

Chapter 12

Energy

Energy is vital for human livelihood and underpins all aspects of life: our dependence on different forms of energy to run our lives and our ability to live, the food we consume and the energy we use in the course of our daily lives.



Chapter 12

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12.1 INTRODUCTION

Energy is vital for human livelihood and underpins all aspects of life: our dependence on different forms of energy to run our lives and our ability to live, the food we consume and the energy we use in the course of our daily lives. So why is energy so important? Since the advent of the industrial revolution our dependence on fossil fuels in the production of energy for work, leisure, transport, technology and the production of food, has increased exponentially. Energy is critical to sustainable development, to poverty alleviation and to economic development as well as environmental



sustainability, and as such is complex and cuts across a range of fields.

The South African economy is fossil fuel dependent – “...coal accounts for three-quarters of primary energy supply, and for over 90 per cent of electricity generation...” (Winkler 2009). Coal and other fossil fuels, including coal-derived synthetic fuels, result in high levels of gaseous emissions and are dependent on extensive feedstock supply lines and distribution networks. South Africa is ranked among the world’s top 15 largest carbon dioxide emitters, largely due to our heavy dependence on coal which supplies 92 per cent of our electricity (CDIAC 2012; DME 2010; Eberhard 2011). Our energy supply and consumption therefore place considerable pressures on the environment in that they generate greenhouse gas emissions, thereby causing climate change, they cause air pollution, alter land use patterns, and consume water resources. These effects impact on climate change, cause damage to natural ecosystems, and the environment, are hazardous to human health and hinder sustainable development (Modi *et al.* 2005).

Historically, South Africa has always considered itself blessed with an abundance of easily accessible and cheap coal. This meant that energy generation was cheap, that sufficient energy could be provided to a growing energy-hungry economy and resulted in South Africa developing an energy intensive industry sector. In retrospect though, the coal ‘wealth’ could rather be seen as ‘resource curse’. Leading analysts such as Winkler *et al.* (2006) argue that the low-cost of commercial energy did not offer the country an important economic edge, but rather led to inefficient energy use, accelerated national reserve depletion and significant pollution. It also made South Africa one of the highest greenhouse gas emitters in the world. The ‘low’ cost was artificial, since most of the social and environmental costs were externalized and therefore not paid for by the energy sector.

This chapter describes the supply chains of the various forms of energy generated and used in South Africa, the drivers that shape demand for energy, and the impacts that the generation and consumption of energy have. The chapter also takes a look at how both government and the private sector are responding to the changing energy field, taking into account key energy policy documents and energy related legislation, as well as initiatives that focus on energy security.

12.2 DRIVERS

12.2.1 Our energy legacy

South Africa’s economy for the past 100-plus years has been built around a mineral-energy complex that continues to dominate other areas of economic activity (Fine 1999). In fact, the energy-supply sector of South Africa has been dominated by coal from as early as 1880 when the Kimberley diamond fields were supplied with coal from the Vereeniging area (Winkler 2009). Mining and energy have previously gone hand-in-hand in South Africa, not only because mining is an energy intense activity, but also because mining offered the country access to energy embedded in the locally abundant coal reserves.

South African coal is contained in thick, level seams at shallow depths, and is fairly free from faulting, giving it a competitive advantage over northern coal (DoE 2010a). The abundance and ease of extraction mean that as an energy source, coal was relatively cheap to extract and use as long as any negative environmental and social costs were externalized. Energy in the form of coal and coal-based electricity consequently developed as a backbone to the economy, driving the nature of development and the growth of energy intensive manufacturing and other industries (Winkler 2009). Indeed, the low-cost coal-based electricity has been key in attracting energy intense minerals beneficiation to South Africa, and in particular steel and aluminium smelting (Eberhard 2011). Much of the country’s manufacture and service activity is also horizontally linked to the mining sector, so that the contribution of these sectors to GDP can often not be decoupled from the primary economic activity of mining.

Over time, the large-scale mining of coal and its dominance in electricity generation led to structural dependencies and infrastructure systems dedicated to its extraction and application, as well as an economic and industrial system that externalized the life-cycle costs of the use of coal. This is especially evident in the electricity sector where most of the impacts of electricity are localized to the mining/power station areas of Mpumalanga and KwaZulu-Natal, with significant water and air pollution, denudation of the natural environment, and a high contribution to accelerated climate change. These environmental costs, especially the costs in terms of environmental remediation, sterilized farmland and compromised tourism opportunities, as well as costs of health care associated with respiratory diseases due to exposure to air pollution, were never incorporated into the costs of the electricity. By implication, even though the use of electricity was ‘cheap’, the global consequences were paid for by other sectors, the general public or government in the form of environmental rehabilitation and health care.

‘Cheap’ energy and lack of awareness on the environmental impacts of coal-based electricity subsequently limited the need for investment in energy efficiency or renewable energy sources (Winkler & Marquand 2009). Characteristics of the South African development pattern included:

- The economy being closely linked to energy consumption (i.e. energy use tracks GDP) (Winkler 2009);
- Energy driven, rather than labour intensive growth (Winkler & Marquand 2009);
- Energy wastage, typically through heat losses, flaring of combustible gas emissions at petrochemical refineries, unnecessary electricity usage;
- Low efficiency in appliances, vehicles, electrical motors and fossil fuel burning facilities;
- High reliance on either coal-based electric or oil-based liquid fuel powered transportation; and,
- A built environment with low thermal efficiency.

As with many other things in the country, the legacy of the Apartheid era also came to bear on the energy sector. Possibly bolstered by the sense of independence offered by the coal-based energy wealth, but in a bid to improve energy security, the government of the 1950s embarked on the development of both a synthetic fuels (synfuels) platform and nuclear

capacity (Winkler 2009). Heavy investment in the synfuels industry in Sasolburg, the construction of the Koeberg nuclear power station, as well as the expansion of the electricity generation capacity through coal-fired power stations created a sense of security that was, for the most part, independent of energy imports and was in response to high economic growth.

However, economic growth slowed down by the 1980s which resulted in new build plans being cancelled and older power stations being mothballed. The excess generation capacity lasted until the 1990s, when the focus shifted from generation capacity to the expansion of the energy distribution networks (Winkler & Marquand 2009). However, by this time, energy inequality had been deeply entrenched in the socio-economic realities of the country. Spatial development patterns effected by the discriminatory bureaucratic systems created 'whites only' towns and cities with 'blacks only' dormitory townships at some distance from the main electricity networks. The result was a built environment in which only the privileged had access to electricity, and which kept the residents of the townships dependant on using alternative means of energy for cooking and lighting and dependant on expensive public transportation such as point-to-point bus services and omnipresent minibus taxis. Energy was consequently a further means of control over the disenfranchised. These spatial patterns remain in existence even where the townships have been swallowed by urban growth, and hence perpetuate the inequitable access to affordable energy and to economic opportunities (SEA 2011).

In comparison with the discounted rate (by excluding environmental and social costs) at which coal-based energy could be supplied, renewable energy technologies appeared particularly expensive. This ensured that little investment found its way to the renewable energy sector, with the exception of small scale off-grid technologies such as the ubiquitous wind-driven water pump or *windpomp*, and large-scale international hydropower projects such as the Lesotho Highlands Water Project. Lack of investment in renewable technologies and capacity also meant that affordable renewable power remained out of reach for the poor and for rural areas. The stranglehold of centralized coal-based energy systems also came at the cost of individualized off-grid, mini-grid or micro generation opportunities.

12.2.2 Externalized costs of fossil fuel

The externalization of costs is a central characteristic of the coal-dominated energy sector in South Africa, and a significant reason why, as a 'cheap' form of energy, it could be the basis of an energy inefficient economy. Externalization of cost refers to an accounting practice that only accounts for part of the true life cycle costs of a commodity, whether intentionally or because of the difficulties of costing ancillary costs. In the case of coal-based energy, the only costs directly ascribed to coal and charged to users of coal or coal-based electricity, are the actual financial costs of buying coal from a mine. Other life cycle costs such as the mining subsidies, mitigation of air and water pollution, compromised rural productivity due to pollution, personal health costs and the costs of constructing coal-fired power stations are easily excluded from the stated cost of coal-based energy. Other economic sectors consequently subsidise the coal-based energy by paying

some of the externalized costs. For example, Scorgie (2012) calculates that fossil fuel based energy costs individuals R2 billion directly due to respiratory disease each year. These costs never accrue to the fossil fuel industry despite being a direct consequence of the polluting nature of fossil fuels.

The more one examines the life cycle costs of coal, and for that matter any other fossil fuel based energy, the more externalized costs are uncovered. One of the most important costs is accelerated climate change due to the accrual of greenhouse gases in the atmosphere. A rising concentration of carbon dioxide in the atmosphere and related climate change impacts, although proven to be directly linked to the combustion of fossil fuels, are virtually impossible to relate directly back to the use of fossil fuels in financial terms as the effects are too diffuse to quantify. The social and environmental costs of responding and coping with climate change impacts, such as preventing or recovering from natural disasters or loss of livelihoods due to falling soil productivity, are absorbed by individuals or welfare systems rather than the energy sector.

The end result of the externalization of costs is an unfair playing field where an energy source with the greatest opportunities for cost avoidance can be the most competitive, and consequently dominate.

12.2.3 Supply side electricity planning

One of the consequences of the highly regulated and State-controlled energy sector was a near absence of demand side management of energy use. Common opinion has it that supply side entities are unlikely to be particularly good at regulating demand for energy, precisely because their primary business is generating and selling more, not less, energy. The 2008 electricity crisis in South Africa is a good case in point, with demand management interventions only receiving attention when the rolling blackouts provided evidence of the failure of electricity supply side management measures.

Supply side planning typically means that the energy sector is technically and strategically designed to serve the interests of the energy producers (Eskom, coal suppliers and liquid fuel companies) or high volume users (mines, smelters, heavy industry and transportation). This ignores the needs and interests of distributed or indirect interest groups (e.g. residential consumers and climate change interest groups). Simply put, supply side planning tends to focus on generating energy at the lowest cost to the suppliers, generally by producing bigger volumes, but also by limiting the scope of what are considered costs. This tends to limit benefits to the utilities and high volume users, with limited penetration of the overall socio-economic system. In contrast, demand side planning seeks least-cost solutions that have benefits distributed throughout the energy value-chain. This starts with reducing the overall cost to users in terms of financial resources and health impacts, and increasing the opportunity value that access to affordable energy offers. General distributed benefits to the economic system can then result.

In terms of electricity, the centralized supply side planning is exacerbated by the structure of the electricity supply system, especially in respect of the role of municipalities in supplying domestic energy. For many municipalities, electricity supply

is a considerable revenue stream. About 240 local authorities buy bulk electricity from Eskom and distribute it in their areas of jurisdiction. Because of this, they consequently have little interest in reducing the amount of electricity consumed by users. In addition municipalities are dependent on the sale of electricity for the generation of revenue, thus the more they sell the more revenue they generate. It is only through the incorporation of external costs such as carbon taxes or human resource constraints that demand side planning becomes a priority.

Structural failures in the energy sector can result from external strategic impacts, especially if the sector cannot adjust quickly enough to absorb or counter the impacts. Examples in South Africa include the internalization of previously externalized environmental and social costs, the redirection of resources into expanding access to previously disadvantaged users, and the volatile nature of international energy prices. Each of these confronted the energy sector with sudden-onset adjustments to the contextual environment, which supply side planning cannot respond to in the required time frames. The sudden change in national policy direction during the 1990s, for example, meant that investment in generation capacity was cut in favour of rapid expansion of the electricity reticulation networks. The entrenched focus on supply, rather than demand management, subsequently failed to accommodate the rapid escalation of demand. The result was supply shortages and rolling blackouts as the only demand management tool available to the electricity utilities.

12.2.4 Energy balance

12.2.4.1 Generation

Local energy production in South Africa, i.e. the production of basic forms of energy for either direct application or as feedstock for energy conversion processes, consists of the extraction of coal, crude oil and gas, electricity produced from nuclear, or harnessing of hydroelectric schemes, solar radiation and wind, as well as energy obtained from combustible renewable materials and waste (solid biomass, liquid biomass, biogas, industrial waste and municipal waste). The most recent information on energy supply and consumption released by the Department of Energy (DoE)

(DoE 2013) tracks national energy accounting up to 2009. According to the DoE, South Africa produced 10,283,884 TJ of energy in 2009 (excluding imports, exports, marine fuel bunkers and stock changes) (DoE 2013). A total of 1,470,358 TJ were imported in the form of coal, oil, petroleum products and electricity (DoE 2013).

Information on energy balances for 2009 is found in the annual publication of energy balances by the International Energy Agency (IEA) (IEA 2012). This differs substantially from the DoE data, presumably due to differences in data sources and analysis methods, but matches information from StatsSA (2012a) (refer to Table 12.1). According to data from the IEA, primary domestic energy supply in South Africa in 2010 amounted to 6,799,991.22 TJ, with 1,334,626.24 TJ being imported (IEA 2012). This equals about one per cent of world energy production and roughly 20 per cent of the total produced in Africa (IEA 2012). South Africa is the smallest energy player when it comes to the 'Brazil-Russia-India-China-South Africa' (BRICS) group, accounting for only four per cent of the energy generation in the BRICS countries (BRICS 2013).



Table 12. 1: Energy intensity per GDP for the period 2002 to 2009

Year	GDP of 2005 constant prices (R millions)	Primary energy supply in Terajoules*	Energy intensity in Megajoules per Rand
2002	1,236,270	8,647,126	6.99
2003	1,273,129	8,728,384	6.86
2004	1,330,390	7,804,789	5.87
2005	1,401,067	7,949,201	5.67
2006	1,478,492	7,742,673	5.24
2007	1,561,076	7,538,066	4.83
2008	1,619,738	6,874,635	4.24
2009	1,597,860	6,683,347	4.18

* Excludes imports and electricity; includes coal, crude oil, gas, hydro, nuclear, petroleum products, and renewables and waste.
Source: Adapted from StatsSA (2012a)

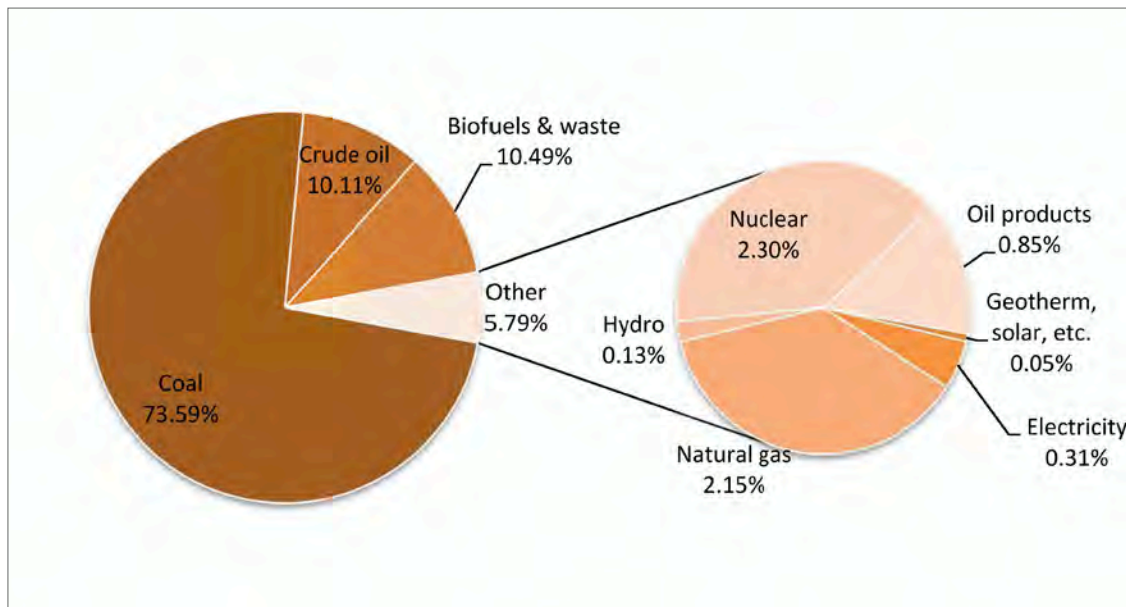


Figure 12. 1: Domestic energy supply 2010

Source: IEA (2012)

As shown in Figure 12.1, the bulk (73.59 per cent) of the local energy supply (local generation and imports) is obtained from coal.

12.2.4.2 Consumption

After discounting 3,158,103 TJ of energy lost through transformation and distribution, the direct consumption of energy in South Africa in 2010 totalled 2,572,370 TJ (IEA 2012). This implies that South Africa uses 0.7 per cent of the world's energy and 12.2 per cent of the energy in Africa (IEA 2012).

The bulk of the energy use takes place in the industrial field, with residential and transportation use a distant second and third highest respectively (Figure 12.2).

and Russia and India for about 17 per cent each (IEA 2012). In terms of consumption per capita though, South Africa is the second worst (after Russia) of the BRICS, but just below the world average (Figure 12.3).

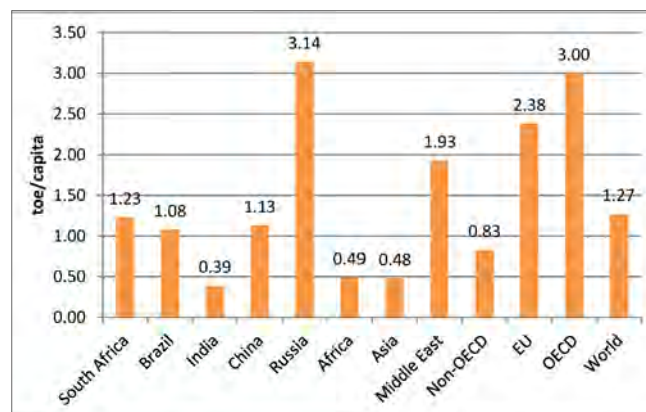


Figure 12. 3: Final energy consumption per capita for 2010

Source: IEA (2012)

Energy intensity can also be expressed as the amount of energy required to produce a unit of GDP value. Care should be taken when using this measure though as explained by StatsSA:

“The ratio of aggregate energy use to GDP, often called ‘energy intensity’ or the ‘energy ratio’, is not an ideal indicator of energy efficiency, sustainability of energy use, or technological development. The aggregate ratio depends as much on the structure of the economy as on the energy intensities of sectors or activities, and changes in the ratio over time are influenced almost as much by changes in the structure of the economy as by changes in sector energy intensities.” (StatsSA 2012a).

Nevertheless, as officially published, for each Rand unit of the GDP, 4.18MJ of energy was required in 2009. This has steadily decreased over time (StatsSA 2012a).

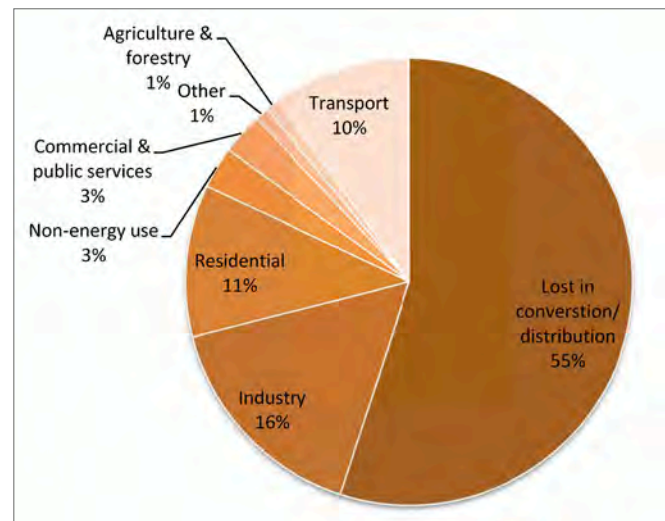


Figure 12. 2: Sectoral energy consumption as percentage of total for 2010

Source: IEA (2012)

As with its energy production, South Africa's final energy consumption figures pale into insignificance against the other BRICS countries. Whereas South Africa consumes 2.3 per cent of the energy in the BRICS, China accounts for 56 per cent,

12.3 PRESSURES

12.3.1 Economic sectors

Worldwide, sustainable development is recognized as being in part characterized by economic development and growth that is low in carbon intensity and carbon footprint, and whereby poverty and inequality are reduced. Using this as a measure, it is clear that economic development and growth in South Africa has not been on an environmentally sustainable path and poverty and inequality have not reduced substantially. Generally speaking, all economic sectors have been guilty of driving carbon intensive energy use as a consequence of the limited range of options available in the country.

The South African economy has grown since 1994, demonstrated by an annual growth rate of 5.4 per cent between 1999 and 2008, with a drop following the global financial crisis of 2009 and recovering slightly by 2010 (Camco & TIPS 2010; DEA 2011a; Hanival & Maia 2008). However the country continues to face a particular set of fundamental development challenges (NPC 2011). Growth in the South African economy is mostly driven by local consumption and exports of minerals (NPC 2011).

In the absence of major energy source alternatives, the local economy relies on energy derived from fossil fuels. The relatively cheap energy from coal is especially important in satisfying the demand. Unfortunately, this reinforces the structural dependencies on coal and other fossil fuel supply networks, and reduces the incentives for the introduction of alternatives into the supply mix.

According to the 2012 figures (IEA 2012), final energy consumption per sector in South Africa in 2010 shows 36 per cent consumed by industry, 22 per cent by transport and 24 per cent by the residential sector of which most is urban and falls in the mid to high income group (Figure 12.4).

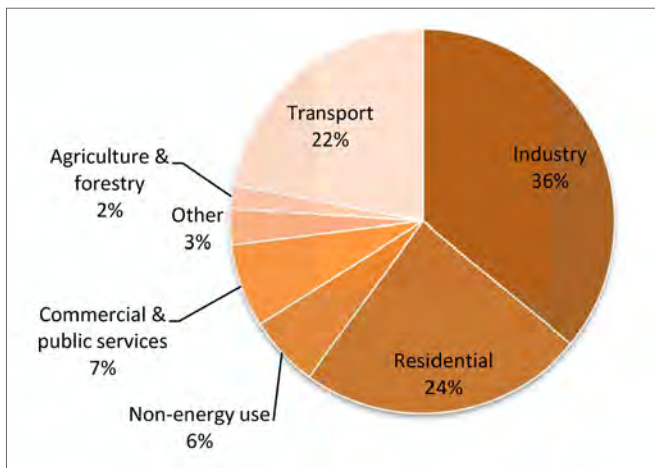


Figure 12. 4: Final energy consumption by sector for the period 2010

Source: IEA (2012)

Based on a different classification, local information from StatsSA (2012a) indicates that in 2009 the industrial component consumed 36 per cent, 22 per cent of which was used for transportation and 14 per cent by domestic users (Figure 12.5).

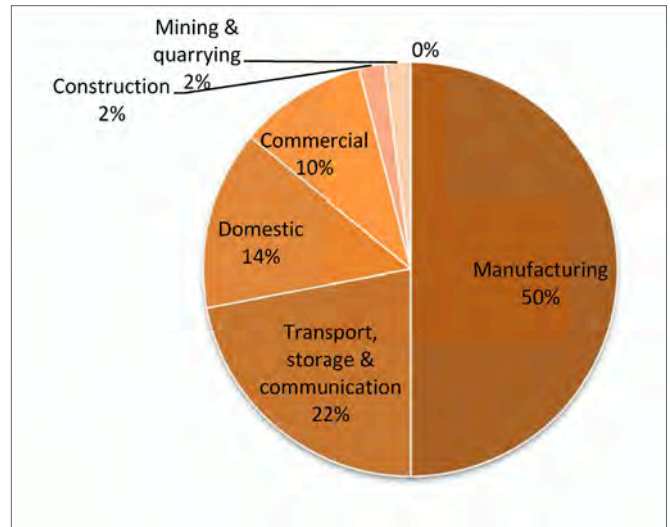


Figure 12. 5: Final energy consumption by sector for the period 2009

Source: StatsSA (2012a)

12.3.1.1 Industry and mining

The industrial sector is the largest user of energy in South Africa, consuming slightly over 51 per cent in 2009 (StatsSA 2012a). Manufacturing, in particular, is the most energy intensive sub-sector (Figure 12.6). As an inherent part of the development and growth of the fossil-fuel driven local economy, this sector includes several energy heavy activities such as metal smelters, petrochemical facilities, as well as paper, sugar and pulp mills. By all accounts, it can be expected that the industrial and manufacturing sector will continue to grow in the future, with a commensurate appetite for energy.

South Africa also intends to continue to exploit its plentiful mineral resources (DME 2009). Mining is generally an energy-intensive activity, with South Africa having 87 per cent of the world's platinum group metals, 80 per cent of the high grade manganese, and 70 per cent of the world's chromium (Rossouw & Baxter 2011).



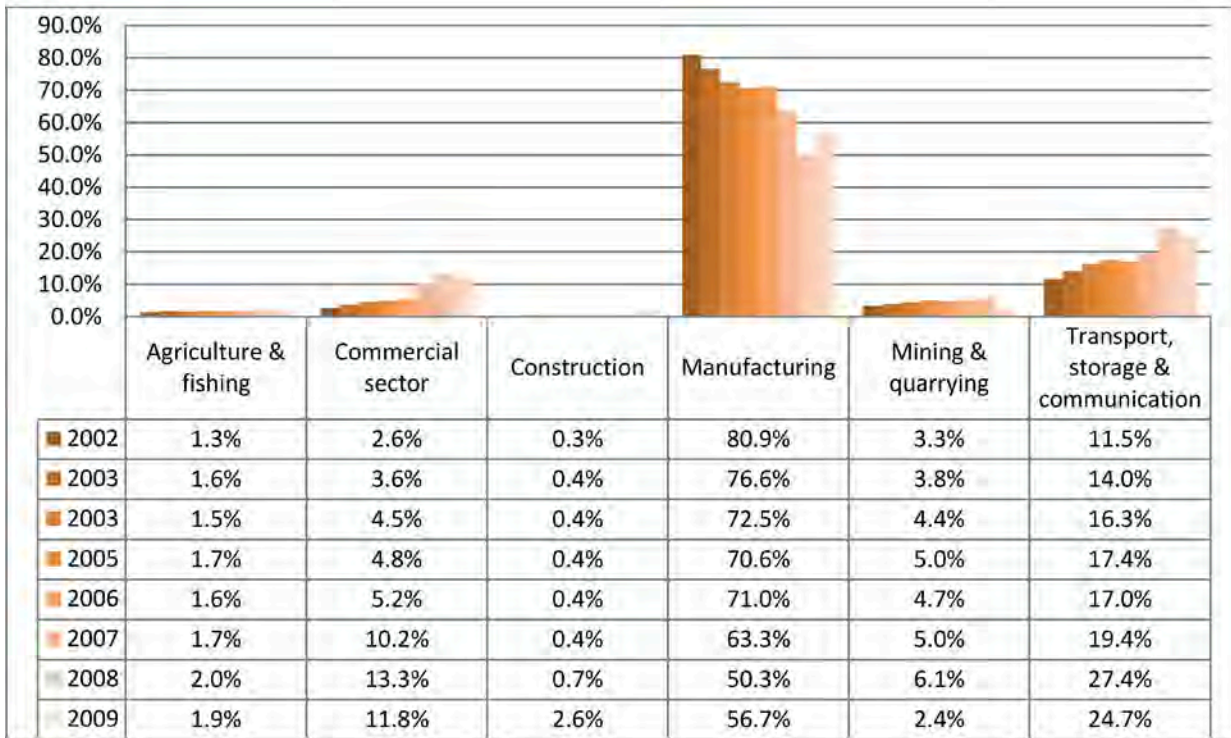


Figure 12. 6: Percentage distribution of energy to the industrial sub-sectors in South Africa for the period 2002 to 2009
 Source: StatsSA (2012a)

12.3.1.2 Commerce

Energy use in the commercial sector (including public services) is relatively small, with energy consumption of just over ten per cent in 2009, but it is growing at a fast rate (StatsSA 2012a). This sector consists of government, office buildings, financial institutions, shops, recreation and education. Electricity contributes the most to the commercial sector's energy use mainly in the form of lighting, heating and air-conditioning. With the high reliance on the national electricity grid, this sector is tied to the production of coal-based electric power.

Many opportunities exist in the built environment to improve the efficiency of energy use or to include renewable energy sources into the energy supply mix. However, the need for rapid return on investment commonly limits the upfront capital investment that can be made in favour of the long-term benefits from clean or renewable forms of energy.

12.3.1.3 Agriculture

The agricultural sector is smaller than the commercial sector in terms of energy consumption and its energy use was less than two per cent in 2009 (StatsSA 2012a). Liquid fuels are used in the agricultural sector alongside electricity and gas, rendering the sector completely reliant on fossil fuels. Globalization and commercialization of farming are likely to lead to a search for more energy efficiency in order to maintain the financial viability of agriculture amidst global competition. It is therefore expected that fossil fuels will be given up in preference of renewable forms of energy such as those that can be obtained out of organic wastes, solar power and wind.

12.3.2 Transportation

12.3.2.1 Energy use

The transport sector deals with transport of people and goods by land, sea and air. Transport is a significant energy user in South Africa, accounting for 22 per cent of final energy use (IEA 2012). The bulk of this energy is expended in the form of fossil fuels, specifically liquid fuels (74 per cent) and electricity (26 per cent) (IEA 2012).

The challenge of making energy mobile means that it is very difficult to switch to other sources that are less energy dense (Demirbas *et al.* 2009). Land transport is currently dominated by liquid fuels derived from coal and oil, with some electricity used by rail. Very little renewable-powered or non-motorized transportation is present. Air transport is similarly liquid-fuel dependent, using either jet fuel or aviation gas, as is marine transport which mostly uses heavy fuel oil including diesel.

Energy use is driven primarily by distance travelled, and the energy needed for each passenger, or freight, kilometre. As energy intensity decreases dramatically with occupancy, occupancy rate is a major driver of energy efficiency in transport. A study by Venter and Mohammed (2013) calculated that the energy intensity between different transportation modes in the Nelson Mandela Metropole varied between 4.8 MJ per person per trip in a minibus taxi to 25.8 MJ per person per trip in a private vehicle (Table 12.2).

Table 12. 2: Comparison of transport energy use by mode: Nelson Mandela Bay 2004

Mode of travel	Mean energy use (MJ/person trip)
Motor vehicle	25.8
Bus	7.1
Minibus taxi	4.8

Source: Venter and Mohammed (2013)

12.3.2.2 Greenhouse gas emissions

Recent comprehensive transport energy modelling suggests that carbon emissions from the transport sector will more than double in South Africa by 2050 if current trends continue (Merven *et al.* 2012). With a basket of efficiency, pricing and investment measures combined, it is possible to reduce emissions in the passenger sector, although emissions in the freight sector are more resilient to overall reduction (Merven *et al.* 2012). Further work is necessary to unpack which measures have the best value and local relevance.

Fuel use in transportation can be broadly considered as either freight-related or passenger-transport related. The freight sector as a whole accounts for 44 per cent of carbon emissions, whereas the passenger sector accounts for 56 per cent (Figure 12.7).

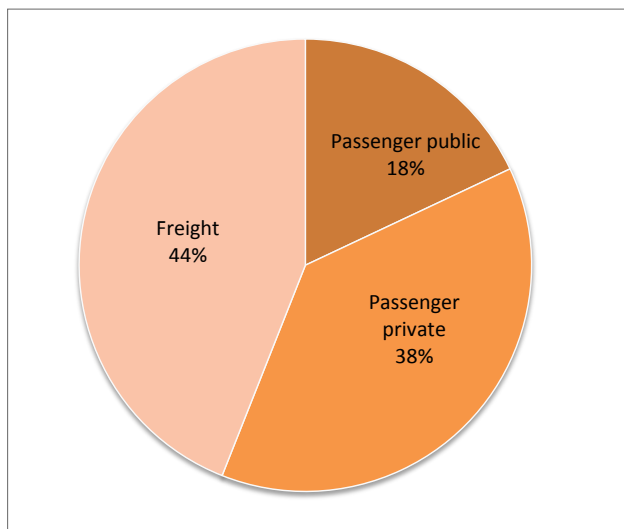


Figure 12. 7: CO₂ Emissions in the South African transport sector for 2010

Source: Merven *et al.* (2012)

Within the passenger sector, private transport accounts for approximately 70 per cent of emissions and public transport the remaining 30 per cent (Merven *et al.* 2012). This aggregate figure, however, does not reflect the relative energy and emissions intensity of private travel. On average a private trip is two to three times more emissions producing per passenger than a public transport trip (Figure 12.8).

In general terms, the majority of fossil fuel externalities in South Africa are directly related to the use of private passenger transport, that is, cars, and particularly private motoring. Car ownership in South Africa has historically tended to track GDP

growth, at three to four per cent per annum, although this has been disrupted in recent years. Car ownership is still relatively low in South Africa, at around 18 per cent of people, although it is higher in metropolitan regions (31 per cent in Gauteng), but this is still significantly lower than the 80 per cent car ownership in some countries (although 50 to 60 per cent is more typical).

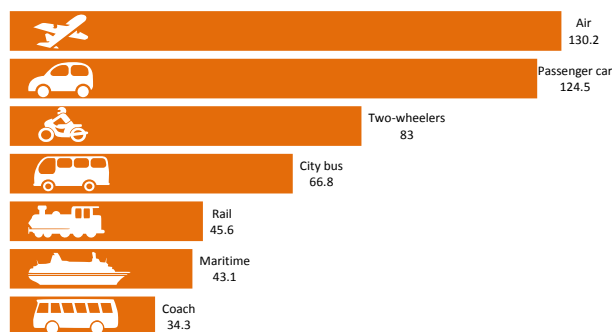


Figure 12. 8: Carbon dioxide emissions per passenger (grams per km)

Source: European Environment Agency (undated)

12.3.2.3 Externalized costs of fossil fuel driven transport

Accounting for transport externalities are dogged with problems of measurement but it is well known that motoring and freight movement accounts for multiple externalities (that is, costs which are not accounted for in the cost of travel) including impacts on biodiversity, landscape, noise, water, social fabrics, health, road accidents, congestion, oil dependence and emissions (Kane 2010).

Of particular relevance to discussions on energy use is the inefficient use of urban space through road and parking provision. South Africa's high reliance on road based transportation has brought about, or stemmed from, low-density urban sprawl, an increasing demand for private cars, as well as decreasing efficiencies in public transport.

Over-reliance on private transport, and in the South African case on a poorly regulated minibus taxi industry, also gives rise to unnecessary high road accident rates. In 2010 13,900 people were killed on South African roads (Arrive Alive 2013). Writers in developing countries have long highlighted the disproportionately violent nature of roads in developing countries, and have argued that more attention should be paid to this issue. It is even argued that the relatively small contribution to global greenhouse gas emissions by developing countries is of less concern than the high road death toll.

12.3.3 Socio-economics and energy

12.3.3.1 Domestic energy use

Much of the high energy consumption in South Africa is attributable to energy intensive industries and transport, but the residential or domestic sector used just under 15 per cent of the national electricity supply from 2002 to 2009 (StatsSA 2012a). Winkler *et al.*, (2006) deduced that more affluent households rely on electricity while less affluent households use a variety of energy sources ranging from electricity to paraffin, gas and wood fuel to satisfy their energy needs. In much the same way, urban households would tend towards

the use of electricity, whilst rural households would rely on alternative energy sources.

The historical availability of cheap electricity and legacy of high levels of service provision to a small minority has resulted in high levels of consumption amongst mid to high income households and a high degree of inequity in consumptions. Winkler and Tait (2012) in their paper *Estimating greenhouse gas emissions associated with achieving universal access to electricity in South Africa* noted that in 2006 middle-income households consumed 63 per cent of all residential electricity. "It is also evident that the poor constitute a very small proportion of residential electricity consumption and at a national level they account for only half a percent of total electricity consumption. This equates to just less than one TWh of electricity consumed by 3.2 million households in 2006." (Winkler & Tait 2012).



This situation also persists in urban areas, where services are arguably most readily available. Within the City of Cape Town, low-income houses represented 70 per cent of all households in 2003 but consumed just under half of all residential electricity in the city (SEA 2006). Similarly a study undertaken in eThekweni showed that 64 per cent of households are low-income and yet only use 25 per cent of electricity (SEA 2012) (Figure 12.9).

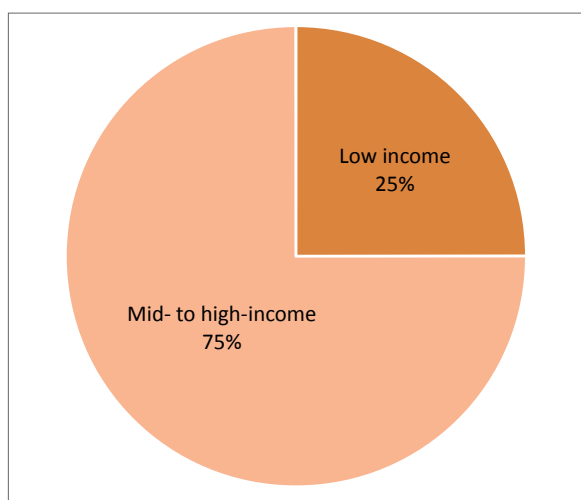


Figure 12. 9: Residential electricity consumption by income band for eThekweni 2012

Source: LEAP modelling undertaken for eThekweni Municipality in 2012¹

¹ Based on eThekweni greenhouse gas inventory 2010 and electricity sales data, modelling undertaken by Sustainable Energy Africa.

Similar results were found by a study undertaken in Gauteng (SEA 2009). The study showed that when categorized into mid-high income households, low-income electrified households and low-income non-electrified households, the residential energy consumption sits very much within the high income households which are the largest users of electricity in the province (Table 12.3).

Table 12. 3: Residential energy consumption by income group and end-use in Gauteng in 2009 [PJ]

	Mid/high	Low/elec	Low/non elec	Total
Space heating	2.6	11.1	18.1	31.8
Lighting	6.1	5.2	0.1	11.4
Cooking	6.0	2.8	6.9	15.7
Water heating	21.4	6.0	0.0	27.4
Refrigeration	6.2	1.6	0.0	7.8
Other	7.8	4.5	0.0	12.3
TOTAL	50.1	31.2	25.1	106.4
% of TOTAL	47%	29%	24%	

It is significant that the poor use more energy for cooking and space heating than the mid to high income group. Space heating can be explained by the fact that many low-cost houses were built without insulation including ceilings which makes these homes very susceptible to temperature changes.

In terms of the type of fuel used in households, Table 12.4 illustrates that the mid to high end users consume relatively more electricity than the poor electrified households. Lower income households also continue to use a wider mix of fuels. It is acknowledged that poor household use significant amounts of coal and wood for cooking, space heating and lighting requirements whether or not they are electrified. The cost of electrical appliances and the ability to pay the high capital costs is a significant hurdle in the use of electricity in low-income households and will impact on the use of alternative energy sources.

Table 12. 4: Residential energy consumption by income group and energy carrier in Gauteng [PJ]

	Mid/high	%	Low/elec	%	Low/non elec	%
Electricity	49.0	97.6	20.5	65.9	0.0	0
Coal	0.3	0.6	9.9	31.8	22.5	90
Kerosene	0.5	1.0	0.7	2.3	2.5	10
LPG	0.4	0.8	0.0	0.0	0.0	0
TOTAL	50.2		31.1		25	



12.3.3.2 Energy poverty

Households require energy for essential services in order to satisfy basic human needs and a lack of choice in accessing adequate, reliable, safe and environmentally benign energy services is the way in which energy poverty manifests itself (UNDP 2000). The compromised well-being of households due to poor access to energy is known as energy poverty. It is very well illustrated in terms of relative domestic spend on energy: poor households spend up to 20 per cent or more of their household budget (a ratio used to express the energy burden of a household) on energy compared with two or three per cent for wealthier households (SEA 2006). In practical terms, energy poverty has three implications. First, energy poverty implies that poor households do not have access to adequate, appropriate and safe energy sources and appliances to service their most basic energy needs. Second, it implies that the negative impacts associated with their energy consumption place an additional burden on them in terms of illness and other hazards such as fires and burns. Third, energy poverty implies that the income-generating activities of low-income households are compromised.

Energy poverty is entrenched in low-income residential areas. The national low-cost housing programme (under the RDP) undertaken from 1995 onwards to accelerate housing and service delivery to the poor often resulted in poorly built structures with no ceilings or other forms of insulation. Moreover, in urban areas these low-income homes were largely located on the outskirts of cities, resulting in a perpetuation of the apartheid spatial form, where poor people continue to be far from economic and job opportunities and faced with high transport costs to access these opportunities, further entrenching the poverty cycle.

Energy poverty is also particularly prevalent in informal settlements and in households living in backyard shacks of formal properties (serviced plots) in overcrowded conditions. At least ten per cent of South Africa's population (4.7 million people), reside in approximately 2,700 urban informal settlements comprising more than 1.2 million households (Misselhorn 2010; SACN 2011). The majority of informal settlements are situated on the periphery of cities and do not have formal access to Eskom or municipal distributed electricity. Those that are electrified are generally receiving electricity through illegal connections and figures show that non-technical losses from electricity provision as a percentage of total revenue in municipalities ranged from two per cent- to nine per cent in 2004 (SEA 2006).

Research has also pointed to the problem that even where poor households are electrified they continue to use a mix of energy sources to meet their energy needs due to cost, ability to purchase electricity and affordability of electrical appliances. However, StatsSA has shown that overall there has been a shift towards electricity as an energy source in the domestic sector. For instance comparing the 2001 and 2011 census, 74 per cent use electricity for cooking now compared to 52 per cent in 2001, 24 per cent used paraffin in 2001 and by 2012 the figure had risen to 85 per cent (StatsSA 2012b). Obviously in part the explanation is the increase in electrification. Interestingly, it is found that although the level of access to electricity is improving throughout the country, the use of electricity for heating decreased in the Western Cape between 2001 and 2011 (StatsSA 2012b). It can be deduced that the cost of different energy sources has a significant role to play in determining the actual application of electricity as energy source. This would imply that low-income households would remain exposed to high levels of indoor air pollution despite having access to electricity.

Inequality and inadequate energy service provision has proven a difficult task for government to address despite a number of pro-poor policies, and to continue on a business-as-usual trajectory will result in a deepening of the problems associated with energy poverty. The informal sector is now recognized as a permanent part of the urban landscape. According to Turok and Parnell (2009) South Africa's six metros are "...growing at nearly twice the national average, putting considerable strain on their services and on poorer communities, as these cities now accounted for almost half of all informal housing in the country...". Thus many poor households will remain inadequately serviced and without formal housing in the long-term, particularly in the urban context. Misselhorn (2010) has shown that the cost of providing housing and basic services, including electricity, to all poor households is prohibitive to the State.

12.3.3.3 Patterns of consumption as an indicator of wealth/status – the use of private vehicles

There is a well-known and general relationship between GDP growth and increases in car ownership, although this relationship varies globally, and since 2008 has shown some signs of stalling (Merven 2012; Newman & Kenworthy 2011a). In countries where densities and investments in public transport are high, then transport-related fossil fuel use (and associated externalities) tends to be lower (Newman & Kenworthy 2011b). In countries (including South Africa) which have followed a more US-style of traffic engineering and city development, fossil fuel use tends to be higher, sometimes dramatically so.

Perceptions clearly play a role here. A society in which the affluent only drive will tend to equate affluence with car ownership, and the car becomes an aspirational product which talks of wealth and status. Mass marketing of vehicles plays into this mind-set. In northern European cities where the affluent will frequently be seen travelling by less energy intensive modes (e.g. walking, cycling, various forms of public transport), then the link between car and wealth is disturbed. For this reason the criticism of Integrated Rapid Transport (IRT)/BRT systems in South Africa as being insufficiently targeted at the poor (which appears to have some merit) needs to be countered with a need in South Africa to shift the cultural perceptions of public transport (as being only for the poor) and car ownership (as being an indicator of wealth).

12.3.3.4 Urbanization

Around 40 per cent of national energy consumption takes place in our largest cities, which are responsible for almost half of the country's energy related emissions (SEA 2006; SEA 2011). The rate of urbanization is still growing with currently 64 per cent of the population living in urban centres, and estimated to rise to 70 per cent by 2030 (NPC 2011) with most of that growth occurring in the informal and low-income sectors.

Unfortunately, South African cities demonstrate high carbon emissions per capita relative to our level of development; in fact, our carbon intensity is similar to cities of industrialized countries such as London, Berlin and Tokyo (SEA 2011). By implication, it can be expected that the energy needs of our

cities are likely to play an increasing role in shaping the energy picture in the future.

12.3.3.5 Rural livelihoods

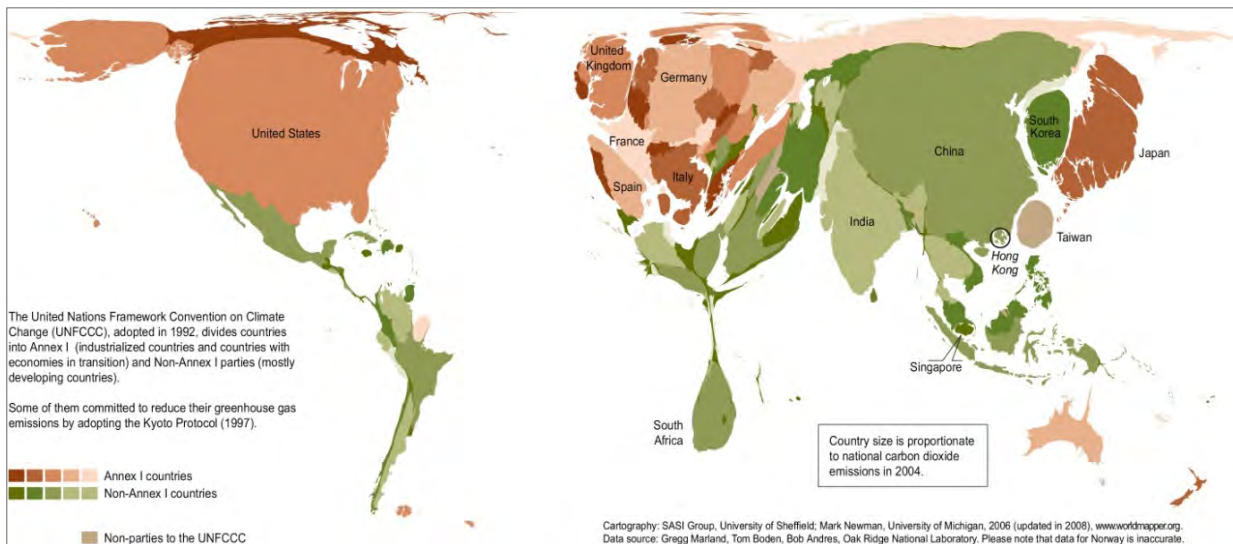
It is reported that at least 84.5 per cent of households in South Africa have electricity connections (StatsSA 2012b). Of the 15 per cent not yet electrified, a majority of these households are in deep rural areas (DoE 2012a). The deep rural areas, such as those found in the Eastern Cape, KwaZulu-Natal and Limpopo provinces, have a low load demand and highly dispersed settlements which make the capital costs of individual connections to the national electricity grid expensive. Innovative measures to extend access to clean and affordable sources of energy as alternatives to customary grid-connection electricity are therefore considered by the DoE under the Non-grid Electrification Policy (DoE 2012b). It is hoped that through such innovation, ancillary benefits can also be achieved such as positive impacts on pollution, carbon emissions, health and safety.

The dynamics of low-income rural households need to be considered though, since not all energy needs will necessarily be met through simple electrification. Research has shown that rural electrification does not necessarily replace the use of fuelwood to a significant extent. About 80 per cent of electrified rural households in rural parts of Limpopo and Eastern Cape provinces were found to cook with wood, kerosene and LPG despite being electrified, because they cannot afford to pay for electricity (ERC 2004). In the Eastern Cape, the 2011 Census found that even though 74.8 per cent of households have access to electricity, only 31.2 per cent use it for heating purposes (StatsSA 2012b).

12.3.4 Global greenhouse gas emissions

China, the United States, European Union and Brazil together account for over 50 per cent of annual global emissions in absolute terms (not per capita), and the 17 top emitting countries account for more than 80 per cent of global emissions (Map 12.1). South Africa counts itself under the top 20 global emitters in terms of total emissions (RSA 2013). This is largely confirmed by data from the US Oak Ridge National Laboratory which ranks South Africa as 10th highest in terms of total emissions and 24th in the world in terms of per capita emissions in 2009 (World Bank 2013). When adjusted for per capita and per GDP emissions, and moderated according to how harsh (hot or cold) the local climate is, South Africa ranks as the heaviest greenhouse gas emitter (Sivak & Schoettle 2012).





Map 12.1: Relative country contribution to global carbon dioxide emissions in 2004
 Source: *Sealthedeal* (2009)

Internationally, climate scientists and economists point to a narrow window of opportunity if we are to meet the 'required by science' challenge of 80 per cent emissions reduction for climate stability by 2050. The current goal is to restrict global greenhouse gas emissions to a level that will not allow temperatures to rise 2°C above pre-industrial levels. South Africa's contribution to the global effort is outlined in the NCCRWP (DEA 2011b), which guide the country in meeting its Copenhagen commitment of 34 per cent carbon reduction from business-as-usual by 2020 and 42 per cent by 2025.

In South Africa, the energy sector is the main source of carbon emissions, and thus there is significant pressure on this sector to transform. A sustainable future will involve a steady move away from fossil fuels, including coal-generated electricity and crude oil derivatives (petrol, diesel, LPG, paraffin, heavy fuel oil etc.), improved energy use efficiency in all sectors (residential, commercial, transport and industry) and maximizing the use of transitional cleaner fuels in the medium term (e.g. natural gas), as well as steadily developing large-scale renewable energy options to replace fossil fuels.

Energy's key role in meeting the country's carbon reduction commitments is illustrated by the flagship projects listed in the NCCRWP. These include the consolidation and expansion of the expanded public works programme, water conservation, renewable energy, energy efficiency, transport, waste management, carbon capture and sequestration and adaptation programmes. In addition the country has responded with a renewed focus on energy efficiency and the inclusion of significant renewable energy in the latest national electricity plan (the Integrated Resource Plan 2010), which is being implemented through the new Renewable Energy Independent Power Producer Procurement Programme (REIPPPP) for mainly solar photovoltaic and wind renewable electricity roll-out.

12.3.5 Energy cost

The rising costs of electricity in the country further supports a low carbon transition as individuals, particularly the mid to high end users, governments and industry look to alternative, more efficient and cheaper solutions to their energy needs.

12.3.5.1 Electricity

In response to the national demand for electricity, Eskom, the national power utility, is constructing two new large coal-fired power stations (Medupi and Kusile). It is estimated that electricity produced from these modern and efficient stations will cost 97c/kWh, as compared to 89c/kWh to procure wind power from IPPs (SAREC 2013). The cost of producing electricity has to be absorbed into the pricing strategy over the coming years, which is evident in Eskom's application for a 16 per cent price increase for 2013. The eight per cent yearly increase granted by the National Energy Regulator of South Africa means that with current prices at 65.5c/kWh (after 2012/2013 price hikes), the cost of electricity will increase steadily to 89.13c/kWh after the 2017/2018 increase (NERSA 2013).

Electricity price increases could result in the mid to high income households turning to alternative solutions, such as small rooftop solar photovoltaic systems, which in turn will impact negatively on municipal revenue flow. For instance, research undertaken in two South African cities suggest that the expected implementation of own-generation photovoltaic could lead to revenue losses of up to 25 per cent (Trollip *et al.* 2012). This has resulted in some resistance from municipal electricity departments to implement renewable energy and energy efficiency initiatives. Municipalities generate a significant amount of their overall revenue from electricity sales, which is used to subsidize a range of other important municipal services. In addition, revenue is used to cross subsidize losses from providing electricity to poor households which are not covered by the equitable share grant received from treasury. This issue will need to be addressed to protect municipalities, ensure ongoing electricity provision to poor households, whilst also directing the country along a more economically optimum renewable energy transition.

12.3.5.2 Rising cost of transportation

While liquid fuel prices tend to be variable, overall the costs have increased significantly above the inflation rate over the last decade. Amongst other impacts, this is resulting in an increasing pressure on government to emphasize public transport initiatives.

Research indicates that fuel price is a significant driver of fuel use, with a rule-of-thumb measure that a ten per cent increase in fuel costs will lead to a one to three per cent decrease in fuel use in the short term, for a variety of reasons, and significantly more in the longer term (Victoria Transport Policy Institute 2011). Fuel cost increases have the additional benefit, for government, of requiring no investment, although fuel costs do in the short-term impact on the price of goods and inflation. The long-term impacts are far less clear, since fuel price is known to impact on behaviour changes in both freight and passenger systems and, ultimately, on land choices. Anecdotal evidence, for example, suggests that recent increases in fuel price in South Africa may have led to increased long distance park-and-ride and associated increases in rail use, and in car sharing. Toll roads, similarly, have been shown to reduce trips and so energy use, although some of these may be diverted onto longer routes and so add to overall energy use.

12.3.6 Clean and renewable energy sources

With a growing recognition that the energy sector in South Africa needs to be demand driven, rather than through supply side interests, drivers and pressures related to the emergence of less carbon intensive and renewable energy sources have become increasingly important. As shown in a number of government policy documents, a large scale switch to more environmentally sustainable energy sources makes general sense and does not need to have severe financial implications.

With the potential to produce energy from biomass, wind, solar, small-scale hydro, waste and ocean activity, South Africa can be seen as very gifted regarding renewable energy sources, though these resources remain largely unexploited. Renewable energy can be harnessed in bulk or on micro scale, and as stand-alone systems or in combination with traditional power generation.

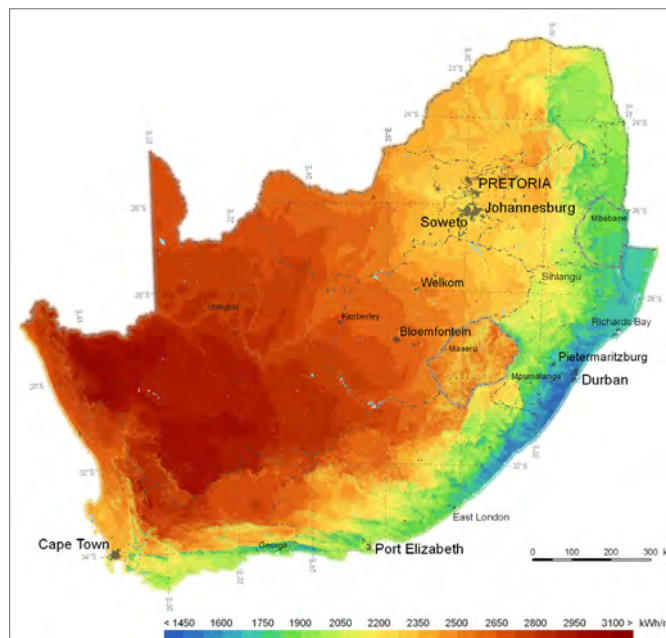
Key to the drive for renewable energy is rapidly evolving government policy and strategy. The DoE's Renewable Energy White Paper stipulates a target of 10,000 Giga Watt hours (GWh) by 2013 to be produced from renewable energy source. Similarly, the IRP for electricity states targets for each renewable energy type (DoE 2010b). According to the IRP for electricity, renewable energy will contribute 18.2 Giga Watt (GW) by 2030, wind will contribute 8.4 GW, solar photovoltaic energy will contribute 8.4 GW, Concentrated Solar Power (CSP) will contribute one GW and 'other' will contribute 0.4 GW of new build. Actual achievements might need to be more than the stated targets though if the envisaged low-carbon economic growth of the LTMS is to be realized. Thus far a total of 47 preferred bidders have been approved under Windows One and Two of the REIPPPP, for a total of 2,614 MW to be added to the national grid by 2016 (DoE 2012a).

Some of the renewable or cleaner energy alternatives are described below.

12.3.6.1 Solar

South Africa has particularly high solar power potential, as illustrated by the level of solar irradiation received annually (Map 12.2). Almost the whole interior has an average annual total insolation in excess of 2,000 kWh/m² with parts of the Northern Cape reaching 2,360 kWh/m². This potential

is significant as, in comparison, few areas around the Mediterranean Sea exceed a total of 2,000 kWh/m² per year yet Spain already has more than 4,400 MW solar photovoltaic energy and 1,878 MW CSP facilities installed. The South African IRP plans for 8,400 MW from photovoltaic and 1,000 MW from CSP to be added to the future planned energy mix in the country through the REIPPPP by 2030 (about the same as two Kusile/Medupi type coal-fired power stations) (DoE 2010b).



Map 12. 2: Global horizontal irradiation in South Africa

Source: SolarGIS © (2013) GeoModel Solar s.r.o.

Solar power lends itself to application for direct collection of heat or light, or the conversion of the solar radiation into energy carriers such as electricity. Of particular value is the ability to scale up the power generation from solar energy through modular additions to the power generation facilities. In a basic form, solar power can be used in small collector set-ups to heat food or buildings, but the same principle can be applied at scale to concentrate large amounts of sunlight and drive power generation facilities. Photovoltaic collector panels can also be used to convert sunlight directly into electricity as robust stand-alone electricity generation systems.

Diverse developmental opportunities offered by solar power, all contribute to a lower carbon-intense energy consumption in South Africa. On one end of the scale, off-grid electricity access can be provided through stand-alone photovoltaic systems, whilst solar water heaters can be rolled out at a massive scale to save energy users money and reduce the overall reliance on coal-based electricity for water heating. At the other end of the scale, massive CSP arrays can generate commercial scale electricity for main electrical grid tie-in.

Solar power is a particularly clean form of energy, with very little environmental impacts emanating from the operation of a solar power installation or facility. Most environmental costs relate to the manufacturing of the facilities and opportunity costs related to the use of land (of course, the generation of renewable energy will improve this footprint).

Operational pressures on the environment include:

- The use of land for large solar panel arrays, which could preclude it from being used for other productive functions and create aesthetically intrusive surfaces;
- Large solar panel facilities could bring about changes in environmental infrastructure, wetlands, ecosystems and habitats, especially if they, and their supportive infrastructure, are located in marginal or sensitive areas;
- Some technologies rely on water for cooling and cleaning of the surfaces of the solar collectors, or as steam to drive generators, but re-use is possible to some extent; and,
- Ancillary infrastructure such as powerlines and roads extend the footprint of the facilities to beyond its boundary.

One of the benefits of solar panels is the potential for co-use of land. Photovoltaic systems and solar water heaters, in particular, can be placed on other structures and thus does not require any additional land.

12.3.6.2 Wind

It is estimated that terrestrial wind power could realistically provide 81 TWh of power to the national energy accounts (Hagemann 2008). This is equal to 11 per cent of the country's consumption of energy for 2010, or enough to fulfil the energy requirements of Mozambique. The coastal regions have the highest potential for power generation from wind, but other areas such as the eastern Highveld, Bushmanland, southern Karoo and the Drakensberg foothills show moderate potential for wind power generation. A further potential for offshore wind development also exists.

Two pilot wind farm facilities were constructed in the Western Cape, at Klipheuwel and Darling (Box 12.1). These are likely to soon be dwarfed by the commercial scale facilities being erected in the Eastern Cape, KwaZulu-Natal and Western Cape under the auspices of the IPP Procurement Programme. The scaling up of wind power facilities is further supported by the Wind Atlas for South Africa project which is tasked with compiling databases of the country's wind resources (<http://www.wasa.csir.co.za>).

As with solar, most environmental impacts result from the manufacturing and installation of windmills, but some do occur during the operational phase. Manufacturing requires large amounts of energy and raw materials, whilst the construction process similarly uses energy and carbon-intensive materials such as concrete. The limited operational impacts include:

- Opportunity costs of the ecological and aesthetic impacts of wind turbines;
- Impacts from ancillary infrastructure such as powerlines and roads;
- Bird, insect and bat kills; and,
- Noise and pressure wave effects.

Box 12. 1 :Cape Town: Darling Wind Farm

- South Africa's first grid-connected, independent wind energy power-generating facility;
- 4 x 1.3 MW wind turbines powered up in May 2008. 8.6 GWh/year;
- Power Wheeling Agreement with Eskom; and,
- 20-year Power Purchase Agreement between DWF and City of Cape Town. Power bought at a premium and sold on to voluntary green customers.



Source: Website: <http://www.darlingwindfarm.co.za/>

12.3.6.3 Biomass

Similarly to most renewable energy alternatives, the use of biomass takes many forms and finds application at different scales. Traditionally, biomass in the form of wood, charcoal or dried dung is used as a domestic fuel source. Commercial applications of biomass as fuel are found in the sugar industry where bagasse is used as feedstock for coal-fired boilers. The sugar refineries where the bagasse is used are considered to have an installed generation capacity of about 245 MW equivalent (Winkler *et al.* 2006).

Energy from biomass can also be extracted through processing that converts organic materials into flammable gasses, either through natural decomposition processes or by artificial refining. Natural decomposition that takes place in the absence of oxygen generates methane and other gases, which can be captured and used as fuel. The gases can be cultured in biogas digesters or tapped from larger sources such as waste disposal facilities (landfills) (Box 12.2). Energy from landfills is considered to have an energy content of about 11 TWh per annum, roughly equivalent to two per cent of national consumption (Haw & Hughes 2007).

With pressures growing to find alternatives to carbon intensive liquid fuels, much work has been done on investigating the

potential for biofuels to augment fuel supplies in this sector. At the same time research and development in electric vehicles is advancing in leaps and bounds.

Biomass also holds potential as a liquid fuel. Carbohydrate-rich crops such as sugarcane, sunflowers, maize, canola, soya beans or sugarbeet, or even waste vegetable oils, can be refined into biodiesel or bioethanol. Due to its renewable nature, fuels from biomass have a lower carbon intensity, and if properly refined, also a lower emissions footprint than conventional fossil fuels. They are therefore an important consideration as a transitional fuel used to temper the current carbon intense fuel use.

Some concerns related to the use of biofuels include a fear that biofuel crops will supplant food crops, or that it merely extends the dependence on fossil fuels without significant change to the amount of energy that we consume. The 2007 Biofuels Strategy (DME 2007) motivates though that only 1.4 per cent of the country's arable land will be sufficient to achieve a two per cent penetration of biofuels in the national liquid fuel supply.

Box 12. 2: eThekweni: landfill gas project

- First electricity generation from landfill gas (methane) in South Africa;
- Electricity sold under long-term Power Purchase Agreement with eThekweni;
- Carbon finance channelled through sale of Certified Emission Reductions (CERs);
- Plants at Mariannhill (1 MW), La Mercy (0.5 MW) and Bisasar Road (6.5 MW); and,
- Bisasar: electricity supply for 3,750 small houses; 20,000 tonnes carbon destroyed/month; 2-year payback.

Lessons learnt: Clean Development Mechanism administratively onerous, but projects not financially viable without CERs. La Mercy closure due to insufficient gas: verify gas amount beforehand.



12.3.6.4 Nuclear

The use of enriched uranium in nuclear power stations is a well-established technology, many times more energy dense than conventional energy fuels, and finds application in South Africa at the Koeberg reactor just outside Cape Town. Current contribution to the energy supply mix stands at about

2.3 per cent (IEA 2012). Nuclear power stations use nuclear fission reactions as a source of heat, which is then converted to electricity as a carrier. Enriched uranium is used as fuel in the power stations. In South Africa, uranium is found at commercially exploitable concentrations at selected locations in the Karoo, and as a by-product of gold mining. There is an estimated 261,000 tonnes of uranium in South Africa (Winkler *et al.* 2006). Uranium enrichment is costly though, and it is still more cost effective to import nuclear feedstock than to produce it locally (ERC 2004).

Despite its energy potential and low carbon intensity, nuclear power comes with a list of concerns that make it a politically and socially sensitive topic. The concerns relate to the fact that nuclear power is not cheap when compared to other forms of energy, the dangerous radioactive waste produced in the power stations, and the sensitive locations required for the power stations. A strong argument asks whether nuclear power has more value than other forms of renewable energy when considered in terms of local content, operational costs and international dependencies.

12.3.6.5 Hydro

An assessment conducted by the DoE, the Baseline Study on Hydropower in South Africa, indicated that specific areas in the country show significant potential for developing all categories of hydropower in the short and medium terms. The Eastern Cape and KwaZulu-Natal are gifted with the best potential for developing small, i.e. less than 10 MW hydropower plants. Specific sites are, however, also available with generation capacity large enough to be used in the national electricity grid.

Since these plants can either be stand-alone, exist in a hybrid combination with other renewable energy sources or be associated with other uses of water such as water supply, irrigation, flood control, etc., it makes them all the more attractive. This is critical to the future economic and socio-economic development of South Africa. Hydropower plays a role in energy balances, since it can be used in the form of pumped storage schemes to store energy in off-peak times and release it during peak hours. Importantly, this balancing function can be used to store energy generated by renewable power sources such as wind and solar for use during times when energy use and generation is not equally matched. Eskom is building the Ingula pumped storage scheme near Van Reenen in KwaZulu-Natal which has an electricity generation potential of 1,332 MW.

Future water crises' pose challenges for the development of hydropower. Based on water use demand projections, South Africa is projected to run out of water for allocation to users between 2020 and 2030 unless widespread reuse of water takes place (StatsSA 2010). The focus for hydro power in South Africa will therefore be on small-scale rather than larger projects. For larger projects, South Africa collaborates with other countries in the continent where better potential and resources exist. The main projects are the Lesotho Highlands Project, the Mozambican Cahora Bassa project, and the Inga-3 Project in the Democratic Republic of the Congo. Inga-3 has a potential of producing 40,000 MW which can be shared amongst the partners making up the South African power pool.

12.3.7 The environmental costs of using fossil fuels

12.3.7.1 Mining

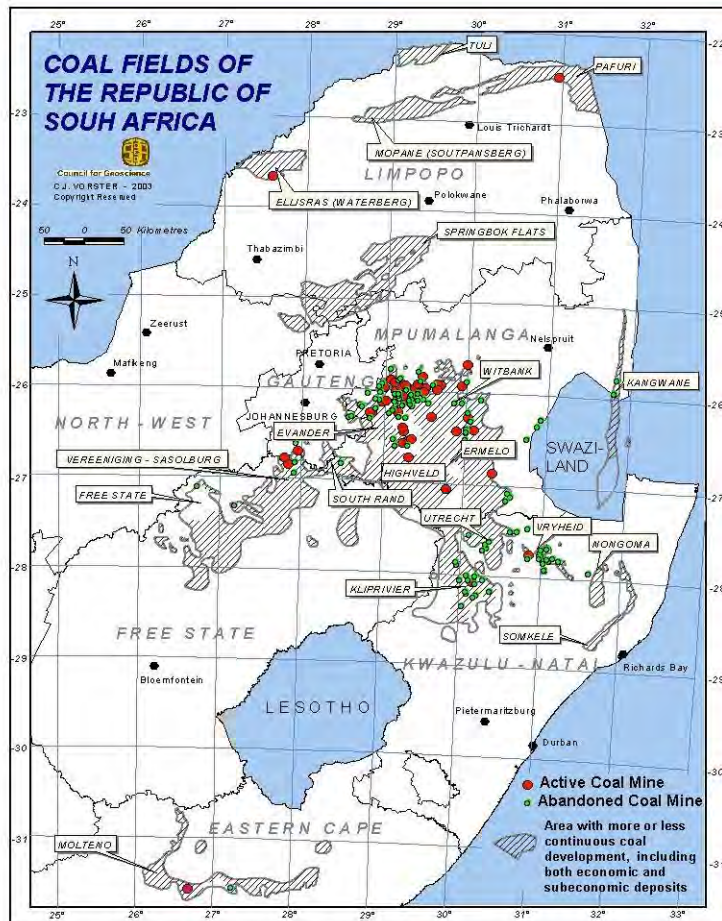
Mining is a form of resource exploitation that is extractive and non-renewable in nature as it removes minerals or other resources from the environment at rates that can never be matched by regenerative natural processes. This extractive character means that mining leaves behind artificial voids on or below the earth's surface, leading to both direct and indirect impacts on environmental systems. Energy generation and consumption is closely tied to the mining of fossil fuels for use as feedstock for the production of energy, or base minerals for the construction of energy generation facilities and transmission infrastructure. Importantly, mineral resources are location bound, and mining therefore has to take place wherever minerals are found, which could potentially lead to conflicts with human presence or ecological sensitivities.

Coal mining, which drives the South African energy sector, is present in the grassland areas of Limpopo, Mpumalanga, Free State and KwaZulu-Natal, with limited reserves in the Eastern Cape (Map 12.3). These coal fields are, especially in Mpumalanga, unfortunately also associated with extensive wetland systems and therefore ecologically sensitive. Mining, especially the open cast mining characteristic of the area, eliminates these sensitive wetland systems and eliminates the ecosystem services (groundwater recharge, surface water filtering etc.) that they provide. Natural soil characteristics are altered and/or destroyed when the surface of the

soil is removed in order to access the coal. This lowers the productivity of the soil for agriculture or biodiversity. Soil structure may also be disturbed by pulverization or aggregate breakdown.

Water related impacts are also associated with underground mining. Groundwater percolation gives rise to AMD as groundwater collects contaminants or reacts to exposed rock surfaces and then naturally moves through rock and soil strata to contaminate soils and water resources. Surface water runoff from exposed sites may also contain significant levels of contaminant that natural filtration and decontamination processes cannot cope with.

Mining activities furthermore give rise to atmospheric emissions such as dust fallout, vehicular emissions from hauling and handling, and emissions due to the power requirements of crushing and grinding (and other) processes. Dust is generated by the removal of vegetative cover and activities associated with the construction of haul roads, and can have adverse impacts on vegetative life and the health and safety of mine workers and nearby communities. In addition, gases trapped in substrata may be released through the breaching of the earth's surface, such as methane found along with coal seams. Unanticipated combustion of coal seams and stockpiles also occur. These smouldering fires are hard to control and extinguish, leading to long term burns and associated effects such as emissions, and a risk to public safety.



Map 12. 3: Location of the coalfields of South Africa

Source: Council for Geoscience

The environmental impacts of mining should consequently be seen as opportunity costs since the potential for alternative land uses of both the directly mined land and any impacted surroundings such as for agriculture, tourism or ecosystem services will be lost permanently.

A study on the contribution of coal mining to the externalized costs of producing electricity at the Kusile power station currently being constructed in Limpopo found that mining will add between 20.2 and 39.3c/kWh to the effective cost of generating electricity. This was quantified on the basis of the following impacts:

- Global damage as climate change;
- Transportation related global damage through climate change;
- Human health damages due to accidents;
- Human health damages due to air pollution;
- Water pollution;
- Water consumption;
- Loss of agricultural potential; and,
- Loss of ecosystem services.

12.3.7.2 Fossil fuel-based energy generation

Fossil fuels, in the form of coal, oil, oil products and natural gas, are burned (oxidized) in order to release energy in the form of heat. This efficiency of the combustion process varies along with the type of fuel, the quality thereof, and the technology used, as does the associated environmental impacts. Common examples of combinations include coal burning in dry cooled electricity generating power stations, low sulphur content diesel in internal combustion engines, and the use of heavy fuel oil in marine ships, each of these would have a different environmental footprint.



Air pollution is one of the main effects of the use of fossil fuels for energy generation. Different refining and combustion processes will generate different levels of pollutants such as carbon dioxide, methane, oxides of nitrogen, carbon monoxide, particulate matter, VOC, hydrocarbons, lead and other heavy metals, sulphur dioxide, mercury and a wide range of carcinogenic radionuclides. For example, the low temperature burning of poor quality coal in a small fire will result in high levels of particle emissions (smoke) and gases, whilst a more complete combustion of refined gas would generate virtually no smoke and much lower gaseous emissions. The release of energy from all fossil fuels, however, results in the release of greenhouse gases such as methane or carbon dioxide, thereby contributing to human induced climate change.

Energy generation often also requires the use of large quantities of water, typically as propellant to drive steam

turbines or as a cooling agent. The wastewater generated is often polluted and heated, and when discharged into the natural environment can disrupt ecological functioning.

Waste, in the form of ash, is also associated with the burning of lower grade solid fuels. The ash can contaminate water resources, soils and the air when containment fails. This impacts on the lives and livelihoods of people exposed to the pollution.

12.3.7.3 Transmission and distribution

Large distances often separate energy sources, generation facilities and uses. Coal, for example, is mined in one place, then transported to a power station where it is converted into electricity, after which it needs to be distributed to users. The transmission or distribution networks should therefore be seen as part of the overall energy system, and hence also as part of the environmental footprint of the supply and use of energy. The transportation of fuels requires different forms of transportation and the associated road, rail, pipe or harbour infrastructure, each with its own environmental impacts. A multi-products pipeline, for example, has been built between the Port of Durban and Johannesburg, as has a gas pipeline from Mozambique to Secunda. Electricity supply takes a similar form. The large-scale use of electricity is in part related to the ease at which it can be used as a carrier of energy across a landscape, but the long distance transmission networks are based on networks of powerlines and pylons.

The transmission or distribution networks have impacts on the environment, including:

- Destruction of environmental infrastructure, wetlands, ecosystems and habitats;
- Opportunity costs including the loss of productive land, impacts on property value, degradation of aesthetic values, and loss of ecosystem services;
- Bird kills through collisions and electrocution;
- Linear obstructions through migration routes;
- Conflicts between animals and humans and land-based transport; and,
- Pollution and spread of invasive alien species through marine shipping.

12.3.8 Natural gas

Natural gas is often considered as a transitional fuel, since as a fossil fuel it contributes to accelerated climate change, but at the same time it is one of the 'cleaner' fossil fuels with a lower environmental impact than coal. Natural gas has as yet not been explored extensively in South Africa, although it is extracted from the offshore gas and oil fields off Mossel Bay. Significant interest is being shown though for potential gas extraction from shale gas reserves in the Karoo basin, and verification of the potential is currently underway.

Most of the local infrastructure related to natural gas is located at the synfuel production plant at Mossel Bay owned by PetroSA, previously known as Mosgas. It is fed by the F-A offshore gas field and produces about 45,000 barrels/day (crude oil equivalent) of liquid fuels (DoE 2010a). Sasol also imports natural gas via an 865 km pipeline from Mozambique to its gas-to-liquid operations at Secunda, Mpumalanga.

Figure 12.10 below shows the volumes of gas produced and consumed in South Africa between 1998 and 2008.

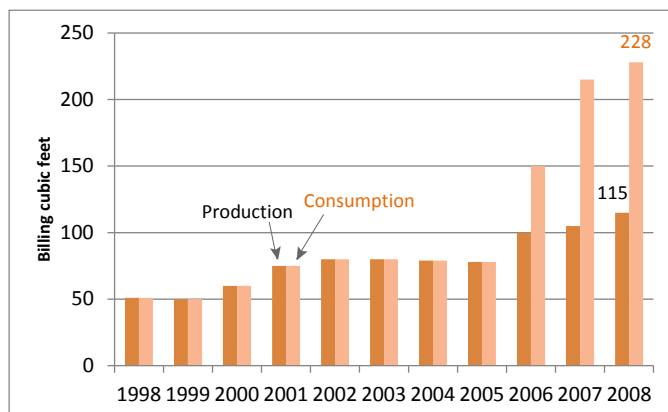


Figure 12. 10: Natural gas production and consumption for the period 1998 to 2008

Source: Energy Information Administration (2011)

Other than the conventional natural gas resources mentioned above, two, relatively recent, technological developments have made the exploitation of unconventional gas resources economically viable. In this regard, the technological developments of horizontal drilling and induced hydraulic fracturing (also known as hydrofracking or fracking) have turned previously unexploited reserves of shale gas into commercially viable gas fields. In this regard, natural gas extracted from dense shale rock formations has become the fastest-growing source of gas in the United States and there is a growing sense in the global energy sector that shale gas could become a significant new global energy source. Indeed, the International Energy Agency is predicting a 'Golden Age of Gas' (IEA 2011).

With the United States Energy Information Agency's first pass estimate of 485 trillion cubic feet of technically recoverable shale gas in the Karoo Basin, South Africa has not escaped the current excitement and controversy associated with this new potential fossil fuel resource. Following the release of these estimates, three foreign-owned companies were granted permission by government, through the Petroleum Agency SA, to explore for gas. The first stage of such exploration takes place under an arrangement known as a Technical Co-operation Permit with Government and entails desktop research. Applications to convert these Technical Co-operation Permits to physical exploration permits were halted by a moratorium imposed by the DoE in April 2012. The moratorium which was subsequently lifted on 7 September 2012 following Cabinet's acceptance of the Inter-departmental Task Team on Shale Gas and Hydraulic Fracturing's recommendations to, among others, allow normal exploration (excluding hydraulic fracturing activities) to proceed under the existing regulatory framework.

At this stage, although the existence of commercially exploitable reserves of shale gas in the Karoo is still nothing more than theoretical possibility, given that the development of Mosgas was based on a confirmed gas resource of only one trillion cubic foot, it is clear that confirmation of any

significant commercially exploitable reserve could have a substantial impact on South Africa's energy profile. However, despite the excitement around the potential economic and employment opportunities such a finding could unlock, shale gas is still a fossil fuel and its extraction and use will have environmental impacts that will need to be avoided, mitigated or managed. Of these, apart from the potential economic lock-in to yet another fossil fuel and the greenhouse gas emissions associated with its extraction and use, the quantity of water and resulting waste water associated with the hydraulic fracturing process is considered to be the most significant environmental concern at present.

12.4 STATE

From the descriptions provided in the preceding sections, it becomes clear that the supply and use of energy places significant pressure on the environment. Impacts extend to all facets of the natural system, including water, air, soils, oceans, animal life and human lives. Some discussion on the contribution of energy generation and use to change in the environment is provided below. Further exposition on the impacts on specific environmental themes can be found in other theme chapters. For instance, more in-depth discussion on ambient air pollution and indoor air pollution due to emissions of greenhouse gases, is found in Chapter 10: Air Quality. For land use impacts refer to Chapter 6: Land; for biodiversity impacts Chapter 7: Biodiversity and Ecosystem Health; and, for discussion on water impacts, refer to Chapter 8: Inland Water. More on the contribution to climate change and the impacts of climate change is provided in Chapter 11: Climate Change.

12.4.1 Reduced air quality

As indicated, one of the main effects of the use of fossil fuels is a decline in air quality. This takes place at macro and micro level, i.e. either as bulk generalized emissions, or as localized smaller impacts.

Bulk impacts are related to large-scale combustion of fossil fuels, especially in power stations or industrial boilers, as well as the combined effect of transportation related emissions. The South African energy supply is dominated by coal with 71 per cent of the primary energy supply being provided in the form of coal (IEA 2012). Local coal typically has high ash content and low calorific value, which means that in the absence of appropriate filter technologies, the burning of this poor quality coal produces large amounts of atmospheric pollutants (Winkler 2009).

As shown in Figure 12.11, the production of electricity consumes 94.5 per cent of the coal in South Africa. Of the remaining 5.5 per cent, industry uses 3.7 per cent and non-energy use accounts for 0.5 per cent (IEA 2012). Electricity generation is therefore the major driver of coal-related emissions. Winkler (2009) calculates that in 2001, Eskom coal-fired power stations produced 59.64 kilo tonnes (kt) of particle emissions, 1,500 kt of sulphur dioxide and 684 kt nitrogen dioxide.

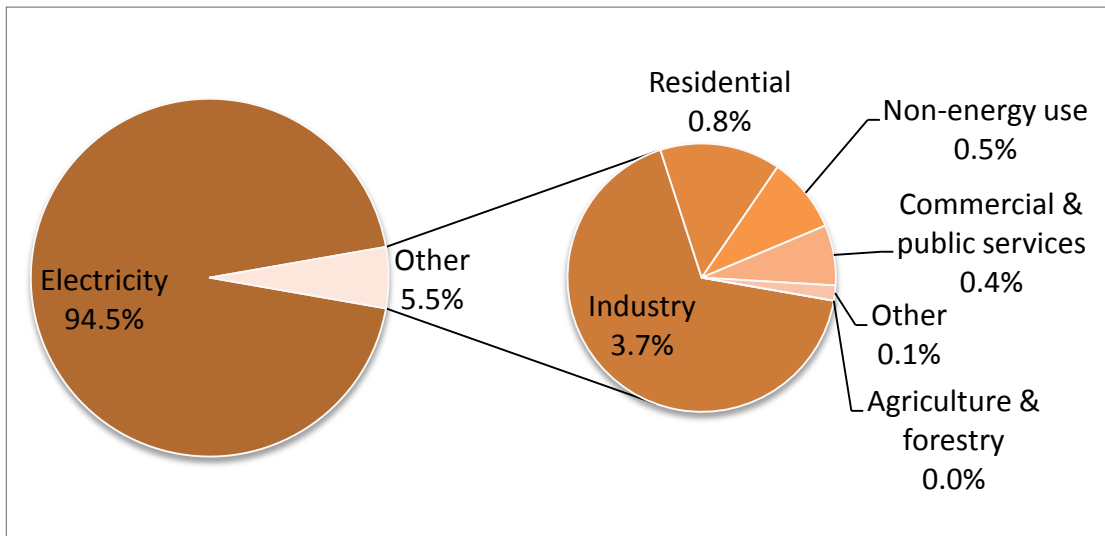


Figure 12. 11: Consumption of coal in different sectors

Source: IEA (2012)

Most of the country's power stations are situated in the coalfields of Mpumalanga, thus concentrating about 90 per cent of the scheduled emissions of dust, nitrous oxide and sulphur dioxide in the province. Climatological conditions in this region further exacerbate the pollution because of stable atmospheric conditions unfavourable for low-level dispersion (Winkler 2006).

Particulate matter control installed at Eskom power stations in the past 20 years or so, such as bag filters, electrostatic precipitators for removing the smaller remaining particles, and flue gas conditioning plants, are shown to be successful in reducing particulate emissions. Figure 12.12 shows the average amount of ash emitted per one kilowatt hour of power, with a marked decrease evident between 1992 and 2001 (Winkler 2006).

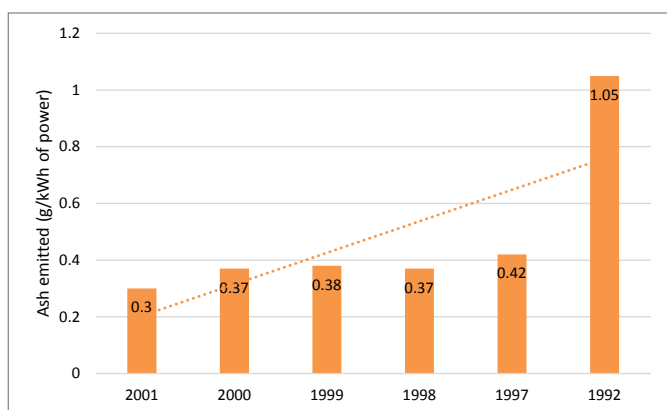


Figure 12. 12: Ash emitted per 1 kWh of power

Source: Winkler (2009)

Transportation is another major contributor to air pollution due to the sector's reliance on the refining and combustion of oil and oil related products. The orientation of the transport sector towards private cars contributes to this pollution, as do the high emissions from extensive bus and taxi commuter networks (Winkler 2006). Emissions associated with transportation include sulphur dioxide, carbon dioxide, nitrous oxides, carbon monoxide, suspended particulate matter and volatile organic carbons, and are known to be toxic or have

carcinogenic effects (Winkler 2006). Photochemical smog, also known as a 'brown haze', is another characteristic effect of the pollution emanating from transportation, especially from the use of diesel fuels (Wicking-Baird *et al.* 1997). In addition to the vehicular emissions, further emissions are due to shipping, aviation and rail, as well as vehicle entrained road dust, brake and tyre wear fugitives. Ancillary emissions such as fugitive emissions at filling stations can also be identified.

Scorgie (2012) estimated the total annual emissions due to vehicle emissions for the major conurbations in South Africa based on 2002 data. The results are presented in Table 12.5.



Table 12. 5: Total annual vehicle emissions (exhaust and evaporative releases) for 2002

Pollutant tonnes per annum	Johannesburg	Cape Town	Vaal Triangle	eThekweni	Tshwane	Ekurhuleni	Mpumalanga	Total
NO _x	45,939	56,461	10,639	62,457	29,573	37,359	24,065	266,495
SO _x	5,433	8,106	1,904	11,121	4,054	6,049	5,781	42,448
1,3 butadiene	367	261	60	239	215	236	81	1,460
Benzene	395	447	65	404	230	254	82	1,877
Particles	1,085	1,603	400	2,286	827	1,257	1,247	8,704

Source: Scorgie (2012)

The direct use of fuels as energy in domestic applications gives rise to indoor air pollution, with severe impacts on human health. Fuels commonly used in domestic settings include wood, dung, kerosene/paraffin, LPG and coal. Although the use of such fuels is more prevalent in rural areas where grid-supplied electricity is not available, it persists in urban areas, especially for purposes of heating and cooking (StatsSA 2012b). It is thought that the cost implications of acquiring electrical appliances and buying electricity prevent many households from moving away from domestic fuel use (Winkler 2006). *“Indoor air pollution increases the risks of chronic obstructive pulmonary disease in adults (primarily women) and acute respiratory infections in children, in some cases leading to death. It is also associated with certain cancers (lung cancer, for example), infant mortality, low birth weight, cataracts and tuberculosis.”* (Winkler 2006). The use of open flames in dense settlements also increases the risk of residential fires (Winkler 2006). Scorgie (2011) found that household fuel burning was estimated to be responsible for 68 per cent of the total health costs estimated across all conurbations, vehicle emissions for 13 per cent, industrial and commercial fuel burning for 13 per cent and power generation for about six per cent.

12.4.2 Reduced water quantity and quality

About 28 per cent of South Africa’s coal is exported and over 95 per cent of the remaining coal used for energy generation locally. Most of the coal mining impacts on water quality and water resource balances can therefore be ascribed to the energy sector. Impacts include AMD, destruction of groundwater reservoirs and contamination of surface water through polluted runoff or disposal of mine wastewater. As coal mining takes place in the headwaters of several of South Africa’s main catchments, the impacts are felt by all downstream users.

Surface water pollution emanating from coal mines are specifically blamed for the deterioration of the water quality in the Limpopo, Crocodile (west) & Marico, Upper Vaal and Olifants River catchments, although agriculture, industry and wastewater treatment compounds the problem.

Coal mining is also estimated to consume seven per cent of the water allocated to the mining sector, and therefore 0.2 per cent of the water supplies of the country (StatsSA 2010).

The total water consumption of the energy sector, however, also includes water used in power generation. For every kWh of electricity generated, 1.26 litres of water is used (mainly in coal-fired power stations (DEADP 2010)), with conventional wet-cooled cooling towers sometimes reaching 22 litres per kWh (Winkler 2009). Modern dry-cooled stations, such as Kendal and Matimba, dramatically reduce the water use though, as they require only 0.1 litres per kWh (Winkler 2009). Nevertheless, it is officially estimated that two per cent of the national available water resources are applied in power generation (StatsSA 2010). Wassung (2010) finds that this is an underestimation since it excludes the water used during coal extraction, processing, pollution control and the disposal of by-products. Accordingly, based on full life-cycle water consumption for coal-fired electricity, 4.84 per cent is considered possible.

12.4.3 Reduced soil quality and land availability

Energy supply and use needs land resources for supply and distribution networks, as well as for locating facilities associated with refining, handling, pumping and storage, or power generation.

At the one end of the energy supply chain, mining and other extractive processes can destroy or sterilize large areas. Out of the 22 mines that supply Eskom with coal, 12 are opencast mines, five are underground, and five mines have both opencast and underground facilities (Wassung 2010). Mpumalanga is host to the bulk (84 per cent) of the country’s coal mining (DoE 2010a), and the 50 or so collieries potentially cost the province 26 per cent (225,217 ha) of its high potential agricultural soils through disturbance (BFAP 2012). Rehabilitation of disturbed areas can never replace the original productivity of soils, since compaction, disruption of the ecological processes and mixing of soil layers would have taken place. Current best practice seems to suggest that only up to 70 per cent of the original productivity can be retained through rehabilitation (BFAP 2012). Further degradation takes place in the form of edge effects such as dust from haul roads, groundwater drawdown, ground and surface water pollution, and effects of surface subsidence.

Wood is also used as a primary fuel source, both as a commercial fuel (pulp mill residue) and for domestic use. The

exact amount of residential wood fuel used is unknown but estimates put it at 86 Peta Joule (PJ) per year, roughly equivalent to seven Mega tonne (Mt) of wood per year (DoE 2010a). The collection of fuelwood often requires the collection of wood from natural areas around residential settlements. Should the residential density or collection intensity be too high, this would lead to denudation of the natural vegetation.

The different land uses associated with energy includes 27,000 km of electricity supply powerlines, which cross the landscape along with their associated servitude areas. Some of these servitudes may be co-used for agricultural activities, but maintenance of the vegetation and visual impacts generally have negative impacts on the biodiversity and for land uses that rely on landscape quality. A similar impact is associated with large-scale transformation of land parcels for the purposes of wind or solar farms.

The production of crops for use in the production of biofuels requires agricultural land, and would either replace food crops on existing fields, or convert natural vegetation to new fields, unless previously disturbed areas are utilized. The

National Biofuels Industrial Strategy pushed for a two per cent penetration of the local liquid road transport fuels market which would translate into a 1.4 per cent of the arable land of the country (Letete & Blottnitz 2012). To date though, biofuels have not taken off in South Africa.

12.4.4 Climate change

A contribution to global climate change is one of the main effects of the generation and consumption of fossil-fuel based energy. The liberating of carbon embodied in fossil fuels lead to the accumulation of greenhouse gases in the atmosphere, and consequently a progressive warming of the planet. Carbon dioxide is the most important greenhouse gas in terms of amounts emitted, but other gases such as methane and nitrous oxide also play significant parts.

South Africa is one of the world's most carbon intensive countries, with per capita emissions that are higher than many European countries and several times the average for developing countries (Winkler 2009) (Table 12.6).

Table 12. 6: A comparison of energy sector carbon dioxide emissions for selected countries and/or regions

	CO ₂ /capital	CO ₂ /GDP	CO ₂ /GDP PPP	Cumulative energy CO ₂ emissions from 1950 to 2000	
	Tonnes/capita	Kg/1995 US\$	Kg/1995 PPP US\$	Mt CO ₂	% of world total
South Africa	6.65	1.65	0.75	10,165	1.29
Africa	0.89	1.16	0.45	13,867	1.75
Non-OECD	1.65	1.33	0.45	318,117	40.23
OECD	10.96	0.44	0.56	472,635	59.77
World	3.89	0.68	0.56	790,753	100.00

Notes: Percentages in the last column do not add up to 100 as rows are not mutually exclusive (for example, South Africa is part of Africa).

PPP – purchasing power parity

Mt CO₂ – million tonnes of carbon dioxide

Source: Winkler (2009)

Data regarding the South African carbon footprint differs due to differing sources of data and conversion factors used to aggregate the information. Two figures are consequently quoted for the purposes of this report, totals reported by South African Government sources (DoE 2013; National Treasury 2013), and time-series data generated by the European Commission (2011).

Official figures indicate that total greenhouse gas emissions in South Africa in 2009 totalled 547 Mt CO₂e, an increase from 461 Mt CO₂e in 2000 and 380 Mt CO₂e in 1994 (National Treasury 2013). In comparison, the European Commission reports a total greenhouse gas emissions footprint of 459.22 Mt CO₂e in 2008 and 437.87 Mt CO₂e in 2009 (Figure 12.13).

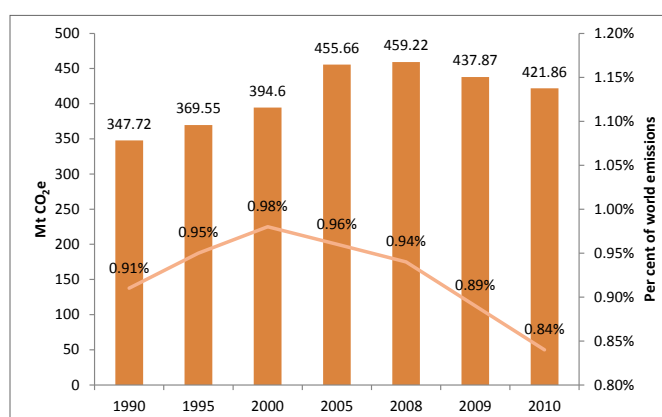


Figure 12. 13: Greenhouse gas emissions for the period 1990 to 2010

Source: European Commission (2011)

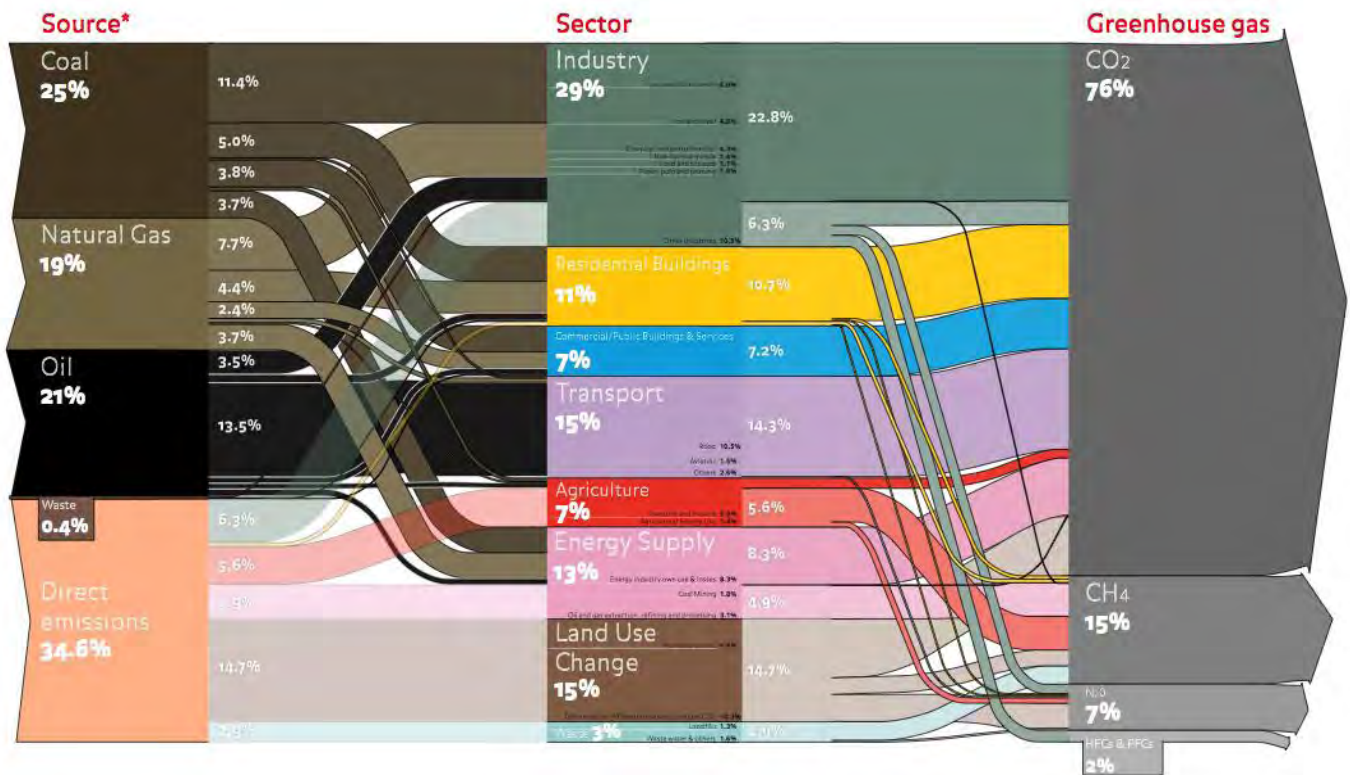


Figure 12. 14: World greenhouse gas emissions flowchart for 2010
 Source: Ecofys (2013)

Greenhouse gas emissions are closely related to the energy sector, and in South Africa specifically due to emissions associated with electricity generation, petroleum refining and transport. These three components were collectively responsible for more than 80 per cent of total emissions in 2000, followed by the agricultural and industrial sectors at 8.4 per cent and seven per cent, respectively (National Treasury 2013). The energy balance reports for 2009 from the DoE suggest that the use of energy can be held responsible for 64 per cent of the total greenhouse gas emissions of the country, i.e. 351.09 Mt CO₂e (DoE 2013).

By comparison, the global average percentage contribution as shown in Figure 12.14 notes a 13 per cent contribution by energy supply, 15 per cent by transport, and a mere three per cent by refining (Ecofys 2013). The use of coal, gas and oil products directly for industrial application makes up a significant portion of the 29 per cent contribution to world greenhouse gas emissions.

12.5 IMPACTS

12.5.1 Reduced air quality

Air pollution stemming from the use of energy, and specifically the use of fossil fuels, impacts on both the health of the natural environment and the health of people.

The impacts of poor air quality and/or air pollution hotspots resulting from energy generation and use are determined by the nature and location of the emissions. Emissions occur at the source of fuel extraction (e.g. dust from coal mines), during conversion to different carrier/fuel types (e.g. fossil fuelled power/electricity/steam generation or petrochemical refining) and where energy carriers are consumed by end users (vehicular transport or household solid fuel usage). In all three

cases, the pollution gives rise to health impacts on humans, creating a commensurate burden on health-care services. A 2004 NEDLAC report estimated that the health costs associated with domestic coal use cost the State more than R1.1 billion annually (DEAT 2007). Various epidemiological studies found that air pollutants contribute to the incidence of potentially life-threatening diseases such as cases of bronchitis, asthma and lung cancer, hospital admissions related to respiratory, cardiac, asthma and coronary obstructive pulmonary disease, as well as asthma-related emergency room visits (Business Enterprises UP 2011).

Mortality outcomes calculated for South African urban areas estimates that outdoor air pollution caused 3.7 per cent of total mortality from cardiopulmonary disease in adults aged 30 years and older, 5.1 per cent of mortality attributable to cancers of the trachea, bronchus, and lungs in adults, and 1.1 per cent of mortality from acute respiratory infections in children under five years of age (Norman *et al.* 2007). Acute lower respiratory infections were related to 24 per cent of deaths of children under five years in 2000, and also mostly attributable to indoor air pollution from household fuel use (Norman *et al.* 2007). Indoor air pollution from household fuel use was responsible for 2,489 deaths, or 0.5 per cent of the total health burden on the individual, and resulted in the loss of 60,934 disability adjusted life years, or 0.4 per cent of the total burden (Norman *et al.* 2007).

The lack of insulation and the absence of ceilings in most low-income dwellings, together with persistent use of paraffin, coal and wood for heating and cooking purposes, lead to a high incidence of respiratory and other health related problems in the country. "Air pollution in dense, low-income communities, largely resulting from the burning of coal and wood for cooking and space-heating, is one of the most pressing air quality issues in South Africa." (DEAT 2007).

Norman *et al.* (2007) determined that respiratory infections lead to approximately 14 per cent of deaths amongst children younger than five. Barnes *et al.* (2009) points to literature that shows an association between exposure to indoor air pollution and chronic obstructive pulmonary disease, lung cancer, nasopharyngeal cancer, tuberculosis and diseases of the eye in adults, low birth weight and, of particular concern, acute lower respiratory infections such as pneumonia, amongst children less than five years of age.

Energy related activities are associated with all three Priority Areas designated under the Air Quality Act. These are the Highveld, the Vaal Triangle Airshed and the Waterberg Priority Areas. The combined effect of coal mining, coal-based electricity generation and metal smelting on the Highveld has left the area around eMalahleni (Witbank) as a particular hotspot for air pollution. Maximum levels for ambient chromium, nickel, vanadium, iron and cobalt were much higher than the maximum values recorded in other polluted areas around the world (Žibret 2012). Other provincial and municipal hotspot areas are typically situated around petrochemical refineries, mining areas and industrial zones, indicating the close association between air quality and energy intensive land uses.

12.5.2 Reduced water quantity and quality

A close relationship exists between energy and water. Water is involved at most stages in the energy cycle, and the quality and quantity of water is therefore influenced by the type of energy being produced and consumed. Because both resources are limited though in terms of spatial distribution and absolute availability, they need to be managed in unison where strategic planning is used to inform the consequences of energy generation and use.

Reduced water quality and quantity affects any economic sector that is dependent on water resources. Energy generation is a water intensive activity, and therefore competes with other land uses for limited water resources. Water resources in South Africa are already oversubscribed, which implies that water users have to resort to progressively lower quality supplies, with consequences for productivity and health. Where water resource competition reaches down to the level of domestic use, a reduced water availability means higher water stress and associated human health issues due to poor levels of sanitation.

Pollution of water resources, such as through mining for coal or fallout from power stations, increases water stress. The impacts could escalate though to levels where agricultural productivity is ruined through AMD, or ecological functioning in watercourses is lost due to polluted surface water runoff. Again, this could impact on the community level where people are reliant on water from watercourses. There are also significant costs associated with rehabilitation of diffusely contaminated or degraded water recharge areas, and the costs are likely to be carried by the public rather than the point-source pollutant activities.

12.5.3 Reduced soil quality and land availability

Poor air quality leads to lower soil productivity in agriculture due to chemical damage to vegetation or through dust

fallout. This reduces food production volumes, and reduces the value of agricultural land. Significant air pollution also impacts on other economic sectors that rely on a quality natural environment, such as tourism and residential use. Aesthetic considerations can impact on the perceived or actual environmental health of a particular location, thereby determining the attractiveness to visitors or land owners and consequently also the value of land and property.

Ecosystem functioning is further compromised through the combined impacts of water and air pollution stemming from the energy sector. Where ecosystems don't function optimally, their delivery and value in terms of ecosystem services such as water treatment, carbon capture, pest control, flood mitigation, etc. are reduced at cost to society and the economy.

12.5.4 Climate change

Energy-related greenhouse gas emissions are the largest contributor to South Africa's greenhouse gas emission profile. The changing climate that results from concentrations of greenhouse gases in the atmosphere will occur faster than what natural and social systems can adapt to. This means that significant costs will need to be carried by society in terms of adapting economic sectors to changed climatic conditions, changes to water availability, health impacts, as well as accommodating a growing global resistance towards carbon intensive activities. South Africa's carbon intensive energy sources and economy, combined with the country being a long-haul air travel destination would, for example, impose severe carbon taxes on international travellers which would impact on the tourism industry.

12.6 RESPONSE

12.6.1 Access to electricity

The national electrification programme has had an enormous impact on household's access to electricity in South Africa. In 2011, 85 per cent of the population had regular access to electricity in their homes as compared to 58 per cent in 1996 (StatsSA 2012b), and the intention is to reach 100 per cent electrification. In addition, informal dwellers countrywide desire access to electricity rather than alternative energy, such as LPG. This is largely because of the convenience, health and safety that electricity offers for lighting, media and other uses.

There is a clear need to extend access to electricity as widely as possible, as well as ensuring clean alternative energy options. The combined increased demand will ultimately put more pressure on electricity supply, although in relative terms it will have a small impact on the electricity demand profile given that residential electricity demand is not as high as the demands from industry and transportation. It will nevertheless impact on peak demand which is already under strain and however small the increased consumption might be, it will still have an overall impact on the environment given that most of our electricity is obtained from coal.

12.6.2 Demand-side management and improving energy efficiency

12.6.2.1 Energy efficiency policy and strategy

There are a number of policies and strategies that have emerged in response to the country's climate change mitigation imperatives. One area of focus has been on improving our energy efficiency. As an energy intensive country with a history of cheap electricity, there has been historically little incentive to introduce efficiency until recent years. Government has recognized the benefits of efficiency in terms of impacting on the environment as well as economic benefits. The DoE's 2005 Energy Efficiency Strategy set out to strive for affordable energy and to minimize the *"negative effects of energy usage on human health and the environment through sustainable energy development and efficient practices."* The strategy set a target of 12 per cent energy savings by 2015. In 2008, the strategy underwent its first review with a second taking place in 2012. The 2012 Draft Second National Energy Efficiency Strategy Review states that there should be a total final energy intensity reduction of 12 per cent, off an adjusted (for growth) baseline year of 2000, by 2015, thus maintaining the overall targets.

In the wake of the electricity supply crisis and rolling blackouts of 2008 and 2009, National Treasury set up a municipal allocation, through the Division of Revenue Act, for Municipal Energy Efficiency and Demand Side Management, to be managed by the DoE. The programme initially had public lighting as its focus but has now, in its second three-year cycle, included full building retrofits. Funding is limited, so that only some 15 to 30 municipalities may participate in any budget year.

Around 2010 the major national energy efficiency programme, the IDM programme, run through Eskom, was again an important national focus after some years of relative dormancy during which time institutional arrangements and funding processes were being restructured. The mass implementation of compact fluorescent lamps through the Eskom Demand Side Management (DSM) (now IDM) programme was concluded in 2010/11. Since the inception of the DSM programme in December 2003 over 47 million bulbs have been installed country-wide in the residential sector, realizing demand savings of 1,958 MW. The public sector benefited substantially through this programme. IDM has a budget of R5,45 billion to achieve 1,074 MW savings over the period 2011 to 2013. This fund includes the Solar Water Heater rebate programme and other models relevant to different users and circumstances.

The National Climate Change Response Strategy (2011) identifies various near-term Priority Flagship Programmes, of which energy efficiency and energy demand management is one that has high potential for emission reductions. It further identified that government will lead by example through improving energy efficiency in public buildings.

Local governments such as the City of Cape Town and Ekurhuleni also allocate 'own' funding to energy efficiency retrofits, largely through budgetary allocations rather than 'ring-fenced savings from efficiency', as this can be difficult

in terms of the budgetary process and Municipal Finance Management Act. Funding of energy efficiency throughout government also takes place through ongoing Buildings Maintenance budgets.

12.6.2.2 New energy efficient building standards

South African buildings have traditionally been built with little regard for energy efficiency. In the historical context of cheap and abundant electricity, this was not seen to be a problem as a comfortable building climate could be created with heaters and air conditioning units. However, within the current context of constrained electricity supply and the drive to reduce greenhouse gas emissions, energy efficient building design is seen to be one of the key interventions in the move towards a more resource efficient future.

The industry standard describing performance standards for different building classes is the South African National Standard, SANS 204. This standard was effectively made mandatory in buildings when, in November 2011, the Department of Trade and Industry (DTI) promulgated Amendment XA to the South African National Building Regulations. This amendment requires that all new buildings or building alterations in South Africa meet minimum energy efficiency standards. These standards are quantified in the supporting technical document SANS 10400 XA. The DTI has embarked on a national training campaign for municipal plan approval departments and the construction industry.

Some of the key interventions in the regulations are:

- Minimum wall and roof insulation requirements;
- Maximum window size controls to minimize heat loss and gain;
- Orientation;
- Building shading; and,
- Efficient water heating (minimum 50 per cent of water heating energy to come from a sustainable source).

While the regulations do apply to all new buildings in South Africa, it is still being determined whether they will be enforced in low-cost housing, due to budgetary constraints.

12.6.2.3 Energy efficiency accord

In 2005, following the adoption of the Energy Efficiency Strategy, a number of South African companies signed a voluntary Energy Efficiency Accord with Government. The Accord was facilitated by the National Business Initiative and its main aim was to assist in the implementation of the strategy and contributing to the achievement of the announced energy efficiency targets. In terms of the National Energy Efficiency Strategy, the industry and mining target has remained at 15 per cent. To convene the business of the Accord and its link with government, an Energy Efficiency Technical Committee was formed with the National Business Initiative playing the management and secretariat roles.

In 2011, this Accord was re-launched as the 'Energy Efficiency Leadership Network' at the UNFCCC COP 17. Since then, it has provided the platform wherein the companies affiliated through Business Unity South Africa and the National Business Initiative interact with the Minister of Energy and the DoE on energy matters.

12.6.2.4 Ripple switches

Ripple control switches are typically installed in residential properties and are wired into the water heating circuit of the property. The switches can be activated from a central control point and cut electricity supply to the electric geyser. This technology has been used effectively by several cities in South Africa to reduce water heating at peak times, when the electricity system is under pressure. A pilot in Cape Town of three suburbs resulted in a peak reduction of 40 MW.

12.6.2.5 Solar water heaters/heat pumps

Solar water heaters (SWH) and heat pumps have the potential to reduce a typical mid to high income household's water heating bill by 60 per cent, equating to a typical reduced overall energy use of up to 25 per cent. Low-income households would also benefit from a low pressure SWH as they will reduce the need to boil kettles for hot water. Water heating with an electric geyser is the biggest consumer of electricity in a mid-high income household and water heating with a kettle forms a large proportion of a low-income household's energy costs. As this heating typically takes place at peak times, it has been recognized that the country would stand to benefit greatly from an efficient water heater programme.

In this regard, in 2009, the DoE set a national target of installing one million SWHs by 2015, and Eskom embarked on a national SWH rollout programme. The rollout was funded through the Eskom Demand Side Management Programme, which received its funding from a surcharge on the electricity tariff. Initially Eskom's focus was on subsidising systems for mid-high income households, but a free low-income rollout programme was introduced in 2010. The DoE also ran a pilot low-income rollout scheme. The solar water heaters on the Eskom and DoE programmes needed to meet SABS manufacturing standards, and had to be installed by an appropriately qualified plumber. SWHs which have an electrical backup are required to have a timer switch installed to ensure that it does not activate in peak electricity periods (7-9am and 6-7pm).

To date the mid-high income programme has rolled out 62,914 units, while the low-income programme has rolled out 242,709 (Eskom) and 30,768 units (DoE). Eskom has since also included a heat pump subsidy in its demand side management programme as an alternative to SWHs in the mid-high income market.

Eskom is moving away from playing a major role in SWH rollout, and the DoE has been tasked with running the programme into the future. R4.7 billion has been allocated through the fiscus for this purpose over the next three years.

12.6.3 Transport and especially public transport

12.6.3.1 Carbon tax

The research evidence is categorically clear that the most effective policy tool for reducing fuel use, and related emissions, from the transport sector is some form of price charges. The most justifiable of these in terms of reducing emissions is a carbon, or general fuel, tax. A general fuel tax has the benefit over other charges (for example route

tolls, congestion charges, parking charges, other taxes) of leaving much choice in the hands of the end-user for them to prioritise trip-making according to their own preferences. It is also relatively simple to implement (given that the existing structures are in place). Such a policy, however, requires strong complementary policy around the direction of new funds towards the transport sector generally, and alternative modes specifically, if they are to find political acceptability (National Treasury 2013).

Environmental taxes on the transport section are slowly being phased in, with an environmental levy imposed on new vehicle sales since September 2010. This levy is proportionate to the carbon intensity of the vehicle. A general carbon tax to be imposed from 2015 will further this disincentive for using unnecessarily large or fuel inefficient vehicles (National Treasury 2013).

In South Africa, and elsewhere, there have been arguments made that the road sector is already over-burdened, and that such an additional fee cannot be justified, but such studies frequently limit the definition of externalities included in their accounting and, as with all transport costing studies, suffer from measurement problems. Unfortunately then, the costing of transport becomes an ideological war of environment versus economics which is difficult to resolve. Empirically, though, it is clear from international fuel price comparisons that South African fuel is not excessively expensive (GIZ 2013), and that the international trend is towards increasing, rather than decreasing, fuel tax for transport.

Critics of fuel tax also point to likely negative impacts on economic growth but recent modelling of the South African economy suggests that *"...a carbon tax, coupled with various revenue recycling options, will have a limited negative impact on economic growth and will assist in nudging the economy onto a more sustainable and low-carbon growth path."* (National Treasury 2013).

12.6.3.2 Integrated city planning

The NDP makes clear and strong recommendations with regard to public transport, identifying it as an important capability of the poor (alongside education, health and social services), a measure of a 'decent standard of living', a means for broadening opportunities and access to services, and as a poverty-alleviation 'critical action' (NPC 2012).

Investment in public transport is also seen as a key means for generating employment opportunities in construction and operations and so, in future planning terms, public transport investment suggests a win-win for development. The environmental benefits of this investment, however, are less clear, and the NDP makes no recommendations for constraining private vehicle use which is also required in order to meet environmental goals. Public transport investment alone will simply not provide the necessary behaviour changes. The NDP does advocate for upgrading in fuel quality vehicle emission standards and a general commitment to carbon-pricing, but specific direction is not given.

While the policy direction identified within the NDP towards transport is generally supportive of reducing the impact of the

transport sector on the environment (and certainly focused on the many social benefits of public transport), it will not be sufficient, on its own, to lead to the changes necessary to reduce emissions from transport.

12.6.3.3 Gautrain and bus rapid transport systems

The most remarkable mindshift amongst transport engineers in the last decade in South Africa has been the widespread acceptance of the need for better transport systems. This has found expression in the major investments in BRT systems across the country (new BRT systems are operational in Cape Town and Johannesburg, under construction in Nelson Mandela Bay (Port Elizabeth), in advanced stages of design in Rustenburg and Tshwane, and are under serious conceptual review in eThekweni); and in the construction of the Gautrain. Although most of these systems are in their earliest stages of operation, indications are that despite their high profile, local popularity and enthusiastic reception by user groups, they have done very little to impact on carbon emissions.

It is clear, though, that such systems are necessary to stem the trend of the new middle classes towards car ownership and use, and to encourage retention of the middle classes on an improved quality public transport system. The possibilities, under existing pricing regimes, of tempting established car users out of their vehicles and into new public transport systems seems currently relatively limited.

The 80 km Gautrain system, operating with 24 train sets and 125 feeder buses, has been criticized for being elitist. It's expensive infrastructure caters for an estimated 120,000 passenger trips per day, in comparison to the existing underfunded rail network (serving mainly the poor) which moves an estimated 2.2 million trips per day. Similar criticisms have been aimed to some BRT lines. Modelling work suggests that the Gautrain is unlikely to account for more than one per cent of all passenger kilometres by 2030; and BRT systems between four to six per cent (Merven *et al.* 2012). From an environmental perspective, however, the key issue is to what degree these investments reduce overall energy use in the short, medium and long-term through their contribution in building momentum for the required large-scale modal shift. The degrees to which public transport investments can encourage modal shift on a corridor level is unclear, and this important monitoring and evaluation work has not been done in a way that can serve decision-makers.

Improved quality public transport aspirations in South Africa come at considerable cost, and it is clear that government will continue to face bills for operational subsidies on the new systems. Again, the exact extent of that forward cost burden is unclear.

12.6.3.4 Taxi recapitalization programme

The minibus taxi system operating in South Africa forms the majority commuter public transport mode overall, accounting for 65 per cent of all commuter trips in an estimated 120-175,000 vehicles (Walters 2013). From an environmental perspective, the taxi system offers a key complement to the IRT/BRT systems being rolled out across South Africa. The taxi system has several environmental benefits such as its operating model of waiting until full before travelling which ensures that, while the user experience may suffer, the

occupancies are routinely very high and so the carbon cost per user is low. This is in contrast to the BRT systems which, in promising a certain frequency of service, are forced to travel relatively empty in the off-peaks). It is also a completely unsubsidized system, in contrast with other modes.

From a user perspective, however, the taxi system has been criticized for its vehicle safety record, lack of safety at taxi ranks, and lack of vehicle roadworthiness (Walters 2013). From the government perspective, the taxi recapitalization process, initiated in 1999 and implemented in 2006 whereby taxi owners were given a lump sum to scrap their vehicle and retire, or as a down payment on a new vehicle, seemed a worthwhile process to upgrade the industry. Although over 42,000 vehicles have been scrapped under the scheme, and more than 83,000 taxi owners are now within the formal tax system, the take-up has been slower than anticipated.

Although the taxi recapitalization policy, appeared in principle to be a promising policy for both retaining the benefits of the taxi operating model while also improving the user experience and safety, continued skilled engagement with the taxi industry has been shown to be a necessary, and at times very difficult, pre-requisite (Van Schalkwyk 2011).

12.6.3.5 Climate change transport policy flagship

The measures advocated within the Transport Flagship programme of the NCCRWP are:

- An enhanced public transport programme;
- An efficient vehicles programme;
- Rail recapitalization programme; and,
- Government fleet vehicle efficiency programme.



While each of these are a welcome development from a social and/or environmental perspective, the impacts on greenhouse gases and energy use is likely to be small in the context of prevailing government investment constraints and increasing in car ownership and use.

Modelling of the carbon impacts of interventions in the transport sector is required in order to provide policy guidance to the DoT, and others. At present the likely impact of the interventions in South Africa are not well understood, and are not benchmarked against the requirements of climate change, and energy strategy. Some modelling of this nature is planned by a non-governmental project of WWF. Recent work by the Energy Research Centre at the University of Cape Town has quantified the energy needs for the transport sector at a national level, and provided some scenario forecasts, and provides a useful first step in this regard (Merven *et al.* 2012).

12.6.3.6 Electric vehicles

'Range anxiety', the cost of charging infrastructure and battery costs have hampered the take-up of electric and hybrid vehicles by consumers. Despite this, electric, and hybrid, vehicles are expected to be an important part of the worldwide vehicle fleet by 2050. It is deeply ironic, then, that while the National DoT Flagship project included in the National Climate Change Response includes the intent to develop an Efficient Vehicle programme; and the DEA have recently launched a Zero Emission Electric Vehicle Pilot Programme with a small fleet of Nissan Leaf vehicles, the home-grown electric vehicle programme, embedded for the most part in the vehicle developed by Optimal Energy has recently floundered.

In general, the electric and efficient vehicle policy in South Africa which has potential for cross-cutting job-creation, energy and emissions reduction potential, has suffered from challenges in co-ordination between government departments and other interested parties. The DTI, specifically, sees the value to be unlocked and has embarked on a process to develop and implement an Electric Vehicle Industry Road Map aimed at facilitating investment, job opportunities and human capacity building in the electric vehicle market.

12.6.3.7 Biofuel strategy

The Biofuels Industrial Strategy of 2007 provided the policy framework for voluntary inclusion of biofuels into the South African fuel sector, in a way which managed food security concerns and also provided for jobs, particularly in impoverished rural areas (DME 2007). It set a target of two per cent of fuel to be from varied sources by 2013, a target which was not achieved (Letete & Von Blottnitz 2012).

The potential for biofuel production in South Africa is argued to be significant. It is said that a combination of agricultural and forestry residues, invasive species, and high yielding energy crops such as sugarcane (on less than one per cent of land mass) could readily yield enough biofuels to cover South Africa's liquid fuel needs. Newer technologies will also progressively enable more efficient conversions, and so reduce the burden on the land (Van Zyl & Prior 2009).

Water security remains a concern though, as does biodiversity. There is also tension between major agricultural companies

which are managing to upscale production in neighbouring countries such as Mozambique, and the local strategy which, while socially progressive in terms of favouring small scale rural producers, has failed to deliver biofuel production targets. This failure is attributed to a mix of reasons including insufficient incentives for investors, poor training and incentives to the targeted rural farmers, and the absence of mandatory fuel blending.

The latest moves from the DoE have been towards a mandatory blending of biofuels (a minimum five per cent in diesel and two to ten per cent in petrol). These regulations were tabled during 2012 and will lower the risk to developers, investors and suppliers, and should increase the granting of new licenses to producers. They are expected by the DoE to yield increases in biofuel production and to exceed the two per cent target originally set.

12.6.4 Spatial form

The spatial form and structure of cities play a crucial role in the productivity of urban economies, the efficient use of resources in a city, particularly energy for mobility and distribution of services, as well as an impact on the environment.

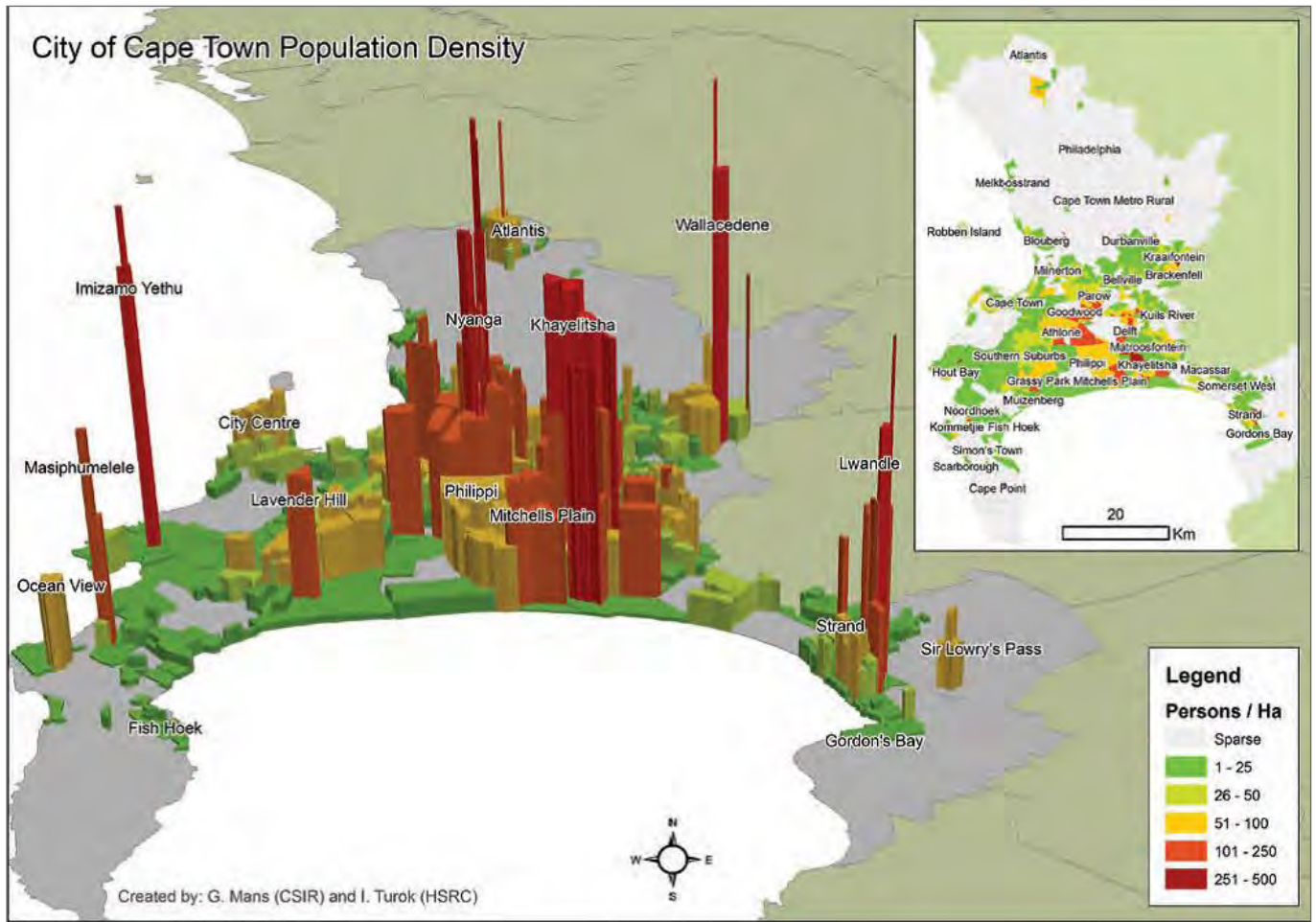
South African cities have historically developed along sprawling, low-density suburban lines. This was rooted in apartheid's inequitable and segregated spatial land distribution policies, but also a consequence of modernist planning, which emphasized suburban development, separation of urban activities of work and leisure as well as the prioritization of technical efficiency over social and environmental imperatives (Biermann & van Rhyneveld 2007; Ewing & Mammon 2010; FFC 2011; SACN 2011).

Our cities are consequently hugely resource inefficient in comparison to similar size international cities (FFC 2011). The average South African metro has a carbon footprint of 6.5 tonnes of carbon dioxide equivalents (Map 12.4).



Map 12. 4: Per capita carbon emissions for some global cities
Source: eThekweni (2007); Kennedy *et al.* (2009)

Since 1994, whilst government has built many houses for the poor, most have been built on the outskirts of our cities further perpetuating the apartheid spatial form. While marginal locations provide an important point of access (relatively cheap and easy) in gaining a foothold in the city, the 'locking' in of the poor into these locations, and continuing low-density suburban development of the rich, is socially, economically and environmentally unsustainable. By 2030 such persistent, unaddressed spatial polarization with regard to access to resources and employment opportunities, will present enormous and severe challenges in the political stability functioning and management of cities.



Map 12. 5: Population density of the City of Cape Town showing densities increasing with distance from the city centre
 Source: SACN (2011)

Marginal locations furthermore present service challenges to cities because they are often costly as service distribution infrastructure must run long distances, maintenance is more difficult due to distance and local needs for materials result in stripping of infrastructure. Such low-density and dispersed urban form makes for less efficient use of natural resources, with higher bulk infrastructure costs, and greater energy consumption and carbon emissions. This is illustrated in Map 12.5 which shows the spatial spread of the City of Cape Town. Cities will be hugely vulnerable to any carbon pricing arising out of international climate negotiations. They will also be vulnerable to disruptions to oil supplies, whether through political sanction/disruption or relating to peak oil.

Studies have indicated that mobility is a critical factor in developing a service economy (Altman 2009). If our cities fail to address spatial form such that it facilitates greater mobility, this will particularly increase the severity of poverty through increased transport costs eating into small household budgets, or inhibiting mobility altogether and with that blocking critical access to jobs, education and social amenities.

Addressing the effects of the apartheid spatial plan was of course a major concern of the post-apartheid government. Cities are also capacitated through planning tools such as the Spatial Development Framework, Integrated Zoning Schemes (which has an impact on land use and development for years in fact several decades to come), Densification Strategies, Urban Edge policies and Housing policies.

In line with this, city departments are looking to new approaches to urban development and now acknowledge that urban planning is a key driver in moving to a sustainable city and cognizant that this takes time to effect. The vision is one of cities developed along the line of mixed use urban forms, that utilize land efficiently and protect the natural environment, biodiversity and food producing areas and where public transport, walking and cycling become key elements of the city and large freeway and road infrastructure investments are de-emphasized (Kenworthy 2006). Densification policies are in place in some cities.

12.6.5 Climate change responses

The LTMS project conducted in 2007 (Scenario Building Team 2007) explored two opposing projections of an energy future for South Africa up to 2050. In the base case, existing energy usage trends and development plans at the time were used to determine what South Africa's carbon emissions profile would look like in 2050. The opposing scenario considered the interventions that would be required to bring the local emissions to within the bounds required by international agreements and climate change science. The main findings were that a business-as-usual emissions scenario is implausible, given trends in global oil pricing, carbon awareness and the consequences of climate change, and that a large part of an aggressive emissions reduction scenario will in fact be beneficial to the local economy.

The main concerns related to the economic development that follows a business-as-usual or 'Growth without Constraints'

trajectory include (Scenario Building Team 2007):

- Emissions will grow exponentially, quadrupling by 2050;
- Carbon intense development can only take place in a world without international agreement on climate change mitigation;
- Resource constraints, such as the need for water, are not factored in; and,
- Negative feedbacks from climate change impacts are not considered.

The alternative scenario, labelled 'Required by Science', incorporates the concerns to the fullest extent possible within a future that brings carbon emissions to within the scientifically recommended bounds. In order to achieve the necessary emissions reductions, four strategies need to be employed (Scenario Building Team 2007):

- Start Now – that kicks off cost effective (i.e. financially beneficial) emissions reduction actions early in order to maximize systematic long term reductions;
- Scale Up – which extends the Start Now interventions to actions that have limited overall nett costs;
- Use the Market – with taxes and incentives that encourage low-carbon economic development; and,
- Reach for the Goal – as actions based on future technologies and behavioural change.

Box 12.3: Policy for the promotion of energy efficiency in land use development, Johannesburg

The City of Johannesburg has taken the lead in the critical task of transforming building and development approval processes to ensure a resource-efficient and lower carbon end-result. They have developed a groundbreaking *Policy for the Promotion of Energy Efficiency in Land Use Development*, with an associated manual and criteria for developers. To establish the criteria as legally binding, they have included a clause in the Zoning Scheme requiring development applications to comply with the abovementioned policy. This is important as it would not have been mandatory without such a clause. The Policy has been officially approved by the city and forms part of their overall approach to the reduction of greenhouse gases. The next step will be to build and develop the capacity and commitment of officials to implement and manage the new approach. The core areas covered by the policy are energy efficiency in building construction and operation, more sustainable transport, waste recycling, and improved water management.



What the modelling results show, is that the first two strategies only achieve 64 per cent of the emissions reduction goals, and market-based incentives under the third adds approximately another ten per cent. To achieve the main goal of reducing carbon emissions below current levels before mid-century, even the fourth strategy needs implementation. The growing pressure on the South African Government to effect carbon emissions reductions imply that active pressure needs to be applied to the energy sector as the main contributor to our carbon footprint (Box 12.3).

Changes that will need to take place in the energy sector include (Scenario Building Team 2007):

- Large scale improvements in energy use efficiency;
- Nuclear and renewable energy generation must receive major stimulation;
- Transportation needs to achieve a modal shift for both passengers and freight, and move away from liquid fuels;
- Small interventions in a myriad of applications and forms must contribute to the overall mitigation effect; and,
- Research in future technologies and energy systems.

The UNFCCC's CoP15 talks in Copenhagen in December 2009 resulted in the Copenhagen Accord, which was formalized in Cancun in 2010. South Africa undertook to contribute to the global effort to reduce greenhouse gas emissions and set a target of cutting emissions by 34 per cent from business-as-usual by 2020 and by 42 per cent by 2025 which will allow emissions to grow, plateau and then decline as per the LTMS. These targets of a business-as-usual baseline represent a relative and not an absolute decline in emissions.

12.6.6 Provincial government responses

The institutional framework for government in South Africa was established in 1996 when the country adopted its first democratic constitution. National, provincial and local government were established as three spheres of government, each with expected distinctive functional responsibilities but operating as a single system of co-operative government.

Although provinces have no specific energy mandate, the fact that energy is a cross-cutting theme, and energy and climate change are high on government's agenda, provinces are increasingly taking energy issues on board. In addition, energy plays a role in many of the core provincial competencies, particularly the Departments of Environment, Air Pollution, Health, Education, Transport, Regional Planning and Development and Urban and Rural Development. Provincial government is often best placed to ensure that implementation at the local level is co-ordinated and thus more effective, via the provision of an overarching strategy. Provincial oversight can also compensate for capacity constraints at smaller local governments that prevent them from implementing sustainable energy strategies.

12.6.6.1 Western Cape

The Western Cape developed the first provincial level Sustainable Energy Strategy in South Africa. The primary aim was to institutionalize the sustainable energy objectives of the province by developing and implementing a Sustainable Energy Facilitation Act empowering the Member of the Executive Council for Environment to gazette subsequent

regulations. The regulations were to ensure sustainable energy implementation takes place. It would potentially focus on supporting local governments in the province to develop energy strategies and implementation plans. The Western Cape also developed a provincial Greenhouse Gas Emissions Inventory and has begun work to develop renewable energy initiatives through their Economic Development Department.

12.6.6.2 Gauteng

The Gauteng Provincial Government identified a need for the province to shift to a more sustainable energy profile and consequently developed the Gauteng Integrated Energy Strategy in response to the challenges associated with global climate change, the global economic meltdown and the electricity crisis in South Africa. The strategy aimed to improve Gauteng's environment, reduce its contribution to climate change and tackle energy poverty, whilst at the same time promoting economic development in the province. A detailed strategy and implementation plan was drawn up that advocated a drive for energy efficiency and support for an energy supply mix that included renewable energy technologies across the province. Within Gauteng, solar energy (solar water heaters) and energy from landfill gas were identified as the most obvious short-term renewable energy sources with the potential to buy renewable energy from wind and concentrated solar power from outside the provincial boundaries. An energy office was set up to implement the strategy.

12.6.6.3 Eastern Cape

The Eastern Cape Provincial Government held a provincial energy summit in 2008 as precursor to a provincial Sustainable Energy Strategy, and two Eastern Cape Energy Efficiency Conferences have also taken place. This is clear evidence that the province is eager to take advantage of the opportunities for renewable energy development that the region has to offer. A Climate Change Response Strategy was also released in 2011.

12.6.6.4 KwaZulu-Natal

Sustainability in the energy sector is being driven under the banner of the KwaZulu-Natal Sustainable Energy Forum (KZN Energy). Its focus is information dissemination and networking opportunities, with the primary purpose of facilitating

development and investment in a sustainable energy sector. Provincially, a number of feasibility studies have been carried out, focussing on solid biofuels, feasible alternative energy sources and the energy forum. This includes the Renewable Energy Resources, Best Applicable Technology and Policy Considerations for KwaZulu-Natal (2007).

12.6.7 Local government responses

The scale and pattern of the energy use in cities is increasingly recognized as having significant implications for global resource consumption, related issues of equity and poverty, and greenhouse gas emissions. Just a decade ago the energy picture at the level of local government in South Africa was not visible. For the majority of local government politicians and officials the standard response to the issue of strategic energy management was a blanket 'it's not our mandate'. Local government, pressed to meet service delivery backlogs, were very reluctant to go beyond the operational functions around electricity distribution.

Today we have a detailed picture of urban energy consumption within the national energy picture and of the drivers of energy consumption within cities. Nearly all metros and a few of the larger towns have energy and climate policies in place. Regulation and guidelines promoting efficient building and development is underway nationally and locally and in leading cities dedicated positions and structures (political and managerial) have been created, budgets allocated and energy and climate performance management indicators instituted, to drive sustainable energy implementation. Actual project implementation includes the full spectrum of efficiency projects (lighting, ceiling installations, behaviour campaigns, and efficient appliances), efficient/solar water heating, efficient housing delivery, waste to energy and other renewable energy developments, sustainable transport and urban planning initiatives. The rapid growth of a demand-driven, local energy management approach is illustrated in Table 12.7. This table marks, against a set of indicators, the uptake of energy management at the local level in South Africa between 2006 and 2011. Furthermore, Table 12.7 gives an indication of some of the progress made at the city level in terms of policy development, regulation and implementation (SEA 2011).



Table 12. 7: City level progress in terms of policy development, regulation and implementation

	Data and policy							Regulation		Institutional development				Implementation						
	Audit of municipal energy use	State of energy data report	Energy and Climate Change Strategy or policy	Energy and climate change visible in IDP	Routinely collected energy and climate related data	Planning framework speaks to energy efficiently issues, e.g. densification	Transport plan incorporates low carbon city goals	Green procurement: efficiency an aspect of fleet procurement	Regulation relating to sustainable energy development/emissions reduction	Energy efficient building codes or guidelines	Dedicated energy and climate change staff	Energy and climate change management structure	Budget allocated to energy and climate change management	Community - commerce, citizens, industry - energy or climate forum	Renewable energy generation in municipality or purchase	efficient water heating/SWH programme underway	Government housing delivery: efficiency, notably ceilings, included in TOR	Engaged in lighting (Street, traffic, building) efficiency retrofit	Community awareness program around efficiency or climate change	Smart meter roll out programme underway
Cape Town	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Ekurhuleni	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
eThekweni	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Joburg	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Tshwane	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
NMBMM	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Buffalo City	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Mangaung	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
SPM	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Polokwane	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Saldanha	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Sedibeng	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Tlokwe	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
Mombombela	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
King Sabata	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
uMhlatuzi	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006
uMsunduzi	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006	2006

2006 2011

It can be seen from Table 12.7 that the data collection (forming the picture) and policy development put in place in the early years of the last decade laid an important foundation for the substantial growth clearly visible across the spectrum of policy, regulation, institutional development and implementation. The table also shows how energy management has been mainstreamed into municipal management: in 2004 energy strategies were developed in a number of cities, but are not yet visible in the overarching, legally mandated, development plan of municipalities. By 2007/09, this area of work is included in a substantial number of the IDPs. The experience has shown that this is a critical step for these issues to find traction in cities, and Table 12.7 indicates the growth in

financial, human and institutional capacity flowing from this. Another area where integration is becoming visible is the presence of sustainable energy and climate change concerns within Transport and Planning frameworks (these documents must, legally, address the strategic concerns of the IDP) (Box 12.4 and 12.5).

Significant work and policy development has been taking place in South African municipalities and some provinces. Yet substantial transformation of the existing system remains a challenge. With cities being at the heart of implementing sustainable transport, changing urban form, energy efficiency and embedded small scale renewable energy, the necessary

capacity and institutional arrangements, as well as linkages with national government around policy and regulatory issues, are still not adequately developed in spite of the progress to date. These issues remain a critical focus for the country into the future.

Box 12. 4: Joe Slovo Sustainability Advisor - Implement sustainable interventions in low-income housing

The National Department of Human Settlements appointed a Sustainability Advisor company for the Joe Slovo low-income development (LOCATION), some 2,600 houses employing a high density design. This involved:

- A review of all sustainable interventions possible at Joe Slovo;
- Technical support for intervention implementation;
- Development and implementation of a monitoring and evaluation programme;
 - Qualitative – monitoring building thermal performance and hot water usage from SWHs in the Joe Slovo high density design and comparing those to a typical stand-alone low-income house. Computer model were verified against real building energy performance data to serve as a reference point for future policy development; and,
 - Quantitative – a door-to-door surveys to assess the impact of the interventions on the households;
- Setting up and ensuring the smooth running of a community sustainability awareness programme; and,
- Compiling a report which will feed back to the Department in terms of future policy development.



12.6.8 Private sector

Issues of energy sustainability are being taken seriously by private sector stakeholders. The South African Coal Road Map developed by relevant industry and other stakeholders looks at issues relating to coal production, regulation and cost. The Energy Intensive Users Group established in 1999 and made up of industries that collectively consume approximately 44 per cent of all the country’s electrical energy, are looking at a future South Africa that has a sustainable and affordable energy industry. There is also an Industry Task Team on Climate Change set up in 2010 by a group of concerned industry representatives to address issues related to the environment and climate change.

Box 12. 5: Cape Town Optimum Energy Future, 2011

National investigations into a low-carbon energy future were matched by the City of Cape Town in the ‘State of Energy and Energy Futures Report’ in 2011 (CoCT 2011). This study aimed to determine which strategies and interventions will be required to ensure that anticipated future city growth is achieved while simultaneously reducing its global warming emissions profile in line with national commitments.

The study shows that a business-as-usual scenario, with an associated high carbon future, results in an economically and socially vulnerable trajectory for the city, whereas a more responsible, lower carbon strategy will result in greater financial and social benefits as well as economic robustness and efficiency.

A low-carbon future economy would require that the following changes be effected to the way in which the City operates (and, in turn, the energy sector) including the following:

- Costly investment in carbon efficient infrastructure, especially public transport, will be required but can be offset against the efficiency gains and economic benefits over time;
- Expansion of the nuclear power station complement is likely, but must take place with appropriate sensitivity towards lead times, costs and comparative benefits;
- All sectors can and must become significantly more energy efficient. This results in significant short- and medium-term financial returns, and improved economic competitiveness; and,
- A major shift towards renewable energy supply is required, and this needs proactive development of a renewable energy industry to maximize local content and job creation.

An important finding is that total costs of implementing the more optimum energy path will be roughly the same as the cost of maintaining the current development path. Since much of the costs of transforming the transportation sector would accrue at national level, the costs at local authority level will be less than the business-as-usual reference case (City of Cape Town 2011).

12.6.9 Facilitation of renewable power generation

South Africa has huge renewable energy potential, particularly regarding solar and wind power. However, power from these sources is considered variable, and thus national energy planning needs to factor in adequate base load supply while actively pursuing mass renewable energy rollout. Natural gas, which is a lower carbon fuel than coal, and which may be available in the country in significant quantities in future through onshore shale gas or offshore gas fields, can help maximize the use of variable renewable energy sources. This is due to natural gas generation being able to respond relatively quickly to changes in the national electricity supply situation, making it ideal to use in combination with more variable sources.

South Africa has in place a target of 10,000 GWh of Renewable Energy by 2013. This is based on the White Paper on Renewable Energy Policy (2003) which calls for government to establish a renewable industry through a phased and flexible strategy which builds on partnerships. The White Paper states that South Africa has abundant renewable energy resources and to enable the take up of these resources government must introduce fiscal and financial support mechanisms. The Minister of Energy has determined that 3,725 MW is required to be generated from Renewable Energy sources to ensure the continued uninterrupted supply of electricity. This 3,725 MW is broadly in accordance with the capacity allocated to Renewable Energy generation in the IRP for electricity. Eskom is also to continue with its exploration of new hydroelectric and pumped storage schemes, seeing that electricity demand continues to grow (StatsSA 2012a).

12.6.9.1 Integrated Electricity Resource Plan for South Africa 2010-2030

The IRP (DoE 2010a), which was finalized in early 2010, specifies the national electricity generation plan for the country and associated investment needs. The 20-year plan was developed by the DoE ahead of the overarching National Integrated Energy Plan (IEP) which is being developed in 2013, because the electricity crisis faced by the country at the time urgently required new generation investment decisions to be made. The IRP is intended to be a living plan which would be revised and updated every two years. It was due for revision in 2012 but will only be revised in 2014 after the IEP is complete. The final scenario adopted by the IRP (called the 'policy adjusted' scenario) included a more significant component of renewable energy in the mix because of increasing competitiveness of these options in the market. Under the IRP the DoE is to source 8,400 MW from photovoltaic, 8,400 MW from wind and 1,000 MW from CSP through the Renewable Energy Independent Power Producer Programme (REIPPPP) by 2030. By 2030 the renewables share of all generation capacity will be 21 per cent excluding hydro, which will represent nine per cent of all electricity generation capacity compared to 65 per cent of fossil fuels. The IRP is considered progressive compared with previous electricity plans in terms of the introduction of renewable energy generation, although the generation mix still falls short of the carbon reduction profile specified in the NCCRWP. There is thus a contradiction in stated national intentions. It is also widely held that the IRP has not factored in demand-side interventions with adequate thoroughness.

A recent study undertaken by the Energy Research Centre (ERC 2013) shows that many of the projections in the 2010 IRP can already be improved and refined, in particular, the electricity demand growth projections appear to be lower than expected which will have an impact on the need for new build and the emissions profile coming from the energy sector. Modelling also shows that the cost of renewable energy technologies is now lower than shown in the IRP whilst the costs of nuclear are considerably higher. The updated projections suggest that a future energy mix could be possible without additional nuclear capacity and less investment in fossil fuel technologies.

12.6.9.2 Renewable Energy Independent Power Producer Procurement Programme

Government's intention in developing the REIPPPP was to facilitate independent power producers to generate a total of 3,725 MW of renewable energy for the period from 2010 to 2016 as set out in the IRP 2010-2030. In December 2011, it announced the selection of 28 preferred bidders to generate 1,415 MW from a first round of submissions. These bidders are required to finalize their funding and contractual agreements by June 2013. This entails each bidder signing an implementation agreement with the DoE, a power purchase agreement and connection agreement with Eskom and achieving financial close. The bidding for the second round of the REIPPPP closed on 5 March 2012 with a total of 79 bids received. The total capacity of bids amounted to 3,255 MW, far exceeding the cap that was set at 1,275 MW across all technologies. As with the first round, wind and solar photovoltaic dominated with nine projects totalling 417.1 MW for solar photovoltaic and seven projects totalling 562.5 MW for wind. In addition, two small hydro projects totalling 14.3v MW and one CSP project were given the nod. A further 3,200 MW of renewable capacity is to be added between 2017 and 2020 from a mix that includes concentrated solar power, solar photovoltaic, biomass, biogas, landfill gas, and hydro.

The REIPPPP programme has been designed not only to contribute towards the target of 3,725 MW, but towards socio-economic and environmentally sustainable growth, and to start and stimulate the renewable industry in South Africa. Bidders are evaluated according to their proposed tariffs as well as the identified socio-economic development objectives set by the Department.



12.6.9.3 Green Economy Accord

The Green Economy Accord was signed in 2011. Minister Patel stated that it "launches a green partnership to create large numbers of jobs, provide a spur for industrialization and help create a sustainable future". It provides a detailed list of low carbon policy measures and targets, and was signed by a partnership including government, business, organized labour and civil society. It advocates an increased use of renewable energy, mass installation of solar water heaters, energy efficiency, clean coal, retrofitting, expanded production of clean stoves, support for biofuels, and the establishment of finance facilities for green projects.

12.6.9.4 National Development Plan

The country's NDP was adopted by government in 2012. In the State of the Nation address for 2013, President Zuma stated that the NDP must underpin all government policies and be a guiding document for the country. The 2013 National Treasury Budget also makes mention of the Plan. It provides an overarching plan for the country going forward. It advocates achieving the 'peak, plateau and decline trajectory' of greenhouse gas emissions for the country, and the concurrent need for a move to a less carbon intensive electricity sector through procuring 20,000 MW renewable electricity, as well as the need for demand-side measures and 90 per cent access to electricity by 2030. It advocates a greater share of natural gas in the energy mix, the need to revise the national electricity plan, and the ring-fencing of the electricity distribution businesses of the 12 largest municipalities.

12.6.9.5 New Growth Plan

The New Growth Path developed by the Department of Economic Affairs focuses strongly on developing a green economy. It has employment creation as a founding motivation – setting a target of 300,000 'green economy' jobs by 2020. Underpinning the New Growth Path is promoting economic growth and competitiveness.

12.6.9.6 Industrial Policy Action Plan 2

The Industrial Policy Action Plan is the DTI's industrial policy and plan for the country, and includes a focus on growth, industrial development, employment creation, development of innovation and technology and the promotion of green industries. Some of the low carbon endeavours include the revision of building standards, which will require higher levels of energy efficiency and mandatory installation of solar water heaters in new buildings, support of a renewable energy and green industry through the South African Renewables Initiative which will leverage international climate finance, to supplement domestic funding sources, for renewable energy production linked to domestic manufacturing.

12.7 CONCLUSION

It is an enormous challenge to achieve energy security in a developing country that has varying and different interests and demands on energy supply, on poverty alleviation, on environmental concerns, and ensuring an appropriate societal response is therefore critical. Our energy legacy suggests that the entrenched supply side systems and links between mining, energy and industry might need to be reviewed and adjusted in order to bring concerns about environmental and social externalities into consideration. When accounting for all externalities such as air pollution, health impacts, impacts on water quantity and quality, soils and land productivity, and most of all, climate change, it becomes clear that the heavy reliance on coal and liquid fuels for our bulk energy needs is not sustainable.

Changes are being made though, both on governmental and civil society level. An important shift in administrative approach has been the separation of the Energy and Minerals portfolios. Government has also instituted numerous programmes to address energy poverty, a high national energy intensity

and problems with access to energy. Vast improvements in household access to electricity and facilitation of independent renewable energy production are two of the most notable achievements. Regulated building standards are also being rolled out, leading to improvements in the energy efficiency of the built environment.

Further work is required though, specifically in terms of integrated planning of transportation, spatial form of human settlements and water resources.

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12.9 ANNEXURE A: Policy programmes relevant to the energy sector

Existing legislation
Nuclear Energy Act (No 46 of 1999)
National Nuclear Regulator Act (No 47 of 1999)
National Energy Regulator Act (No 40 of 2004)
Central Energy Fund Amendment Act (No 48 of 1994)
Petroleum Products Amendment Act (No 58 of 2003)
Electricity Act (No 41 of 1987)
National Energy Act (No 34 of 2008)
National Environmental Management Act (No 107 of 2008)
The National Environmental Management: Air Quality Act (No 39 of 2004)
Existing policies
White Paper on Energy Policy of the Republic of South Africa, 1998
White Paper on Renewable Energy Policy for South Africa, 2003
Radioactive Waste Policy and Strategy, 2005
Nuclear Energy Policy, 2006
Draft Revised White Paper on Renewable Energy, 2010
Free Basic Alternative Energy Policy (Households Energy Support Programme), 2007
Draft Beneficiation Strategy, 2009
Existing international commitments
Convention on Nuclear Safety, 1994
SADC Protocol of Energy, 1996
United Nations Framework Convention on Climate Change, 1997
Kyoto Protocol, 2002
SAPP agreements
Programmes and strategies
Draft Renewable Energy Strategy
National Energy Efficiency Strategy (reviewed, 2012)
Solar Water Heating Programme
SA Wind Energy Programme
Bio-fuels Strategy
UNCSO report on Energy
Energy and Climate Change Strategy
Integrated Energy Plan
Free Basic Electricity
RE Independent Power Producer Programme
Integrated Demand Management Programme
Standard Offer Programme
National Climate Change Response Strategy for South Africa 2004
Fuelwood Strategy
Nuclear Disaster Management
Development Bank of South Africa Renewable Energy Market Transformation Project
South African Renewables Initiative