Cape Town energy futures: Policies and scenarios for sustainable city energy development

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EXECUTIVE SUMMARY

The purpose of this report is to develop some scenarios for Cape Town's energy future. The simulation model, the Long-Range Energy Alternatives Planning (LEAP) system, has been used to simulate how energy might develop in Cape Town over the twenty years from 2000 to 2020. These developments are driven not only by the nature of the energy sector itself, but also by broader factors, notably population, household size, economic growth (which may vary by sector) and other factors.

The report builds on previous work done on the 'state of energy' for Cape Town (CCT & SEA 2003). That report was useful in capturing the current status of energy in the city, informed the City Energy Strategy conference and Cape Town's own strategy (SEA, CCT & ICLEI 2003) and provided the starting data for this study. This report takes the work further in developing a tool that simulates what might happen to energy *in the future*, in a business-as-usual case and with policy interventions.

A range of policy interventions are selected, and how these would change energy development in the city is examined, compared to a reference case. Interventions were selected based on various criteria, including implementation cost and technical feasibility, environmental priority, and political will. Different policies can be grouped for their sectors – industry, residential, commercial, government and transport – and also combined to form multiple-policy scenarios. These scenarios should be understood as a series of 'what if' questions, e.g. what if the City of Cape Town increased efficiency in its own buildings. The scenarios are *not* any prediction of the future, nor are any of these scenarios considered more likely than others.

Instead, we report the implications of different policies and scenarios. The implications for energy, environment (both local pollutants and global greenhouse gases) and development are of particular interest. This study reports the cost implications of different scenarios only to a limited extent, as to do this adequately for many of the scenarios is beyond the scope of the project. Areas where further work is required, including around costing, are also identified.

The following are the main conclusions of the work:

- **Policies can make a difference to energy consumption in Cape Town.**

The energy scenarios examined in this study generally show energy consumption rising as economic activity (GGP) and population increase. However, significant energy savings are possible *relative to business-as-usual*. Unsurprisingly, since transport currently accounts for 54% of energy consumption, the biggest energy savings potential lies in this sector.

- **Major energy savings can be made from modal shifts in the transport sector and with efficient lighting.**

Amongst all interventions considered, by far the largest savings can be gained by a shift from private to public transport modes. Savings of 1200 TJ / year, equivalent to 36 million litres of petrol and diesel in the first year.[1] Switching to more efficient lighting can result in substantial savings in several sectors (see Table 26), amounting to 38 million kWh in 2001. Energy savings are important to the City, since it depends on imports of both electricity and liquid fuels.

- **Energy efficiency saves money over the life of the intervention.**

Efficient lighting in the commercial sector can save R144 million over the projection period. More efficient heating and air conditioning could save R 32 million in the commercial sector, and R1.3 million in government buildings over the projection period.

- **Energy saving in poor households can reduce their energy bills substantially.**

The significance of savings in the residential sector is that is low-income households can save on their energy bills. Each household could save R75 per year just by installing two CFLs (at capital cost of about R30). The payback periods for ceilings and solar water heaters (SWHs) is expected to be longer. Local government should consider subsidising the capital costs of these interventions for

[1] However, electricity use increases 50 TJ with the modal shift due to increased use of electric trains.

poor households. The potential for SWHs is largest in medium- to high-income households, where electric geysers constitute the largest single use of electricity. These households should be able to afford the upfront costs of SWHs.

- **Implementing the city's renewable energy target will have significant costs, which can be partly off-set by selling carbon credits**

The estimated *total* capital costs of implementing the renewable energy target is R4 370 million. These are total costs, and should in future be compared to the costs of the alternative, e.g. building a coal-fired power station. The reduction of GHG emissions could earn the city revenues of R700 million over 20 years – about 17% of the total capital costs.

- **Targeted interventions can reduce local air pollution.**

Cape Town has long suffered from the problem of 'brown haze'. Policy interventions can address this problem of local air pollution, which is largely vehicle-generated. Improved public transport infrastructure will be key in reducing transport energy and emissions by making a modal shift possible. In 2020, a shift to public transport can save 1021 tons of particulates. Total reductions of SO_2 are 1400 tSO2 by 2020, most of which comes from industry (see Table 28).

- **Cape Town can become a leader in addressing greenhouse gas emissions.**

Cape Town has already set a forward-looking target for renewable energy. The scenario modeling shows that this policy could save 49 ktCO_2-equivalent in 2001 already. A surprising result is that transport policy can result in even larger savings in the same year, of 72 ktCO_2-eq. While these interventions require substantial investment in energy and transport infrastructure, they would enable Cape Town to become leader in addressing a critical global environmental problem – in line with its goals as a member of the Solar City initiative (see Appendix B).

- **Some policies are viable in terms of costs, social benefits and the environment.**

CFLs in residential, commercial and government sectors and HVAC in commerce and government sectors stand out as policies that have benefits from every angle, and should be implemented at scale immediately.

The LEAP dataset described in this report is downloadable from the COMMEND and ERC web-sites

http://forums.seib.org/leap/default.asp?action=60 and
http://www.erc.uct.ac.za/Projects/COMMEND.htm

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1. Introduction

The purpose of this report is to develop some scenarios for Cape Town's energy future. The simulation model, the Long-Range Energy Alternatives Planning (LEAP) system, has been used to simulate how energy might develop in Cape Town over the twenty years from 2000 to 2020. These developments are driven not only by the nature of the energy sector itself, but also by broader factors, notably population, household size, economic growth (which may vary by sector) and other factors.

We select a range of policy interventions and examine how these would change energy development in the city, compared to a reference case. Different policies can be grouped for their sectors – industry, residential, commercial, government and transport – and also combined to form multiple-policy scenarios. These scenarios should be understood as a series of 'what if' questions, e.g. what if the City of Cape Town increased efficiency in its own buildings? The scenarios are *not* any prediction of the future, nor is any of these scenarios considered more likely than others.

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The report builds on previous work done on the 'State of energy' for Cape Town (CCT & SEA 2003). That report was useful in capturing the current status of energy in the city, informed the City Energy Strategy conference and Cape Town's own strategy (SEA et al. 2003) and provided the starting data for this study. This report goes further in developing a tool that simulates what might happen to energy *in the future*, in a business-as-usual case and with policy interventions.

2. Demand for energy services

The first step in developing energy scenarios was to create 'current accounts' – the best estimate of the energy situation in Cape Town in our base year, 2000. The analysis focused mostly on demand sectors, namely residential, industry, commercial buildings, government buildings, and transport. As was already clear from the 'State of energy' report, *transport alone constitutes more than half of energy consumption in Cape Town*, Figure 1 shows the shares of demand for all energy services in Cape Town in the base year for this study, 2000.

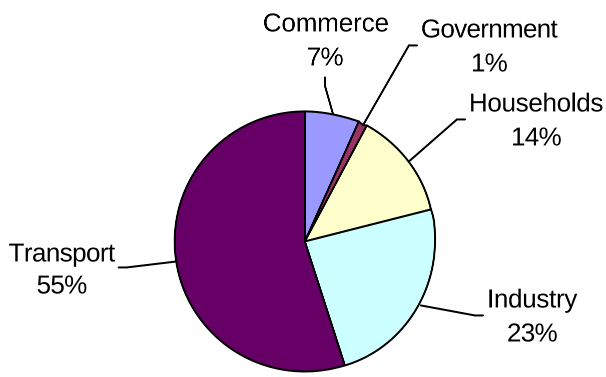


Figure 1: Demand for energy by sector, shares in 2000

2.1 Residential

The City of Cape Town has a population of three million people and approximately 800 000 households with 40% medium-to-high-income and 60% low-income (CCT 2001b). For the purpose of our analysis, the residential sector was divided into two main categories: medium-to-high-income households and low-income households, with the latter being divided into electrified and non-electrified households.

Households consume approximately 14% of the city's total energy (CCT & SEA 2003), which is equally shared between low and medium to high-income households. Approximately 2% of the city's houses are currently unelectrified – these being mostly informal dwellings and backyard shacks. (Ross 2004). Low-income households are characterised by the use of multiple fuel sources (paraffin, candles, electricity etc) (Mehlwana & Qase 1999), whilst medium-to-high-income households use electricity almost exclusively.

2.1.1 Medium-to-high-income households

Medium to high-income households use electricity for all energy services. Households in this category are high consumers of electricity (774 kWh/month) with large carbon footprints. They emit approximately 750kg of carbon dioxide per household per month (Cape Town Energy Strategy, 2003). These households spend 3-5% of their income on energy.

Table 1: Electricity consumption for med- to high-income households by end use

Source: Cape Town Energy Strategy, (SEA et al. 2003)

End use	*Electricity consumption per end use*
Lighting	108.3 kWh / month
Cooking	148.2 kWh/ month
Space heating	80.9 kWh/ month
Water heating	380.8 kWh/ month
Refrigeration	55.9 kWh/ month
Total	774.1 kWh/ month

Table 1 shows that water heating comprises the largest share of electricity consumption for these households. Electricity for cooking divides up into 94.9 kWh for conventional stoves, and 53.3 kWh for microwave ovens. Space heating is only for the three winter months of the year, so that the annual figure would be lower than for the other end uses (multiplied by 12). It is assumed that medium to high-income households use approximately 1 kg of LPG (mostly for cooking) per month though there is little empirical study to support this assumption.[2]

2.1.2 Low-income households: electrified

Low-income households spend 10-20% of their income on energy (Cape Town Energy Strategy, 2003). Although electrified, many households use paraffin for cooking, water heating and space heating. Low-income electrified households were divided into two categories: the lowest of these, assuming 300 000 households, use an average of 195 kWh of electricity per month (Cowan & Mohlakoana 2004) and 200 000 households using an average of 369 kWh of electricity per month. The average electricity usage for low-income households is 274 kWh per month, thus emitting 1.3 million tons carbon dioxide per month (SEA et al. 2003). Low-income households use an average of 0.6 kg of LPG per month, mostly for cooking. Table 2 gives the percentage breakdown of energy consumption by end-use for low-income households.

Table 2: Percentage breakdown of energy consumption in low-income electrified and unelectrified households

Source: Simmonds & Mammon (1996)

End-use	*% electricity consumption*	*% paraffin consumption*	*% gas consumption*
Lighting	12	15	
Cooking	41	45	80
Space heating		35	
Water heating	9	20	20
Refrigeration	26		

[2] Future work might want to add consumption of firewood / charcoal for space heating and braais.

.

Table 3: Energy used by electrified low-income households by end use

Source: Cowan & Mohlakoana (2004); Simmonds & Mammon (1996: 75)

End use	*Electricity consumption per end use*	*Other energy consumption (units / month)*
Lighting	32.3 kWh / month	
Cooking	112.4 kWh/ month	3.3 litres paraffin /month 0.119 GJ 0.6kg LPG/month
Space heating	63.2 kWh/ month (3 months)	2.5 litres paraffin /month (3 months) 0.09 GJ
Water heating	20.3 kWh/ month	1.7 litre paraffin /month 0.06 GJ
Refrigeration	71.7 kWh/ month	

All households use electricity for lighting and refrigeration. Table 7 shows that cooking is the largest contributor to household energy consumption. Approximately 27% ofelectrified households in Khayelitsha use paraffin for cooking and 51% use paraffin for space heating (Cowan & Mohlakoana 2004).

2.1.3 Low-Income households: non-electrified

A very small percentage of households are unelectrified. These comprise mostly unserviced shacks and backyard dwellers. Paraffin is the principal fuel used for all energy services with cooking found to be the biggest contributor to household energy consumption.

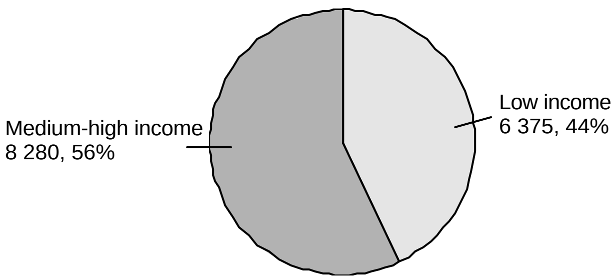
Table 4: Energy used by unelectrified low-income households by end use

Sources: Cowan & Mohlakoana (2004); (Simmonds & Mammon (1996: 75)

End use	*Paraffin (litres)/ month*	*Number of Candles/month*
Lighting	3	6
Cooking	9	
Space heating	7 (3 months)	
Water heating	4	

2.1.4 Summary for residential

The following figures summarise the status of Cape Town's residential sector in 2000, based on the data described in the text.



Note: first figure represent PJ / year, and the second represents the share of total consumption

Figure 2: Total residential energy use by household type, 2000

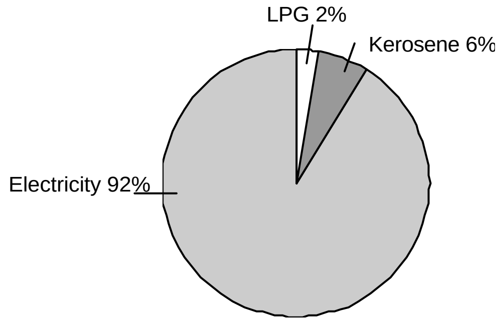


Figure 3: Energy consumption for all households by fuel type, PJ in 2000

Energy consumption is dominated by electricity, with paraffin (kerosene) being the next largest contributor to energy.

Table 5: Residential electricity consumption by end use (PJ), 2000

	Low-income electrified households	*Low-income non-electrified households*	*Med-to-high-income households*
Lighting	436	13.5	1088.6
Cooking	6817.2	33.4	1490.4
Space heating	0	0	183.5
Water heating	342.1	15.5	3836.2
Refrigeration	971.6	n/a	557.3
Total	8566.9	62.4	7156

2.2 Industry

The industrial sector was responsible for 23% of the city's energy demand in the base year. Within the model the industrial sector is divided into four main sub-sectors: pulp and paper, food and beverages, textiles, and a final sub-sector containing all other industry. The base year industrial energy demand was 25.35PJ. The percentage of this used by each sub-sector can be seen in Figure 4 below. Industrial energy consumption and fuel use is not well monitored and several assumptions are used to arrive at the figures entered into the model.

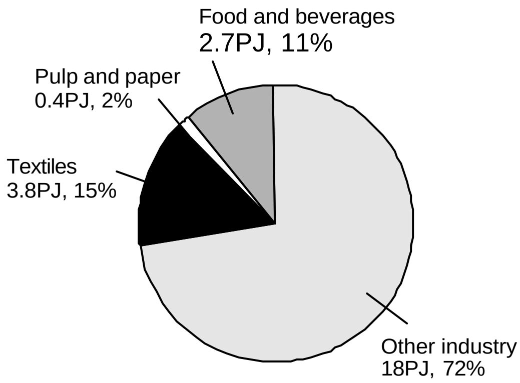


Figure 4: Energy consumption of industrial sub-sectors

2.2.1 Energy use by sub-sector

In each sub-sector, energy consumption data of different fuels is included in the model. Fuel consumption data, for fuels other than electricity, comes from the City of Cape Town air pollution database. The air pollution database gives fuel use by sub-sector (CCT 2003a) and contains fuel consumption data for coal, anthracite, fuel oil, diesel, paraffin, wood, gas and waste. Total industrial consumption of electricity is taken from the *State of energy* report (SEA et al. 2003). Consumption of electricity by the sub-sectors is calculated.

Pulp and paper

Pulp and paper figures for paper production and fuel use are those of the Sappi Cape Kraft plant. This plant makes kraft paper entirely from recycled paper. Electricity and coal consumption figures were supplied by Sappi Cape Kraft for 2001. 2000 coal consumption figures for the plant are taken from the CCT Air pollution database. The ratio of coal to electricity use is fairly consistent and was used to calculate an approximate electricity use by the plant for 2000. Approximate electricity consumption in 2000 was 16.86 GWh, coal consumption was 372MJ or 31MJ/month.

Textiles

Textile energy consumption figures for the Western Cape are given in the *Market survey of the textile industry (Voest 1997)* These are shown below in GJ/month:

Table 6: Textile energy demand by fuel (GJ/month) in the Western Cape (pre 1997)

Source: Voest (1997)

Electricity	*Coal*	*HFO*	*LPG*	*Diesel*	*Paraffin*
139 925.25	120 196.88	98 276.48	3288.06	1096.02	2557.38

These figures were used to establish a relationship between other fuel use and electricity and Paraffin use. Table 7 shows the approximate base year fuel consumption for the textile industry in Cape Town in 2000. Consumption of coal, fuel oil, LPG and diesel is taken from the CCT air pollution database The ratio of other fuel use to that of electricity and paraffin is assumed to be consistent with that of the Western Cape.

Table 7: Textile energy demand by fuel (MJ/month) in Cape Town (2000)

Electricity	*Coal*	*HFO*	*LPG*	*Diesel*	*Kerosene*
123.32	88.21	103.36	2.40	0.37	1.09

Food and beverages

Western Cape coal and electricity use in the food and beverage sub-sector for 2000 are taken from the Western Cape energy balance in the *Baseline report* (Hughes, Howells & Kenny 2002). These energy balances appear more complete than the Western Cape energy balance of the DME for 2000 (DME 2002), which does not include any coal use by the food and beverages industry in the Western Cape. The ratio between coal and electricity use given in the Western Cape energy balance was used to calculate an approximate electricity use for Cape Town. In the Western Cape energy balance the ratio of coal to electricity use in the food and beverages sub-sector is 1:0.97. The coal and other fuel use figures in the LEAP model are taken from the CCT air pollution database, with electricity added according to the Western Cape ratio. The base year fuel use in the food and beverages sub-sector is given below in Table 8.

Table 8: Food and beverage energy demand by fuel (MJ/month) in Cape Town (2000)

Electricity	*Coal*	*LPG*	*Kerosene*	*HFO*	*Diesel*	*Biomass unspecified*
65.29	63.37	2.38	26.25	65.26	5.00	0.03

Other

The remainder of fuel use reported in the *State of energy* report is included under the branch ‘other’. The fuel use of this sub-sector is as shown in Table 9.

Table 9: Other energy demand by fuel (MJ/month) in 2000

Electricity	*Wood*	*Kerosene*	*Fuel oil*	*Diesel*	*Coal*	*Anthracite*
1344.075	41.6	28.6	204.6	6.8	92.7	0.042

2.2.2 Growth rates

Growth rates differ for each industrial sub-sector. Future growth rates for Food and Beverages and Textiles are taken from the *Background report: City of Cape Town: Economic trends and analysis: 1980-2000* report (CCT 2001a). Growth in the pulp and paper sector is assumed to remain constant after 2002, this growth does not include growth in printing and publishing which is included in the commercial sector. All other industrial growth is assumed to keep up with growth in GGP. Growth rates remain constant over the modelling period.

Table 10: Growth rates in the industrial sub-sectors

	Growth rate
Pulp and paper	0%
Food and beverages	2.6%
Textiles	2.1%
Other	2.5%

2.3 Commercial

The commercial sector in Cape Town includes office buildings, financial institutions, educational facilities, hospitals, hotels, shopping malls, places of entertainment, and retailers. Clearly, the energy use characteristics of these facilities will vary widely. In aggregate, the commercial sector accounts for 7% of final energy demand. The sector uses electricity mainly, although small amounts of other fuels are used (paraffin, LPG, coal, fuel oil etc), presumably mainly for heating and cooking purposes.

The two main sources of commercial energy consumption data were the *State of energy* report (CCT & SEA 2003), and the CCT Air Pollution Department database (2003a) of point source pollutants. However the latter excludes LPG figures, which were sourced by other means explained below. The total number of commercial 'customers' in CCT is taken as 34 337. This is derived from the electricity records in the *State of energy* report, and thus assumes that all commercial facilities are electricity customers. Because commercial facilities vary substantially in their energy use characteristics (e.g. from small retailers to huge office blocks), and because neither the energy use characteristics nor the numbers of different types of commercial operations are known with any certainty, energy use characteristics have been 'averaged' across all facilities – for example, the total estimated lighting demand has been divided by the total number of customers (i.e. 34 337) to get an average lighting profile per customer, and the data entered into LEAP in this way.

General assumptions used:

? Buildings use energy 8 hours per working day.

? 220 working days per year.

? Numbers of electrical appliances per building are derived by (details are in Appendix A):

  ? assuming a typical electricity profile in terms of proportional consumption for different categories of appliances – based on office blocks – the largest electricity user in the sector – approximately 60% of total (CCT & SEA 2003);

  ? determining a typical average electricity consumption for different types of appliances

  ? dividing the total consumption for an appliance category with the typical average consumption per appliance, to give an estimated number of appliances.

? Average cost of electricity: 35c/kWh.

2.3.1 Energy characteristics

2.3.1.1 Lighting

Average lighting profile used for a commercial user is as follows:

? Incandescent lights: 100 watts × 8 hrs × 220 days/yr (working days of the year) × 35.3 bulbs per building.

? CFLs: 20 watts × 8 hrs × 220 days/yr × 35.3 bulbs per building.

? Existing fluorescents: 40 watts × 8 hrs × 220 days/yr × 179 tubes per building.

? Efficient fluorescents: 32 watts (35 watt tube + electronic ballast ~32 watts effectively) × 8 hrs × 220 days/yr × 179 tubes per building.

Details of the above profile calculations (showing how electrical appliance numbers per building, etc were calculated) can be found in Appendix A.

Demand costs used are as follows:

? Capital cost:

  ? Incandescent lights: R3 per bulb.

  ? CFLs: R15 each.

  ? Existing fluorescent fittings: R10 each.

  ? Efficient fluorescent fittings: R10 each.

2.3.1.2 HVAC

? HVAC – the use of typical airconditioning office 'units' is assumed: 1kW × 8hrs × 220 days/yr × 10.7 appliances per building (more details are given in Appendix A).

Demand costs used are as follows:

? Capital cost – per HVAC appliance (airconditioning unit): R2000.

2.3.1.3 Other electrical appliances

? Other electrical appliances (often computers, copiers, heaters, urns etc) – assumed to total an average demand of 1kW × 8hrs/d × 220 days/yr × 5.3 appliances per building (see Appendix A for more details on how appliance numbers were determined). Note that the average demand of 1kW is a figure chosen for convenience rather than representing actual use of particular appliance set. The important cross-check here was that the demand over a year added up to the total consumption figure. (See Appendix A for more details).

2.3.1.4 Non-electrical energy use

The source of this data was the Air pollution database (CCT 2003a), except for the LPG data, which is not included in the database. The consumption figures are not 'real' – they take total fuel consumption and divide them by the number of commercial users. This does not consider the substantial variation in actual fuel consumption between different types of users.

? **LPG**: Reliable data on sectoral LPG use for CCT was hard to find. The only data available was a total 'commercial' figure from Lloyd (2003) for the Western Cape province. This was proportioned according to population to obtain a total figure for the CCT area (which has 70% of the population of the Western Cape). The figure used per commercial facility was worked out as follows: total figure calculated for entire commercial sector (305 849 GJ/yr) divided by No. commercial users – 34 337, or 8.907 GJ/user. (Note: this assumption is not 'real' – as most commercial entities are in fact office blocks which do not use LPG. This data is merely one way to represent the total LPG use of the commercial sector). Appliances are typically cookers in hotels, restaurants and hospitals etc, plus some heaters.

? **Coal**: Total of 484 223 GJ for all users from Air pollution database (CCT 2003a) – or 14.102 GJ for each of 34 337 users. Coal is used by some hospitals and prisons for heating and cooking, and in boilers.

? **HFO**: Total of 216 912 GJ for all users from Air pollution database (CCT 2003a) – or 6.317 GJ for each of 34 337 users. HFO is used for boilers at institutions such as prisons, and some businesses.

? **Diesel**: Total of 146 227 GJ for all users from Air pollution database (diesel use of 80 208 GJ + 50% 'diesel/paraffin use figure of 132 038GJ) – or 4.259 GJ for each of 34 337 users. Diesel is used in small quantities by many different facilities, including workshops/garages, hospitals and hotels.

? **Paraffin**: Total of 120 0017 GJ for all users from Air pollution database (paraffin use of 53 998 GJ + 50% 'diesel/paraffin use figure of 132 038GJ) – or 3.495 GJ for each of 34 337 users. As with diesel, paraffin is used in small quantities by several different types of facilities, including bakeries, garages/workshops and hospitals.

? **Coal gas**: Total of 434 076 GJ for all users from Air pollution database – or 12.642 GJ for each of 34 337 users. (NB ASSUMPTION: 'Gas use' in Air pollution database is coal gas – since they do not record LPG use). Substantial coal gas is used by hospitals for central heating and cooking.

2.3.2 Summary

The following figures summarise the status of Cape Town's commercial sector in 2000, based on the data described in the text.

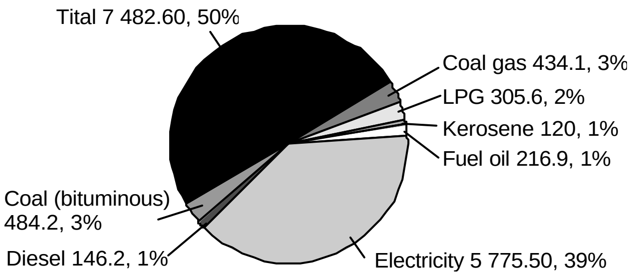


Figure 5: Total commercial energy use by fuel, 2000

Table 11: Total commercial sector energy use by fuel (PJ), 2000

Coal gas	434.1
LPG	305.6
Kerosene	120
Fuel oil	216.9
Electricity	5 775.5
Diesel	146.2
Coal (bituminous)	484.2
Total	**7 482.6**

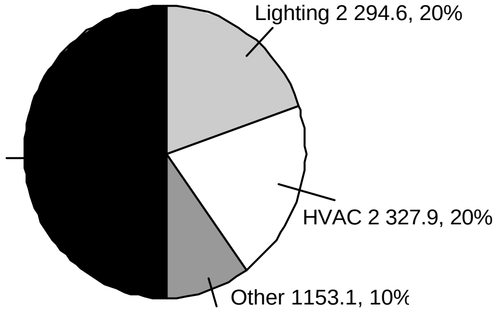


Figure 6: Commercial electricity consumption by end use, 2000

Table 12: Commercial electricity consumption by end use (PJ), 2000

Lighting	2294.6
HVAC	2327.9
Other appliances	1153.1
Total	**5 775.5**

2.4 Government

The government sector is treated separately to the commercial sector, although many energy use characteristics are similar. Office buildings dominate the energy use profile, for example, and electricity is by far the major energy source. There are a large number of other installations – 20 waste water treatment work, 15 water treatment plants, 6 landfill sites, 20 clinics, a number of libraries, pump stations, government garages, electricity depots, etc., thus making 100 facilities a conservative estimate for local government. Non-office facilities such as workshops and depots also make up a lesser (but unknown in magnitude) part of the consumption profile. Government transport is not included under this section, but rather under the transport section. Note that 'government' means 'local government' in this section, as only local authority energy use is included. Other provincial or national government energy use was not easily separable from data sources of the *State of energy* report, and thus is included under the 'commercial' section.

The main data source for government energy use data is the *State of energy* report (CCT & SEA 2003) Local authority chapter, which in turn draws heavily on the greenhouse gas inventory undertaken as part of the ICLEI Cities for Climate Protection Programme (CCT 2003b).

The average cost of electricity for CCT is R85/GJ (R62 662 361 total bill divided by 734 230GJ – (CCT & SEA 2003). This converts to a 'tariff' of 30.6 c/kWh – this is the effective rate at which the city sells itself electricity (since it is the distributor for almost all of it's facilities – excluding those few in the Eskom supply areas within the Metro boundaries).

2.4.1 Non-building energy use

? Streetlights: Total electricity use is 362 110 GJ/yr.

? Water supply and treatment: Total electricity use is 79 700 GJ/year.

We assume all electricity carries the average cost of R85 / GJ (30.6c/kWh) – although some bulk facilities will in practice be billed differently to smaller facilities via the internal billing system.

2.4.2 Government buildings

The number of government buildings is assumed to be 100 for purposes of data entry – the actual number of buildings/users is not known. As with commercial facilities, because details on characteristics of different facilities are not known, energy use characteristics have been 'averaged' across all facilities – for example, the total estimated lighting demand has been divided by 100 (the assumed number of buildings) to get an average lighting profile per customer, and the data entered into LEAP in this way.

General assumptions used:

? An office block represents the typical building electricity use profile.

? Buildings use energy 8 hours per working day.

? 220 working days per year.

? Numbers of electrical appliances per building are derived by (details are in Appendix A):

  ? assuming a typical electricity profile in terms of proportional consumption for different categories of appliances;

  ? determining a typical average electricity consumption for different types of appliances;

  ? dividing the total consumption for an appliance category with the typical average consumption per appliance, to give an estimated number of appliances.

2.4.2.1 Lighting

? Incandescents: 100watts × 8 hrs × 220days/yr × 609.21 appliances (average assuming 100 government buildings in CT).

? CFLs: 20 watts × 8 hrs × 220days/yr × 609.21 appliances.

? Existing fluorescents: 40 watts × 8 hr × 220 days/yr × 3092.19 tubes per building (average per building assuming 100 government buildings in CT).

? Efficient fluorescents: 32 watts (35 watt tube + electronic ballast ~32 watts effectively) × 8 hrs × 220 days/yr × 3092.19 tubes per building.

Note that the numbers of lights and other appliances per facility is often much higher than for the commercial sector. This is because of the assumption that we are dealing with only 100 facilities for local government. In fact the number of buildings is probably much higher (but still unknown).

2.4.2.2 HVAC

This assumes the use of typical airconditioning office ‘units’: 1kW × 8hrs × 220 days/yr × 184.61 appliances per building (average assuming 100 government buildings in CT).

2.4.2.3 Other

Other electrical appliances (often computers, copiers, heaters, urns etc) – assumed to total an average demand of 1kW × 8hrs/d × 220 days/yr × 92.3 appliances per building (see Appendix A for more details on how appliance numbers were determined). Note that the average demand of 1kW is a figure chosen for convenience rather than representing actual use of particular appliance set. The important cross-check here was that the demand over a year added up to the total consumption figure. (See Appendix A for more details).

2.4.2.4 Non-electrical energy use in government

The main non-electrical energy use by local government is in their transport fleet – which is included under the transport section rather than here. Fuels such as paraffin, coal and LPG are also used (e.g. in workshops and staff kitchens), but in relatively small quantities, and so will be ignored here.

2.4.3 Summary

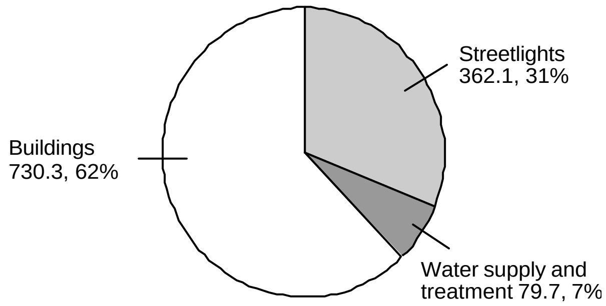


Figure 7: Government electricity consumption by end use, 2000

2.5 Transport [3]

The transport sector is broken down into private and public land passenger transport as well as road and rail freight. Sea and air transport have been ignored in this analysis. In 2000, the transport sector in Cape Town consumed 59.1 PJ of energy, which was over 55% of total final energy demand. Of this, 43.7 PJ was petrol, 13.7 PJ was diesel, and 1.7 PJ was electricity. Transport is by far the biggest user of liquid fuels in Cape Town.

The base year data for the transport sector of this project was taken mainly from the unpublished PhD thesis work in progress of GS Heinrich (ERC and Department of Chemical Engineering, UCT). The data was representative of the Western Cape and was directly scaled down to approximate Cape Town's transport sector. This data was calculated mainly from South African Petroleum Industry Association (SAPIA) figures for petrochemical sales by market category in the Western Cape. The data gaps were approximated using vehicle population figures from the NaTiS (National Traffic Information System) database. The *State of energy* report (SEA and CCT) was also used as a check for data consolidation.

2.5.1 Private transport

Private transport was split into petrol and diesel vehicles. The total passenger kilometres for this sector was back calculated from fuel use, using the average final energy intensity for petrol and diesel vehicles (see Table 13). These numbers were taken directly from the IEP (Integrated Energy Plan) 2003.

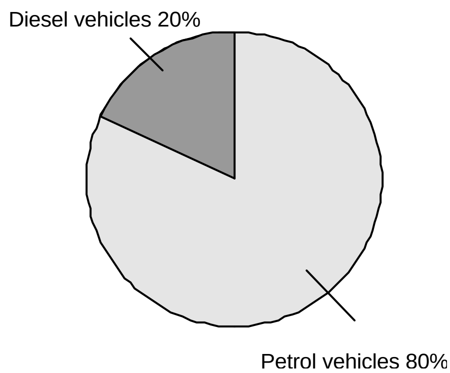


Figure 8: Share of passenger kilometres for petrol and diesel vehicles in private transport

2.5.2 Public transport

Public transport was split into public rail, public bus and minibus taxi, which was in turn split into petrol and diesel taxis. The passenger kilometres were once again calculated from fuel use and final

[3] We acknowledge the input by James Wei, a Masters student in the Energy Research Centre, to earlier versions of the transport section and database.

energy intensities found in Table 13 below as well as vehicle ratios from the NaTiS database. Electricity data for rail was obtained from Eskom's unpublished provincial electricity report.

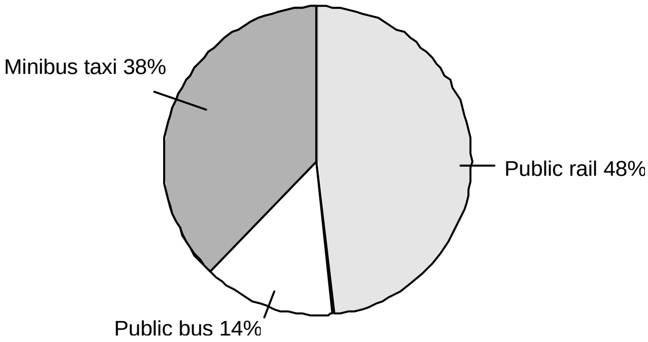


Figure 9: Share of passenger kilometres in public transport

2.5.3 Freight

Freight transport has been separated into rail and road, with road consisting of diesel and petrol trucks. Ton-kilometres were calculated from final energy intensities as before, with fuel use derived from SAPIA data.

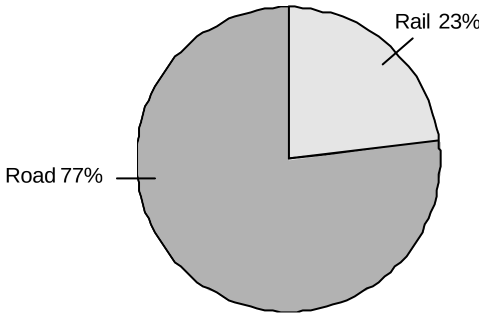


Figure 10: Share of passenger kilometres in public transport

Table 13: Final energy intensities for transport technologies (IEP 2003)

Type of vehicle	*Fuel*	*MJ / passenger-km or MJ/ ton- km*
Passenger		
Private vehicles	*Petrol*	2.912
	Diesel	2.621
Public Rail	*Electric*	0.222
Public bus	*Diesel*	0.454
Minibus taxis	*Petrol*	0.581
	Diesel	0.523
Freight		
Rail	*Diesel*	0.680
Road truck	*Diesel*	0.804
Road truck	*Petrol*	0.893

2.5.4 Summary

In 2000, the transport sector in Cape Town consumed 59.1 PJ of energy, which was over 55% of total final energy demand. Of this, 43.7 PJ was petrol, 13.7 PJ was diesel, and 1.7 PJ was electricity. Transport is by far the biggest user of liquid fuels in Cape Town.

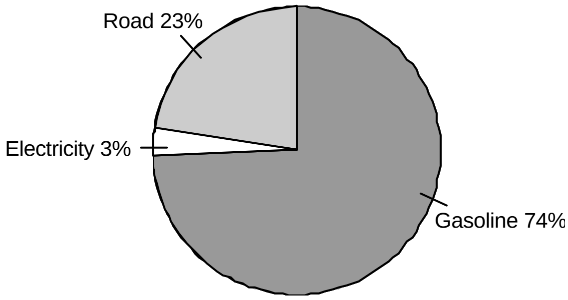


Figure 11: Total transport energy use by fuel, 2000

Table 14: Total passenger transport energy use by vehicle type (PJ), 2000

Passenger transport	*PJ*
Petrol vehicles	40.2
Diesel vehicles	8.8
Public rail	1.7
Public bus	1.0
Petrol taxi	3.4
Diesel taxi	0.1
Total	55.2
Freight transport	
Rail (diesel)	0.8
Diesel truck	3.0
Petrol truck	0.1
Total	3.9

3. Energy supply

Most of the analysis in this work is focused on the demand side, but demand has to be met by supply (‘transformation’ in the LEAP model). Electricity generation is included in the transformation section. Apart from ensuring that the energy system balances, there are two major environmental issues of concern – emission of greenhouse gases (GHGs) contributing to global climate change, and the city’s infamous ‘brown haze’ – local air pollution. The way electricity generation is included is intended to enable analysis of both problems.

3.1 Electricity generation

Local air pollution is the result of emissions within Cape Town. The local coal-fired power station, Athlone, contributes to this problem, even though it is not the largest source and was last used in the winter of 2003 – and in the years preceding that it was only used between June and August. Hence this station is represented separately. Electricity is unique in that the GHG emissions occur in a different place to consumption of electricity. However, it is standard practice (IPCC 2000, 2001) to attribute the emissions at power stations to the use of electricity. Hence there are emissions factors per kWh consumed. Cape Town imports some of its power (particularly in during winter peak demand) and this requires the inclusion of national power stations in the LEAP database. Using public domain data (NER 2000), generic power stations are included for each fuel (coal, gas / jet fuel, bagasse, hydro, pumped storage and nuclear), plus the Athlone station.93% of the electricity generated in 2000 was from coal-fired power plants (NER 2000), using bituminous coal (see Appendix C for discussion of characteristics). Koeberg is treated as a national nuclear power station, for two reasons – its operation is not under the control of the city (unlike Athlone); and to avoid creating the impressions that electrons used by Cape Town are cleaner than the average mix in the grid. Eskom reports the 'environmental implications of using one kilowatt-hour of electricity' as 0.85 kgCO_2 in 2000 (Eskom 2000a).

The generic coal-fired power station thus generates all the electricity of Eskom and municipal power station, minus Athlone, but scaled to the extra demand of Cape Town. Base year output (GWh) for the various stations, as well as capacity (MW) was taken from (NER 2000). The maximum capacity factors from the same NER stats (NER 2004)(weighted average of Eskom, municipal and private for coal), and the draft IRP (NER 2004).

Total demand for electricity was established by detailed investigations for the State of Energy report, based on reports from each of the local municipal councils and an attribution of demand supplied directly by Eskom (CCT & SEA 2003). It reports total consumption of 36 835 284 GJ (which converts to 10 232 GWh), of which 14 096 668 GJ were consumed by households, 22 0002 386 by industry and commerce, and 734 230 by local authorities.

Of the 10 232 GWh final demand in Cape Town, Athlone supplied 0.618 GWh (NER 2000) leaving 10 231.4 GWh to be supplied from national stations. Assuming transmission and distribution losses at 12%, 11 627 GWh of electricity generation are required. Total electricity generation, excluding Athlone, was 198 140 GWh (NER 2000). A scaling factor of 5.87% is used to adjust the generation of national stations to Cape Town's demand. Key parameters for electricity generation are summarised in Table 15. Efficiencies for power stations are taken from the draft Integrated Resource Plan developed for the NER (NER 2004). For Athlone power station, efficiency was averaged over 4 years (1994/5 to 1997/8) (based on CCT 1998).

Table 15: Electricity generation: summary of data assumed for the LEAP current accounts (2000)

Plant type	*Capacity*	*Base year output*	*Efficiency*	*Maximum capacity factor*
Units	*MW*	*GWh*	*%*	*Share of hours out of 8760 hrs*
Gas jet fuel	662	0.3522	32.3	0.1
Coal stations	33 981	10 591	33.9	66.9
Athlone coal	180	66	23.1	8.3
Nuclear	1,840	764	31.5	82.1
Bagasse	105	18	34.0	43.9
Hydro	668	92	90.0	26.7
Pumped storage	1 580	166	76.0	19.2
Wind	–	0	97.0	19.3
PBMR	–	0	40.5	86.0
Gas cycle	–	0	47.0	85.4

As can be seen in Table 15, wind, combined cycle gas turbines and the nuclear PBMR plants are included as potential future supply options, but without any capacity or base year output. The dispatch rule is set 'in proportion to base year outputs', meaning that in the reference scenario, there is no change in the stations delivering electricity to Cape Town.

3.2 Oil refineries

There is one oil refinery in Cape Town, the Caltex refinery or Calref. It produces mainly petrol (34.5% of total output) and diesel (29.4%), with the balance being made up of fuel oil, jet kerosene, LPG, other kerosene (paraffin), refinery feedstock, bitumen and sulphur (the last three in small quantities, see Figure 12). We have assumed that the output of Calref exceeds the demand within Cape Town. The main data source for Caltex was work done for the Integrated Energy Plan (DME 2003). The total production quantities matched with those found in the SAPIA annual report for 2001 although the splits for the different products did not match up (SAPIA 2001). This could be due to SAPIA's use of different units.

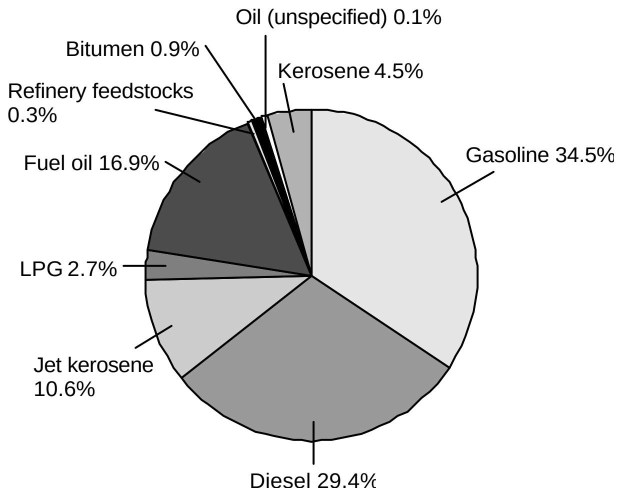


Figure 12: Share of outputs of Caltex refinery
Source: Work done for (DME 2003)

The efficiency used in LEAP (94.2%) was calculated taking own use into account. The refinery was also not run in LEAP to meet the transport demand as our transport sector is as yet not complete. The capacity of the refinery was 27.6 million barrels of oil equivalent per year in 2000 (DME 2003). The model output fuel 'oil unspecified' is actually the sulphur produced by the process. All other information on the refinery is in the LEAP model.

4. Key drivers of energy development

Drivers (in LEAP's 'key variables' branch) are taken from the City of Cape Town's publication on its economy: *Current trends and future perspectives* (CCT 2001b). It reported a gross geographic product (GGP) of R 85.9 billion in 2000 (p. 7), and an average annual real growth rate of 2.6% for the period 1991-2000 (above national GDP growth). The GGP estimates were derived on a survey of 30 000 formal businesses, annual sectoral turnover trends and the RSC Levy Database.

Table 16: Status of key drivers of energy development

Key variables	*Status in 2000*
Population	3 054 000
GGP	85 900
Households	750 000
Household size	4.1
Econ active pop	2 079 000

4.1 Economic output (GGP)

While the past is not necessarily a good predictor of the future, we assume that GGP growth for 2000–2020 will be similar at 2.5%. The City itself is more optimistic, and forecasts 4.1% p.a. growth for 2000–2005, and 4.4% for 2005–2010 (CCT 2001b: 15), based on higher growth rates than national predictions.

Sectoral growth rates for the period 1991-1998 are also given (see Table 17). Future high-growth sectors are expected to be trade and catering (including tourism), manufacturing (esp. beverages and tobacco, electricial machinery, rubber and plastics), transport and communications, and construction (CCT 2001b: 15).

Table 17: Growth rates in Cape Town's manufacturing sector

Source: CCT (2001b: 10)

Sector	*Average annual growth in% over period 1991- 1998*
Electronic and electrical products	9.5
Metal and steel	8
Beverages	6.5
Wood and furniture	5.4
Leather and footwear	4.5
Chemicals, petroleum and pharmaceuticals	3.3
Rubber, plastic and other	3.3
Paper, printing and publishing	3
Food	2.6
Machinery (non-electric)	2.6
Transport equipment	2.3
Textiles and clothing	2.1
Other	1.7
Total average	3.8

Unless there is reason to believe otherwise, these historical growth rates are used where future sectoral growth rates are needed in the reference scenario. Future high-growth sectors are expected to be trade and catering (including tourism), manufacturing (especially beverages and tobacco, electricial machinery, rubber and plastics), transport and communications, and construction (CCT 2001b: 15).

4.2 Population, households and household size

Cape Town's population in 2000 was 3 053 763 people. Population growth has been 3.2% per year for 1996-2000, but is expected to decline with the impact of HIV/AIDS (CCT 2001b). We use the projections of 2.4% growth for 2000–2005 and 1.2% per year for 2005–2010 (CCT 2001b: 22) and thereafter.

A notable trend across South African cities is that households have been growing faster than population (SACN 2004). In Cape Town, average annual population growth during 1996-2001 was 2.45%, while households grew at 3.15% (SACN 2004: 179). Nationally, the difference is larger, with population growth at 2.8%, but households growing at 4.9%. Possible reasons include people moving out of backyard shacks and establishing new households; migration from rural areas to the cities; increased household formation. We assume that in Cape Town in future, growth of households will be about 0.5 percentage points higher per year than for population growth, following the historical pattern. This implies that household size declines over time.

The growth of the labour force and economically active population is slightly higher at 2.7% for 2000–2005, with a relatively high number of young people migrating to the city (CCT 2001b: 17-18).

In linking growth scenarios to drivers, it it therefore important to consider whether growth is related to population (e.g. economic activity, transport) or to households (electricity connections, housing).

Table 18: City of Cape Town's forecast: population, labour force, employment 2000-2010

Source: (CCT 2001b: 22)

	Average annual percentage growth				
Period	*Population*	*Labour*	*Economic growth*	*Employment*	*Unemployment*
1996-2000	3.2%	3.3%	2.5%	1.5%	From 12% – 18%
2000-2005	2.4%	2.7%	4.1%	2.1%	From 18% – 21%
2005-2010	1.2%	1.4%	4.4%	2.2%	From 21% – 20%

The economically active population is assumed to grow at 2.1% from 2000 to 2005, and at 2.2% per year thereafter (CCT 2001b: 22). In other words, in the first five years labour force growth is close to projected population growth (2.4% p.a.), but thereafter is much higher, as population growth declines to 1.2% with the effect of AIDS.

5. Reference case: energy development assuming business-as-usual

The key drivers of energy development have already been described in section 4. The reference case in LEAP represents a base case without policy interventions. It is often referred to as the 'business-as-usual' scenario. In other words, it is a projection of what would happen in the absence of specific energy policies and strategies.

In the reference case, we assume that the household sector grows by household size (see earlier discussion of how this differs from *population* growth rates). The commercial sector is assumed to grow with GGP, but the government sector in relation to population – assuming that more government services are provided for more individuals. The scenario in industry is more differentiated, with the food and beverage sector growing at 2.6%, textiles at 2.1%, other industry as GGP, but pulp and paper remaining flat (there is only one plant in Cape Town). In the transport sector, we assume that, without other policies, passenger transport will grow with population, but freight transport with economic activity (GGP).

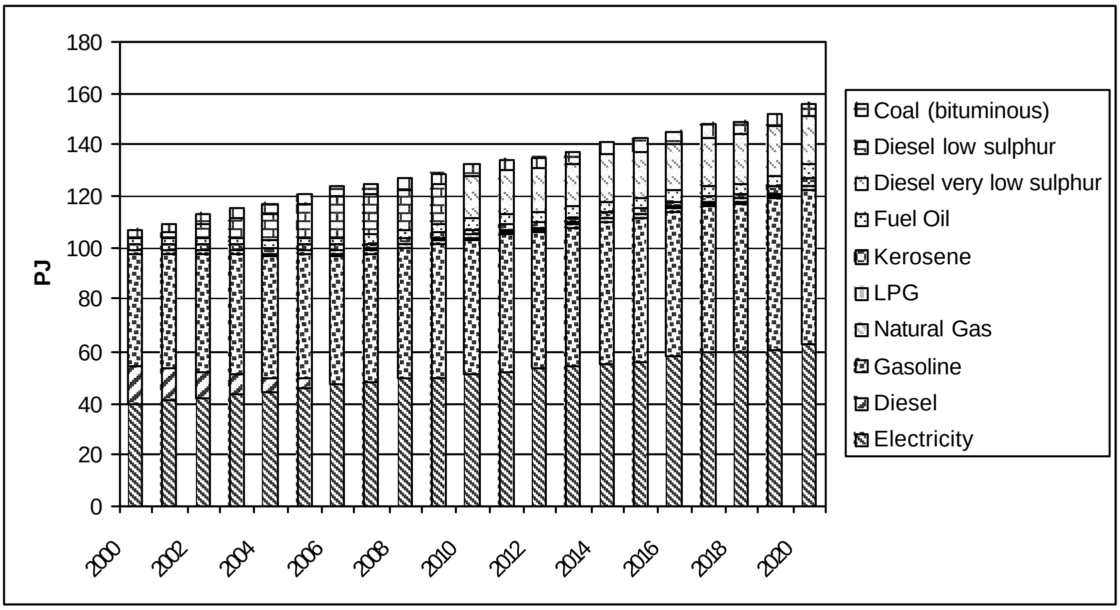


Figure 13: Energy demand in the reference case

A noticeable trend is the increase in consumption of electricity and liquid fuels (esp. petrol / gasoline) over the period. The replacement of diesel by low-sulphur versions can also clearly be seen in Figure 13, confirming that this change is expected to based on existing policy commitments.

6. Energy policies and scenarios

Individual policies have been created for sectors, then combined in sectoral combinations and finally brought together in an 'All policies' scenario. For example, in the residential sector, policies simulating the impacts of solar water heaters, ceilings and CFLs are outlined separately. Residential policies are in turn combined with industry, commerce, government and transport policies. Examining these policies together avoids double counting in the energy system. The policy question addresses the implications if policy were implemented according to the assumptions stated in this section. The question is 'what if energy policy in Cape Town changed the development path away from business-as-usual?' – what would be the impacts of policy?.

The study focuses on four key implications: energy savings, local pollutants, avoided GHG emissions, and selected cost implications. Note that local pollutants are analysed at source, i.e. where the combustion of the fuel leading to the pollution occurs. The 'brown haze' problem in Cape Town exemplifies this problem, with local transport emissions in particular contributing to poor air quality.

The approach taken with global pollution is different. Emissions of GHGs (notably CO_2) contribute to global climate change, and it does not matter where the emissions occur. Most of the GHG emissions are due to the use of coal-fired electricity and actually occur at power stations in the north-east of the country. However, LEAP allows these emissions to be analysed either at source, or to be attributed to the demand sector. We follow the latter approach, so that for every kWh of electricity used less, the avoided GHG emissions *upstream* are taken into account.

Cost implications are considered only for selected interventions. Clearly this is an area for significant further analysis. LEAP has limited ability to conduct cost-benefit analysis. To the extent that cost data was available for the interventions considered, we have combined capital costs and operating costs. LEAP's annualised cost function is used to convert the initial capital costs to a stream of annual payments. We assume a relatively low, public-sector discount rate of 8% and the lifetime of the equipment. Operational costs, whether they are variable or fixed, are entered as annual costs.[4]

6.1 Selection of policies

The selection of policies to be explored in LEAP was done using nine different criteria, covering financial and economic, welfare, environmental, and practical considerations. Because the analysis of policies was to provide a useful input into the Cape Town Energy Strategy process, it was important to consider constraints to implementation in the selection process, in addition to any academic interest which the policies may hold. Factors such as political will, availability of adequate data, availability of necessary capital for implementation, and potential for implementation 'rollout' were all thus amongst the assessment criteria. Data availability, cost effectiveness for local authority in short term, economic growth stimulus, job creation potential and possibility of reducing local and global pollutants were also assessed. Approximately 30 different policies were subject to this selection process (see details in Appendix D), all of which featured prominently in the Cape Town Energy Strategy. Each was weighted according to the set of criteria and a weighting of between 1 (weak/low) and 5 (strong/high) was allocated.

The policies includes in the simulation modeling include:

? In the *residential* sector, implementation of solar water heaters, installation of ceilings and a wide switch from incandescent lights to CFLs.

? In *buildings (commercial and government)*, a similar switch to CFLs, but also to more efficient fluorescent tubes – 10% of these are already efficient, but in the policy scenario we assume 100% penetration of efficient lighting by 2020; and 10% savings in heating, ventilation and air conditioning (HVAC) systems by 2020, driven by changes in user behaviour.

? For the *industrial* sector, we assume 12% savings across all energy use by 2014, to meet a national target; as well as fuel switching from coal to natural gas.

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[4] We use LEAP's annualised cost formula as default method of costing, and add energy costs (worked out as an annual cost for the base year 2000) for the year afterwards. Inputs needed for the annual cost formula are capital cost, lifetime, and interest rate.

? For *transport* systems, which comprise most energy consumption, the policy assumes a modal shift from private to public rail (from 49% to 79% public by 2020); petrol taxis replaced completely by diesel vehicles due to taxi recapitalisation, but also switching to bio-diesel and low-sulphur diesel driven by policy. Low-sulphur diesels are included in the reference case since a phase-in is already mandated; we assume biodiesel grows to a market share of 15% by 2020.

? The only supply-side policy considered meets an existing City of Cape Town target to have 10% of electricity generated from renewable energy sources by 2020.

6.2 Policies for commerce and government

Commerce and government sectors are dealt with in one section, as the main energy use characteristics of these two sectors are similar, and the selected policies for each are the same – i.e. introducing more efficient lighting (CFLs and efficiency fluorescent tubes) and improving the efficiency of HVAC systems.

6.2.1 Lighting

In commercial and government buildings, both fluorescent tube and 'regular' lighting is used. Regular incandescents may be replaced by the more efficient CFLs, and standard fluorescent tubes by more efficient fluorescent lighting. Hence lighting is separated into the following sub-branches:

? Incandescent lights: 100 watts.

? CFLs: 20 watts for same light output as a 100W incandescent.

? Existing fluorescents: 40 watts per tube.

? Efficient fluorescents: 32 watts (35 watt tube + electronic ballast ~32 watts effectively) per tube for the same light output as a 40 watt tube.

We assume that incandescents make up 100% of regular lighting in the base year, while 10% of fluorescent lights are already efficient in 2000. In the policy scenarios, we assume that all lighting in commercial and government buildings has shifted to CFLs and efficient fluorescents by 2020. Both CFLs and efficient fluorescents are implemented in the scenarios called CCFL and GCFL (for commercial and government sectors respectively).

6.2.2 HVAC

Experience with audits in the government and commercial sectors has shown that improving efficiency of HVAC use by 10% by user behaviour change can relatively easily be achieved (Monamodi & Borchers 2003). This is the policy scenario modelled – called CHVAC and GHVAC (commercial and government respectively) in LEAP – and is achieved by simply reducing total energy consumption per building of HVAC services – and thus energy – by 10% by 2020.

6.2.3 Implications of all policies for commercial sector

Table 19 quantifies the energy, cost and GHG savings from the scenarios considered in the commercial sector.

Table 19: Energy, cost and GHG savings from policies in the commercial sector

	Efficient lighting (CCFL scenario)	*HVAC (CHVAC scenario)*
Energy saving at 2020	1466 TJ (407 GWh)	382 TJ (106 GWh)
Cost saving at 2020*	R 144 million	R 32 million
GHG saving at 2020 (CO_2 equivalent)	365 000 tons	95 200 tons
* Cost saving considers all capital costs (e.g. of light replacements) and energy savings. HVAC costs are just savings, as these are initiated by behaviour change rather than capital expenditure on equipment.		

Implementation of the efficient lighting scenario is not expected to be demanding, as the quick payback on efficient lighting retrofitting should alone provide the necessary impetus. An awareness raising strategy may be all that is necessary. The same applies to the HVAC scenario – raising awareness will be the main implementation initiator.

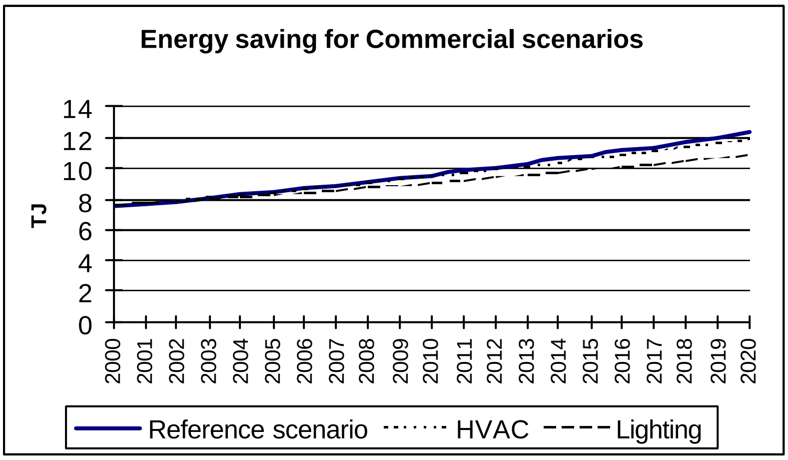

Figure 14: Energy savings in the commercial sector

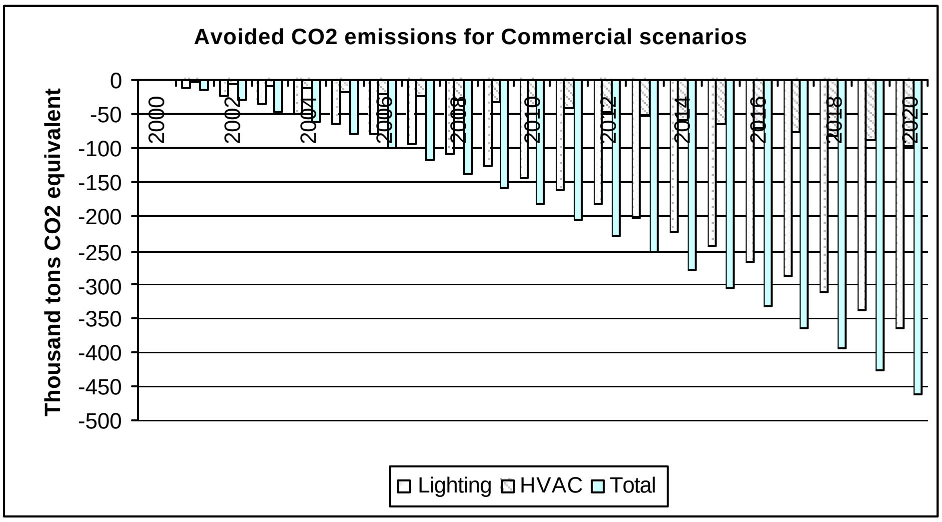

Figure 15: Avoided CO_2 emissions from commercial scenarios

6.2.4 Implications of all policies for government sector

Table 20 quantifies the energy, cost and GHG savings from the scenarios considered in the government sector.

Table 20: Energy, cost and GHG savings from scenarios for the commercial sector

	Efficient lighting (CCFL scenario)	*HVAC (CHVAC scenario)*
Energy saving at 2020	60.6 TJ (16.8 GWh)	15.8 TJ (4.4 GWh)
Cost saving at 2020*	R 1.6 million	R 1.3 million
GHG saving at 2020 (CO_2 equivalent)	15 100 tons	3 900 tons

* Cost saving considers all capital costs (e.g. of light replacements) and energy savings. HVAC costs are just savings, as these are initiated by behaviour change rather than capital expenditure on equipment.

To implement the above efficient lighting scenarios would require slightly increased capital budgets initially, but these capital costs would quickly (within one year) pay themselves back in energy savings, thus (theoretically) making funds available to continue the lighting retrofit with efficient options.

Labour implications for the implementation are not demanding, as retrofitting can take place as a matter of course as old incandescent lights and fluorescent tubes need replacing. Implementation of the reduction in HVAC energy use would require an internal awareness campaign, as well as awareness raising of building maintenance personnel.

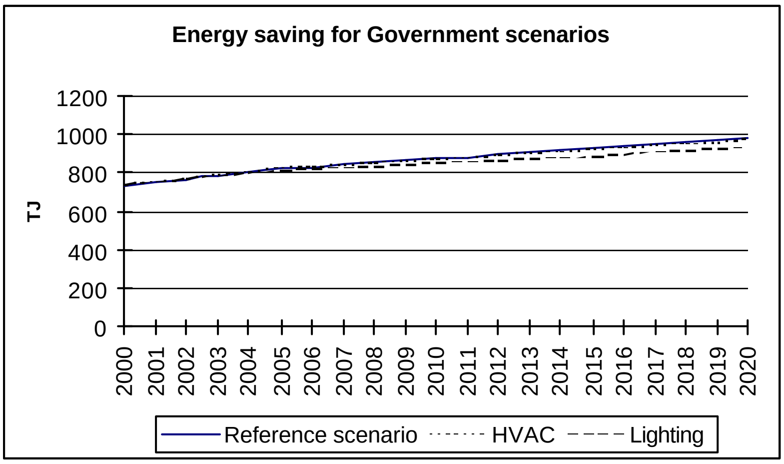

Figure 16: Energy savings in the government sector

The energy savings that can be gained from implementing efficient lighting and HVAC systems in government buildings are shown in Figure 16. While individual HVAC systems show larger savings, the volume of lighting that can be replaced is such that the savings for this scenario show a more visible reduction from the reference case. The deviation might seem small; however, the total savings are shown separately in Figure 17 in units of GWh.

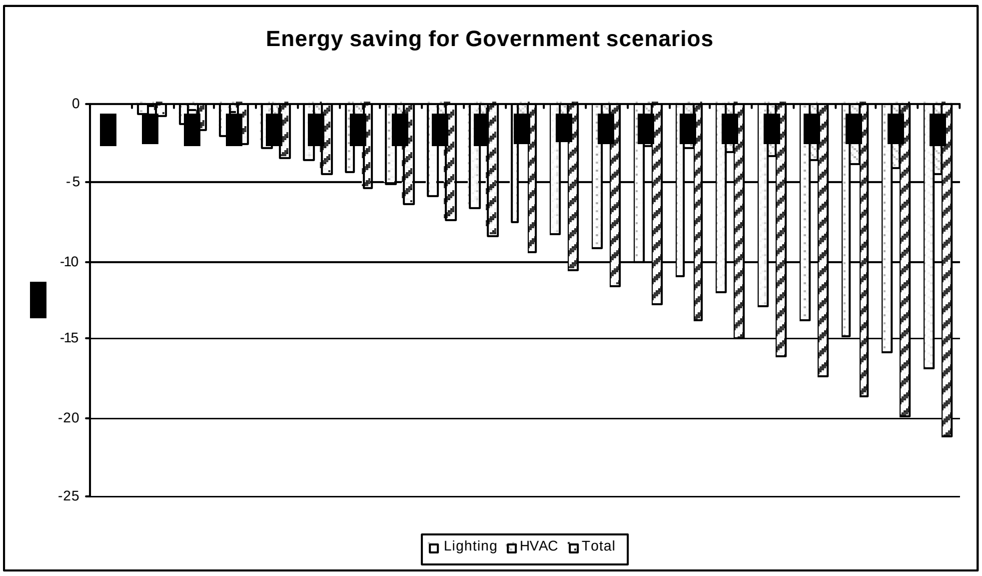

Figure 17: Energy savings in government buildings – lighting, HVAC and total

These energy savings are in the form of electricity. Reduced electricity consumption lowers demand and ultimately decreases the amount of coal burned in power stations in Mpumalanga. Figure 18 shows the avoided CO_2 emissions for the different policies in the government sector, totalling 19 000 tCO_2 by 2020.

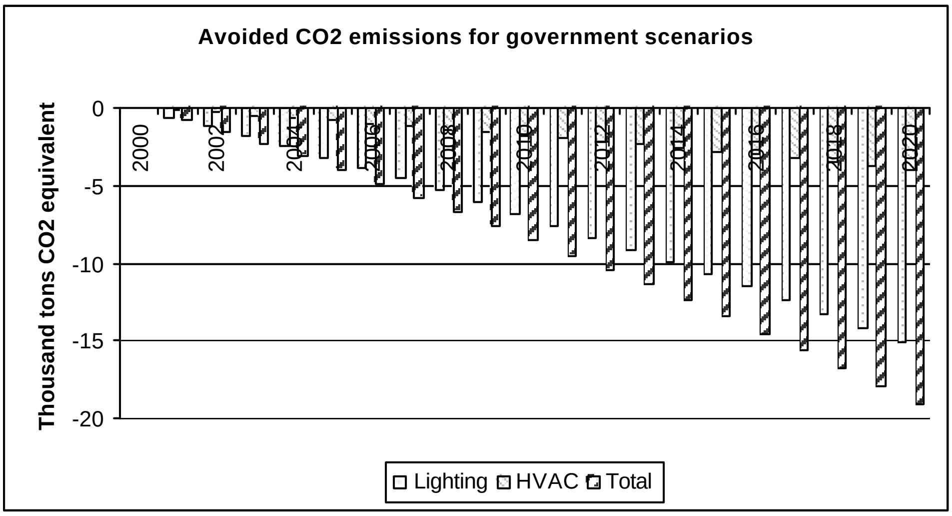

Figure 18: Avoided CO_2 emissions from government scenarios

6.3 Residential sector interventions

Three interventions have been identified: ceilings in low-income houses to improve the thermal performance of the houses, energy efficient lighting and domestic solar heating. This will result in reduced electricity consumption, reduction in CO_2 emissions and local air pollution.

6.3.1 Low-income households: Electrified[5]

Hot water on demand technologies and ceilings and ceiling insulation were currently not installed as part of low cost housing delivery in South Africa (SSN 2004). Low-income households use a variety of sources like paraffin, LPG, electricity and to a lesser extent firewood, to heat water and warm their houses.

6.3.1.1 Solar water heaters

It has been assumed that the alternative to providing hot water on demand using a solar water heater (SWH) is an electric hot water storage geyser (100 litre capacity). Solar water heaters are installed, replacing geysers in electricified households. Penetration rates are about 2% by 2005, rising to 10% in 2010 and 15% in 2020. The SWH will result in a reduction in energy for water heating of 1 132 kWh per year (SSN 2004). This translates into an annual average cost saving of 33.5% per unit for low-income electrified households. Total saving across the electrified low-income households reaches 346 GWh by 2020.

6.3.1.2 Ceilings

The installation of ceilings will result in less thermal energy being required which in turn will lead to less electricity being consumed and less dependence on other fuel sources. Note that ceilings are also installed in non-electrified households, and save fuel use there too. Middle- and upper-income housing already have ceilings. If a 30 square metre house is fitted with a ceiling the electricity saving is estimated to be 1 345 kWh/annum representing an average saving of 19.4% of energy that would have been used for space heating (SSN 2004). Total saving across the electrified low-income households reaches 508 GWh by 2020.

6.3.1.3 CFLs

All electrified households shift from incandescent lights to CFLs by 2020. In poor households, CFLs also displace some paraffin use; while unelectrified households continue to use paraffin and candles.

5 Non-electrified households are not considered in a separate section. Only 3.2% of households were not electrified in 2000, and we assume that by 2020, 99.9% of poor households will be connected. The non-electrified households *are* included in the ceiling intervention, which reduces the need for space heating.

However, in the reference case already, the share of unelectrified households drops from 3.2% in 2000 to 0.1% by 2020. Retrofitting each house with two CFLs (1 × 16 Watts inside, burning four hours and 1 × 11 Watts outside, burning eight hours) will result in a 223 kWh per household reduction in electricity annually.

Table 21: Energy savings of CFLs in low-income households versus reference case (TJ)

	2001	*2002*	*2003*	*2004*	*2005*	*2010*	*2015*	*2020*
Incandescent	34	71	110	151	195	427	702	1 026
CFLs	-9	-18	-27	-38	-49	-107	-175	-256
Net energy savings	26	53	82	113	146	320	526	769

Table 21 shows the pattern of energy savings over the years (every year for the first five, then in five-year steps). Incandescent lights show energy savings against the reference case, as they are replaced. The negative numbers against CFLs indicate that these is rising energy consumption, but this stays lower than it would have been for incandescents. The net energy savings are reflected in the final row.

6.3.2 Middle-to-high-income households

6.3.2.1 Solar water heaters

Replacing a geyser with a SWH has the potential monthly electricity saving of 43% per household (SEA et al. 2003). Penetration rates are initially slightly higher than for poor households, at 2.5% by 2005, thereafter similar. Total saving across the electrified low-income households reaches 1735 GWh by 2020. GHG emissions savings will be 1.018 million tons carbon dioxide/annum.

6.3.2.2 CFLs

For middle and high-income households, a shift occurs from incandescent lights to CFLs by 2020. Only electric lighting is displaced. Retrofitting each house with four CFLs (3 × 16 Watts inside, burning four hours and 1 × 16 W outside, burning eight hours) will result in a saving of 335.7 kWh per household.

Total saving across the electrified low-income households reaches 6,584 GWh by 2020. GHG emission savings will amount to 85 035 500 kg carbon dioxide/annum.

6.3.3 Implications of all policies for residential sector

Summarising the energy savings reported above, we see in Table 22 the total energy savings for the sector. CFLs in medium to high-income households stand out as the largest potential area for savings, but low-income households can also save thousands of GWh by 2020. Solar water heaters in are the next major intervention, again with larger potential in upper-income brackets.

Table 22: Energy savings for the residential sector (GWh)

	2001	*2002*	*2003*	*2004*	*2005*	*2010*	*2015*	*2020*
					Low-income households			
Solar water heaters	7	14	25	32	58	191	263	346
Compact fluorescents	94	191	295	407	526	1 152	1 894	2 768
Ceilings (all low-income)	14	36	54	76	97	216	353	508
					Medium to high-income households			
Solar water heaters	40	83	126	176	223	979	1 328	1 735
CFLs	227	468	724	994	1 278	2 783	4 540	6 584

Several of the interventions are associated with cost savings, due to reduced expenditure on energy. Solar water heaters in electrified low-income households, for example, can reach 33.5% savings on costs of heating water, and in upper-income brackets it can be as high as 43%. CFLs get large savings per unit (a quarter to a fifth of the energy consumption of incandescents) on running costs. This off-sets the higher initial costs within the lifetime of the appliance. Cost savings from CFLs are aggregated across large numbers of lightbulbs. Ceilings installed in low-income houses (both electrified and nonelectrified can achieve costs savings of about 20% of the space heating budget.

The environmental gains made from residential policies can be seen in Figure 19 for GHG emissions. The policies primarily reduce electricity consumption, and hence show an impact on CO_2 emissions. For local pollutants, only the ceiling intervention results in a small deviation from the line of the reference scenario. Some use of fuels (e.g. paraffin) that cause local pollution is avoided as the houses need less space heating.

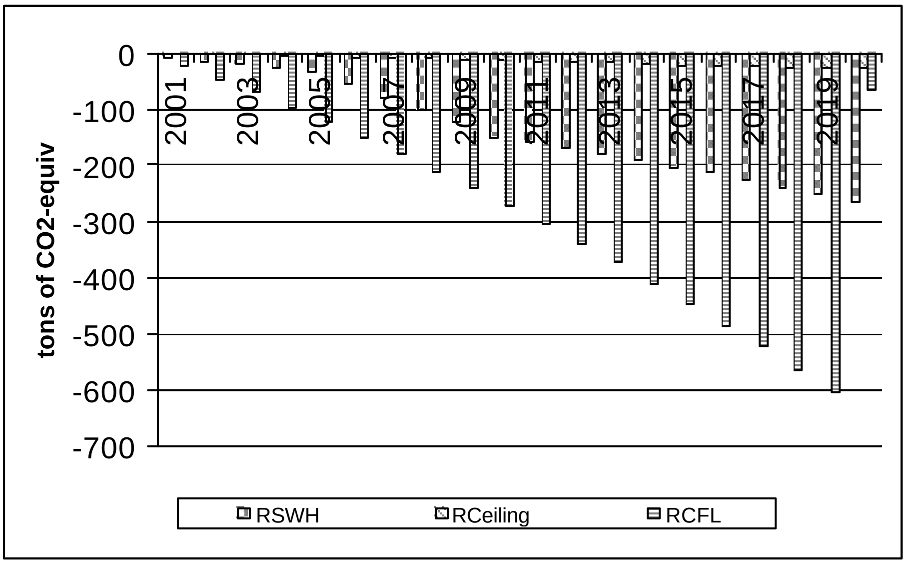

Figure 19: Avoided CO_2 emissions from the residential policies

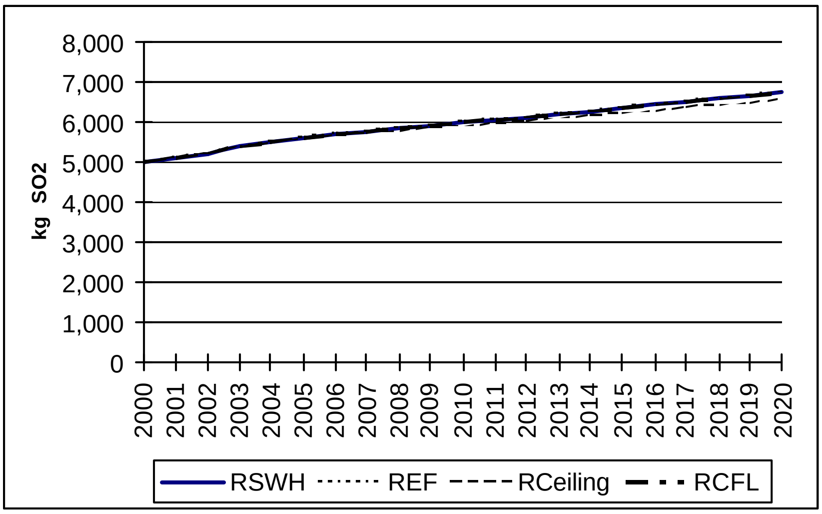

Figure 20: Reductions in local pollution (SO2) for residential policies

6.4 Scenarios for transport energy

The transport scenarios focus on land-based transport.[6] Policy interventions in the transport sector involve behavioural changes (e.g. shifting transport modes from private to public), use of cleaner fuels (e.g. to very low sulphur diesel and bio-diesel) and technological changes (e.g. recapitalising the taxi industry).

6.4.1 Modal shift

In the base year passenger transport splits for passenger-km were 51.4% private vehicles and 48.6% public transport. In the policy case simulating a modal shift, we assume that the share of private transport decreases to 22% by 2020, and public transport increases to 78%. These shifts occur against an increase – in the reference case – of total passenger-km travelled to 45 billion by 2020, and the modal shifts change as below. Such a shift would, of course, imply massive changes in infrastructure, the costs of which are not reflected here. The study models an *assumed* modal shift, to investigate the implications for energy, environment and social factor. Future work should establish whether such a shift is *likely* or not.

Table 23: Transport modal shift assumptions

By 2020	*Assumed modal shares*	*End year totals*
Private	22%	9.89
Public	78%	35.06
Billion passenger km		44.94

6.4.2 Taxi recapitalisation

This policy (‘Ttaxi’) simulates the effects of a shift from petrol to diesel minibus taxis. We simply assume that this policy results in diesel taxis increasing their share from 4.5% in the base year to 100% by the end of the period.

6.4.3 Shifts to low-sulfur diesel

The DEAT and DME strategy indicates that by January 2006 a maximum sulphur content of 500 ppm is to be achieved in diesel, and 50 ppm by January 2010 (DEAT & DME 2003: 9). The *reference* case therefore already includes a shift to a fuel called ‘low-sulphur diesel’ (with 0.05% diesel) and a later shaft to ‘diesel very low S’ (0.005%). These shifts apply to private diesel vehicles, diesel taxis and buses, as well as diesel trucks in freight transport.

6 Air and sea travel are not included due to the difficulties in obtaining data and differentiating the energy use and environmental impacts within the city of Cape Town boundaries, since most of their travel would be outside of the boundary. Air and sea travel, in and out of Cape Town, would influence more the economic aspect of the city as opposed to the energy and environmental aspect.

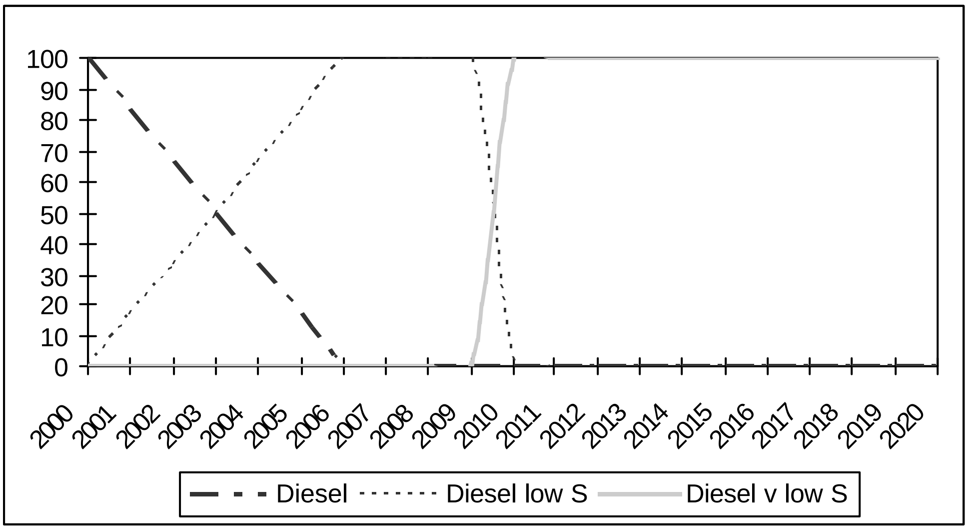

Figure 21: Percentage shares of passenger kilometres for diesel vehicles by fuel in reference case

6.4.4 Biodiesel

In this scenario it was assumed that biodiesel captured 15% of the diesel market by 2020. It gradually replaced whatever diesel fuel was being used at the time (diesel, low sulphur diesel or very low sulphur diesel).

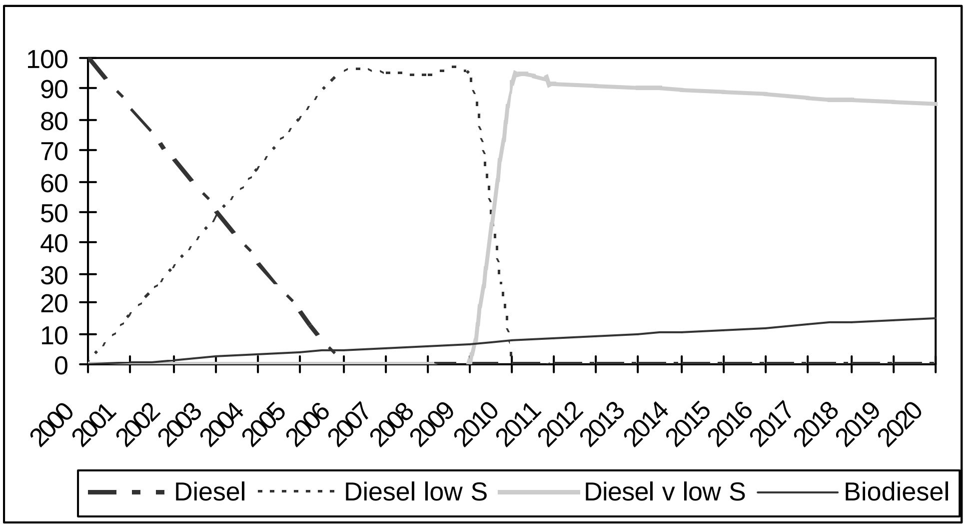

Figure 22: Percentage shares of passenger kilometres for diesel vehicles by fuel in biodiesel scenario

6.4.5 Implications of all policies for transport sector

6.4.5.1 Modal shift

The modal shift from private transport to public transport results in large energy and emission savings as shown in the figures below. This is because of the much lower fuel intensity per passenger-km is in the public transport sector as opposed to the private sector. It is clear that large investments in infrastructure would be required to achieve these savings – these require separate analysis.

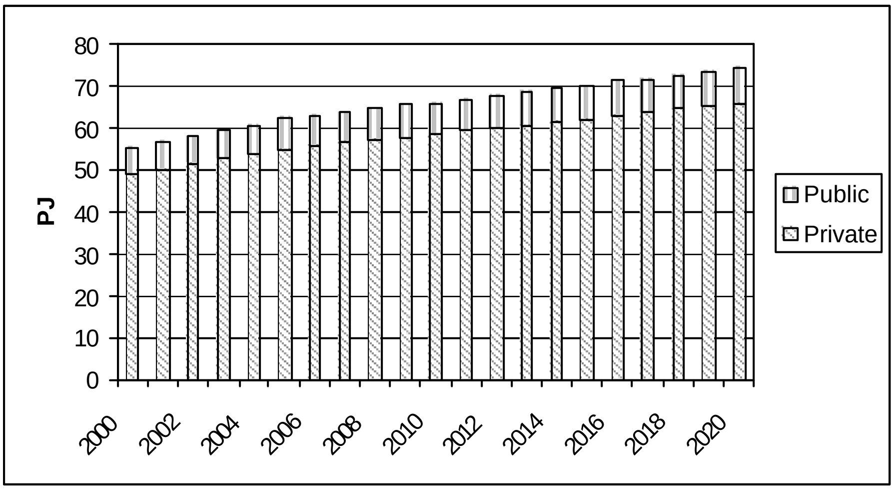

Figure 23: Passenger transport energy results in reference case

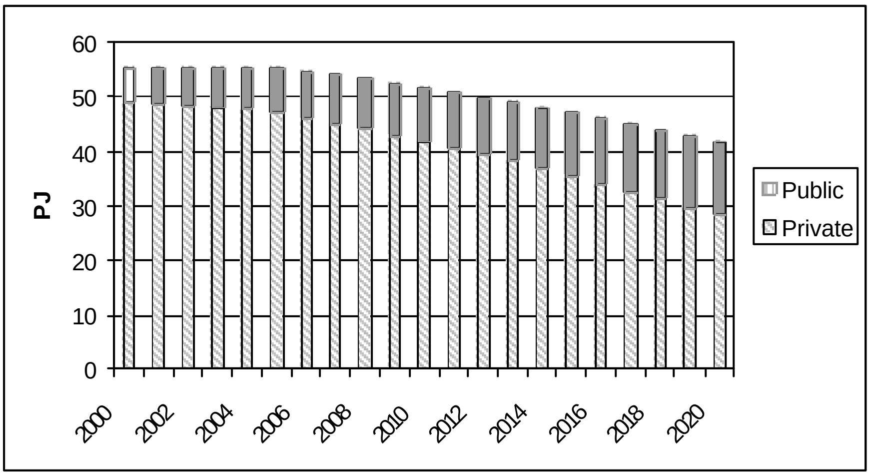

Figure 24: Passenger transport energy results in Tmodal scenario

The transport modal shift results in a decrease in energy use over the time horizon, with a 23% average annual reduction of energy (compared to the reference case).

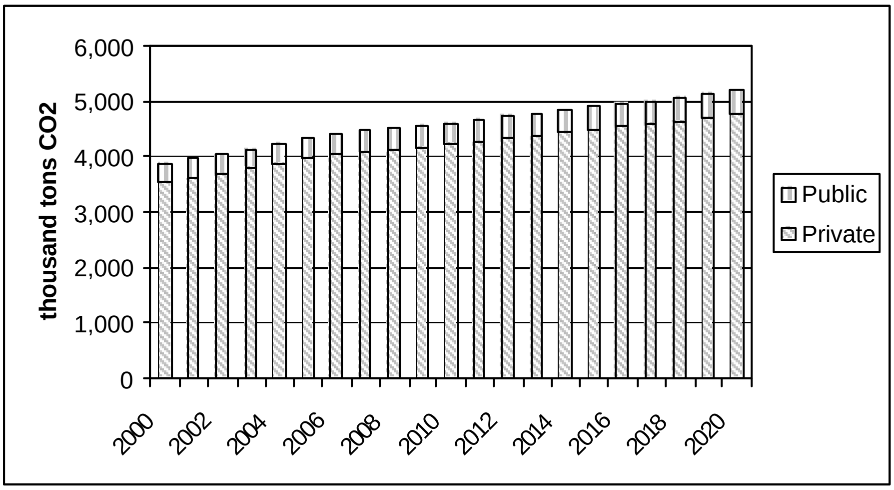

Figure 25: Passenger transport global emission results in reference case

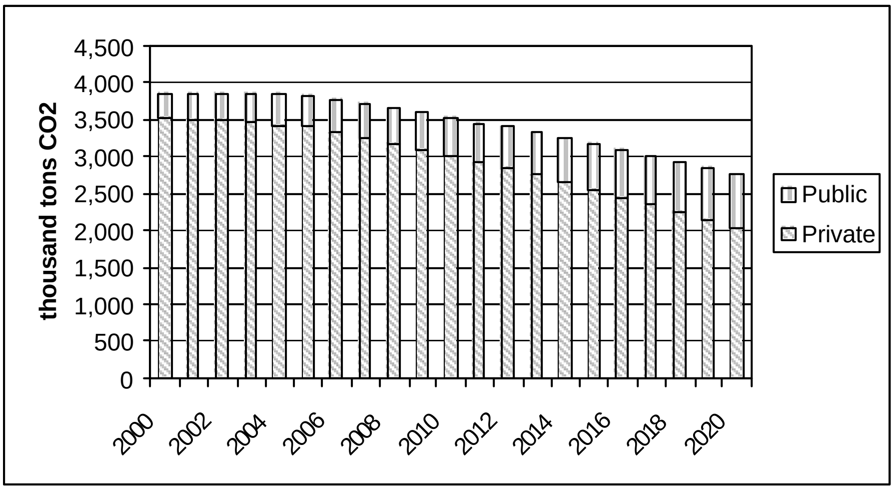

Figure 26: Passenger transport global emission results in Tmodal scenario

The modal shift results in a steady decrease in global emissions while emissions increase in the reference case. The modal shift has an average annual emission savings of 24.7% (compared to the reference case) over the time horizon. Note that the order of magnitude of emission reductions here is in millions of tons (e.g. just less than 4 $MtCO_2$ from 2000 to 2005, each year) – significantly larger than in other sectors.

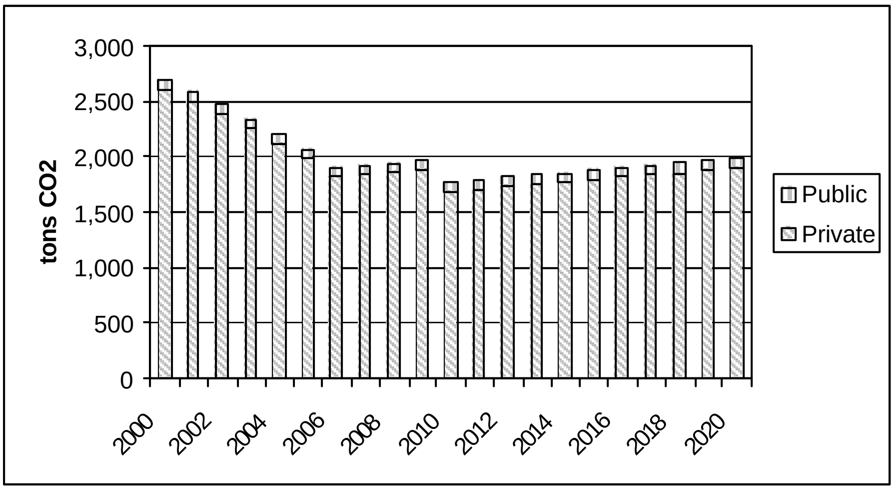

Figure 27: Passenger transport – local (SO_2) emission results in reference case

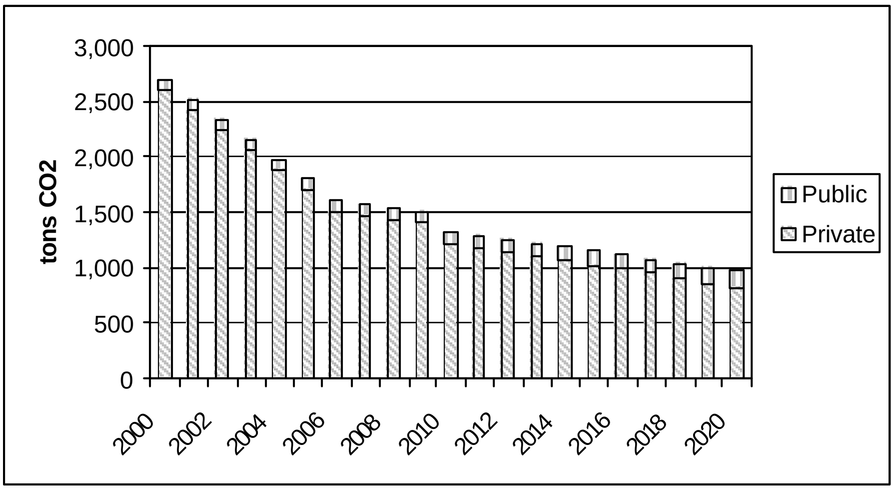

Figure 28: Passenger transport Local (SO_2) emission results in Tmodal scenario

Local emissions reduce in both scenarios over the time horizon, but more so in the Tmodal scenario. Figure 27 and Figure 28 show the emissions for the reference case and policy scenario respectively. The SO_2 emissions decrease in the reference case due to the introduction of low and very low sulphur diesel. The emissions in the Tmodal scenario decrease more because low and very low sulphur diesel are also introduced in this scenario, as well as a shift to a much more efficient means of transport (public).

6.4.5.2 Taxi recapitalisation

The shift from petrol to diesel taxis results in 10% change in net energy demand in the minibus taxi sector per annum when compared to the reference scenario. This is because diesel taxis have slightly lower final energy intensities per passenger kilometre than petrol taxis. This results in an overall saving of 0.6%/annum in the transport sector as a whole.

A 4% annual savings can be seen in GHGs as diesel taxis have slightly higher global emission factors than petrol taxis, but the diesel taxis have lower energy intensities. The net effect is a *reduction* of global pollutants.

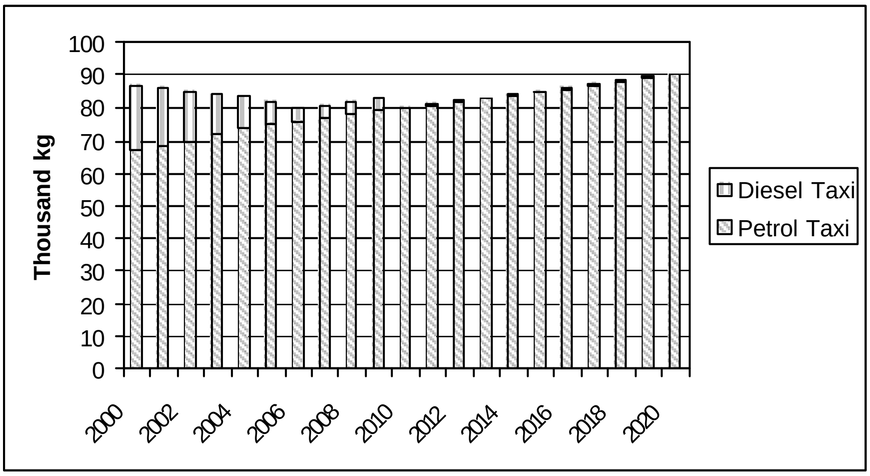

Figure 29: Minibus transport Local (SO_2) emission results in reference case

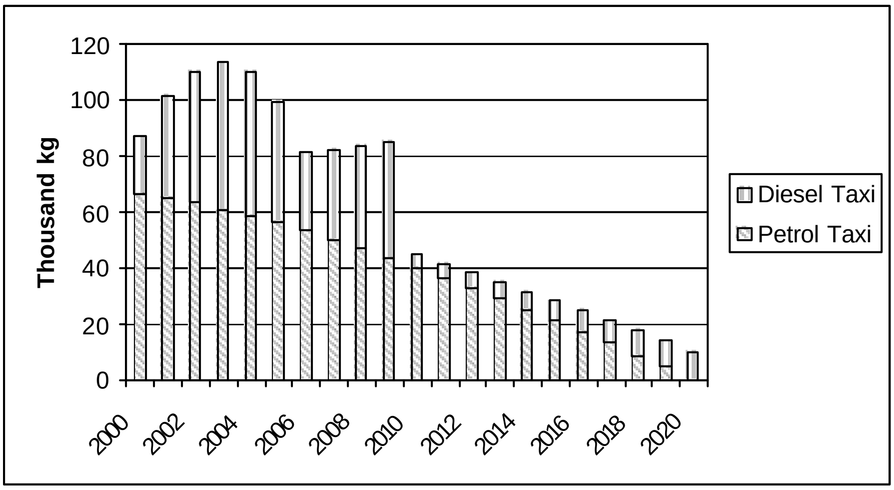

Figure 30: Minibus transport Local (SO_2) emission results in Ttaxi scenario

The taxi recapitalisation scenario has a more interesting effect on the local SO_2 emissions. This is due to the shift to low and very low sulphur diesel happening at the same time as the shift from petrol to diesel taxis. The reference case had an almost constant SO_2 emission level due to the effect of lower sulphur diesel opposing the effect of increase fuel use (due to normal growth in the sector).

The Ttaxi scenario results in a decreasing SO_2 emission level due to the combination of petrol taxis leaving the market and diesel becoming cleaner (lower sulphur content).

6.4.5.3 Biodiesel

There is no energy saving for the biodiesel scenario because it was assumed that biodiesel replaced existing diesel sales and had equivalent energy per litre. There is a decrease in global emissions in the biodiesel scenario because biodiesel was assumed to have no carbon footprint; hence no carbon emission was attributed to this fuel. Due to the assumed penetration of biodiesel, there is a 15% reduction in the global emissions from diesel by 2020 which results in an average annual reduction of almost 2% in the overall global emissions for the transport sector over the time horizon.

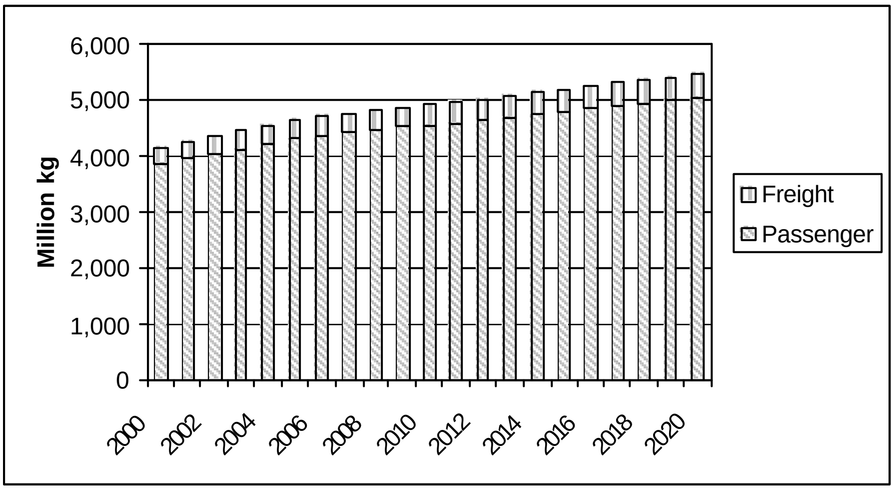

Figure 31: Overall transport global emission results in Biodiesel scenario

Due to the assumption that biodiesel had the same sulphur content as very low sulphur diesel, the biodiesel scenario resulted in a gradual decrease in the sulphur emission levels over the time horizon, which decreased at a slightly faster rate than the reference scenario. This resulted in an average annual SO_2 savings of 0.3% over the time horizon compared to the reference case.

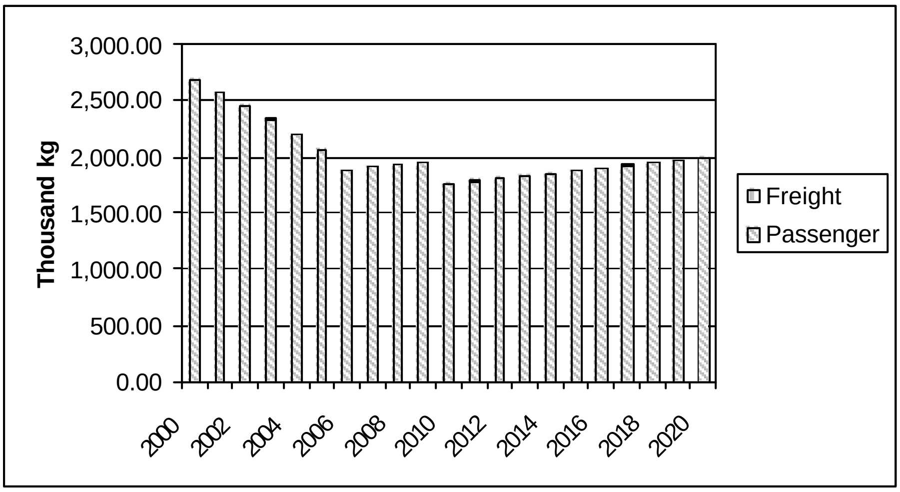

Figure 32: Overall transport local (SO_2) emission results in Biodiesel scenario

Although the costs for the transport policies have not been included, the implications are obvious. Due to the size of the transport sector massive savings in energy and global and local pollutants are possible.

6.5 Industrial energy policy

There are two scenarios in the industrial sector. In the first, it is assumed that all industrial sub-sectors will meet the government targets in the Draft Energy Efficiency Strategy. The second assumes that natural gas is available and that fuel switching takes place between coal and natural gas. The reference case does not include any improvement in energy efficiency over time.

6.5.1 Energy efficiency

In the Energy efficiency scenario, industry in Cape Town meets a 12% improvement in energy efficiency by 2014. The scenario begins in 2000 and energy efficiency improves linearly until 2014. After 2014, the energy intensity of all industries remains constant. The efficiency improvements occur in electricity demand devices as well as suppliers of thermal heat. The improvements are likely to come from lighting, compressed air, motors, variable speed drives improved boiler efficiency as well as steam system efficiency.

6.5.2 Fuel switching

In this scenario fuel switching takes place between coal and natural gas only. The scenario takes effect in 2004 and by 2020. By the end of the period, half of all thermal energy demand supplied by coal is replaced by natural gas. Boilers, furnaces and other heating equipment.

6.5.3 Implications of all policies for industry sector

The reduction in final energy demand in the industrial sector that occurs as a result of improved energy efficiency and fuel switching are shown in Figure 33. The small reduction in energy demand in the fuel switching scenario is due to the higher thermal efficiency of gas fired boilers.

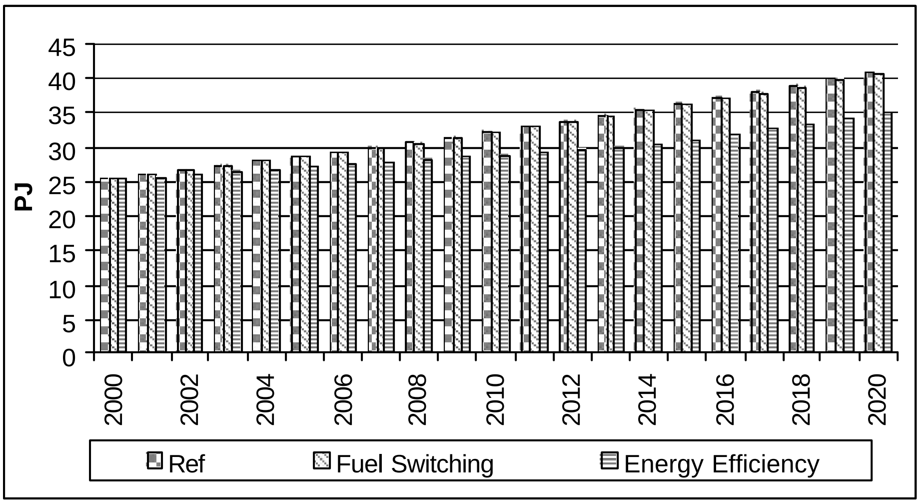

Figure 33: Final energy demand of the industrial sector

A reduction in GHG emissions and local pollutant emissions (sulphur dioxide) occurs in both the Energy efficiency and Fuel switching scenarios. GHG reduction in the Energy efficiency scenario includes both the local reduction in energy efficiency that occurs as a result of improved thermal efficiency and the global reduction resulting from the decrease in demand for electricity generation. Figure 34 and Figure 35 show the reduction in emissions of GHGs in the sub-sectors of industry of the Energy efficiency and Fuel switching scenarios relative to the Reference scenario. Figure 35 and Figure 37 below show the reduction in emissions of sulphur dioxide of the Energy efficiency and Fuel switching scenarios relative to the Reference scenario.

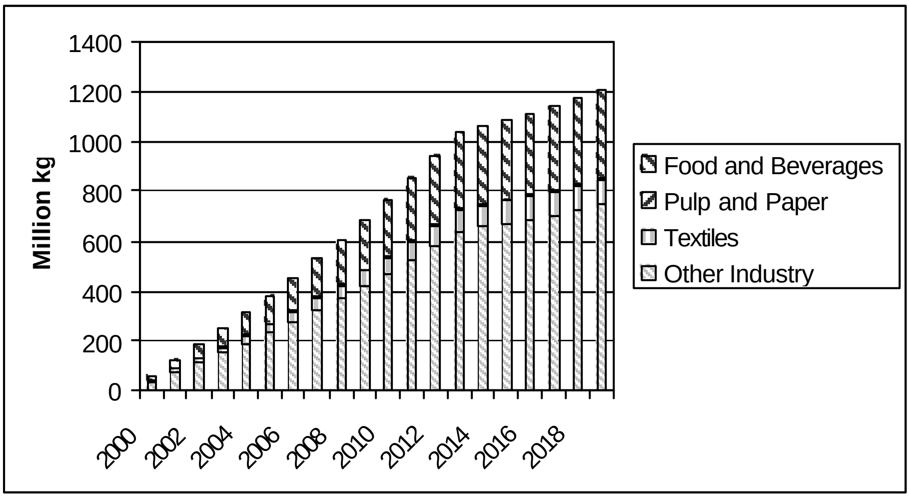

Figure 34: GHG reduction in the Industrial sector under the Energy efficiency scenario

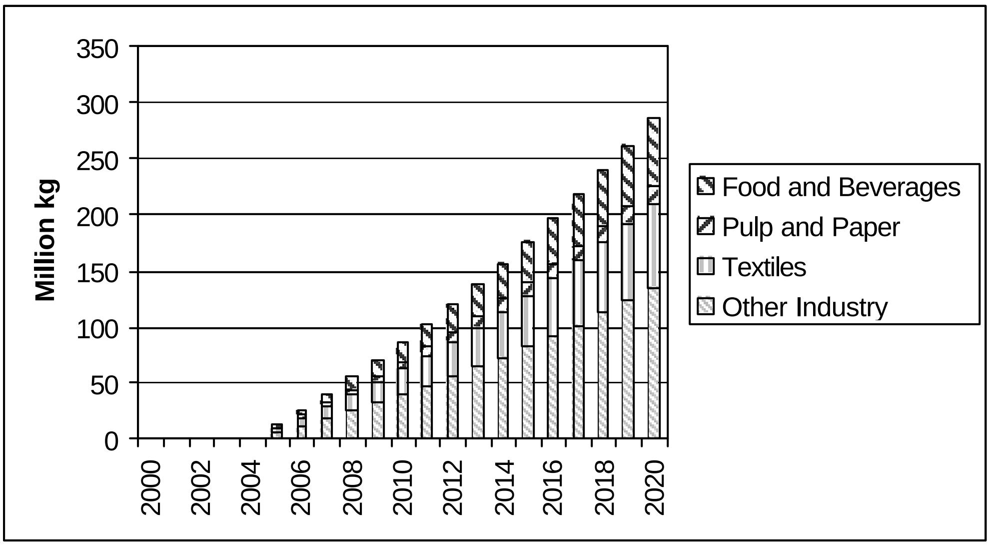

Figure 35: GHG reduction in the Industrial sector under the Fuel switching scenario

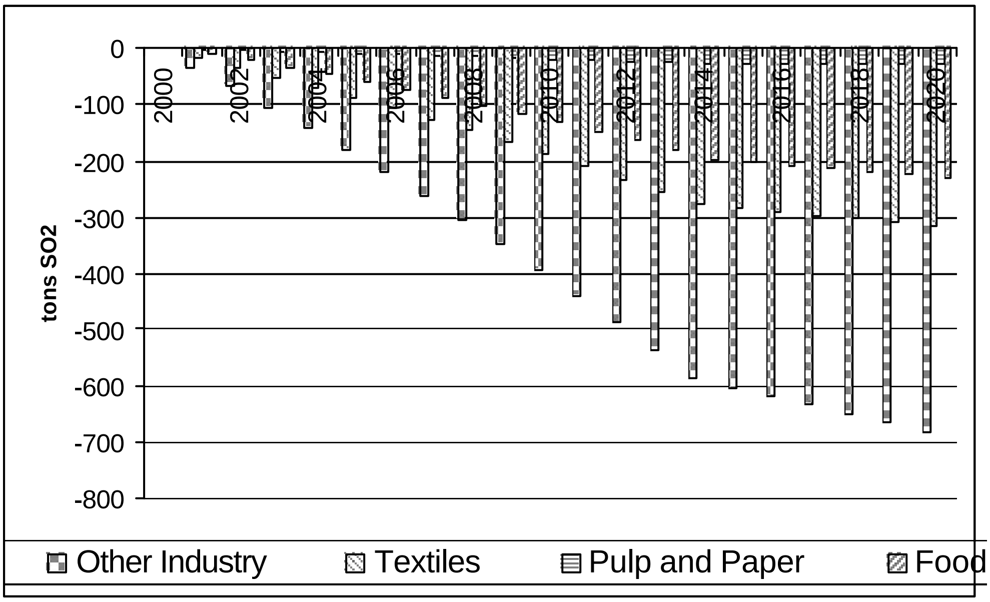

Figure 36: Local pollutant reduction in the Industrial sector under the Energy efficiency scenario

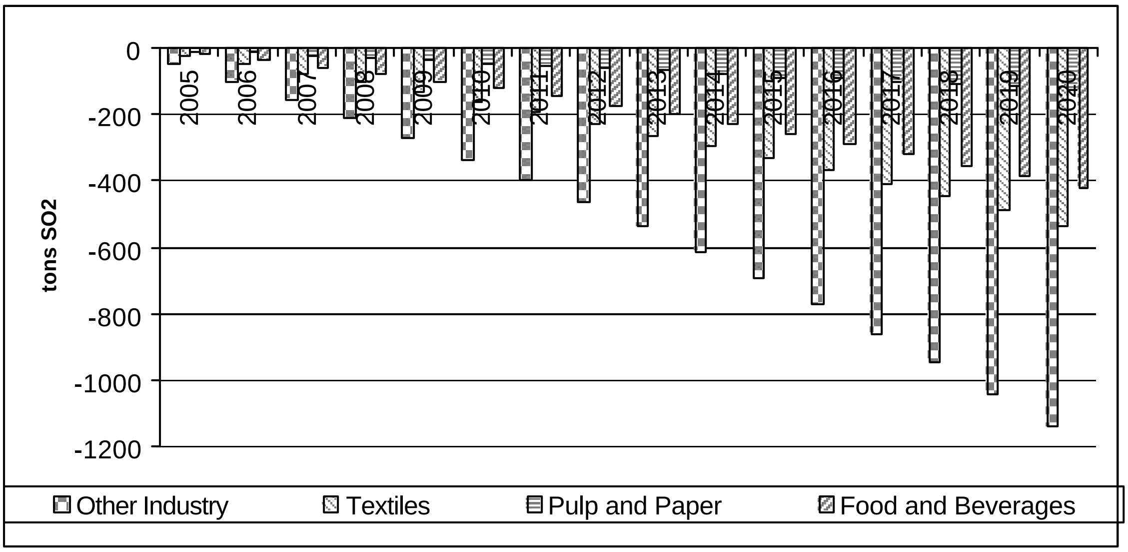

Figure 37: Local pollutant reduction in the Industrial sector under the Fuel Switching scenario

Table 24 below quantifies the energy and GHG savings from the scenarios considered in the industrial sector.

Table 24: Energy and GHG savings in the Industrial sector (2020)

	Efficient efficiency	*Fuel switching*
Energy saving at 2020	5872 TJ	204TJ
GHG saving at 2020 (CO_2 equivalent)	*1 206 418 tons*	*286 172 tons*

The national Integrated Energy Plan (DME 2003) found that energy efficiency, including fuel switching could lead to improved economic and environmental performance. Generating national scenarios, the plan projected:

> Energy efficiency measures are effective in both the 'business as usual' scenario (that resulted in cost savings of up to R62 billion and carbon dioxide savings of up to 294 million tonnes) and the Siyaphambili scenario (that resulted in a decrease in cumulative energy demand of 2981 PJ with a present value cumulative cost saving of approximately R75 billion over the planning horizon).

Future work on the cost implications of industrial energy efficiency and fuel switching at the municipal level is needed.

6.6 Electricity generation from renewable energy sources

Cape Town's target is to have 10% of electricity generation from renewable sources by 2020 (CCT & SEA 2003). Electricity generation in the base year was 10 232 GWh (36 835 284 GJ (CCT & SEA 2003)), which at an assumed 2% annual growth rate would reach about 15 000 GWh by 2020. The target of '10% renewable energy consumption by 2020' (CCT 2004) would therefore require approximately 1 500 GWh. We assume that this would be supplied by wind (as a proxy for local renewables), and that this resource is available 30% of the time. The capacity required to meet the target would be 571 MW by 2020.[7] That is equivalent to about 57 Darling wind farms! Of course the target could be met from other sources as well (some of which have higher availability), but this gives some idea of the challenge.

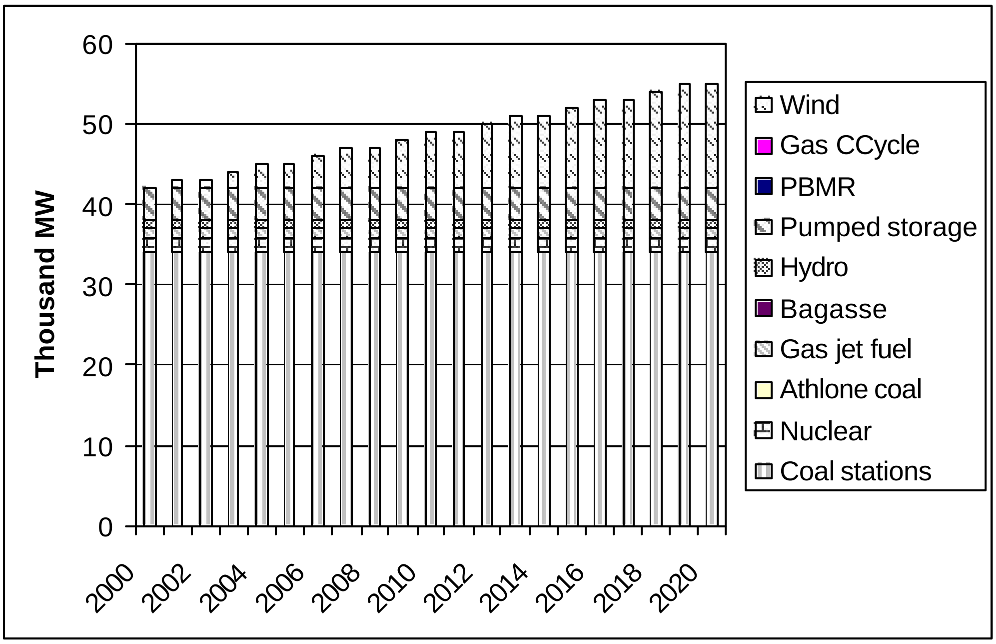

Figure 38: Shifting process shares to wind in the renewables scenario

In the LEAP database, process shares are set for the base year in proportion to the actual output in 2000. Coal-fired power plants contribute almost 90% in 2000, while there is no generation from wind. A renewable energy scenario is implemented to include a process share of wind rising to 10% by 2020, effectively displacing imports of coal-fired electricity.

The results of the scenario simulation show that the 10% renewable electricity target results in significant reductions in greenhouse gas (GHG) emissions. The emission in the reference case

7 In the LEAP model, to achieve 10% of generation, total national capacity includes 10% of wind, which is then scaled to meet only Cape Town demand. With the lower availability of wind, this requires much larger capacity of 13.5 GW.

(without any policy) are shown as a solid line in Figure 39, while those in the 'renewables' scenario are represented by the dotted line. Most of the emissions are in the form of CO_2, with a little reduction in N_2O.

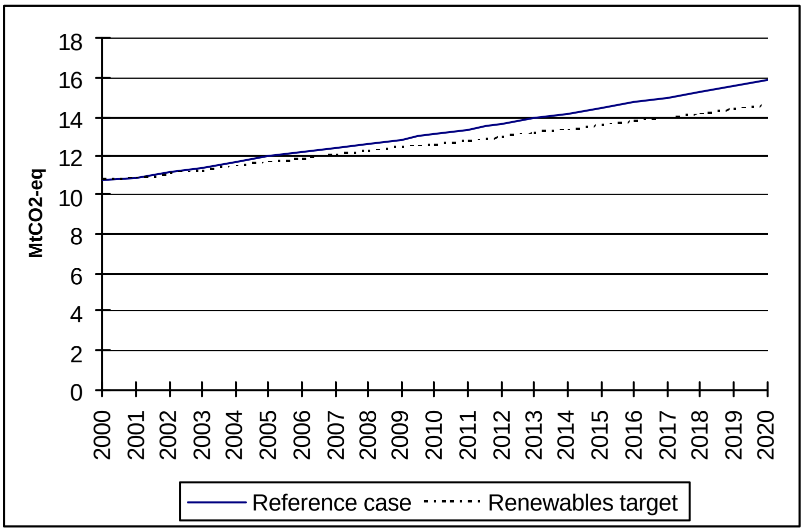

Figure 39: Avoided CO_2 emissions with renewables target compared to reference case

The difference between the two cases may seem relatively small, since the absolute amounts of emissions (in millions of tons of CO_2-equivalent) are large. Taking the emissions *reductions* (emissions in the reference case minus the emissions in the 'renewables' scenario), these are represented differently in Figure 40 – the units have now change to thousands of tons of CO_2-equivalent, and in the starting year the difference is zero.

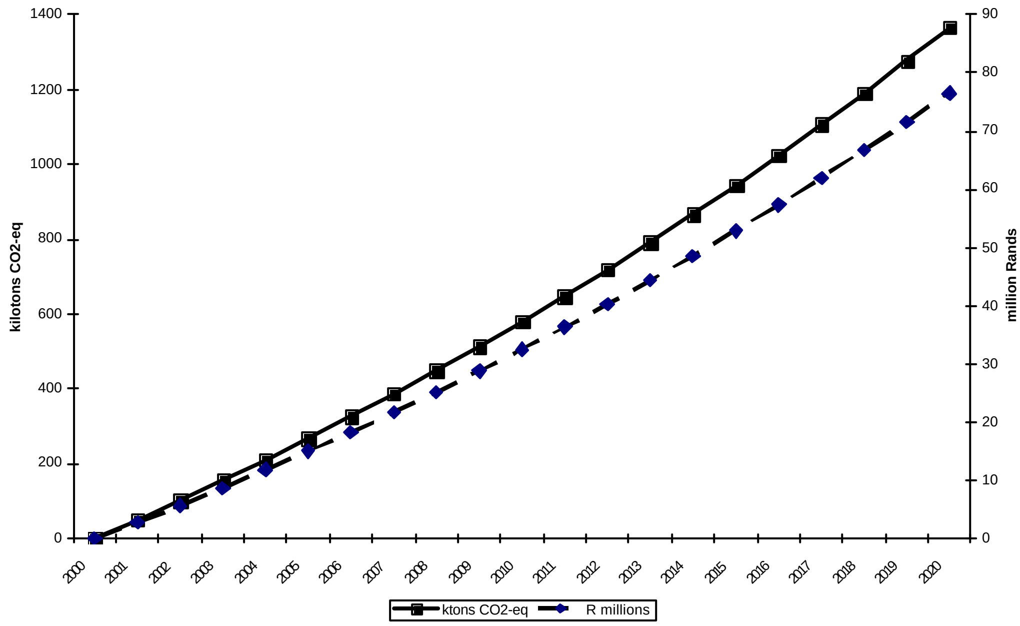

Figure 40: Emission reductions in CO_2 and possible carbon revenues @ €7 / tCO_2

Figure 40 on its second axis shows the potential carbon revenue that could be earned from such emissions reductions. This assumes a price of €7 / tCO_2, with the carbon price having risen after Russian ratification from the November 2004 'floor price' for credits from the Clean

Development Mechanism.[8] Over the twenty year period, the savings might add up to some R700 million.

Additional capital costs for the 571 MW are needed to meet Cape Town's 10% renewable energy target (from electricity). This study only conducted first-order estimates of the costs assuming R7650 / installed kW ($850 / kW (IEA 2003); R9 / $1, exclude integration with the transmission grid and assuming a 20 MW site). Under these assumptions, the capital costs would be R4 370 million. More detailed work on the costing is needed in future.

For this policy, no energy savings are reported since it is a supply-side intervention, assuming constant demand. There would be some impacts on local pollutants, but since most of these occur in Mpumlanga – where the coal-fired power stations are located – these are not reported here. GHG emissions, by contrast, have a global effect, so that it matters less where they are emitted.

7. Summary: comparing policies

This report assesses eleven policies that could change Cape Town's future energy development to a more sustainable path. The policies are summarised in Table 25, and described more fully sector by sector in section 6.

7.1 Summary of policies

Table 25: Description of energy policies for sustainable development in Cape Town

	Policy or measure	*Description*
Residential	Promoting solar water heaters	Solar water heaters are installed, replacing geysers in electricified households. Penetration rates are about 2% by 2005, rising to 10% in 2010 and 15% in 2020.
	Installing ceilings in RDP housing	Installing ceiling in low-cost housing reduces the need for space heating by 20%.
	Switching to CFLs	All electrified households shift from incandescent lights to CFLs by 2020
and government	Efficient lighting in commercial and government buildings	100% switch to CFLs and more efficient fluorescent tubes by 2020 – 10% of the latter are already efficient
	Savings in HVAC in commercial and government buildings	10% savings in heating, ventilation and air conditioning (HVAC) systems by 2020, driven by changes in user behaviour
Industry	Energy efficiency in industry	Industry in Cape Town the national target of 12% increase in energy efficiency by 2014. The improvements are likely to come from lighting, compressed air, motors, variable speed drives, improved boiler as well as steam system efficiency.
	Switching to natural gas in industry	50% of thermal energy currently supplied by coal in industry switches fuel to natural gas by 2020.
Trasnport	Modal shift from private to public rail	The share of public transport increases from 49% to 79% public by 2020, with a corresponding decline of private transport. The infrastructure costs implicit in this major change require separate analysis
	Petrol to diesel taxis	100% of taxis are diesel vehicles by 2020, due to taxi recapitalisation,
	Introducing bio-diesel and low-S diesel	In the *reference case:* Existing DEAT & DME strategy mandates low-sulpur diesel by January 2006 and very low sulphur (50 ppm) by January 2010 Biodiesel grows to a market share of 15% by 2020
Energy supply	Renewable electricity	an existing City of Cape Town target to have 10% of electricity generated from renewable energy sources by 2020

[8] Carbon prices are monitored by PointCarbon, www.**pointcarbon**.com.

We focus on these strategies because they are consistent with the broader policy goals of the City of Cape Town, and its effort to develop in a sustainable manner, for the welfare of all its people. These strategies combined could help the Cape Town realise the objectives set out in its Energy Strategy. The policy interventions address financial considerations – some have cost savings, others meet social or environmental goals cost-effectively. We have also considered whether policies can be implemented practically, balanced with some policies that would drive a long-term change in Cape Town's energy economy. Together, this basket of policies could help clean up the local environment *and* help address the global problem of climate change.

The analysis in this report outlines the implications of different policy scenarios or choices. Because policies are not implemented as packages, we have provided analysis for each policy. However, the LEAP framework ensures that total energy supply and demand match, avoiding double-counting that sometimes occurs with policy-by-policy analysis. The LEAP database and modeling tool is available for further analysis to those who wish to change assumptions or explore different policies (www.erc.uct.ac.za and http://forum.seib.org/leap/)

7.2 Energy savings

The *energy savings* which the different policies can achieve are reported in Table 26. This Table reports in common units (TJ = 10^{12} J or also 3.6 million kWh, for those more familiar with electricity units. Table 27 also reports the energy savings, but in units normally used for each fuel.

Table 26: Energy savings for each policy compared to the reference case

	Policy or measure	*Energy savings*	*TJ / year*							
		2000	*2001*	*2002*	*2003*	*2004*	*2005*	*2010*	*2015*	*2020*
Residential	Promoting solar water heaters	0	13	27	42	58	78	325	442	578
Residential	Installing ceilings in RDP housing	0	4	10	15	21	27	60	98	141
Residential	Switching to CFLs	0	89	183	283	389	501	1 093	1 787	2 598
Commercial	Efficient lighting in commercial buildings	0	46	94	145	198	253	573	972	1,466
Commercial	Savings in HVAC in commercial buildings	0	12	24	38	51	66	149	253	382
Government	Efficient lighting in government buildings	0	2	5	7	10	13	27	43	61
Government	Savings in HVAC in government buildings	0	1	1	2	3	3	7	11	16
Industry	Energy efficiency in industry	0	280	571	876	1 193	1 525	3 401	5 328	6 018
	Switching to natural gas in industry	0	0	0	0	0	10	66	136	222
Trasnport	Modal shift from private to public transport	0	1 200	2 600	3 900	5 300	6 800	14 500	23 000	32 500

	Petrol to diesel taxis	0	17	36	55	75	96	203	324	458
	Introducing bio-diesel and low-S diesel		-	-	-	-	-	-	-	-
Energy supply	Renewable electricity	no demand-side savings in a supply-side intervention								

Note: For space reasons, only selected years are shown – annual steps from 2000 to 2005, and thereafter in 5-year increments.

It is clear from the table that the largest energy savings can be obtained in the transport sector, in particular through shifting transport from private to public modes. This change implies not only large investment in infrastructure, but also changes in behaviour by commuters. Given that transport accounts for more than half of Cape Town's energy demand, it is not surprising that the largest potential energy savings are found in this sector.

Towards the end of the study period, the savings from industrial energy efficiency are also large, as are those to be made in commercial buildings. In both cases, efficiency can be achieved at cost savings as well – there are upfront costs to implement efficiency programmes, but they pay back their investment with a few years, sometimes even within months. Efficiency in industry can be achieved since there are relative few facilities (compared to transport or residential sectors). Creating more efficient buildings provides an opportunity for government to lead by example of its own buildings, with large savings to be made by the larger commercial sector. In the residential sector, the large numbers of lightbulbs that are replaced, together with significant savings per bulb, lead to thousands of TJ savings per year by the end of period.

Not only does Table 27 show the energy savings in more familiar units, but it also shows which fuels contribute to some of the large energy savings. Note, for example, large savings of LPG and coal in industry by total volume. In this comparison, however, the numbers cannot be compared since they have different scales and units.

Table 27: Energy savings in units appropriate to each policy

	Policy or measure	*Energy savings*									
		Units (per year)	*2000*	*2001*	*2002*	*2003*	*2004*	*2005*	*2010*	*2015*	*2020*
Residential	Promoting solar water heaters	GWh	0.0	3.6	7.5	11.7	16.1	21.7	90.3	122.8	160.6
	Installing ceilings in RDP housing	GWh	0.0	1.1	2.8	4.2	5.8	7.5	16.7	27.2	39.2
	Switching to CFLs	GWh	0.0	24.7	50.8	78.6	108.1	139.2	303.6	496.4	721.7
Commercial	Efficient lighting in commercial buildings	GWh	0.00	12.7	26.1	40.2	54.9	70.3	159.1	270.0	407.28
	Savings in HVAC in commercial buildings	GWh	0.00	3.3	6.8	10.5	14.3	18.3	41.4	70.3	106.00
Government	Efficient lighting in government buildings	GWh	0.00	0.64	1.31	2.01	2.75	3.52	7.47	11.89	16.83

	Savings in HVAC in government buildings	GWh	0.00	0.17	0.34	0.52	0.71	0.91	1.94	3.09	4.38
Industry	Energy efficiency in industry	Electricity (GWh)	0.00	54	110	169	231	295	668	1,058	1,197
		Wood (ton)	0.00	250	563	813	1,188	1 437	3 188	4 813	5 500
		LPG (thousand lt)	0.00	25 641	25 641	51 282	51 282	76 923	153 846	230 769	256 410
		Kerosene (thousand lt)	0.00	28	28	56	56	83	167	250	278
		Fuel Oil (thousand lt)	0.00	100	225	325	450	575	1,250	1 925	2 200
		Diesel (thousand lt)	0.00	1 108	2 243	3 405	4 622	5 892	12 730	19 486	21 946
		Coal (ton)	0.00	6 226	12 742	19 581	26 774	34 290	77 581	122 871	139 000
Trasnport	Modal shift from private to public transport	Million liters									
		Petrol	0.00	31	65	99	135	173	368	586	829
		Diesel	0.00	5	9	14	19	25	52	84	118
		Electricity (increase) (TJ)	0.00	50	110	170	230	300	630	1 000	1 410
	Petrol to diesel taxis										
		Petrol	0.00	5	10	16	22	28	60	95	135
		Diesel (increase)	0.00	-4	-9	-13	-18	-23	-49	-79	-111
	Introducing bio-diesel and low-S diesel										
		Petrol	-	-	-	-	-	-	-	-	-
		Diesel	0.00	3	6	9	12	16	34	55	79
		Biodiesel (increase)	0.00	-3	-6	-9	-12	-16	-34	-55	-79

7.3 Local air pollutants

The major sectors that reduce local pollutants are those that use fuels directly. Sectors relying mainly on electricity, such as office and government buildings, produce little local pollution – the impacts are felt upstream in the power stations. Table 28 shows potential reductions by key policy in the transport and industry sectors, both of which use significant amounts of other fuels.

Table 28: Savings in local pollution from policies in transport and industry (tSO_2)

	2005	*2010*	*2015*	*2020*
Modal shift	13	24	39	55
Petrol taxis	19	40	64	90
Industrial efficiency by sector				
Other industry	181	393	604	683
Textiles	88	188	284	315
Pulp and paper	10	20	27	27
Food and beverages	60	131	203	231
Note: positive numbers reflect savings, or reductions in local pollution				

A few policies also reduce total suspended particulates (including particulates of different size, PM-10, PM-5 and PM-2.5), notably the modal shift in transport. Smaller reductions are seen in Table 29 for installing ceilings in the residential sector and the efficiency improvements in industry.

Table 29: Reductions in total suspended particulates (TSP) from key policies

	2005	*2010*	*2015*	*2020*
Transport modal shift	213.339	452.901	721.102	1 020.56
Residential ceilings	0.064	0.138	0.223	0.321
Industrial efficiency gains of 12%	0.172	0.376	0.579	0.657
Note: positive numbers reflect savings, or reductions in local pollution				

7.4 Greenhouse gas implications

The *environmental effectiveness* of the individual policies has been examined in section 6, both for local pollutants (such as SO_2), as well as global GHGs, such as CO_2. Figure 41 shows that GHG emissions from the different sectors – with emissions from electricity associated with demand sectors – show fairly even contributions.

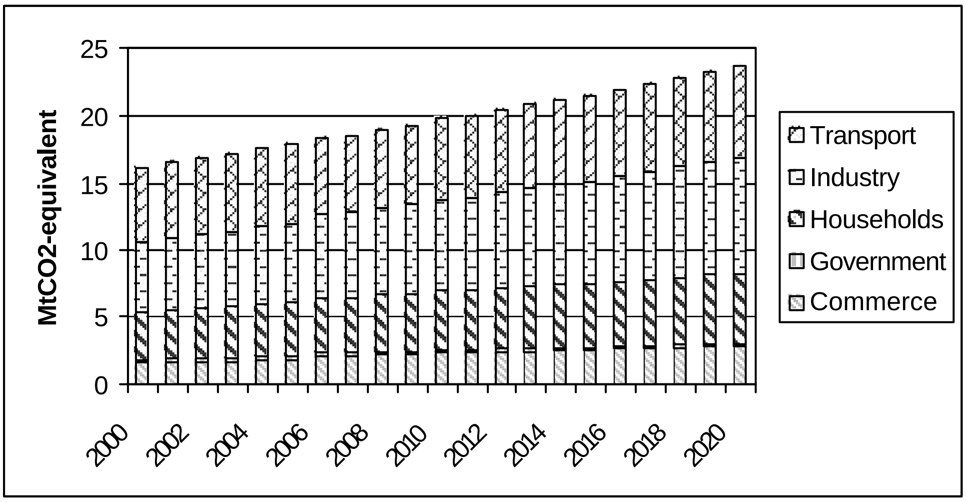

Figure 41: GHG emissions attributed to demand sectors

The potential for emissions reductions, however, follows the pattern of the energy savings. Table 30 shows the potential reductions, comparing the emissions in the reference case to those if all policies are implemented. The potential in the transport sector is of a different order of magnitude than that in other sectors. However, it needs to be borne in mind that emissions from transport come from thousands of mobile sources, and that implementing emissions control is not a simple task.

Table 30: Potential emission reductions by sector (tCO_2-equivalent)

	2001	*2006*	*2011*	*2016*	*2020*
Commerce	41	134	240	339	415
Government	3	17	28	37	43
Households	53	315	544	743	882
Industry	28	428	763	1079	1317
Transport	72 240	481 685	937 527	1 447 716	1 898 308

7.5 Cost comparison

Policies focusing on greater efficiency lead not only to energy savings, but also to cost savings. Table 19 and Table 20 showed that cost savings in the commercial and government sectors were possible from tens to hundreds of millions of rands by 2020. Implementing efficient lighting in the commercial sector alone could save R144 million by the end of the period.

The cost savings in the commercial sector consider the capital costs of replacing existing lights with more efficient ones, but these are more than off-set by the energy bill savings. HVAC systems are an example of pure cost savings, as these are initiated by behaviour change rather than capital expenditure on equipment.

Several interventions in the residential sector are associated with cost savings, due to reduced expenditure on energy. Solar water heaters in electrified low-income households, for example, can reach 33.5% savings on costs of heating water, and in upper-income brackets it can be as high as 43%. CFLs get large savings per unit (a quarter to a fifth of the energy consumption of incandescents) on running costs. This offsets the higher initial costs within the life-time of the appliance. Cost savings from CFLs are aggregated across large numbers of lightbulbs. Ceilings installed in low-income houses (both electrified and nonelectrified can achieve costs savings of about 20% of the space heating budget.

There would be relatively small, but significant cost savings to low-income households from energy efficiency measures. Installing just two CFLs per household would give an energy saving of about 16 kWh per household per month in 2001, which at a tariff of 40c/kWh translates into an annual saving of R75 for each household. If the additional capital costs of CFLs (now reduced to about R15 for CFLs against R3 for incandescents) could be financed by the city or international sources, there would be savings for poor households. As more lights are replaced per household, these savings will increase linearly.

To implement the above efficient lighting scenarios would require slightly increased capital budgets initially, but these capital costs would quickly (within one year) pay themselves back in energy savings, thus (theoretically) making funds available to continue the lighting retrofit with efficient options.

Although the costs for the transport policies have not been included, the implications are obvious. Due to the size of the transport sector massive savings in energy and global and local pollutants are possible.

A rough first-order estimate of the capital costs of implementing the renewable energy target is R4 370 million. However, given current carbon prices, some the emissions reduction might generate revenue over 20 years of R700 million. These would be 17% of the total capital costs of wind – future work should look at the incremental costs (i.e. wind capital costs minus coal capacity) and take into account a number of other factors, e.g. energy costs, discount rates and changes of technology costs over time.

8. Conclusions and recommendations

- **Policies can make a difference to energy consumption in Cape Town**

The energy scenarios examined in this study generally show energy consumption rising as economic activity (GGP) and population increase. However, significant energy savings are possible *relative to business-as-usual*. Unsurprisingly, since transport currently accounts for 54% of energy consumption, the biggest energy savings potential lies in this sector. By far the largest savings can be gained by shift from private to public transport modes.

- **Major energy savings can be made from modal shifts in the transport sector and with efficient lighting**

Savings of 1200 TJ / year, equivalent to 36 million litres of petrol and diesel in the first year.[9] Switching to more efficient lighting can result in substantial savings in several sectors (see Table 26), adding up to 38 million kWh in 2001. Energy savings are important to the City, since it depends on imports of both electricity and liquid fuels.

- **Energy efficiency saves money over the life of the intervention**

Efficient lighting in the commercial sector can save R144 million over the period. More efficient heating and air conditioning could save R32 million in the commercial sector, and R1.3 million in government buildings.

- **Energy bills for poor households can can reduce energy bills for poor households**

The significance of savings in the residential sector is that is low-income households can save on their energy bills. Each household could save R75 per year just by installing two CFLs. The payback periods for ceilings and SWHs would be longer. Local government should consider subsidising the capital costs of these interventions for poor households. The potential for SWHs is largest in medium-to-high-income households, where electric geyser constitute the largest single use of electricity. These households should be able to afford the upfront costs.

- **Implementing the city's renewable energy target will have significant costs, which can be partly off-set by selling carbon credits**

The estimated *total* capital costs of implementing the renewable energy target is R4,370 million. These are total costs, and should in future be compared to the costs of the alternative, e.g. building a

9 However, electricity use increases 50 TJ with the modal shift.

coal-fired power station. The reduction of GHG emission could earn the city revenues of R700 million over 20 years – about 17% of the total capital costs.

- **Targeted interventions can reduce local air pollution**

Cape Town has long suffered from the problem of brown haze'. Policy interventions can address the problem of local air pollution – notably improved public transport infrastructure will be key in making a modal shift possible. In 2020, a shift to public transport saves 1021 tons of particulates. Total reductions of SO_2 are 1400 tSO_2 by 2020, most of which comes from industry (see Table 28).

- **Cape Town can become a leader in addressing greenhouse gas emissions**

Cape Town has already set a forward-looking target for renewable energy. The scenario modeling shows that this policy could save 49 $ktCO_2$-equivalent in 2001 already. A surprising result is that transport policy can result in even larger savings in the same year, of 72 ktCO2-eq. While these interventions require substantial investment in energy and transport infrastructure, they would enable Cape Town to become leader in addressing a critical global environmental problem – in line with its goals as a member of the Solar City initiative (Appendix B).

- **Some policies are viable in terms of costs, social benefits and the environment**

CFLs in residential, commercial and government sectors and HVAC in commerce and government stand out as policies that have benefits from every angle, and should be implemented at scale immediately.

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Appendix A: Detailed assumptions for commercial sector

TYPICAL COMMERCIAL FACILITY PROFILE

Tot users: 34337

Av elec use p.m. 3913 kWh

Service	*% of tot*	*Appliance*	*% of tot*	*GJ/yr*	*Appl demand*	*Units*	*Hrs/day*	*Units/yr*	*Conver-sion*	*GJ/yr ea*	***No Appliances***	***No appl /user***	***Units/ bldg***	
Lighting	38%	Incand	13%	767 070	0.10	kW	8	176.000	3.6	0.6336	1 210 654	35.3	6205.4	kWh
		Fluorescent	25%	1 557 385	0.040	kW	8	70.400	3.6	0.25344	6 144 987	179.0	12598.9	kWh
HVAC	38%	Aircons	38%	2 324 456	1.000	kW	8	1 760.000	3.6	6.336	366 865	10.7	18804.3	kWh
Other	24%	Other elec	19%	1 162 228	1.000	kW	8	1 760.000	3.6	6.336	183 432	5.3	9402.1	kWh
		Other LPG	5%	305 849						305 849	34337		8.9	GJ
TOT	100%		100%	6 116 989										

TYPICAL GOVERNMENT FACILITY PROFILE (excl govt transport)

Tot users: 100 (guess – actual number not known)

Service	*% of tot*	*Appliance*	*% of tot*	*GJ/yr*	*Appl demand*	*Units*	*Hrs/day*	*Units/yr*	*Conversion*	*GJ/yr ea*	*No Appliances*	*No appl /user*	*Units/ bldg*	
Bldg Lighting	40%	Incand	13%	38 599	0.10	kW	8	176.000	3.6	0.6336	60 921	609.21	107220.7	kWh
		Fluorescent	27%	78 369	0.040	kW	8	70.400	3.6	0.25344	309 219	3092.19	217690.4	kWh
Bldg HVAC	40%	Aircons	40%	116 968	1.000	kW	8	1 760.000	3.6	6.336	18 461	184.61	324911.1	kWh
Bldg Other	20%	Other elec	20%	58 484	1.000	kW	8	1 760.000	3.6	6.336	9,230	92.30	162455.6	kWh
		Other LPG	0%	0										
BLDG TOT	100%		100%	292 420										
Streetlights		Streetlights		362 110										
Water supply & treatment		Water supply & treatment		79 700										
GOVT TOTAL				734 230										

Appendix B : Cape Town a Solar City member

The City of Cape Town is likely to become a Solar City member, following recent attendance at the First International Solar Cities Congress in November. The goal of the Initiative is to support energy and climate policies by stimulating the interest of cities into becoming benchmark cities that commit to ambitious emission reduction goals. ISCI will support this goal by:

1. Developing recommended agreed targets for emissions reduction by 2050.
2. Encouraging participant cities to use backcasting planning from the 2050 target to assess the appropriateness of interim targets and projects.
3. Providing a forum for the exchange of scientific and technical knowledge, developed by high-level experts in the field of renewable energy and cooperating urban planners, though journals, electronic media, and conferences.
4. Creating international technical standards for baseline studies, and a scientifically acceptable modelling framework for the unbiased comparison of different technical and policy measures.
5. Assisting the development of regional and international projects and educational programs to implement renewable energy and energy efficiency, by playing an active role in the realization of the Rio resolution through the creation of world-wide cooperation in equitable sustainable development.
6. Assisting member cities in the coordination of global emission targets with other social, economic and environmental goals.
7. Encourage cities to participate in new business opportunities created through the use of advanced emissions reduction techniques.

Appendix C: Notes on bituminous coal

Bituminous coal is the most common form of the fossil fuel in South Africa. This has been used as the coal type for electricity generation and industrial use, with heat value and chemical composition adjusted to assumed Eskom data. There are also deposits of anthracites and 'lean' coal.

Estimates of coal reserves vary, with Pinheiro estimating a life-span of 139 to 151 year from 2000 (1999: 31). This is based on a reserve estimate of 39.2 Gt coal by DME in 1997. With rates of extraction (1990-99), 151 years remain; at the 1997 rate, 139 years (Pinheiro 1999: Table 14).

The calorific value of bituminous coal varies considerably (e.g. Arnot 23.08 MJ /kg; Matla 20.48, Duvha 21.85); but washed export coal from Secunda at 28.42 MJ/kg. Most bituminous coal is used for electricity generation and in industrial boilers. On the other hand, earlier statistical yearbooks (Eskom 1995) reported average gross calorific values at their coal-fired power stations declining from a high of 22.96 MJ/kg in 1956 to a low of 19.95 MJ/kg by 1995. Eskom environmental reports it declining from 19.84 in 1998 to 19.42 in 2001 (Eskom 2002). Yet again, Eskom environmental statistics report 189.3 TWh of electricity produced by stations, or 681.5 TJ and 92 million tons of coal burnt (Eskom 2000b). Using the reported average efficiency of 34.1%, that works out to a calorific value of 21.72 MJ/kg. For the purposes of this study, we use the average calorific value reported by Eskom for 2000, that is 19.50 MJ/kg (Eskom 2002).

The carbon content of SA bituminous coal is taken as only 54%, lower than usual for bituminous coal (often 74%). Pinheiro reports differing percentages carbon for various collieries associated with power stations (on an air-dry basis; there are also figures on a dry, ash-free basis but presumably it's more accurate to take it with ash since the composition of ash is included) (Pinheiro 1999).

The ash content is high around at 28.6% and sulfur content is 0.93% (Eskom 2002) with sulphur retention assumed to be 30% . The fraction oxidised is assumed to be 98% (see LEAP Fuels and 'Assumed data Eskom plants.xls').

Appendix D: Evaluation matrix used to select policies to include in LEAP scenario modelling

Note for following tables

Weight: 1 = low, 5=hi

Areas of concern:	*Practical*			*Financial & economic*		*Welfare/ equity*	
Strategy area	*Political support exists*	*Admin requirements can be accomodated*	*Data availability adequate*	*Cost effective for local authority in short term*	*Economic growth stimulus*	*Impact positively on poor household energy situation*	*Job creation*
Area of concern weighting	4	4	4	3	4	5	5
RESIDENTIAL							
	3.8	2.6	4.6	2.4	3.0	3.8	3.4
SWHs	5	1	5	2	4	2	5
ceilings	5	3	5	2	3	4	4
CFLs	5	4	5	4	2	3	2
house construction	3	2	4	1	3	5	3
Electrical appliance use (reduced indoor pollution etc)	1	3	4	3	3	5	3
COMMERCE							
Efficiency	3.0	2.0	4.0	3.0	3.0	3.0	2.0
Appliances (lighting, aircons...)	2	2	4	3	3	3	2
Building efficiency	4	2	4	3	3	3	2
GOVERNMENT (Commerce sub-category)							
Efficiency	3.5	2.0	4.0	5.0	3.0	3.0	2.0
Appliances (lighting, aircons...)	2	2	4	5	3	3	2
Building efficiency	5	2	4	5	3	3	2
INDUSTRIAL							
Efficiency	3	4	3	3	5	3	2
Fuel switching	2	4	4	3	3	3	2
TRANSPORT							
Average	4.3	3.0	3.0	3.7	3.0	3.3	3.0
Modal shift	4	2	2	3	4	4	3
Private vehicle use							
Public transport use							
Bicycles, pedestrians							
Vehicles – technical	4	3	3	4	3	3	3
Cleaner fuels							
Alternative fuels							
More efficienc t consumption							
Catalytic converters							
GOVERNMENT (Transport sub-category)	5	4	4	4	2	3	3
vehicle efficiency							
alternate fuels							
ELECTRICITY SUPPLY							
	4.4	3.6	4.4	2.8	3.4	3.4	3.2
Connecting informal households (done!)	5	5	5	2	3	5	4
Peak reduction	3.5	3.0	4.5	4.0	3.0	3.0	2.0

Areas of concern:	*Practical*			*Financial & economic*		*Welfare/ equity*	
Strategy area	*Political support exists*	*Admin requirements can be accomodated*	*Data availability adequate*	*Cost effective for local authority in short term*	*Economic growth stimulus*	*Impact positively on poor household energy situation*	*Job creation*
Tariffs (ToU)	3	1	4	4	3	3	2
Geyser ripple control	4	5	5	4	3	3	2
Including renewables in supply mix	5	2	4	1	4	3	4
Natural gas generation at Athlone power station	5	5	4	3	4	3	4

Areas of concern:	*Environmental*		*Other*		
Strategy area	*Reduced local air pollutants*	*CO_2 reduction potential*	*Roll-out feasibility / catalytic value*	*Profile/ visibility for LA of measures*	*SCORE Average weight*
Area of concern weighting	4	3	4	3	
RESIDENTIAL					
	3.4	4.4	4.2	2.8	3.5
SWHs	2	5	5	4	3.63
ceilings	4	4	5	3	3.88
CFLs	2	4	5	4	3.56
house construction	4	5	3	2	3.26
Electrical appliance use (reduced indoor pollution etc)	5	4	3	1	3.26
COMMERCE					
Efficiency	1.0	4.0	4.0	3.0	2.9
Appliances (lighting, aircons...)	1	4	4	3	2.77
Building efficiency	1	4	4	3	2.95
GOVERNMENT (Commerce sub-category)					
Efficiency	1.0	4.0	4.0	5.0	3.2
Appliances (lighting, aircons...)	1	4	4	5	3.05
Building efficiency	1		4	5	3.05
INDUSTRIAL					
Efficiency	4	5	4	4	3.56
Fuel switching	5	4	4	3	3.33
TRANSPORT					
Average	4.7	4.3	3.7	4.3	3.61
Modal shift	5	4	3	4	3.44
Private vehicle use					–
Public transport use					–
Bicycles, pedestrians					–
Vehicles – technical	5	5	3	4	3.56
Cleaner fuels					–
Alternative fuels					–
More efficienct consumption					–
Catalytic converters					–
GOVERNMENT (Transport sub-category)	4	4	5	5	3.84
vehicle efficiency					–
alternate fuels					–
ELECTRICITY SUPPLY					
	3.4	2.2	4.0	4.0	3.6

Areas of concern:	*Environmental*		*Other*		
Strategy area	*Reduced local air pollutants*	*CO_2 reduction potential*	*Roll-out feasibility / catalytic value*	*Profile/ visibility for LA of measures*	*SCORE Average weight*
Connecting informal households (done!)	4	1	5	5	4.12
Peak reduction	3.0	1.0	5.0	3.0	3.2
Tariffs (ToU)	3	1	5	2	2.84
Geyser ripple control	3	1	5	4	3.53
Including renewables in supply mix	3	5	3	5	3.53
Natural gas generation at Athlone power station	4	3	2	4	3.74