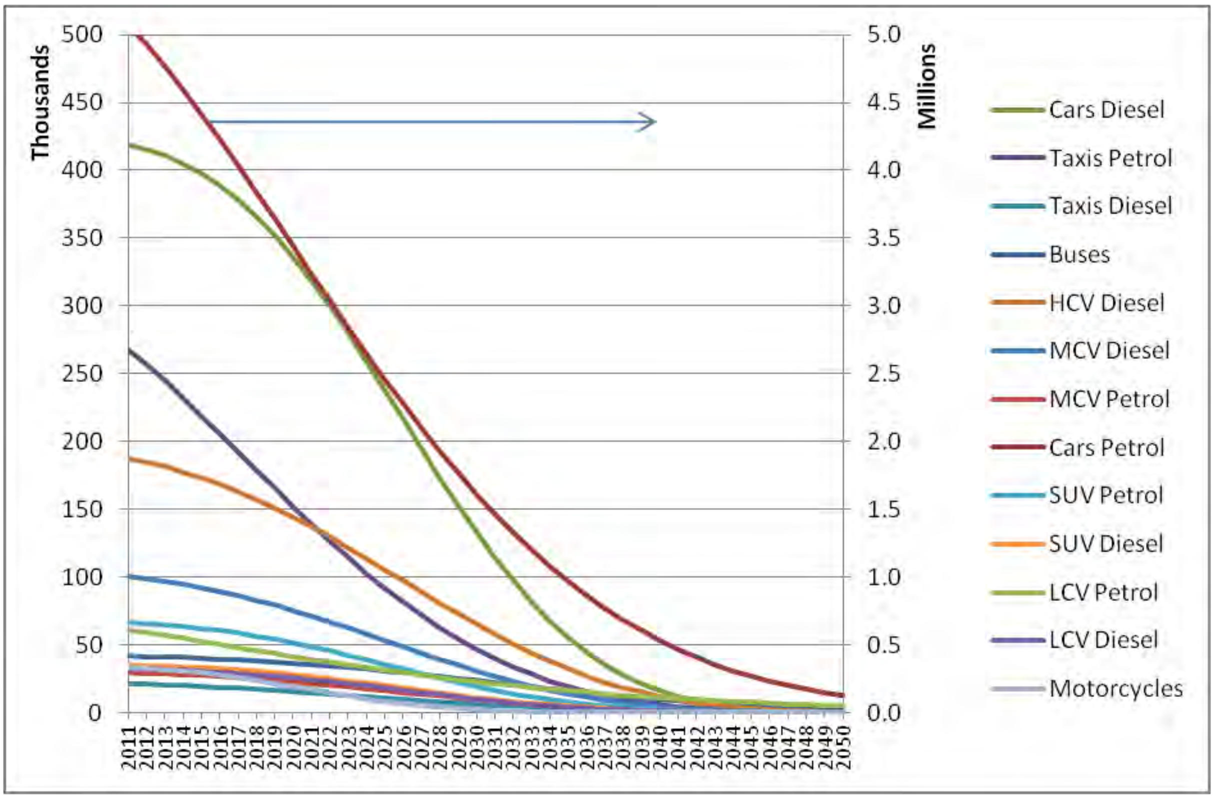

Figure 8-1: Decay of the vehicle fleet by individual vehicle types

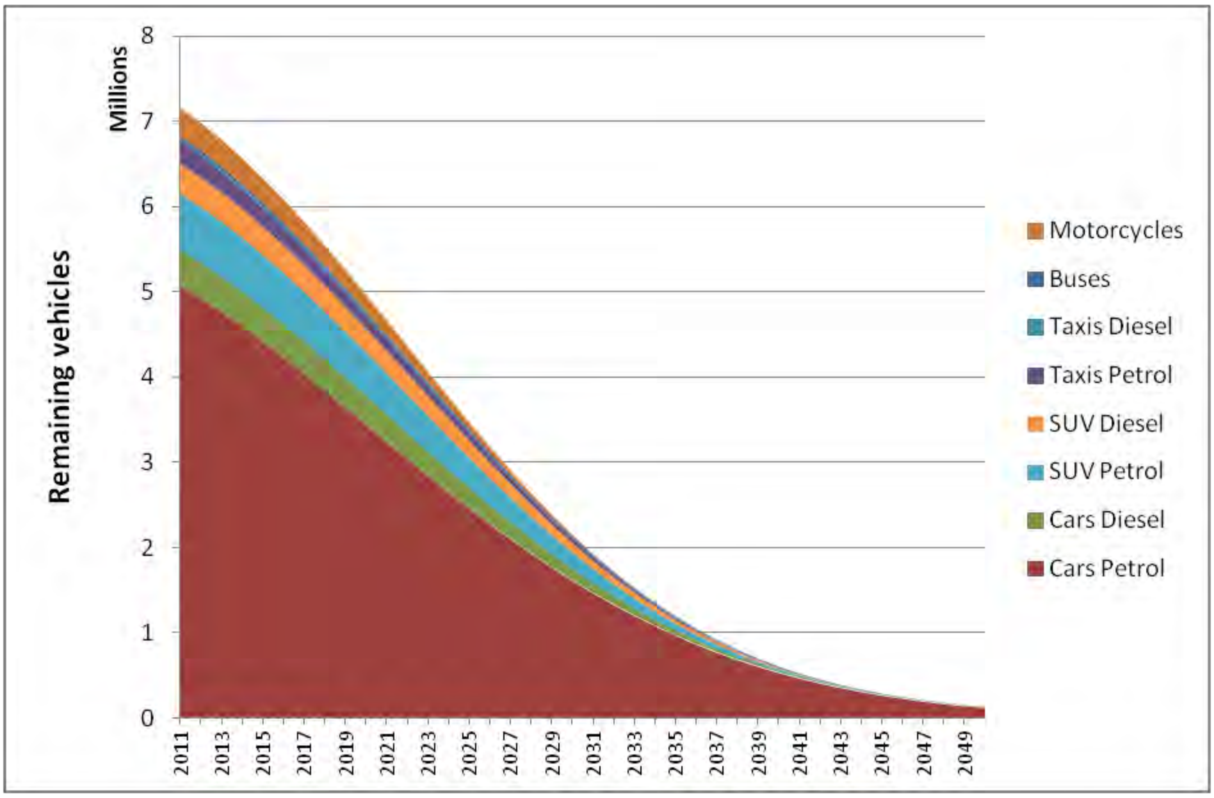

Figure 8-2: Residual passenger vehicle fleet capacity

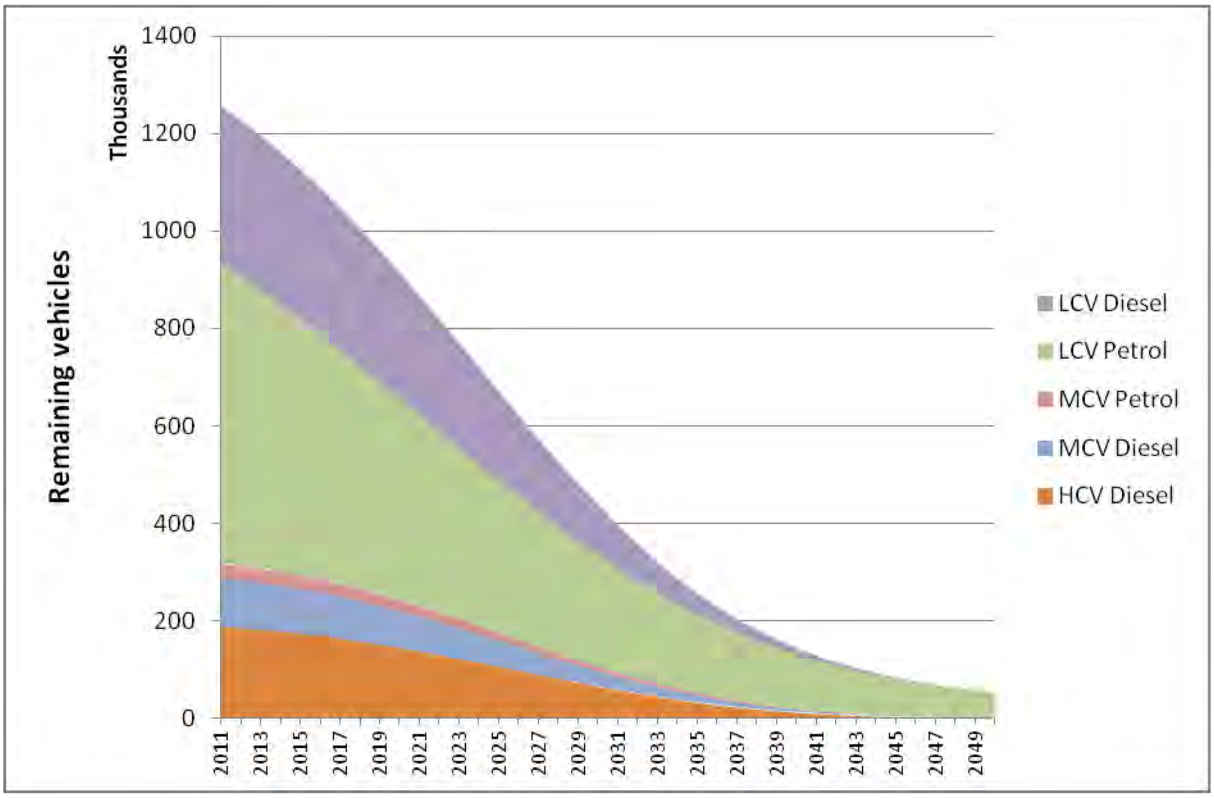

Figure 8-3: Residual freight vehicle fleet capacity

8.4 Future vehicle fleet capacity requirements

Information about the South African motor car and commercial vehicle fleets were obtained from the Road Traffic Management Corporation (RTMC). A linear regression was performed between vehicle population and GDP for freight and public passenger vehicles and GDP/Capita for private passenger vehicles for the years 1990 and 2010. The regressions were then used to extrapolate the vehicle populations against the projected GDP and population to the year 2050. Historical (1990-2010) and projected (2011-2050) vehicle fleets are presented in Figure 8-4.

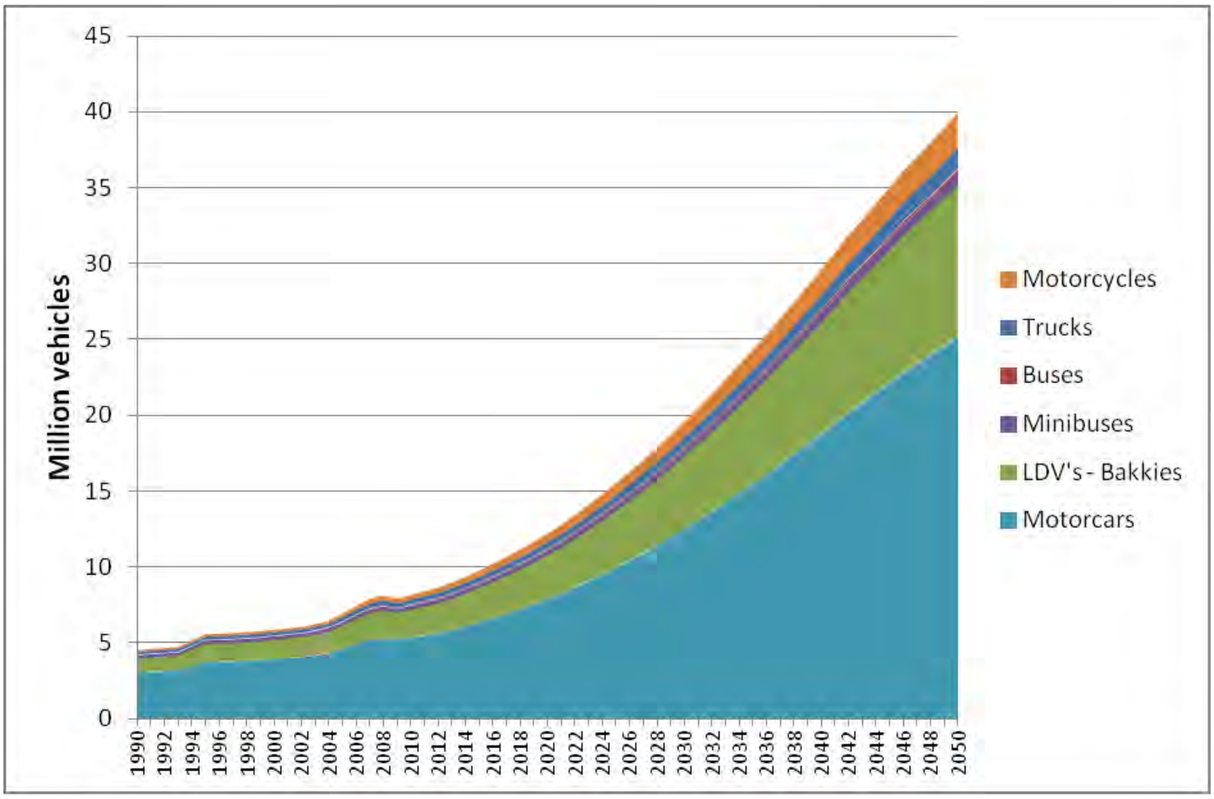

Figure 8-4: Historical and projected vehicle fleet

Many Light Delivery Vehicles (LDVs) are multipurpose vehicles used for both commercial and passenger services. This was accommodated by sharing the total distance travelled by LDVs evenly between passenger and ton kilometres.

Motorcars form the majority of the vehicle fleet at present and within the projected period. The numbers of cars together with a proportion of the LDVs used for passenger transport in the year 2050 indicate vehicle ownership of approximately 500 cars per thousand people. This is equivalent to current vehicle ownership rates in many developed nations.

8.5 Projected vehicle kilometres travelled

Vehicle usage varies by vehicle type and age. Average vehicle kilometres for various vehicle types were obtained from ERC (2012). These are listed in Table 8.1 for existing and new vehicles. Vehicle use by age was not considered.

Table 8.1: Distances travelled by vehicle type and class (ERC, 2012)

Vehicle class	Fuel type	Residual vehicles Ave km/a	New vehicles km/a
Motorcars	Diesel	21254	24000
Motorcars	Petrol	16169	24000
Motorcars	Petrol hybrid	23678	24000
SUV	Diesel	20314	24000
SUV	Petrol hybrid	24000	24000
SUV	Petrol	19128	24000
Minibuses (taxis)	Diesel	43474	50000
Minibuses (taxis)	Petrol	30927	50000
Buses	Diesel	22072	40000
Motorcycle	Petrol	8340	10000
Light Commercial Vehicles (LCV - LDV)	Diesel	19202	25000
Light Commercial Vehicles (LCV - LDV)	Petrol	16662	25000
Medium Commercial Vehicles (MCV - trucks)	Diesel	33417	45000
Medium Commercial Vehicles (MCV - trucks)	Petrol	13575	25000
Heavy Commercial Vehicles (HCV - trucks)	Diesel	48403	70500

Total vehicle kilometres per vehicle type were calculated from the product of the distance travelled per vehicle type and the number of vehicles of that type for each projected year. The historical and projected vehicle kilometres are shown in Figure 8-5.

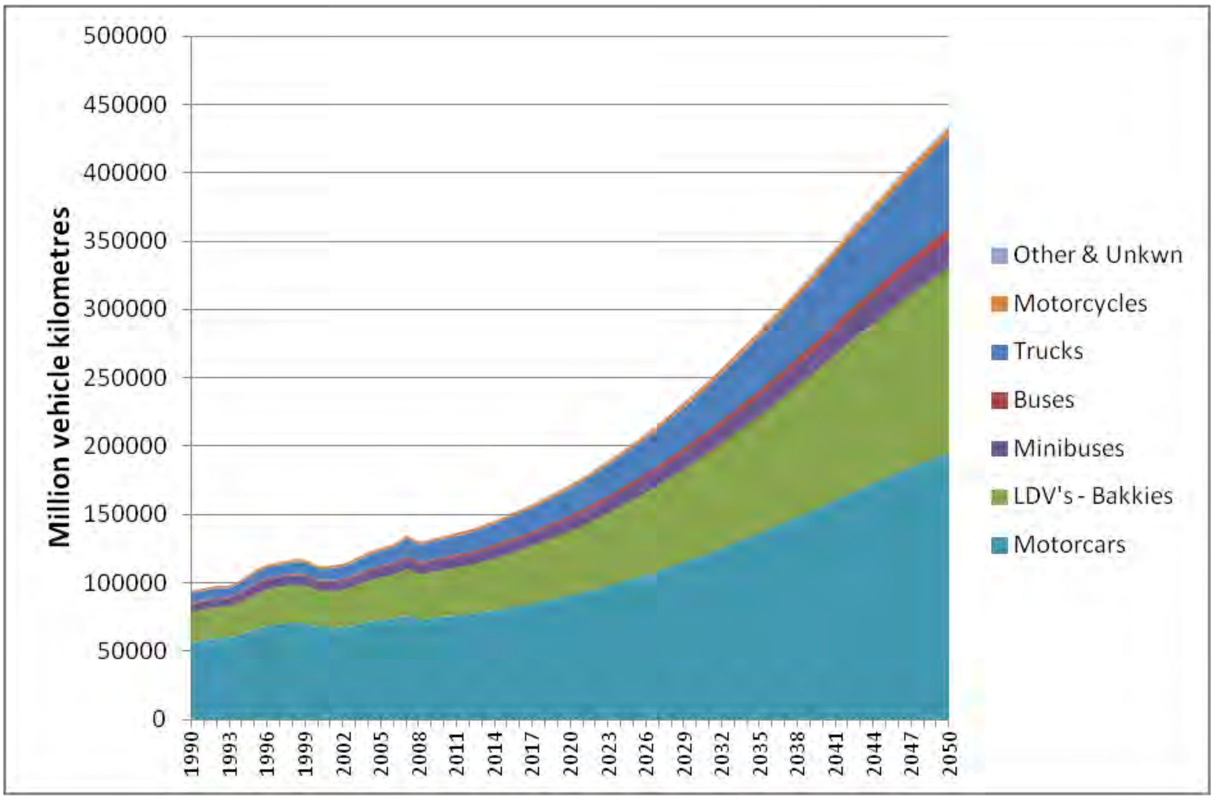

Figure 8-5: Historical and projected vehicle kilometres

8.6 Projected passenger and tonne kilometres

Occupancy rates of 1.1, 1.4, 14, and 25 were obtained from ERC (2012) and were used to determine total vehicle kilometres for motorcycles, cars, mini bus taxis and busses respectively. Total passenger kilometres are calculated from the product of the vehicle kilometres and the occupancy of the respective vehicles types. Total person kilometres by vehicle type are shown in Figure 8-6.

Passenger kilometres by the "other" modes of transport were taken directly from ERC (2012). The use of motorcycles is too small to feature in the figure.

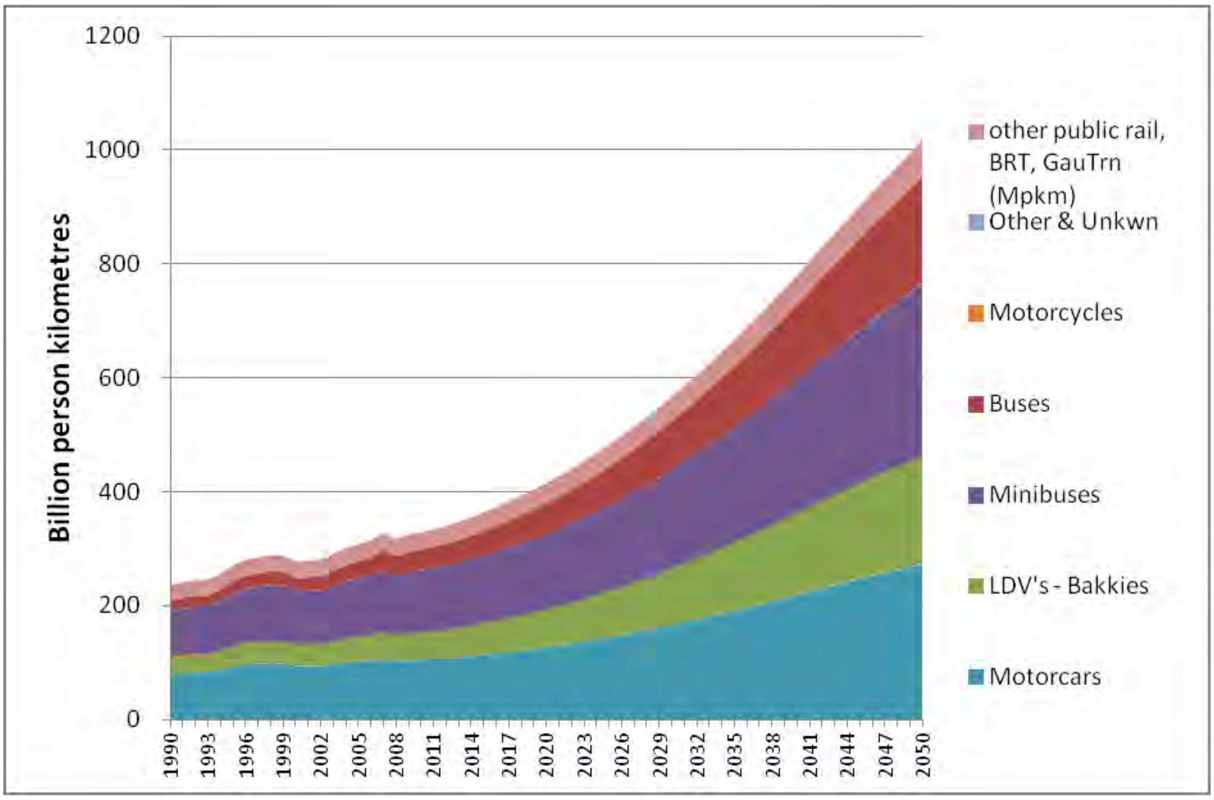

Figure 8-6: Historical and projected passenger kilometres

Similar to passenger vehicles, the freight tonne kilometres were calculated from the product of freight vehicle kilometres and the average loading of freight vehicles. (Different Truck types obtained from the RTMC data were aggregated into light, medium and heavy duty classes by determining the share of trucks in three engine capacity groups using data from the National Transport Information System). Tonne kilometres by freight class are shown in Figure 8-7. Heavy commercial vehicles (HCV) constitute the majority of freight transport.

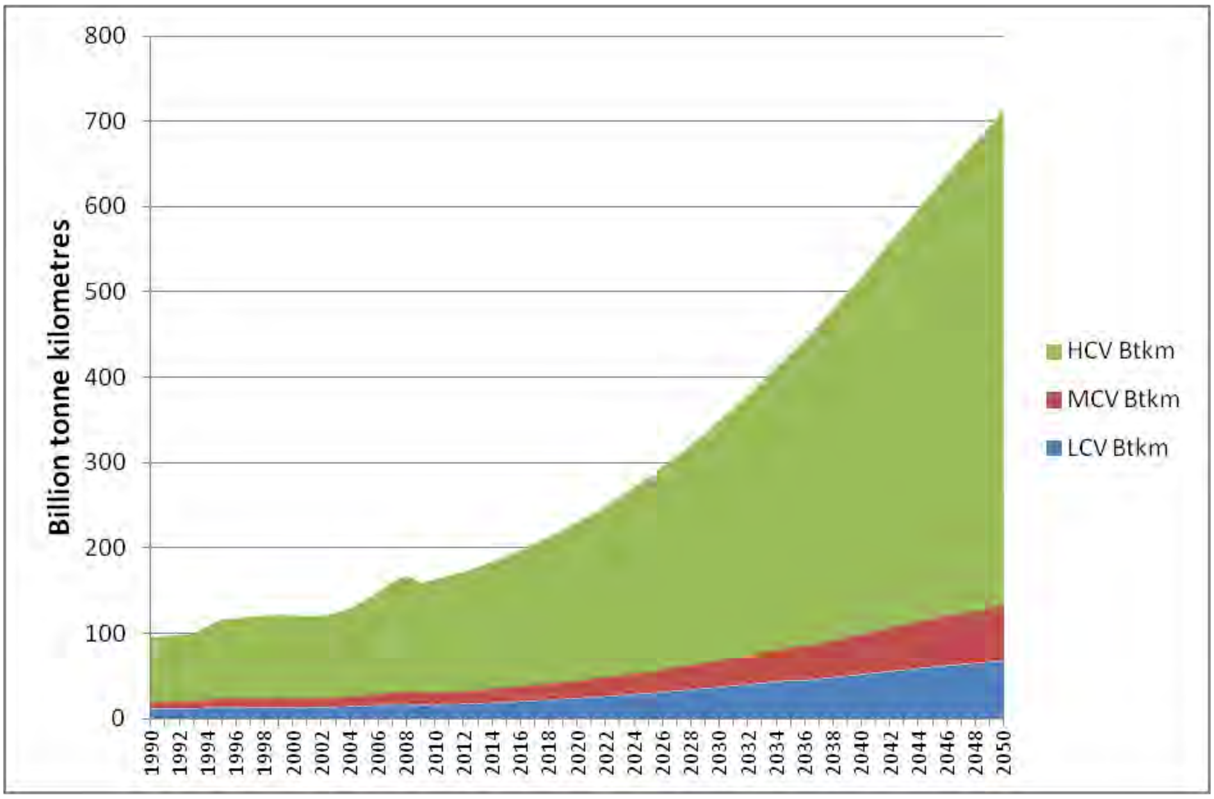

Figure 8-7: Historical and projected freight tonne kilometres

8.7 Required future capacity in fleet capacity

The required future transport capacity is the difference between the existing capacity in a particular year and the transport demand. Capacity of the current passenger vehicle fleet and the demand for future passenger kilometres is shown in Figure 8-8. Existing capacity of the current freight fleet and the future freight demand is shown in Figure 8-9.

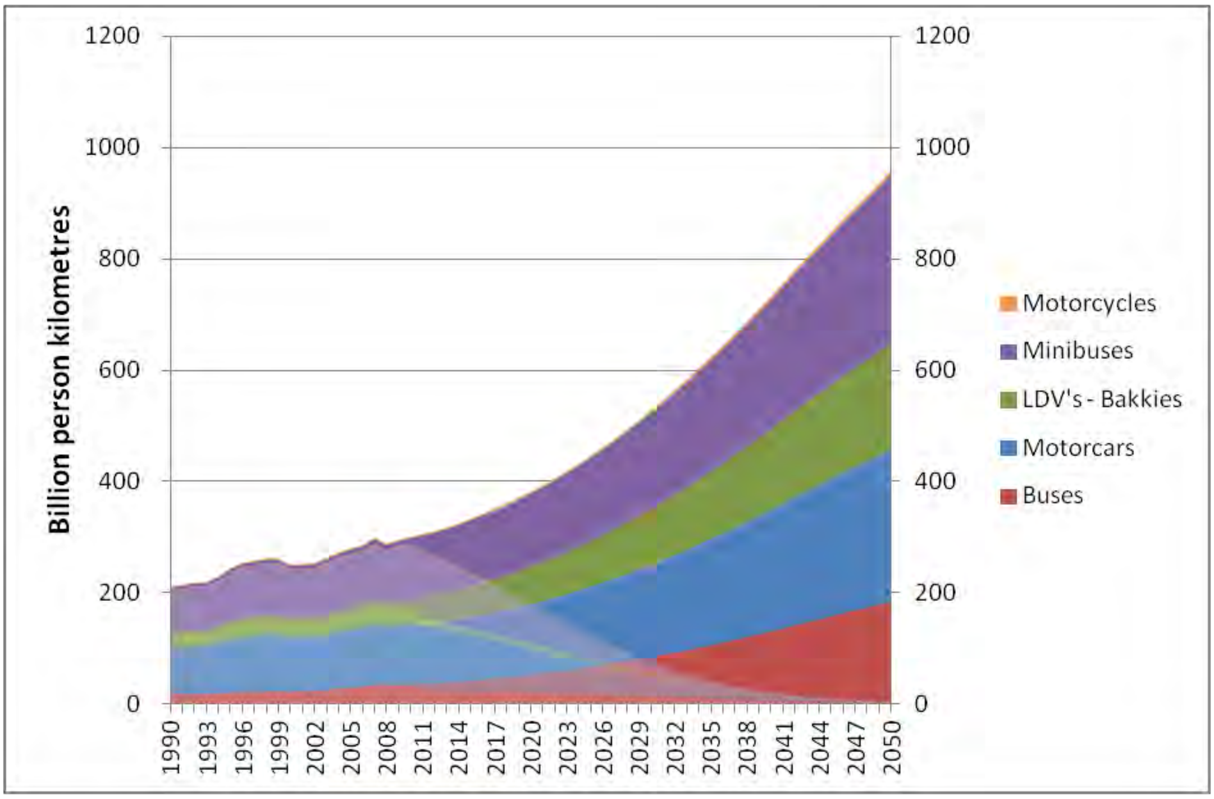

Figure 8-8: Existing passenger fleet capacity (shaded) and future demand

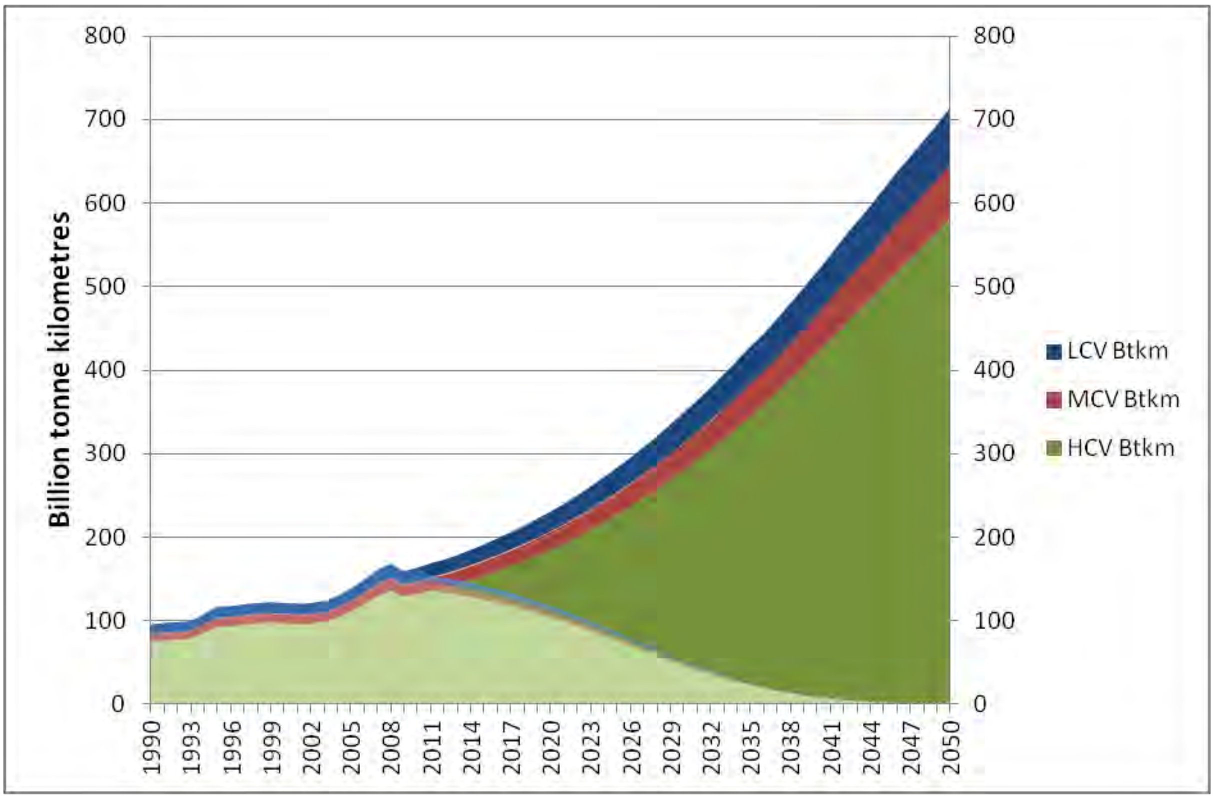

Figure 8-9: Existing total freight capacity (shaded) and future demand

Transport technologies available for new investments to fill the gap between future demand and residual capacity are provided in Annexure B - Appendix C.

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