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Policies and scenarios for Cape Town's energy future: Options for sustainable city energy development

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Abstract
This study examines a set of energy policy interventions, which can make a major contribution to sustainable development for the City of Cape Town – economically, environmentally and socially. Major energy savings can be made from modal shifts in the transport sector, and with efficient lighting. The savings make a contribution to economic development, by freeing up resources. The savings from energy efficiency also have important social benefits in energy savings, reducing energy bills for poor households. From an environmental point of view, implementing the city's renewable energy target will have significant costs, but these can be partly off-set by selling carbon credits through the Clean Development Mechanism, and will result in indirect health benefits. Targeted interventions can reduce local air pollution, and help Cape Town become a leader in addressing greenhouse gas emissions.

Apart from examining the social, economic and environmental dimensions of each policy, this paper compares policies to one another. Of particular interest for sustainable energy development are those policies which are viable in terms of costs, social benefits and the environment. Compact Fluorescent Lamps (CFLs) in residential, commercial and government sectors and heating ventilation and air conditioning (HVAC) in commerce and government sectors stand out as policies that have benefits from every angle.

The paper builds on previous work done on the 'state of energy' for Cape Town and develops a tool that can paint a picture of what might happen to energy in the future. Using the Long-Range Energy Alternatives Planning (LEAP) modelling tool, a set of energy policies have been simulated.

Keywords: energy use patterns, Cape Town, energy policy, energy savings, energy development, sustainable development

1. Introduction

Policies can make a difference to future energy scenarios in Cape Town. In this paper, the authors examine a range of interventions and examine how these would change energy development – the supply and use of energy, the environmental impacts, some costs and the potential for savings.

To do this, this study developed several scenarios for Cape Town's energy future. The simulation model, the Long-Range Energy Alternatives Planning (LEAP) system, was used to simulate how energy might develop in Cape Town over the twenty years from 2000 to 2020. We focus on eleven policies – short-listed from a longer inventory – that 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 Cape Town realise the objectives set out in its Energy Strategy. We examine the implications for economic, social and environmental dimensions.

The paper 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. Developing quantified scenarios for the future can help to plan more effectively for Cape Town's energy future.

The paper is structured into three major parts. First, the energy use patterns in Cape Town are reviewed by different sectors – residential, industry, commerce and transport. A brief review of energy supply and imports completes the first section. Secondly, we develop a reference scenario of how energy patterns might evolve over the next 20 years without new policy. The focus of the paper lies in the third part, which deals with energy policies that can make a difference. Implications for energy savings, environmental impacts – local and global air pollutants – and costs are analysed. The conclusion summarises the major policy implication for planning a more sustainable path for Cape Town's energy development.

2. Energy use patterns in Cape Town

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

The first step in developing energy scenarios for different interventions was to quantify the current energy use and supply 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.

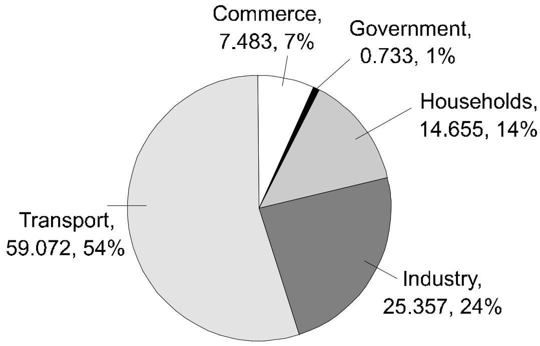


Figure 1: Demand for energy by sector, shares in 2000

2.1 Residential

Households consume approximately 14% of the city's total energy , which is equally shared between low and medium to high-income households. Approximately 2% of the city's houses on formal sites are currently unelectrified[1] – with the unelectrified households being mostly informal dwellings and backyard shacks (Ross 2004). Although low-income electrified households move to using electricity predominantly, multiple fuel use remains a feature of these households (paraffin, candles, electricity etc) (Mehlwana & Qase 1999), whilst medium-to-high-income households use electricity almost exclusively.

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

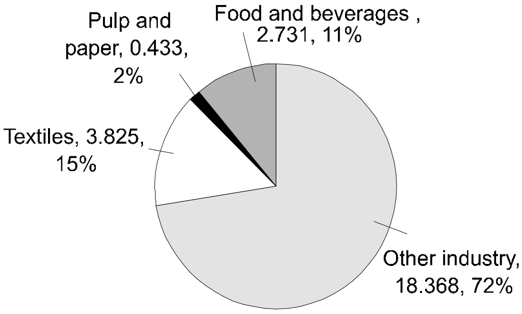
Table 1: Residential energy consumption by end use (TJ), 2000

	Low-income electrified h'holds	*Low-income non-electrified h'holds*	*Med-to-high-income h'holds*
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 (PJ = 10^{15} J). The large energy users in 'other' Industry, which consumes most of the energy, are companies producing plastic, glass, cardboard, packaging, cement and metal works.

Table 2 gives the fuel use of the industrial sector in 2000. Most of the energy used comes from electricity, which is used for lighting, driving motors for instance in fans or pumps and for heating and cooling. The other fuels supply thermal heat largely in



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

Figure 2: Energy consumption of industrial sub-sectors

boilers. Nationally, electricity forms a lower percentage of fuel use in the industrial sector than is the case for Cape Town.

Table 2: Industrial fuel use in 2000 (PJ)

Electricity	*Coal*	*Fuel oil*	*Kerosene*	*LPG*	*Wood*	*Diesel*
16.198	3.306	4.478	0.671	0.057	0.499	0.146

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.

Table 3: Total commercial sector energy use by fuel (TJ), 2000

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

Commercial buildings use energy mainly for lighting and air conditioning (HVAC).

The government sector is treated separately to the commercial sector, although many energy use characteristics are similar. Office buildings dominate this energy use profile, and electricity is by far the major energy source. There are a large number of other installations – 20 waste water treatment works, 15 water treatment plants, 6 landfill sites, 20 clinics, a number of libraries, pump stations, government garages, electricity depots, etc. 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.

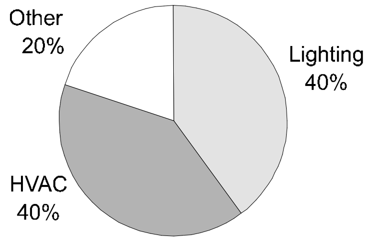


Figure 3: Commercial electricity consumption by end use, 2000

2.4 Transport

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 as not being part of the 'local' transport profile. 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.

Table 4: Total passenger transport energy use by vehicle type (PJ), 2000

Passenger transport	PJ
Petrol vehicles	40.2
Diesel vehicles	8.8
Public rail (electric)	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**

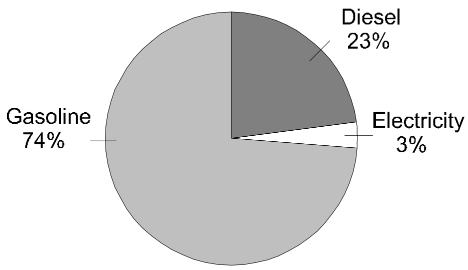


Figure 4: Percentage total transport energy use by fuel, 2000

The passenger sector is dominated by the energy intensive private transport sector, while the public transport sector only occupies 48.6% of the energy share. Although the energy consumption of public rail is low, it is still the backbone of public transport in Cape Town and it is still the most energy efficient mode of transport in terms of the energy expended per passenger-km.

Most freight transport in Cape Town is done by road, with diesel being the predominant fuel.

3. Where Cape Town gets its energy supply from

Most of the analysis in this work is focused on the demand side, but demand has to be met by supply. Electricity generation is included in the supply section. Apart from ensuring that the energy system balances supply with demand, 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.

3.1 Electricity generation

Local air pollution is the result of emissions within Cape Town. The local coal-fired power station, Athlone, potentially 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. Electricity is unique in that the GHG emissions occur in a different place to consumption of electricity – they do not form part of the 'local emissions' for Cape Town. However, it is standard practice (IPCC 2000, 2001) to attribute the emissions at power stations to the users of electricity. Hence, there are emissions factors per kWh consumed. Cape Town imports most of its power. 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. Some 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 nuclear power station is treated as a national power station, for two reasons – its operation is not under the control of the city (unlike Athlone); and to avoid creating the impression 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 2000).

The generic coal-fired power station thus generates all the electricity of Eskom and municipal power stations, 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 . The maximum capacity factors were from the same NER stats (weighted average of Eskom, municipal and private for coal), and the national integrated resource plan (NER 2000).

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 was 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%,[2] 11 627 GWh of electricity generation is required. Total electricity generation, excluding Athlone, was 198 140 GWh (NER 2000). Key parameters for electricity generation are summarised in Table 5. 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).

As can be seen in Table 5, wind, combined cycle gas turbines and the nuclear PBMR plants were included in the LEAP modelling exercise as potential future supply options, but without any capacity or base year output (to reflect the status quo).[3]

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 5). Production figures for Calref indicate that the output exceeds the demand within Cape Town. The main data source for Caltex was work done for the Integrated Energy Plan (DME 2003).

The efficiency used in LEAP (94.2%) was calculated taking own use into account. The refinery was

Table 5: Electricity generation: summary of data assumed for the LEAP current accounts (2000)

Plant type	*Capacity (MW)*	*Base year output (GWh)*	*Efficiency (%)*	*Annual load factor – % (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

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.

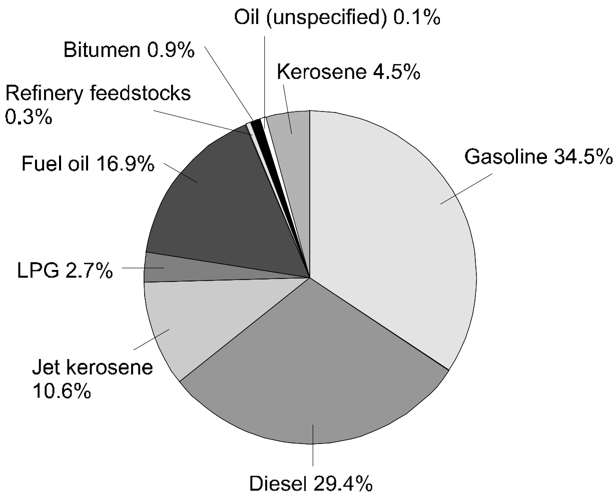


Figure 5: Share of outputs of Caltex refinery
Source: Work done for DME 2003

4. Current trends in energy development

The previous section has outlined the current status of energy use patterns. To shift to a future-oriented analysis, we first examine what Cape Town's energy development might look like *without* new policy. In the LEAP modelling exercise, this means creating a reference case, often also known as the business-as-usual (BAU) scenario. In the following section, new energy policies are compared to this reference case. BAU is strongly influenced by drivers such as economic and population growth.

Drivers of the BAU scenario are taken from the City of Cape Town's publication on its economy: *Current trends and future perspectives* (CCT 2001). It reported a gross geographic product (GGP) of R85.9 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 6: Status of key drivers of energy development

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

Without any policy interventions, Cape Town's energy future would be driven by these factors. In the reference scenario, the household sector grows by household size. 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).

A noticeable trend is the increase in consumption of electricity and liquid fuels (especially petrol / gasoline) over the period. The replacement of diesel by low-sulphur versions can also clearly be seen in Figure 6. This change is already an existing policy commitment.

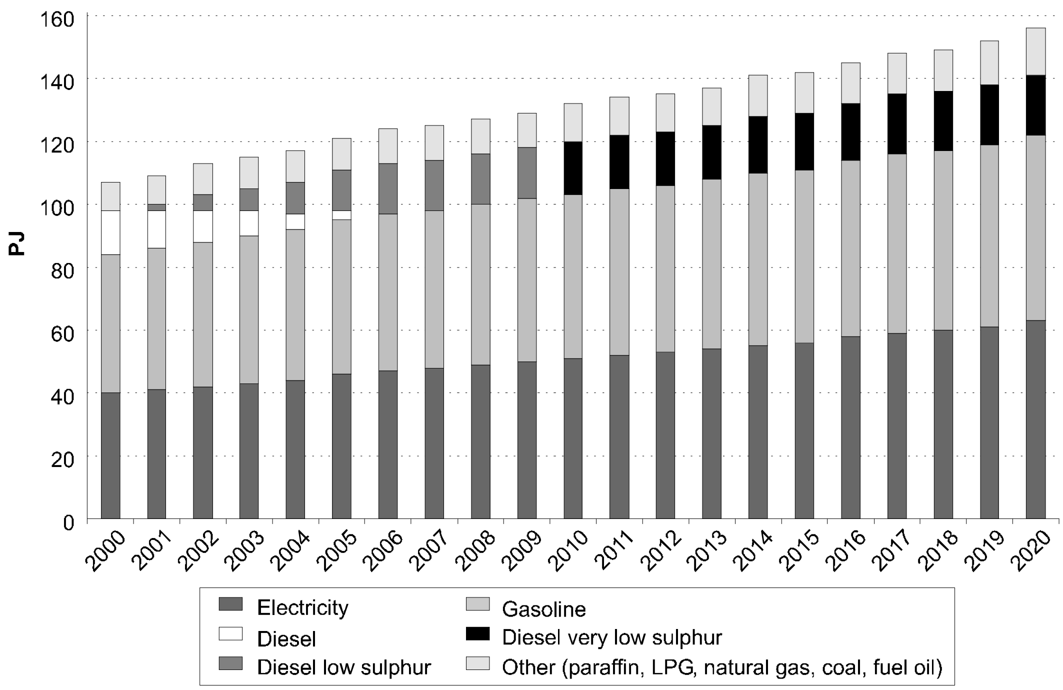


Figure 6: Energy demand in the reference case

5. Forward-looking energy policies

Having examined the BAU or reference scenario, which simply continues current energy development trends, this section shows how targeted interventions and energy policies can change Cape Town's energy future.

The policy interventions to be explored in LEAP were selected 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 practical 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 policy interventions were subject to this selection process (see details in the full report).[4] The selection process results are below:

- In the *residential* sector, implementation of solar water heaters, installation of ceilings and a widespread 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;[5] and 10% savings in heating, ventilation and air conditioning (HVAC) systems by 2020, driven largely 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.
- 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 bio-diesel 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.

This paper focuses on eleven policies that could change Cape Town's future energy development to a more sustainable path. The policies are summarised in Table 7, and described more fully sector by sector in Section 6 of the full report.[6]

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. 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

Table 7: 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 electrified households and thus reducing the amount of electricity used for water heating, one of the largest energy uses for 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. Energy savings of 20% compared to the reference case are possible.
Switching to CFLs	All electrified households shift from incandescent lights to CFLs by 2020. CFLs use far less energy for the same amount of light, and last longer.
Commercial 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. Significant further cost savings are possible.
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. Using HVAC more carefully saves costs and energy.
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 from fuel to natural gas by 2020. Gas burns cleaner and appliances typically have higher efficiencies.
Transport	
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 same number of people can be moved with less energy. 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. Diesel vehicles have better fuel efficiency (l / 100 km).
Introducing bio-diesel and low-S diesel	In the reference case: Existing DEAT & DME strategy mandates low-sulphur diesel by January 2006 and very low sulphur (50 ppm) by January 2010, lowering SO_2 emissions. 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

LEAP modelling framework ensures that total energy supply and demand match, avoiding double-counting that sometimes occurs with policy-by-policy analysis.

5.1 Energy savings

Many of the policies outlined above improve efficiency.[7] Using less energy to deliver the same level of service means energy savings. Since energy costs money, these savings translate into cost savings as well – which we report later in the cost comparison.

The annual *energy savings* which the different policies can achieve are reported in Table 8. This table reports in common units (TJ = 10^{12} J) or 3.6 million kWh, for those more familiar with electricity units. Common units enable a direct comparison across policies using different fuels – e.g. the impact of saving litres of petrol to reducing electricity consumption.

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, and the public transport system is known to be inadequate at present, it is not surprising that the largest potential energy savings are found in this sector.

Table 8: Annual energy savings for each policy compared to the reference case

Policy or measure	*Energy savings TJ / year*					
	2000	*2001*	*2005*	*2010*	*2015*	*2020*
Residential						
Promoting solar water heaters	0	13	78	325	442	578
Installing ceilings in RDP housing	0	4	27	60	98	141
Switching to CFLs	0	89	501	1 093	1 787	2 598
Commercial						
Efficient lighting in commercial buildings	0	46	253	573	972	1,466
Savings in HVAC in commercial buildings	0	12	66	149	253	382
Government						
Efficient lighting in government buildings	0	2	13	27	43	61
Savings in HVAC in government buildings	0	1	3	7	11	16
Industry						
Energy efficiency in industry	0	280	1 525	3 401	5 328	6 018
Switching to natural gas in industry	0	0	10	66	136	222
Transport						
Modal shift from private to public transport	0	1 200	6 800	14 500	23 000	32 500
Petrol to diesel taxis	0	17	96	203	324	458
Introducing bio-diesel and low-S diesel		-	-	-	-	-
Energy supply						
Renewable electricity	no demand-side savings in a supply-side intervention					

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 net cost savings as well – there are upfront costs to implement efficiency programmes, but they pay back their investment within a few years, sometimes even within months. Improved efficiency in industry can be achieved relatively easily since there are comparatively 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, and significant savings can be realised from this intervention by the larger commercial sector. In the residential sector, the large numbers of lights that are replaced, together with significant savings per lamp, lead to thousands of TJ savings per year by the end of period.

Not only does Table 9 (overleaf) 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, that there are 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.

5.2 Local air pollutants

Having considered the energy savings, we turn to environmental implications of the policies. Energy use has particular implications for global and local air pollutants. Of all the local pollutants, we consider sulphur dioxide (SO_2), a contributor to acid rain, and total suspended particulates (TSP), which contribute to Cape Town's 'brown haze' (Dutkiewitz & De Villiers 1995; Wicking-Baird et al. 1997).

The major sectors that reduce local pollutants are those that use fuels directly. By contrast, electricity is clean at the point of use, but very large quantities of coal are burned elsewhere – and produce global pollutants (see the next section). Sectors relying mainly on electricity, such as office and government buildings, produce little local pollution. Table 10 shows potential reductions by key policy in the transport and industry sectors, both of which use significant amounts of non-electric fuels.

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 11 for installing ceilings in the residential sector and the efficiency improvements in industry.

Combined, the policies listed in the two tables above can reduce significant amounts of sulphur and particulate emissions. Clearly, shifts in the mode of transport that will be used in the future make a big difference to the local environment – but changes in transport infrastructure come at a large capital cost. Efficiency measures in industry can make a major contribution to reducing SO_2.

Table 9: Annual energy savings in units appropriate to each policy

Policy or measure		Energy savings					
	Units (per year)	2000	2001	2005	2010	2015	2020
Residential							
Promoting solar water heaters	GWh	0.0	3.6	21.7	90.3	122.8	160.6
Installing ceilings in RDP housing	GWh	0.0	1.1	7.5	16.7	27.2	39.2
Switching to CFLs	GWh	0.0	24.7	139.2	303.6	496.4	721.7
Commercial							
Efficient lighting in commercial buildings	GWh	0.00	12.7	70.3	159.1	270.0	407.28
Savings in HVAC in commercial buildings	GWh	0.00	3.3	18.3	41.4	70.3	106.00
Government							
Efficient lighting in	GWh	0.00	0.64	3.52	7.47	11.89	16.83
Savings in HVAC in government buildings	GWh	0.00	0.17	0.91	1.94	3.09	4.38
Industry							
Energy efficiency in industry	Electricity (GWh)	0.00	54	295	668	1,058	1,197
	Wood (ton)	0.00	250	1 437	3 188	4 813	5 500
	LPG (000 lt)	0.00	25 641	76 923	153 846	230 769	256 410
	Paraffin (000 lt)	0.00	28	83	167	250	278
	Fuel Oil (000 lt)	0.00	100	575	1,250	1 925	2 200
	Diesel (000 lt)	0.00	1 108	5 892	12 730	19 486	21 946
	Coal (ton)	0.00	6 226	34 290	77 581	122 871	139 000
Transport							
Modal shift from private to public transport	Million litres						
	Petrol	0.00	31	173	368	586	829
	Diesel	0.00	5	25	52	84	118
	Electricity (increase) (TJ)	0.00	50	300	630	1 000	1 410
Petrol to diesel taxis							
	Petrol	0.00	5	28	60	95	135
	Diesel (increase)	0.00	-4	-23	-49	-79	-111
Introducing bio-diesel and low-S diesel	Petrol	-	-	-	-	-	-
	Diesel	0.00	3	16	34	55	79
	Biodiesel (increase)	0.00	-3	-16	-34	-55	-79

5.3 Greenhouse gas implications

Global climate change is one of the major environmental and development challenges of the 21st century. This section examines the implications of future energy policies for greenhouse gas emissions, such as CO_2. shows that GHG emissions from the different sectors – with emissions from electricity associated with demand sectors – resulting in fairly even contributions in the reference scenario. Without new policy, Cape Town can expect its emissions to rise from 16.1 million tons of carbon dioxide ($MtCO_2$) in 2001 to 23.6 $MtCO_2$ by 2020. Such an increase of almost 50% over twenty years stands in stark contrast to the reductions that the science

Table 10: Savings in SO_2 local pollution from policies in transport and industry (tons)

	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

Table 11: Annual reductions in total suspended particulates (tons 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

Table 12: 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

Table 13: 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

Table 14: Energy, cost and GHG savings from policies in the commercial sector

	Efficient lighting scenario	*HVAC 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. Costs are in 2000 Rands.

Table 15: Energy, cost and GHG savings from scenarios for the government sector

	Efficient lighting scenario	HVAC 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.

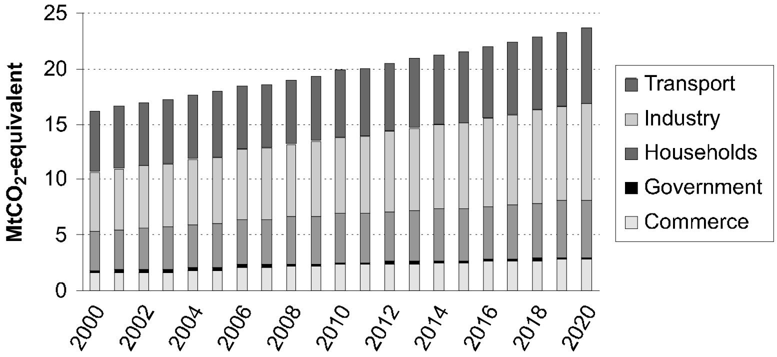


Figure 7: GHG emissions attributed to demand sectors

tells us are required – some 50% to 70% *minus* over the next century (IPCC 1996).

The potential for emissions reductions follows the pattern of the energy savings. Table 12 shows the potential reductions each year, comparing the emissions in the reference case to those if all policies are implemented.

GHG savings are typically associated with energy savings, as shown by the figures in Table 13 for the industrial sector.

The potential to reduce emissions in the transport sector is of a different order of magnitude than that in other sectors, as shown in Table 12. 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. Nonetheless, the large tCO_2 reduction in 2020 in the transport sector would amount to 8% of Cape Town's projected emission in that year.

Absolute tons of emission reductions, however, are not the only consideration. shows the GHG reductions for the commercial sector, but also the energy and cost savings that can be gained while reducing emissions.

Such win-win policies are not restricted to commercial buildings. Local government can implement the same policies in its own buildings, with savings for GHG, energy and costs that are reported in Table 15.

Renewable energy is a long-term solution to energy-related greenhouse gas emissions. Cape Town's target is to have 10% of electricity generation from renewable sources by 2020 (CCT & SEA 2003), which is simulated in our analysis using LEAP. The results of our policy simulation show that the 10% renewable electricity target results in significant reductions in greenhouse gas (GHG) emissions, most in the form of CO_2, with a little reduction in N_2O.

Figure 8 shows the emissions *reductions*[8] as well as the potential carbon revenue that could be earned from such emissions reductions. Emission reductions can be sold under the Clean Development Mechanism of the Kyoto Protocol.

This assumes a carbon price of E7 / tCO_2 in

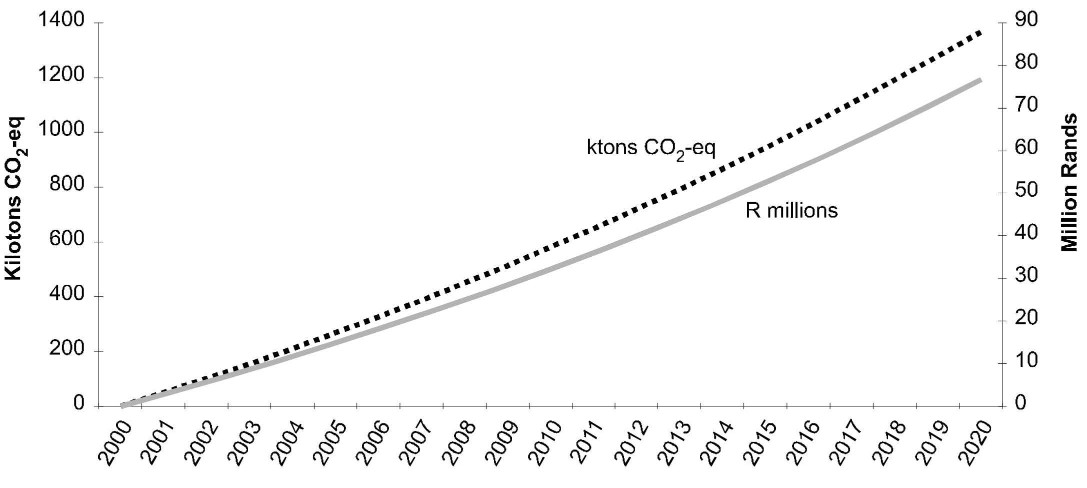


Figure 8: Emission reductions in CO_2 and possible carbon revenues at 7 euros per ton CO_2

November 2004[9] – over the twenty year period, the savings might add up to some R700 million. This should be compared to the additional capital costs for the 571 MW needed to meet Cape Town's 10% renewable energy target (from electricity). This study assumed that the target would be met by wind electricity generation,[10] and only conducted first-order estimates of the costs assuming R7650 / installed kW.[11] Under these assumptions, the capital costs would be R4 370 million. More detailed work on the costing is needed in future.

5.4 Cost comparison

Policies focusing on greater efficiency lead not only to energy savings, but also to cost savings. Tables 14 and 15 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 achieve large savings per light (a quarter to a fifth of the energy consumption of incandescents) on running costs. This, and the much longer lifespan of CFLs, offsets their higher initial costs. Cost savings from CFLs are aggregated across large numbers of light bulbs. Ceilings installed in low-income houses (both electrified and non-electrified) 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, using wind generation only, 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. It is also important that the City of Cape Town explores the most cost-effective mix of options to achieve the '10% renewables' target in future, as relying on wind generation exclusively is likely to be a relatively expensive way forward.

6. Conclusions

Having considered the energy use patterns in Cape Town, business-as-usual trends and the impacts of eleven possible future energy policies, we conclude that energy policy can make a major contribution to sustainable development in the city.

Major energy savings can be made from modal shifts in the transport sector and with efficient lighting. By far the largest savings can be gained by a shift from private to public transport modes – savings up to 36 million litres of petrol and diesel in the first year.[12] Switching to more efficient lighting can result in substantial savings in several sectors (see Table 8), amounting to 38 million kWh in 2001. Energy savings are important to the City, since it is dependent on imports of both electricity and liquid fuels.

Energy savings translate into financial savings. All policy interventions have upfront costs, but 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 R32 million in the commercial sector, and R1.3 million in government buildings over the projection period.

Such savings do not only have an economic benefit, they make a contribution to social development by benefiting poor households. Their energy burden is known to be significant, as a relatively high proportion of their income is spent in meeting basic energy requirements, so the reduced energy bills are felt most keenly in this sector. Each household could save R75 per year just by installing two

CFLs (at capital cost of about R30). The energy savings from installing ceilings in all low-income households is also substantial, and it is significant that the City is moving towards implementing this measure already. 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 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.

On the supply side, implementing the city's renewable energy target will have significant costs, although this partly will be off-set by selling carbon credits. The estimated *total* capital costs of implementing the renewable energy target, assuming wind electricity generation is exclusively used to meet the 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. It should be kept in mind, however, that the target is probably best achieved through a more cost-effective mix of options than just wind generation, including the use of solar water heaters, landfill gas, biomass generation etc. This optimum mix is yet to be clarified.

Cape Town has long suffered from the problem of high local pollution levels – most visible as the 'brown haze' phenomenon. Targeted 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. A steady shift to public transport is expected to save 1021 tons of particulates in 2020. Total reductions of SO_2 are 1400 tSO2 by 2020, most of which comes from industry (see Table 10).

Cape Town has the opportunity to become a leader in addressing greenhouse gas emissions. It has already set a forward-looking target for renewable energy. The scenario modelling shows that this policy could save 49 $ktCO_2$ equivalent after the first year of implementation already. A surprising result is that transport policy can result in even larger savings in the same year, of 72 $ktCO_2$ equivalent. By 2020, transport energy policies could lead to an 8% reduction of emissions compared to the reference case, which itself is projected to grow by 47% over the period.

Current development trends show problems of local air pollution, global warming contributions, inefficiency in resource use with associated higher costs, and reduced welfare of poor households. Several of the policies examined in this study are viable in terms of costs, social benefits and positive environmental impact. 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 scales immediately. The work undertaken illustrates that forward-looking energy policies can strongly promote sustainable development in its social, environmental and economic dimensions.

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The LEAP dataset described in this report is downloadable from the COMMEND and ERC websites:

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

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Notes

1. For the study, the percentage of unelectrified households was taken at 2%, based on available national statistics (NER 2002). Some evidence suggests that this percentage may be substantially higher. There are 80 000 informal settlement shacks, 25 000 formal site shacks and 60 000 backyard shacks (CCT 2002). Of these 165 000 households, only about 15% are electrified (Ballantyne 2005), which would imply 17% of all households are not electrified. This issue requires further investigation in future, including the extent to which backyard shacks are informally electrified, e.g. using extension cords.
2. A common assumption for technical losses is closer to 10%; however, this ignores non- technical losses, which can be significant (Borchers et al. 2001).
3. 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.
4. The study team, in consultation with City officials, selected key energy policies to include in the simulation modelling. Criteria in policy selection covered financial and economic, welfare, environmental, and practical considerations. See the Appendix D in the full report on Cape Town's Energy Futures, available at http://www.erc.uct.ac.za/Projects/COMMEND.htm.
5. A 100% penetration of efficient lighting goes beyond what is found in industrialised countries. Studies in the Netherlands, Germany, and Denmark have gathered detailed data on the uptake of CFLs – about half the households have CFLs installed (NL 56%, DE 50%, and DK 46%) (Kofod 1996). The thought experiment here to consider is a 'what if' scenario – the implications if Cape Town could go even better than the countries mentioned.

6. The LEAP database and modelling tool is available for further analysis to those who wish to explore different policies or change assumptions for the ones examined here (www.erc.uct.ac.za and http://forum.seib.org/leap/).
7. The exceptions are the use of more renewable energy – for electricity generation, and biofuels for transport. The introduction of low-sulphur diesel primarily improves local air pollution.
8. Emissions reductions = emissions in reference case minus emission with renewable policy.
9. Carbon prices are monitored by PointCarbon, www.pointcarbon.com, and are expected to increase in future. Assume R 8 to 1 euro.
10. In fact, a mix of solar water heating and other electricity generation technologies (including wind) is more likely in practice, and will be more cost effective than the use of wind generation exclusively.
11. ($850 / kW; R9 / $1, exclude integration with the transmission grid and assuming a 20 MW wind generation site).
12. However, electricity use increases 50 TJ with the modal shift due to increased use of electric trains, but this is small compared to the 1200 TJ liquid fuel saved.

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