ENERGY SCENARIOS FOR CAPE TOWN:

Exploring the implications of different energy futures for the City of Cape Town up to 2040

2015 update

Linked to the Cape Town 2012.3 LEAP model

Completed by: Sustainable Energy Africa, with the support of the SAMSET Project

Contents

1. Acronyms and Terms

AvGas	Aviation Gasoline
BAU	Business as Usual
BRT	Bus Rapid Transit
Cape Town	Refers to City of Cape Town metropolitan area (not the local government authority)
CCT	City of Cape Town
CFL	Compact Fluorescent Bulb. An efficient lighting option.
City of Cape Town (City)	Refers to City of Cape Town local government
CPI	Consumer Price Index
CSP	Concentrated Solar Power
DoE	Department of Energy
ECAP	Energy and Climate Action Plan
EE	Energy Efficiency
ETE	Electricity and Transport Efficiency scenario
GJ	Gigajoule. One billion Joules.
GVA	Gross Value Add. Used for measuring entities smaller than a whole economy. GVA = Gross Domestic Product - taxes on products + subsidies on products
GW	Gigawatt
GWh	Gigawatt-hour (one million kWh)
HFO	Heavy Fuel Oil
HVAC	Heating, Ventilation and Cooling
IPCC	Intergovernmental Panel on Climate Change
IRP	Integrated Resource Plan. The national electricity build plan from 2010 until 2030.
ITP	Integrated Transport Plan
Joule	Unit of energy
kWh	Kilowatt-hour. A “unit” of electricity.
LEAP	Long-range Energy Alternative Planning
LED	Light-Emitting Diode. A very efficient lighting option.
LPG	Liquefied Petroleum Gas
LPU	Large Power User. City of Cape Town tariff category.
LSM	Living Standards Measure
LTMS	Long-Term Mitigation Scenarios
LV	Low Voltage. City of Cape Town tariff category.
MV	Medium Voltage. City of Cape Town tariff category.
MW	Megawatt
MWh	Megawatt-hour. One thousand kWh.
OEF	Optimum Energy Future
PDG	Palmer Development Group
PPD	Peak, Plateau, Decline
PV	Photo-voltaic
SEA	Sustainable Energy Africa
SNAPP	Sustainable National Accessible Power Planning
SoE	State of Energy

Solar PV	Solar Photo-Voltaic
SPU	Small Power User. City of Cape Town tariff category.
SSEG	Small-Scale Embedded Generation. In this report it refers to rooftop solar PV.
StatsSA	Statistics South Africa
SWH	Solar Water Heater
tCO_2e	Tonnes carbon dioxide equivalent
VAT	Value-Added Tax
VSD	Variable Speed Drive
WCG	Western Cape Government
WWTW	Wastewater Treatment Works

2. Tables and Figures

Tables

Figures

3. Purpose of Document

This document forms part of a State of Energy and Energy Futures modelling update for the City of Cape Town. Three outputs were produced:

State of Energy	Cape Town energy and emissions baseline update
Energy Scenarios for Cape Town	Models and costs different energy futures for Cape Town
Energy Scenarios for Cape Town: Annexure A (this document)	Intended for those wanting to engage with the data, assumptions and methodologies used in the *Energy Scenarios for Cape Town* report

4. Background

The City of Cape Town was the first African city to establish an *Energy and Climate Change Strategy* (completed 2006); a document that sets out a vision for the delivery and consumption of sustainable, environmentally sound energy, and provides quantifiable targets in this regard. It was also a leading city in the implementation and support of such a strategy through the implementation of institutional reforms. The Strategy built on the City's *State of Energy* report (first completed 2003, updated 2007), which provided a picture of energy supply and demand in Cape Town. Initial energy modelling (covered in the report labelled: Cape Town Energy Futures) was undertaken in 2005 in order for the City to assess the implications of different future development paths for the energy sector.

In response to the Strategy and modelling report, the City developed an *Energy and Climate Action Plan* (ECAP), which was adopted by Council in May 2010. The ECAP is made up of 11 key objectives, further divided into programme areas consisting of individual projects, currently underway or planned, extending over a three year period. The projects were taken through an initial prioritisation process. However, additional information regarding consumption patterns, costs, trends, risks, etc., was required to underpin the ECAP and thereby verify the initial prioritisation, assist with the setting of targets, and extend the plan into the longer term.

Energy data gathered was used to identify what was termed the Optimum Energy Future (OEF) Scenario, which provides a more in-depth energy sector analysis and projections than previously; based on an extended and up-to-date set of energy consumption data, supply mix options, costing and trends. This exercise was completed in 2011.

This report forms part of a State of Energy and Energy Futures modelling update, to identify any energy use and emissions trends and update the energy futures modelling. It will also form part of a process in 2015 to update the ECAP targets.

5. Methodology

Overview

The project included a detailed energy data collection exercise; building on previous work carried out on the State of Energy reports (2003, 2007) for Cape Town, the Cape Town Energy Futures report and the Energy Scenarios for Cape Town (2011) report. The first step in any energy modelling process is to develop a baseline of current energy use patterns. This information forms the foundation of all the modelling outputs that follow, and as such it is critical for it to be as accurate and meaningful as possible. Data was collected for the following sectors:

- Residential
- Commercial
- Industrial
- Agricultural
- Local government
- Transport

The Long-Range Energy Alternatives Planning (LEAP) simulation tool was used to examine the implications of a number of possible future energy scenarios for Cape Town from the base year of 2012 up to 2040 (the model was initially run up to 2050, but results are presented until 2040 – a year in line with the City's 2040 energy vision timeline). Each scenario contained a combination of specific energy efficiency interventions and supply mix options. The scenarios were informed by a stakeholder workshop that took place in August 2014. The following primary scenarios were modelled:

- Business As Usual (BAU) Scenario: No changes in current energy demand trends of Cape Town (based on State of Energy reporting) and the implementation of national electricity plans drawing on the Weathering the Storm Scenario of the IRP 2010 – 2013 Update Report (2013)[1].

- Electricity and Transport Efficiency Scenario (ETE): Includes a combination of all electricity and transport efficiency interventions/scenarios.

Additional supply-side scenarios were modelled:

- City Local Generation Policy Scenario (GEN): This builds a local generation component on to the ETE scenario, as currently planned by the City: 300 MW CCGT, 50MW large-scale solar PV and 50MW wind by 2020. It is assumed that the same amount of capacity is added every 5 years thereafter.

[1] Discussion with national electricity planning experts indicated that the cabinet approved IRP 2010-2030 is 'unlikely' given the inability of Eskom or international players to fund the nuclear build contained in this iteration of the plan. Planners pointed to the 'weathering the storm' scenario of the IRP 2010-2030 Update Report as the most likely electricity build plan to take place.

- Embedded Solar PV Scenario (SOL): This builds on the ETE scenario a local embedded rooftop PV generation component of 50% of high income households adopting a 2kw system by 2040 and commerce and industry supplying 15% of their electricity needs through embedded solar PV by 2040.

- City Local Generation and Embedded Solar PV Scenario (GSOL): GEN Scenario with embedded (rooftop) solar PV in 50% of high and very high income households by 2040, and supplying 15% of electricity needs in commercial and industrial sectors.

- IRP (IRP): Based on BAU, but with electricity supply according to IRP 2013 Update *Base Case Scenario* (Step 5) [2] rather than the *Weathering the Storm Scenario*.

Sensitivity test scenarios were modelled based on a combination of the primary and supply-side scenarios listed above:

- Peak Oil Scenarios: modelled by an annual increase in liquid fuel prices 5% above the current real price increase

- Carbon Tax Scenarios: a carbon tax of R40/tonne in 2015 increasing to R47/tonne in 2019 and R117/tonne in 2025[3]

- Economic Growth Scenarios: high and low growth rates

- Population Growth Scenario: models higher population growth than used in BAU

Precedent Studies

Previous studies on energy data and energy scenarios modelling include:

- Two *State of Energy* reports that were completed for the City of Cape Town. The first was commissioned in 2003 and compiled by Sustainable Energy Africa (SEA); the second, an update of the 2003 report, was compiled by the Palmer Development Group in 2007.

- The *Cape Town Energy Futures* report commissioned in 2005. The Energy Research Centre at the University of Cape Town developed policies and scenarios for sustainable city energy development, by simulating how energy might develop in Cape Town during the period from 2000 to 2020. This study refined the data presented in the first State of Energy report for use in its base year analysis.

- The *Energy Scenarios for Cape Town up to 2050* report, *State of Energy and Energy Futures 2011* report, and the *Moving Mountains* report. These reports are all outputs resulting from a state of energy and energy futures modelling update exercise for Cape Town by SEA.

[2] The IRP 2013 Update Base Case Scenario was produced by updating the IRP 2011 report assumptions with new information regarding the electricity demand curve, Eskom's fleet availability, Ministerial determinations, and life extension options for the Eskom coal-powered fleet. As the IRP Update Report, 2013, provided better data for modelling purposes, this was used in place of the official IRP Policy Adjusted Scenario of the 2011 IRP Report.
[3] Parameters used in IRP 2010 (2013 update)

- Two *State of Energy in South African Cities* reports (2006, 2011), compiled by SEA. Energy issues and energy consumption for a selection of cities in South Africa, including Cape Town, were assessed.

- The Western Cape Government: Environmental Affairs and Development Planning, *Western Cape Climate Change Mitigation Scenarios exercise for the energy sector* developed by PDG in March 2015.

Earlier studies relied heavily on assumptions, due to a lack of disaggregated data. Later studies (2011) had access to more disaggregated data. Data collection is improving considerably over time, though some difficulties still remain. All reports discuss data collection challenges and suggest mechanisms for improving data collection.

Data Problems and Limitations

Electricity

Electricity is distributed either directly by Eskom or by the City who buys electricity from Eskom.

Eskom electricity distribution data is not publicly available and required the signing of a non-disclosure agreement. This can be a lengthy process.

The City provided figures on total electricity bought from Eskom and total sold to customers. The difference is calculated as losses. City sales are recorded by tariff, not by sector (although obtaining the data by sector is theoretically possible, this could not be achieved in this data collection round). There is not always a one-on-one match between a tariff and a sector, e.g. (1) the Large Power User tariff covers both industrial customers and large commercial customers such as shopping malls, and (2) the Small Power User tariff covers commercial customers and residential complexes.

Having sectoral data available for customers will be of benefit to the electricity department, as they will be instituting a Time of Use tariff in the future. Having access to data on a specific customer type's average load profile will assist in the design of sector-specific ToU tariffs.

Coal

Unlike liquid fuel data, coal data is deregulated. There is no one data repository for local-level coal data. Coal data was obtained from various sources, including the City's air quality department, the Western Cape Government's air quality department, a student doing a resource-flow analysis for the area and industry suppliers. What these datasets showed is that the data from air quality departments underestimate coal use by a large margin. It would be preferable to use air quality data, as this data is captured consistently and is easier to access, but the discrepancies with actual figures when checked through follow-up phone calls with coal suppliers and some coal users remained too great. It was decided to rely on coal supply estimates from the major coal suppliers in the area.[4] These figures also tied in better with the figures from previous state of energy reports, also obtained through interviews with major suppliers.

[4] The major coal suppliers in Cape Town are Wescoal/Chandler Coal, MacPhail/Coalcor (now part of Wescoal), A1 Energy Consultants, Redcliff Investments, PGK Consultants

Liquid fuel

Liquid fuel sales data by fuel type by magisterial district is publicly available on DoE's website. This dataset gives no indication as to the sector where the fuel is being consumed. Data of sales by trade category was obtained, but required the signing of a non-disclosure agreement. The trade categories assisted in the allocation of fuel to sector by some degree (e.g. "commercial" category sales were assigned to the commercial sector), but there were some trade categories that were not descriptive (e.g. "retail – garages" and "general trade").

Magisterial districts do not align with municipal boundaries. Magisterial fuel sales were assigned to municipal area according to the percentage geographical overlap of the areas.

In the DoE dataset received, marine fuels were supplied as one fuel type, but in actual fact it is made up of three fuel types: HFO, diesel and oil (potentially used as a lubricant and not a fuel at all). There was no way to disaggregate this data. The data also varied substantially over the years, with a difference of billions of litres between the 2008/09/10 and 2010/11/12 figures. Due to data concerns, the original source of data collation for this sector was approached. Having recently taken over from BP in this regard, Chevron only had data for the last couple of years. The 2010 and 2011 DoE figures are more in line with Chevron figures, but are still fairly different and heading downward, whereas Chevron 2012 and 2013 data seem to display an upward trend. Chevron, as the data source, is likely the most accurate, and its figures are therefore used as the source of data for this fuel.

Energy use by end-use and sub-sector

Energy use by end-use (HVAC, lighting, etc.) and by sub-sector is particularly difficult to obtain, although data has improved over time. There are locally-specific studies available that focus on the commercial sector's energy use by end-use with regards to electricity, but data is sparse when it comes to liquid fuel and any data on energy use by end-use in the industrial sector. The industrial sector is small in Cape Town when comparing it to, say, Durban. Further research might focus on improving energy use data for the commercial sector first and foremost, as this is the more dominant sector within Cape Town.

In the case of household energy use by end-use, data is available from StatsSA on the type of fuel used as the main fuel for lighting, space heating, and cooking, but not on the amount of fuel used. A study was commissioned by SEA in order to gain insight into this area, but results were not yet compiled by the time the energy model was completed.

Main Data Sources

Data	Source
Electricity	City of Cape Town electricity department Eskom Department of Energy
Liquid fuel	Department of Energy Caltex
Coal	Major coal suppliers

Interventions and Costing

A set of interventions were modelled for each sector, in order to determine impacts on the energy use, carbon emissions and cost of differing future energy macro scenarios for Cape Town. Most macro scenarios modelled the same interventions, although the penetration rates for these interventions differed according to each scenario. The macro scenarios are discussed in more detail in the *Scenarios* section of the report.

The cost of each intervention was modelled in LEAP by considering the capital cost of the intervention (duplicated whenever the end of the unit's lifespan was reached) and the annual operation and maintenance costs, wherever available. The number of units for each intervention was estimated by dividing the total annual consumption for each end use by the annual energy consumption per unit for the existing systems. For example, when considering a retrofit from incandescent lights to CFLs:

Number of CFLs required = total annual consumption for lighting / annual energy consumption per incandescent light bulb

The total cost of each intervention was calculated by considering the difference between the inefficient and efficient technology option costs. Costs include the annualised capital cost and fuel costs. The equation in LEAP would be as follows:

Annualised Cost (number of units x capital cost [ZAR]/lifespan [years]) + Final Energy Intensity [GJ] x Key/Electricity Tariff [ZAR]

Calculating Supply-Side Data using LEAP

Due to the nature of the electricity supply in South Africa, it is challenging to model electricity supply at the municipal level for each of the future energy scenarios. In South Africa, electricity is currently supplied by a single national operator (Eskom). The electricity consumed in Cape Town is drawn directly from the national grid. It was decided to use the electricity demand of Cape Town to determine the amount of capacity (supply) required to meet that demand now and into the future. Unfortunately, because LEAP does not have iterative functions, this meant that some calculations needed to be done outside of the LEAP model, with the results being fed back into LEAP before the final calculations could be undertaken. The iteration is thus manual rather than automatic. A Microsoft Excel spreadsheet '*Elec supply tool for CoCT 2012.xls*'[5] (referred to as the Supply Tool from here onwards) was used for the external calculations.

The LEAP user must first complete the demand side 'current account' (i.e. the 2012 electricity demand side picture for Cape Town) as well as all of the demand side scenarios (e.g. Business As Usual, etc.) before undertaking any supply side calculations. If any changes are made to the demand side figures that would alter the total amount of electricity demand in any of the scenarios, the supply side figures would need to be recalculated.

Once the total electricity demand for each scenario had been calculated in LEAP, these figures were used to calculate the required capacity to meet the demand. The capacity figures were calculated

[5] This spreadsheet can be obtained from Sustainable Energy Africa. Contact: info@sustainable.org.za.

using the Supply Tool and entering the total annual electricity demand figures for the years (2012, 2015, 2020, 2025, 2030 and 2040) in the '*demand*' tab of the Supply Tool. The Supply Tool used the reserve margin (leave the default value of 15%, unless this has also been changed in the LEAP model) to calculate the total required capacity needed to meet the demand while still retaining the specified reserve margin. This was calculated by dividing the total annual electricity demand (in MWh) by the number of hours in a year and multiplying this figure by the reserve margin plus one, i.e.

Capacity (MW) = demand (MWh) / hours in the year (365*24) x reserve margin plus one (1.15)

Electricity Demand	2012	2015	2020	2025	2030	2040	2050
Demand (MWh)	12,974,089	13,853,338	15,514,163	17,447,429	20,145,291	27,964,126	40,665,333
Capacity required incl. reserve margin (MW)	1,703	1,819	2,037	2,290	2,645	3,671	5,338

Reserve Margin	15%

Figure 1: Entering electricity demand and reserve margin into the supply tool

It must be noted that LEAP is able to calculate the Peak Power Requirements (excluding reserve margin) in the same way as with the Supply Tool, but it was reasoned that it would be more intuitive for the user to calculate the required capacity from the actual electricity demand.

The supply mix to be modelled in LEAP for each of the scenarios was entered on the 'Supply' tab. The Supply Tool used this data to produce the required '*interp*' equations for insertion into LEAP. The equations were inserted into the '*Exogenous Capacity*' field in LEAP for the relevant supply technology.

% MWh	2012	2015	2020	2025	2030	2040	2050
Pumped Storage	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Bisasar & Mariannhill	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar PV large-scale	0.2%	0.5%	1.0%	1.9%	2.8%	2.7%	2.6%
Solar Th Elec with st	0.2%	0.5%	1.0%	1.0%	0.9%	0.9%	0.9%
Solar PV embedded	0.0%	0.0%	1.8%	3.8%	6.1%	9.0%	12.0%
Wind	0.6%	1.5%	2.9%	3.8%	4.7%	4.6%	4.4%
New Nuclear	0.0%	0.0%	0.7%	8.7%	16.3%	16.8%	16.8%
New Coal	0.0%	21.2%	44.7%	60.8%	61.0%	59.2%	57.2%
CCGT	0.2%	0.5%	1.0%	1.0%	0.9%	0.9%	0.9%
Hydro	4.8%	4.5%	3.9%	4.3%	4.7%	4.6%	4.4%
OCGT	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Existing Base	89.2%	66.8%	39.8%	11.8%	0.0%	0.0%	0.0%
Existing Nuclear	4.8%	4.5%	3.2%	2.9%	2.5%	1.4%	0.8%
Total	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%	100.0%

*Note: Totals must **NOT** be greater than 100%.

2012	Interp Functions
0	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0,2050,0)
0	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0,2050,0)
18	interp(2012,18,2015,47,2020,103,2025,227,2030,384,2040,517,2050,727)
8	interp(2012,8,2015,21,2020,46,2025,50,2030,57,2040,76,2050,108)
0	interp(2012,0,2015,0,2020,186,2025,454,2030,836,2040,1700,2050,3289)
35	interp(2012,35,2015,94,2020,207,2025,304,2030,428,2040,576,2050,810)
0	interp(2012,0,2015,0,2020,17,2025,238,2030,515,2040,736,2050,1073)
0	interp(2012,0,2015,449,2020,1062,2025,1625,2030,1883,2040,2534,2050,3565)
4	interp(2012,4,2015,10,2020,22,2025,24,2030,27,2040,37,2050,52)
149	interp(2012,149,2015,149,2020,145,2025,180,2030,226,2040,304,2050,427)
0	interp(2012,0,2015,0,2020,0,2025,0,2030,0,2040,0,2050,0)
1744	interp(2012,1744,2015,1395,2020,930,2025,310,2030,0,2040,0,2050,0)
98	interp(2012,98,2015,98,2020,78,2025,78,2030,78,2040,63,2050,50)

Figure 2: Enter supply mix for each scenario to calculate required 'interp' functions for LEAP

The '*interp*' equations were copied into the correct scenarios in LEAP. Once all the exogenous capacities for each supply technology were entered into each scenario in LEAP, the model was run again to calculate the supply costs.

By default, LEAP does not have a way of using the supply costs to influence the cost of electricity (i.e. an iterative function). In this project, it was desired for the costs of various supply scenarios to be reflected in the cost of electricity. Once the supply figures were entered for all scenarios and the model was run successfully, the costs associated with each supply type were used to alter the electricity tariff, using the '*Supply Costs*' tab in the Supply Tool. Total supply costs for each year were entered into the relevant field of the Supply Tool. The Supply Tool provided a growth equation, which was copied into LEAP's Key Assumption '*Cost Elec Incr*' function. Each scenario would have a slightly different tariff factor equation if the supply mixes are different.

Years	Growth Rates
2012-2015	23.0%
2015-2020	12.4%
2020-2025	12.4%
2025-2030	8.0%
2030-2040	3.8%
2040-2050	4.0%

Year	Supply Costs (ZAR)
2012	606,555,746
2015	1,128,309,461
2020	2,023,746,447
2025	3,627,744,301
2030	5,331,394,617
2040	7,743,591,288
2050	11,452,592,792

Growth Function
Growth(0.23,2015,0.124,2020,0.124,2025,0.08,2030,0.038,2040,0.04)

Figure 3: Calculating tariff factor using total supply costs

Finally, once the tariff factor for each scenario was entered into LEAP, the model was run for the last time. The results of this run presented the final demand, the final supply and all associated costs.

Supply-Side Costing

All supply costs (capital, operation and maintenance), as well as efficiencies and availabilities, were taken from the '*SNAPP 2.0 IRP2010 base and policy adjusted'* tool.[6] Below is a summary table of electricity supply costs extracted from SNAPP.

Table 1: Electricity power plant parameters from SNAPP[7]

		Capital cost overnight (2010)	Capital cost Present Value (2010)	Fixed O&M	Variable O&M	Efficiency	Availability
Plant Description	Technology Type	R/kW	R/kW	R/kW	R/MWh	fraction	fraction
Existing coal Large	Existing coal large	7065	7065	199	8.18	0.35	87.1%
OCGT liquid fuels	Open-Cycle Gas Turbine diesel	3955	4051	22	21.74	0.30	93.0%
PWR nuclear	Nuclear PWR type 2	37205	47451	365	99.10	0.33	83.7%
Hydro	Hydro existing	0	0	130	0.00	1.00	15.0%
Supercritical coal	Supercritical Coal	17785	20323	8	8.34	0.37	85.7%
Wind 29% availability	Wind high resource	14445	14796	266	0.00	1.00	29.0%
Solar CSP	Solar Parabolic Trough 9 hrs storage	50910	54150	635	0.00	1.00	43.7%
Solar PV	Solar PV Chrystalline (10MW)	20805	20805	474	0.00	1.00	19.4%
CCGT	Combined Cycle Gas Turbine	5780	6233	148	0.00	0.48	90.3%

[6] SNAPP (Sustainable National Accessible Power Planning Tool) developed by the Energy Research Centre of the University of Cape Town

[7] ERC SNAPP tool (2.0 IRP 2010 base and policy-adjusted). Note: Fixed O&M includes fuel cost.

Hydro imported new	Mphanda Nkuwa hydro import	15518	19883	344	0.00	1.00	70.0%

Learning rates from the SNAPP tool were used to obtain 2012 costs. These learning rates were also applied to future capital costs in LEAP. Embedded solar PV costs were obtained for 2014.[8] Solar PV learning rates were applied to bring the cost back to a 2012 value.

Table 2: Electricity power plant learning rates

Learning rates	2010	2011	2012	2013	2014	2015	2020	2030
Existing coal large	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Open-Cycle Gas Turbine diesel	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Nuclear PWR type 2	1.00000	0.99917	0.99838	0.99793	0.99646	0.99507	0.98909	0.97087
Hydro	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Supercritical Coal	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Wind high resource	1.00000	0.96241	0.93541	0.91651	0.90606	0.89007	0.85074	0.81668
Solar Parabolic Trough 9 hrs storage	1.00000	0.94023	0.82662	0.74724	0.68543	0.59939	0.46786	0.41285
Solar PV Chrystalline (10MW) learning indices	1.00000	0.91518	0.83038	0.76739	0.71052	0.65900	0.46234	0.33745
Combined Cycle Gas Turbine	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000
Pumped Storage	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000	1.00000

Table 3: Electricity supply capital costs

Plant	2010	2011	2012	2013	2014
Existing coal Large	7,065	7,065	7,065	7,065	7,065
OCGT liquid fuels	3,955	3,955	3,955	3,955	3,955
PWR nuclear	37,205	37,174	37,145	37,128	37,073
Hydro	0	0	0	0	0
Supercritical coal	17,785	17,785	17,785	17,785	17,785
Wind 29% availability	14,445	13,902	13,512	13,239	13,088
Solar CSP	50,910	47,867	42,083	38,042	34,895
Solar PV	20,805	19,040	17,276	15,966	14,782
CCGT	5,780	5,780	5,780	5,780	5,780
Hydro imported new	15,518	15,518	15,518	15,518	15,518
Solar PV embedded	30,963	28,337	25,711	23,761	22,000

Plant lifetime

All plant lifetimes were set as 100 years in LEAP. Usually LEAP has internal calculations that allow it to build more power plants when the end of a plant's life is reached. In this model, plant capacity is entered explicitly (under exogenous capacity) rather than allowing LEAP to add/retire plants. If plant lifetime is set as a number of years that is fewer than the number of years until the last model year (in this case 2040), there will be no capital cost assigned to plant capacity built after the end year of plant life, despite the fact that new capacity of that plant type is being built.

LEAP dispatch rules

[8] Source: Communication with Andrew Janisch, Environmental Resource Management, City of Cape Town, who sourced the data through telephonic interviews with solar PV suppliers in Cape Town.

Coal and nuclear are run to full capacity, others are run proportional to capacity. This is not the same as plant availability.

Key to Scenarios in LEAP

Table 4: LEAP scenarios key

Acronym	Name	Interventions
Main scenarios		
BAU	Business as Usual	No changes in current energy demand trends. Elec supply-side: IRP 2013 Update Weathering the Storm Scenario.
ETE	Electric and Transport Efficiency	Combination of all interventions in ELEC and TRN scenarios
Electricity-focused efficiency scenarios		
AGR	Agricultural	BAU with electricity efficiency measures in agricultural sector: 90% of all pumps, irrigation, HVAC and fans efficient by 2040, 100% efficient lighting by 2025.
COM	Commercial	BAU with electricity efficiency measures in commercial sector: all lighting efficient by 2025, 90% of HVAC and refrigeration efficient by 2040, 47% of water heating efficient by 2040 (40% in 2035, 20% in 2025).
IND	Industrial	BAU with electricity efficiency measures in industrial sector: all lighting efficient by 2025; 90% of all other systems (HVAC, motors, mechanical equipment, refrigeration, etc.) efficient by 2040.
LOC	Local Government	BAU with efficiency measures in local government sector: all building and street lighting efficient by 2025, 80% of water heating efficient by 2040 (70% efficient by 2035, 50% by 2025), 90% of HVAC and motors/pumps efficient by 2040. All traffic lighting already efficient in baseline.
RES	Residential	BAU with electricity efficiency measures in households: 90% efficient lighting by 2025 in high- to very high income, 96% by 2040; 100% efficient lighting in mid-income by 2025; 90% efficient lighting in low-income by 2025, 100% by 2040; 25% efficient water heating by 2040 in low-income electrified, 20% in low-income non-electrified, 50% in mid-income, 75% in high- and very high income; 89% efficient fridges by 2040.
ELEC	Electric Efficiency	Combination of electricity efficiency interventions in agricultural, commercial, industrial, local government and residential sectors.
Transport-focused efficiency scenarios		
VEH	Efficient Vehicles	Private (car) passenger-km by 2040 made up of 3% conventional diesel, 5% conventional petrol, 25% efficient diesel, 46% efficient petrol, 11% diesel hybrid and 10% electric. 90% of all buses and minibuses are efficient by 2040.
BEH	Transport Behaviour	BAU with occupancy of private vehicles changes from 1.4 in 2012 to 1.8 in 2040.
MOD	Passenger Modal Shift	BAU with 10% modal shift by 2035; increase at same rate until 2040 (therefore 45% public by 2035, 47% by 2040). Occurs in tandem with occupancy increase in non-rail public transport: 6% by 2040.
BRT	Bus Rapid Transit	BAU with 38% of all bus pass-km by BRT by 2040.
FRE	Freight Modal Shift	BAU with road-to-rail freight modal shift: 22.66% rail in 2012, 30% in 2025, 34% in 2035, 36% in 2040.
TRN	Transport Efficiency	Combination of all interventions in VEH, BEH, MOD, BRT, FRE scenarios.
Supply scenarios		
GEN	ETE Local Generation	ETE with local generation: 300MW CCGT, 50MW large-scale solar PV, 50MW wind by 2020. Same amount of capacity added every 5 years thereafter.
SOL	Solar PV	ETE with embedded solar PV in 50% of high and very high income households by 2040, and supplying 15% of elec needs in commercial and industrial sectors by 2040.

Acronym	Name	Interventions
GSOL	GEN Solar PV	GEN with embedded solar PV in 50% of high and very high income households by 2040, and supplying 15% of elec needs in commercial and industrial sectors by 2040.
IRP	IRP Base Case	Based on BAU, but with electricity supply according to IRP 2013 Update Base Case Scenario.
Sensitivity tests		
HIGH	BAU High Growth	BAU with GVA growth figures multiplied by 1.3
LOW	BAU Low Growth	BAU with GVA growth figures multiplied by 0.7
POP	High Population	BAU with higher population growth (5.3 vs. 4.6 mill by 2040)
B PO	BAU Peak Oil	BAU with fuel price increase 5% above current real rate
E PO	ETE Peak Oil	ETE with fuel price increase 5% above current real rate
B TAX	BAU Carbon Tax	BAU with carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025.
E TAX	ETE Carbon Tax	ETE with carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025.
S TAX	Solar PV Carbon Tax	SOL with carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025.
G TAX	Local Generation Carbon Tax	GEN with carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025.
GS TAX	Solar and Local Gen Carbon Tax	GSOL with carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025.

6. Baseline Energy and Emissions Overview

LEAP Baseline

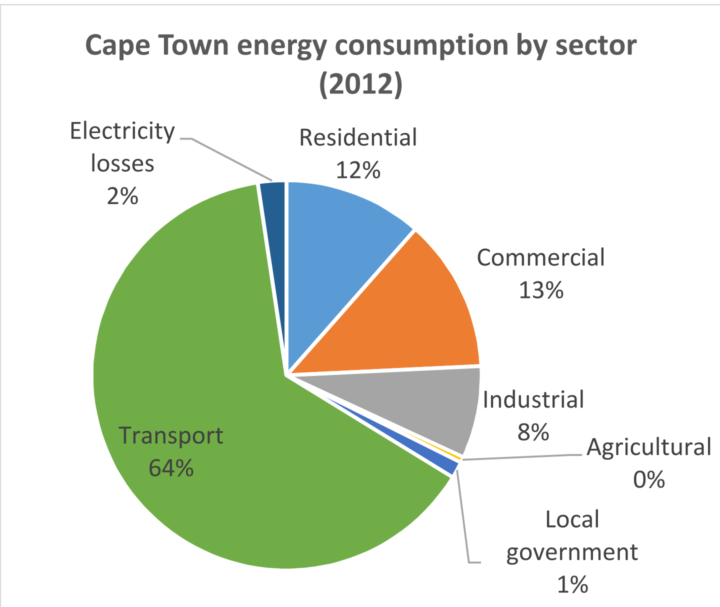

Figure 4: Cape Town energy consumption by sector 2012

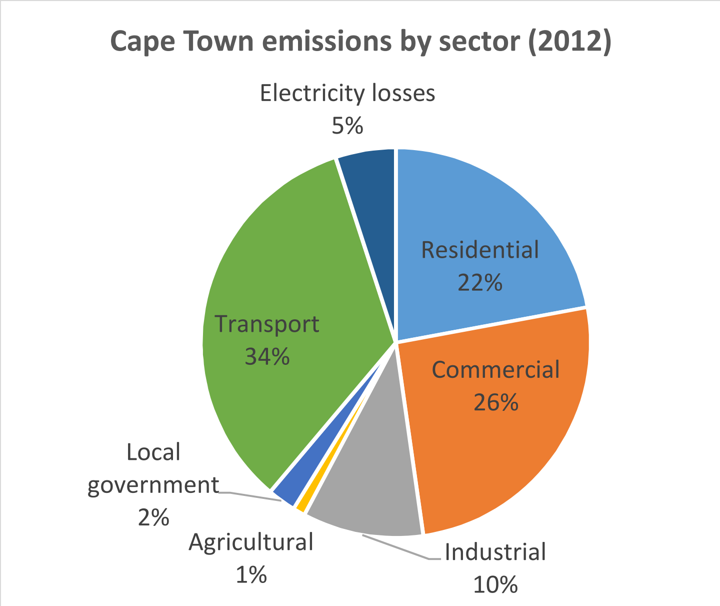

Figure 5: Cape Town emissions by sector 2012

The transport sector accounts for the bulk of energy consumption in Cape Town, followed by the commercial, residential and industrial sectors (Figure 4). This is a fairly typical energy breakdown for a South African metro.[9]

Despite the fact that transport accounts for 64% of energy consumption within the metro, it only contributes to 34% of emissions (Figure 5). This is because the fuels used by the transport sector (largely petrol and diesel) produce fewer emissions per unit energy than the main fuel used in the remaining sectors (electricity). Most (90%)[10] of South Africa's electricity is produced by coal-fired power stations, which burn low-grade coal to produce electricity.

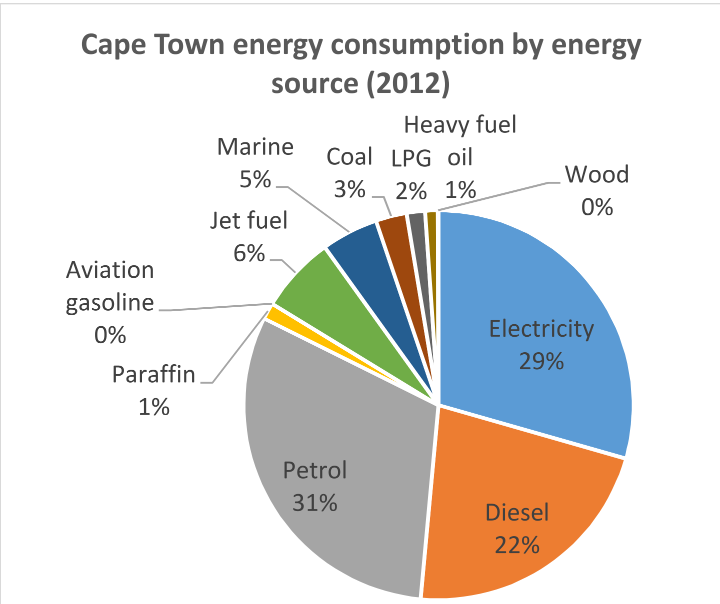

Figure 6: Cape Town energy consumption by energy source 2012

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[9] References: *State of Energy in South African Cities 2015* and *State of Energy in South African Cities 2011*. Both available at www.cityenergy.org.za.
[10] IRP 2010 Policy-Adjusted Scenario

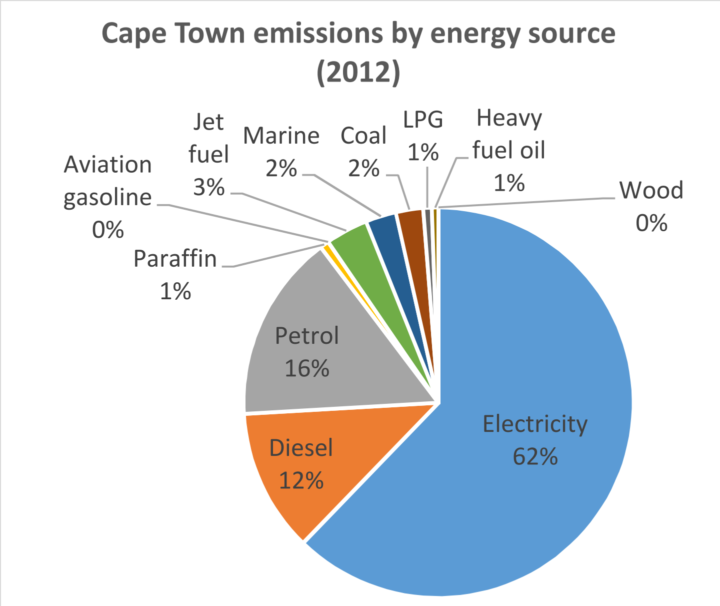


Figure 7: Cape Town emissions by energy source 2012

Figure 6 and Figure 7 illustrates the emissions intensity of electricity compared to other fuels. Electricity accounts for 29% of all energy consumption in Cape Town, but produces 62% of all emissions.

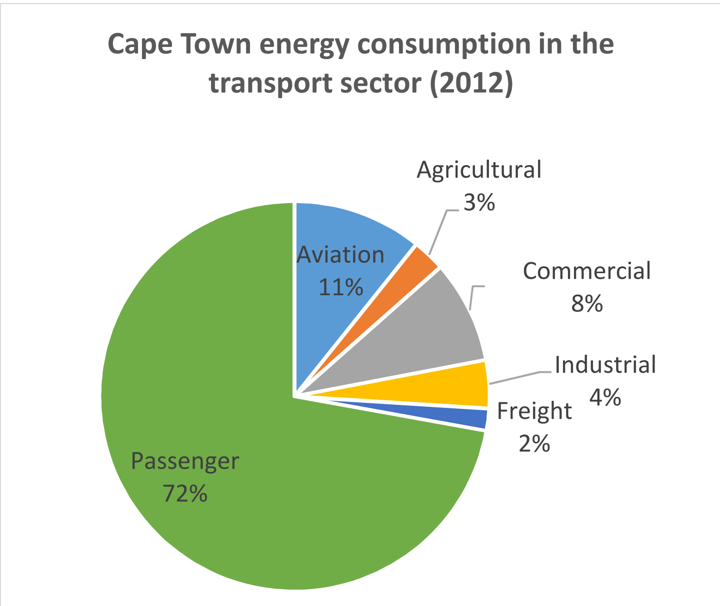


Figure 8: Cape Town energy consumption in the transport sector 2012

Figure 8 provides a break-down of the 64% of energy consumption that takes place in the transport sector. The Transport sector includes all transport across the city, whether it is passenger, commercial or industrial sector related.

Figure 9, for clarification, shows energy consumption by sector in Cape Town (left-hand-side graph) alongside a detailed breakdown of transport-related energy consumption (right-hand-side graph), i.e. how the 64% of energy consumption is allocated.

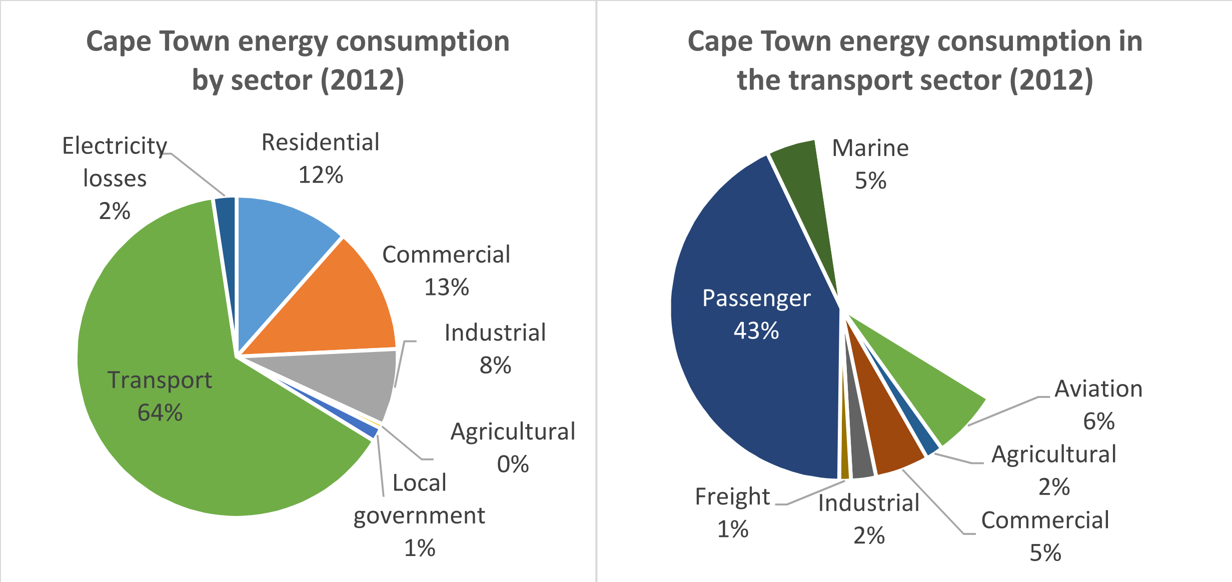


Figure 9: Cape Town energy consumption by sector with transport detail 2012

Passenger transport (moving people around, not goods) represents the bulk of all energy consumption in the transport sector. Private passenger transport (i.e. cars) make up more than 90% of passenger transport energy consumption. ***Private passenger transport in fact represents the single-largest energy-consuming sector in the city***.

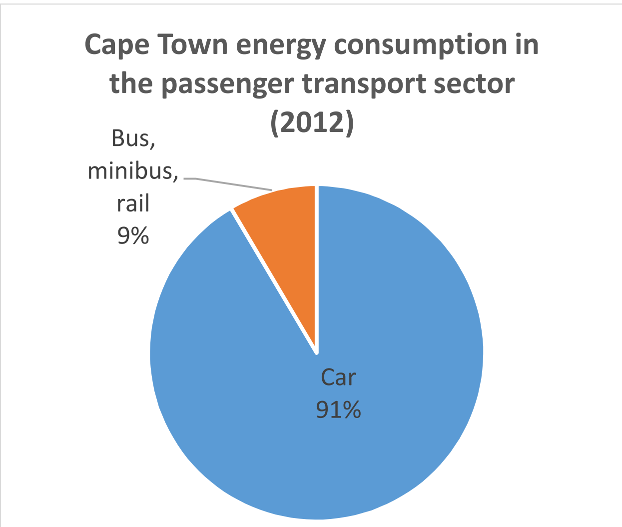


Figure 10: Cape Town public vs. private passenger transport energy consumption 2012

Public passenger transport includes all forms of public transport: minibus taxi (the majority of fuel consumption), busses and rail. Moving people around in private vehicles, especially single-occupancy private vehicles, is extremely inefficient when it comes to energy use and the use of road-space. It is also not an equitable situation to spend government funds continually increasing road width to address congestion when this is, in essence, catering to the needs of the higher-income population, i.e. those that drive cars.

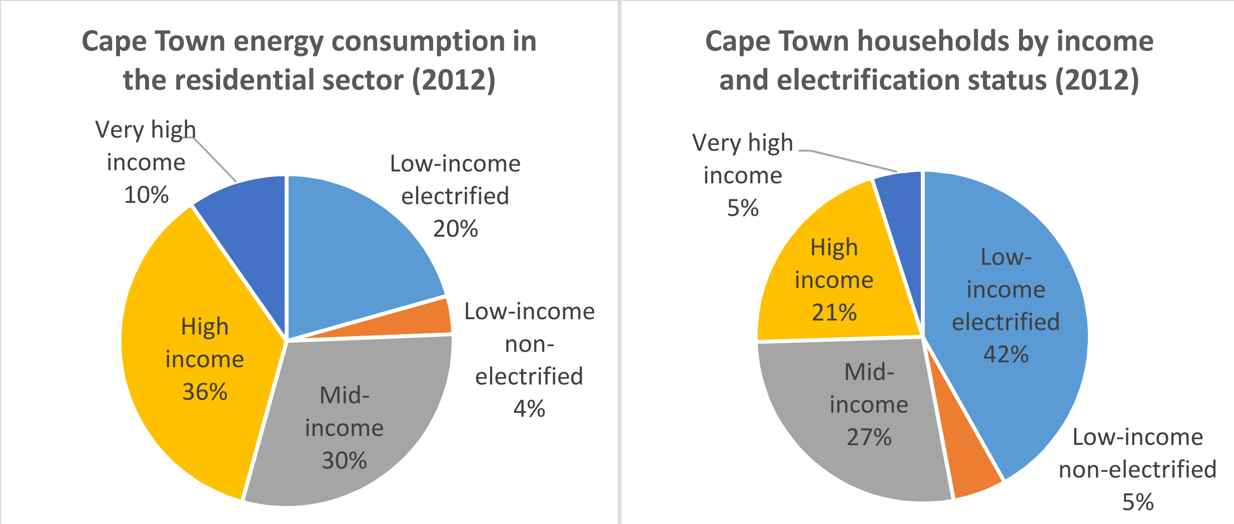


Figure 11: Cape Town residential sector: energy consumption vs. number of households 2012

A disproportionately high amount of energy is consumed by the high- and very high-income households, when comparing energy consumption with household numbers. Low-income households, on the other hand, only contribute towards 24% of all residential energy consumption, while making up 47% of all households.

LEAP Baseline vs. State of Energy

This model has been worked to align as closely as possible with the baseline data presented in the *Cape Town State of Energy 2015* (hereafter referred to as the *State of Energy 2015*). The very small discrepancies that do persist between the baseline pictures presented above and those presented in the *State of Energy* are due to the fact that the LEAP model uses a bottom-up approach when building an energy picture, while the *State of Energy* applies a top-down approach. This is especially true for electricity emissions. In the *State of Energy*, one emissions factor is applied to electricity. In LEAP, an emission factor is assigned to each fuel used to generate electricity (coal, diesel, etc.) and LEAP calculates the final electricity output's emissions based on these fuel stock emissions factors and the power plant mix specified. It is impossible to fully recreate an electricity production process that matches the real-life situation completely.

There are differences in the energy and emissions conversion factors used in LEAP and in the State of Energy report. The State of Energy used energy conversion factors sourced from the national Department of Energy (DoE),[11] and South Africa-specific emissions conversion factors sourced from www.emissionfactors.com (using the IPCC 4th Assessment Report Global Warming Potential), whereas LEAP uses default IPCC energy and emissions conversion factors. This iteration of the modelling exercise has been worked to adjust the LEAP energy and emissions conversion factors so that they align as closely as possible with those used in the State of Energy.

Table 5: State of Energy 2015 v.s. LEAP default energy and emissions conversion factors

	kg CO_2e/unit			GJ/unit			kg CO2e/GJ		
	LEAP	SoE	Difference	LEAP	SoE	Difference	LEAP	SoE	Difference
Electricity (kWh)	0.90	1.03	-13%	0.0036	0.0036	0%	248.8	286.1	-13%

[11] Department of Energy, Draft 2012 Integrated Energy Planning Report, Annexure B - Model Input and Assumptions (Optimisation Model) (Published September 2013)

Petrol (lit)	2.29	2.28	1%	0.0332	0.0342	-3%	69.2	66.6	4%
Jet Fuel (lit)	2.56	2.52	2%	0.0361	0.0343	5%	70.8	73.4	-4%
Paraffin (lit)	2.64	2.58	3%	0.0362	0.0370	-2%	72.9	69.6	5%
Diesel (lit)	2.78	2.70	3%	0.0377	0.0381	-1%	73.6	70.9	4%
HFO (lit)	2.93	2.97	-1%	0.0382	0.0416	-8%	76.7	71.3	7%
LPG (lit)	1.81	1.62	12%	0.0255	0.0267	-4%	70.9	60.7	17%
Coal (bituminous) (kg)	2.73	2.81	-3%	0.0293	0.0243	21%	93.3	115.6	-19%
AvGas (lit)	2.29	2.21	4%	0.0327	0.0339	-4%	70.1	65.0	8%
Coal (elec gen) (kg)	5.06	N/A	N/A	0.0293	0.0243	N/A	172.6	N/A	N/A

Table 6: Emissions factors used in LEAP modelling exercise[12]

Fuel	kg CO_2e/GJ	kg CO_2e/unit	unit
Electricity	248.81	0.90	kWh
Petrol	66.58	2.28	lit
Jet Fuel	73.35	2.52	lit
Paraffin	69.65	2.58	lit
Diesel	70.92	2.70	lit
HFO	71.35	2.97	lit
LPG	60.75	1.62	lit
Coal (bituminous)	115.64	2.81	kg
AvGas	65.04	2.21	lit
Coal (electricity generation)	172.59	3.47	kg

The LEAP model was adjusted so as to match top-down figures as close as possible within the constraints of the model set-up. All emission factors above are entered explicitly into LEAP, aside from electricity, which is calculated in LEAP by factoring in the emissions per each fuel type for each power plant type (e.g. diesel, coal). Since it is difficult to match real-world power plant availability exactly, the emissions factors for electricity won't match completely. As can be seen in the table below, the figures are similar.

Table 7: LEAP baseline vs. Cape Town State of Energy

	State of Energy 2015	LEAP	State of Energy 2015	LEAP
Sector	GJ		tCO_2e	
Residential	11.6%	11.5%	22.3%	22.1%
Commercial	12.6%	12.7%	25.8%	25.7%
Industrial	7.9%	7.7%	10.6%	10.0%
Agricultural	0.5%	0.5%	1.0%	1.0%
Local government	1.4%	1.4%	2.4%	2.4%
Transport	63.6%	63.9%	32.8%	33.8%
Electricity losses	2.4%	2.4%	5.1%	5.0%
Total	100%	100%	100%	100%
Energy source	GJ		tCO_2e	
Electricity	29.5%	29.4%	62.9%	62.2%
Petrol	30.9%	30.9%	15.3%	15.6%

[12] All are State of Energy factors, aside from electricity (calculated internally in LEAP) and coal used for electricity generation

Diesel	22.0%	22.0%	11.6%	11.9%
Paraffin	1.4%	1.4%	0.7%	0.7%
LPG	1.5%	1.5%	0.7%	0.7%
HFO	1.0%	1.0%	0.5%	0.6%
Coal	2.6%	2.6%	2.2%	2.3%
Jet fuel	6.3%	6.3%	3.5%	3.5%
Aviation gasoline	0.0%	0.0%	0.0%	0.0%
International marine	4.7%	4.7%	2.5%	2.5%
Wood	0.0%	0.1%	0.0%	0.0%
Total	100%	100%	100%	100%

It is important to note that LEAP's function is to give an indication as to the relative scales of impact of various energy efficiency and renewable energy interventions as part of a scenarios modelling process. The baseline picture is robust enough for this purpose.

7. Energy Supply Data

Coal

Coal data was obtained from a variety of sources. As mentioned in the *Data Problems and Limitations* chapter, coal data is very hard to source and various datasets differ substantially from one another. Ultimately it was decided to use the coal supply estimates provided by major coal suppliers in Cape Town for the industrial coal use supply figure.

Table 8: Coal use supply by sector in Cape Town

Sector	tonnes pa
Commercial	13.05
Industrial[13]	167,734.95
Residential	252.00
TOTAL	168,000.00

Coal used by hospitals was sourced from Western Cape Hospitals and assigned to the commercial sector. Residential coal use was calculated by assigned 10kg/month to households that used coal for space heating and/or cooking, as provided in the Census 2011. It must be noted that the residential coal amount is a discrepancy when comparing the LEAP model with the *State of Energy*, as this data methodology was decided upon at too late a stage to incorporate into the *State of Energy*.

Liquid Fuel

Liquid fuel sales data by magisterial district, fuel type and trade category was sourced from the Department of Energy (DoE). Magisterial districts do not align completely with municipal areas. Liquid fuel sales were assigned according to the proportion of geographic overlap of the areas.

Table 9: Assigning magisterial district liquid fuel sales to the City of Cape Town metropolitan area

[13] Communication with Wescoal and A1 Energy Consultants

Magisterial district	Percentage assigned to metro area
Bellville	100%
Cape Town	100%
Eerste River	100%
Goodwood	100%
Kuils rivier	95%
Malmesbury (south of 33o30' latitude)	50%
Mitchell's Plain	100%
Simon's Town	100%
Somerset West	95%
Strand	100%
Wynberg	100%

Liquid fuel sales were assigned to sectors, using the trade category as a guide.

Table 10: Assigning liquid fuels to sectors

Product Name	Trade Category Name	Assigned sector
Aviation	All trade categories	Transport/Aviation
Aviation Gasoline	All trade categories	Transport/Aviation
Diesel	Agricultural Co-ops, Farmers	Transport/Agricultural
Diesel	Commercial	Transport/Commercial
Diesel	Construction, Local marine fishing, Mining	Transport/Industrial
Diesel	Road Haulage, Transnet	Transport/Freight
Diesel	Remaining trade categories	Transport/Passenger
Furnace Oil	Commercial	Commercial
Furnace Oil	Remaining trade categories	Industrial
Int. Marine Fuels	All trade categories	Transport/Marine
LPG	All trade categories	Industrial, Commercial or Residential (detailed notes further below)
Paraffin	Agricultural Co-ops, Farmers	Agricultural
Paraffin	Commercial, Government	Commercial
Paraffin	Construction, Local marine fishing, Mining	Industrial
Paraffin	Remaining trade categories	Residential or Commercial (detailed notes further below)
Petrol	Agricultural Co-ops, Farmers	Transport/Agricultural
Petrol	Commercial	Transport/Commercial
Petrol	Construction, Local marine fishing, Mining	Transport/Industrial
Petrol	Road Haulage	Transport/Freight
Petrol	Remaining trade categories	Transport/Passenger

Diesel and petrol from the remainder categories were assigned to the passenger transport sector. This results in an overestimation of fuel used in this sector when compared to commercial transport activities including couriers, small business (gardening, pool maintenance), etc., but excluding freight. Freight energy consumption was cross-checked with major freight companies based in Cape Town and it appears that the actual freight energy consumption figure is in the ballpark of that used in the LEAP model.[14] In future iterations of the LEAP model, more research would need to be done on the split of petrol and diesel use between the passenger and small commercial transport sectors.

Residential paraffin and LPG use was calculated using a bottom-up approach, e.g. litres per households per household income band x no. of households = total litres of paraffin used in residential sector. The remaining paraffin from the "Remaining trade categories" was assigned to the commercial sector.

Table 11: Paraffin usage by sector

Paraffin	%
Total	100.0%
Agricultural	0.0%
Industrial	7.4%
Residential	72.1%
Commercial	20.4%

Communication with major LPG suppliers in Cape Town indicated that LPG use was split roughly as 25% residential, 25% commercial and 50% industrial. The bottom-up LEAP residential LPG use calculations resulted in an amount of LPG use in the residential sector that was 24% of the total LPG use. This is very close to what was indicated by LPG suppliers. The remainder was split between the commercial and industrial sectors according to the proportions supplied by the LPG industry.

Table 12: LPG usage by sector

Sector	%
Residential	24.0%
Commercial	25.3%
Industrial	50.6%
TOTAL	100.0%

The jet fuel and diesel use at Eskom's peak power plants, Acacia and Ankerlig, had to be subtracted to avoid double-counting of energy/emissions, as the electricity produced by these plants is already counted.

Table 13: Liquid fuel use by Eskom's peak power plants[15]

Fuel	Litres (2012)

[14] Telephonic interview with Mr Rabie, who previously worked at Imperial Trucks, May 2015. An estimate of diesel consumed at the Imperial Depot was provided. Assuming that each of the other large companies (Value, Unitrans and SuperGroup) consume the same amount, the total figure consumed made up almost 70% of the amount given as sales under the DoE Road Haulage trade category (Transnet is captured separately in the DoE dataset). The remaining 30% would be consumed by smaller players. A future data research iteration may consider contacting the Road Haulage Association for more accurate figures.

[15] Source: Eskom website: http://www.eskom.co.za/OurCompany/SustainableDevelopment/Pages/Sustainable_Development.aspx

Diesel (Ankerlig)	267,322,211
Jet Fuel (Acacia)	2,694,100

Ankerlig's diesel use was subtracted from the Transport/Passenger diesel category in Table 10 and Acacia's jet fuel use was subtracted from the Transport/Aviation category.

Local government's petrol and diesel use was subtracted from the Transport/Commercial category for each respective fuel.

Table 14: Local government diesel and petrol use[16]

Fuel	Litres (2012)
Diesel	9,999,489
Petrol	5,996,777

The international marine fuels figure from DoE was not used, as more reliable data on bunker fuels use was sourced from Caltex.

Electricity

Grid

Information on electricity power plant capital costs (with learning rates), operations and maintenance costs, efficiency, availability and lifetime by power plant type was obtained from the SNAPP tool (2.0 IRP 2010 base and policy-adjusted) developed by the Energy Research Centre.

Sales

Electricity sales by tariff data were received from the City of Cape Town and Eskom.

Table 15: Assigning City electricity sales to sectors

City of Cape Town	kWh (2012 calendar year)	LEAP sector assigned
Municipal - street	128,542,704	Local Government
Municipal - traffic	11,878,705	Local Government
Municipal - other	234,801,904	Local Government
Domestic	3,460,717,785	Residential
SPU (Small Power User)	1,690,550,090	Commercial
LPU (Large Power User)	3,859,334,288	Industrial (30%), commercial (70%)
Off-Peak	173,123	Commercial
Total sold	**9,385,998,599**	

LPU customers are either industrial or large commercial, such as malls. A study by Caroline Martin on all 1300 LPU customers in 2006/07 had indicated that 30% of the electricity used by these customers was used in the industrial sector, while 70% was consumed by the commercial sector. The City's electricity department had indicated that they did not expect this proportion to have changed dramatically by 2012.

[16] Source: City of Cape Town

Table 16: Assigning Eskom electricity sales to sectors

Eskom	LEAP sector assigned
Agriculture	Agricultural
Bulk / Distributors	N/A - sales to municipalities
Commercial	Commercial
Industrial	Industrial
Internal	Industrial
Mining	Industrial
PrePayment	Residential
Public Lights	Local Government
Residential	Residential
Total	

Eskom's prepayment tariff most likely includes sales to the commercial sector, but all sales were assigned to the residential sector.

The difference between the total amount of electricity bought by the City from Eskom and the total sold was used to calculate electricity losses.

Small-scale embedded generation (SSEG) (e.g. solar PV on rooftops) was assumed to be consumed in the commercial sector. A total of 194,910 kWh was generated in 2012.[17]

Sales from Eskom to the City's wastewater treatment works was subtracted from Eskom's industrial-assigned sector sales.

Metrorail is supplied directly by Eskom.[18] The amount of electricity used by rail was calculated using a bottom-up approach in LEAP (see *Transport Sector Energy Data* chapter). These sales were also subtracted from Eskom's industrial-assigned sector sales. Electricity use by the transport sector represents a discrepancy between the LEAP model and the *State of Energy* report.

8. Residential Sector Energy Data

Energy Demand

Households

The main energy driver for the residential sector is the number and growth of households. Data is worked to render figures of household growth, disaggregated down to dwelling type, and energy consumption per household, disaggregated down to income band. This means that residential sector energy consumption is 'grown' in the model in proportion to various end use applications of energy in households. Household growth closely follows population growth.

Household and population numbers were available for 1996-2011 from the StatsSA Censuses. Population projections were available until 2050 from the Western Cape Government (WCG). The

[17] Source: City of Cape Town
[18] Communication with Wouter Roggen, City of Cape Town

number of households until 2040 was inferred by assuming the same number of people per household from 2011 onwards. This provided an average growth rate projection for households across all dwelling types. There is a dramatic drop in average growth per annum between 2012 and 2020. This is based on data used by the City and WCG, drawn off a detailed study undertaken for both governments. The study indicated that previous assumptions relating to growth were flawed and the projections presented here are accepted as more realistic, given in and out-migration patterns, etc. [19]

Table 17: Population and household growth[20]

Year	Households	Average growth p.a.	Population	People per household
1996	651,755	N/A	2,562,277	3.93
2001	759,484	3.11%	2,892,243	3.81
2011	1,068,574	3.47%	3,740,026	3.50
2012	1,096,399	2.60%	3,837,414	3.50
2020	1,180,486	0.93%	4,131,720	3.50
2030	1,262,893	0.68%	4,420,145	3.50
2040	1,324,052	0.47%	4,634,202	3.50
2050	1,367,587	0.32%	4,786,575	3.50

Household growth rate projections for informal vs formal households were calculated as follows:

1. StatsSA provides number of households by dwelling type. This data was amalgamated into informal (consisting of informal dwelling in back-yard and informal dwelling in informal settlement) and formal (all other categories). It excluded “unspecified” households.
2. Average growth rates per annum were calculated for informal and formal households for 1996-2001 and 2001-2011 using the following formula: (no. of households in end year / no. of households in start year) ^ (1/(no. of years)) – 1.
3. Similarly, average growth rates for the total number of households were calculated for 2011-2020, 2020-2030, 2030-2040 and 2040-2050.
4. Growth rate by dwelling type for 2011-2020 was calculated as a percentage contribution of growth rates in 2001-2011. Example: Formal dwelling growth: 3.26% (formal)/3.47% (total) = 93.90%. Therefore formal growth 2011-2020 calculated as 0.93%*93.90% = 0.87%. Similarly, growth rates by dwelling type for 2020-2030 was calculated as a percentage contribution of growth rates in 2001-2011, etc.
5. Number of households by dwelling type for 2020, 2030, 2040 and 2050 were then calculated from the growth figures.
6. The sum of the resulting figures for households by dwelling type were very close to the total figure given by WCG (“check” row in Table 17 below).
7. The highlighted figures in the table below were used in the LEAP model as the average growth rate p.a. for formal and informal households.

[19] Received from Karen Small, City of Cape Town, Strategic Information. This data derived from a study done by Price Waterhouse Cooper for the Western Cape Government and the City of Cape Town. The Dorrington Medium Scenario used here is the accepted growth scenario of both government institutions. The large jump from previous growth figures was due to these being unduly inflated, for various reasons. The Dorrington Medium is accepted also by academia as a reasonable representation of growth given all factors (pers. com. Prof S Parnell, African Centre for Cities, University of Cape Town).

[20] Source of population figure for 2050: Western Cape Government, 2014: Dorrington Medium Scenario

Of importance is that although informal household numbers are set to grow at a faster rate than formal, the difference is very small and both dwelling types are projected to grow far more slowly than previously forecast.

Table 18: Household growth by dwelling type

Dwelling Type	Number of households						
	1996	2001	2011	2020	2030	2040	2050
Formal dwelling	526,551	616,503	849,794	**918,805**	**978,917**	**1,023,372**	**1,054,938**
Informal	125,204	142,981	218,780	**242,730**	**264,091**	**280,177**	**291,745**
Total	651,755	759,484	1,068,574	**1,161,534**	**1,243,008**	**1,303,549**	**1,346,683**
Check> against WCG total household projections				1,180,486	1,262,893	1,324,052	1,367,587
Dwelling Type	Average growth p.a.						
	1996-2001	2001-2011	2011-2020	2020-2030	2030-2040	2040-2050	2011-2050
Formal dwelling	3.20%	3.26%	**0.87%**	**0.64%**	**0.45%**	**0.30%**	**0.56%**
Informal	2.69%	4.35%	**1.16%**	**0.85%**	**0.59%**	**0.41%**	**0.74%**
Total	3.11%	3.47%	0.93%	0.68%	0.47%	0.32%	0.59%

Bold figures are projections. The figures in the highlighted cells were used in LEAP.

StatsSA reports monthly income in a number of income bands. These were grouped as follows:

Table 19: Household income bands

Income band	Lower limit	Upper limit
Low	R 0	R 3,200
Mid	R 3,201	R 12,800
High	R 12,801	R 51,200
Very high	R 51,201	N/A

StatsSA provides data on main fuel used for lighting, heating and space heating. When a household is electrified, electricity is usually used for lighting, first and foremost, even if other fuels such as paraffin are still being used for cooking and/or space heating. If a household used electricity for lighting, it was assumed that the household was electrified.

Table 20: Household electrification by income band

Households using electricity for lighting	2001	2011
Low-income	80.6%	89.0%
Medium-income	98.6%	97.6%
High-income	99.5%	99.3%
Very high income	98.0%	99.4%

The 2011 household numbers were allocated by income band and electrification status using data from the above two tables. The 2012 figures were calculated by using the household growth rates calculated further above. It was assumed that low-income non-electrified households increased at the informal dwelling growth rate, whilst the remainder increased at the formal dwelling growth rate. ***Households thus grow relatively slowly (at a rate far below economic growth) and this trend is similar across all housing types/income bands.***

Table 21: Household growth by electrification and income band

Household Type	2011	2012	Growth p.a.
Low-income electrified	447,167	449,653	0.56%
Low-income non-electrified	55,243	55,652	0.74%
Mid-income electrified	286,594	288,187	0.56%
Mid-income non-electrified	7,180	7,220	0.56%
High-income	219,485	220,705	0.56%
Very high-income	52,832	53,126	0.56%

Electricity sales on the City of Cape Town's Domestic tariffs and Eskom's Residential and Prepayment tariffs were assigned to the residential sector.

Energy by End-Use

Data on main fuel used for lighting, space heating and cooking, as well as fridge ownership, was obtained from StatsSA's SuperWeb interactive data interface. "Electricity used for lighting" was used as a data filter/layer to define whether a house was electrified or non-electrified. Coal and animal dung were excluded as negligible. There was also little data available on amount of fuel used for these fuel types. In low- and medium-income households, fuel use split for water heating was assumed to be the same as for cooking. It was assumed that all high- and very high-income households had electric geysers for water heating.

Table 22: Main energy source used for cooking in households

Census Year	2011					
Fuel for cooking	Electricity	Gas	Paraffin	Wood	Solar	Total
ZAR/month						
Low (elec)	95.51%	3.58%	0.68%	0.11%	0.12%	100.00%
Low (non-elec)	N/A	29.45%	67.05%	3.20%	0.30%	100.00%
Mid (elec)	94.87%	4.79%	0.15%	0.08%	0.11%	100.00%
Mid (non-elec)	N/A	48.09%	48.66%	2.22%	1.03%	100.00%
High	89.70%	9.88%	0.17%	0.10%	0.15%	100.00%
Very high	78.77%	20.91%	0.12%	0.09%	0.11%	100.00%

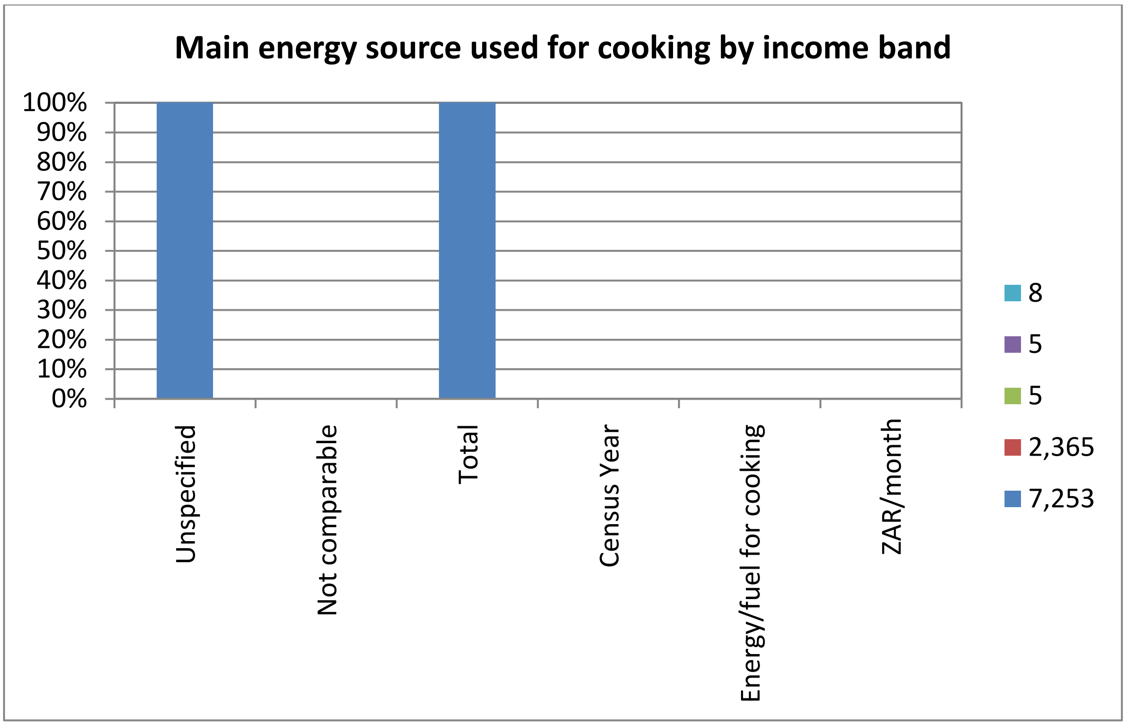


Figure 12: Main energy source used for cooking in residential sector by income band

Table 23: Main energy source used for space heating in households

Census Year	2011						
Fuel for space heating	Electricity	Gas	Paraffin	Wood	Solar	None	Total
ZAR/month							
Low (elec)	57.42%	1.94%	18.48%	0.74%	0.21%	21.22%	100.00%
Low (non-elec)	N/A	5.90%	62.58%	6.20%	0.29%	25.03%	100.00%
Mid (elec)	71.01%	2.40%	11.20%	1.00%	0.30%	14.09%	100.00%
Mid (non-elec)	N/A	15.20%	54.39%	5.19%	0.99%	24.22%	100.00%
High	79.10%	5.93%	2.81%	3.30%	0.65%	8.21%	100.00%
Very high	76.30%	10.08%	N/A	7.38%	1.37%	4.88%	100.00%

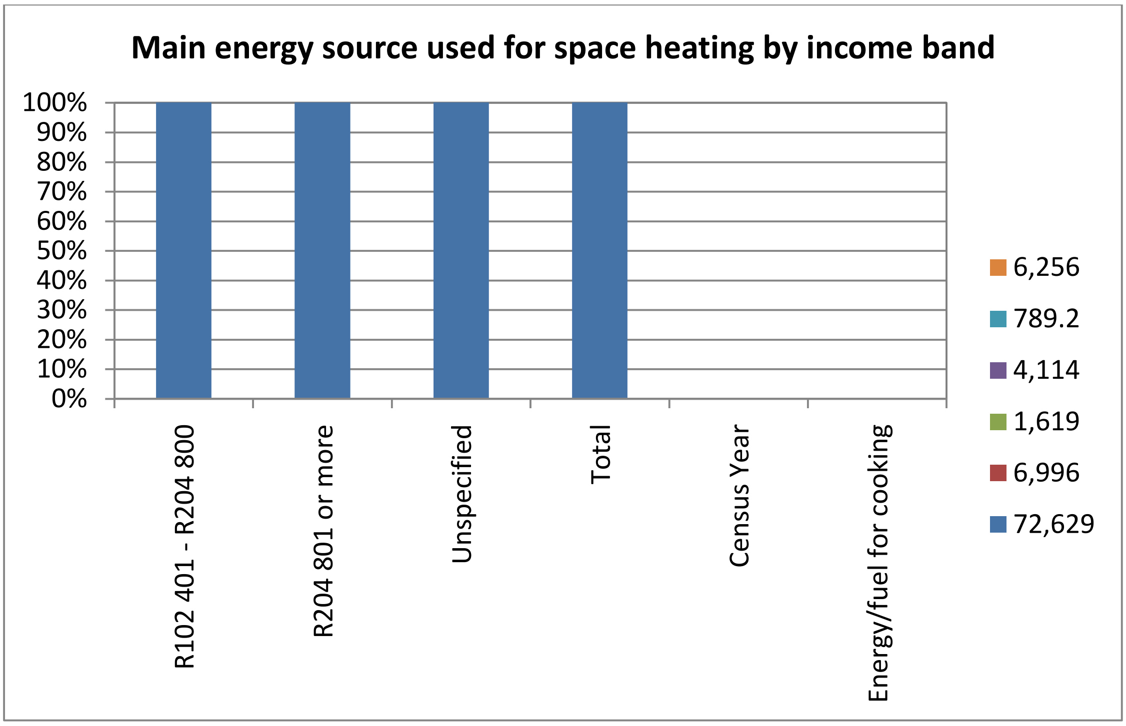


Figure 13: Main energy source used for space heating in residential sector by income band

Table 24: Main energy source used for water heating in households

Census Year	2011				
Fuel for water heating	Electricity	Gas	Paraffin	Wood	Total
ZAR/month					
Low (elec)	73.08%	2.47%	23.52%	0.94%	100.00%
Low (non-elec)	N/A	7.90%	83.80%	8.30%	100.00%
Mid (elec)	82.94%	2.81%	13.08%	1.17%	100.00%
Mid (non-elec)	N/A	20.33%	72.73%	6.94%	100.00%
High	100.00%	0.00%	0.00%	0.00%	100.00%
Very high	100.00%	0.00%	0.00%	0.00%	100.00%

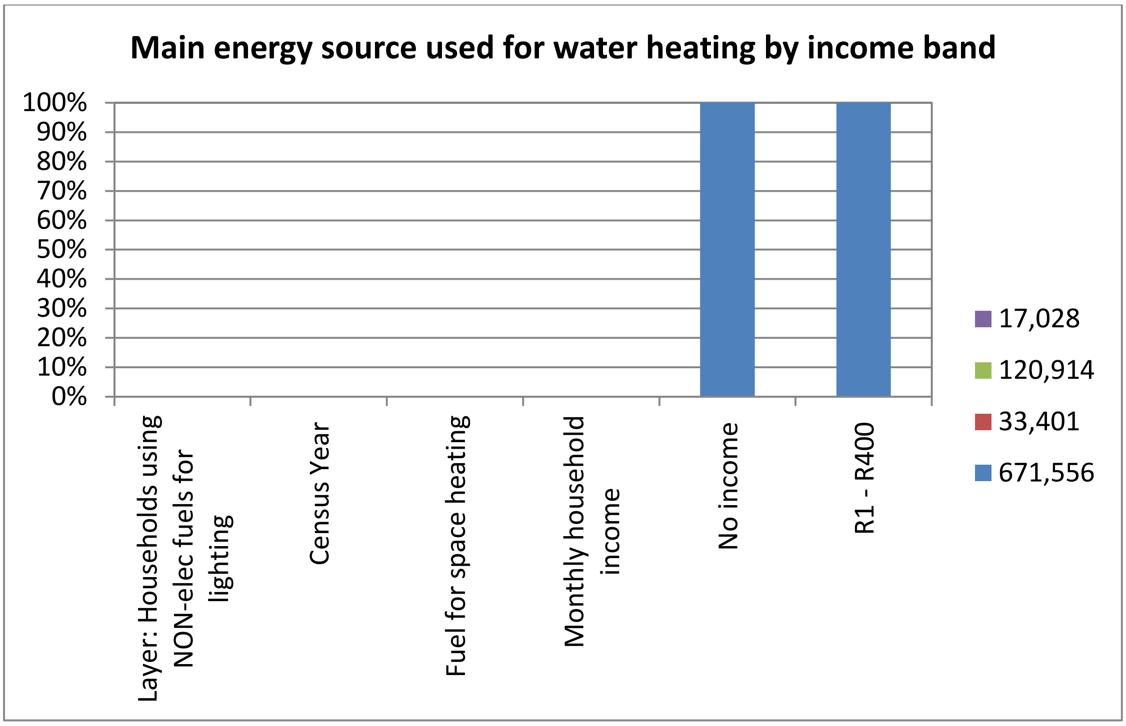


Figure 14: Main energy source used for water heating in residential sector by income band

Table 25: Fridge ownership in households

Type of dwelling	Yes	No
Formal	91.93%	8.07%
Informal, Traditional & Other	47.18%	52.82%
TOTAL	82.16%	17.84%

StatsSA dwelling types were assigned as follows:

Table 26: Assigned dwelling type

Type of dwelling	Assigned
House or brick/concrete block structure on a separate stand or yard or on a farm	Formal
Flat or apartment in a block of flats	Formal
Cluster house in complex	Formal
Townhouse (semi-detached house in a complex)	Formal
Semi-detached house	Formal
House/flat/room in backyard	Formal
Room/flatlet on a property or larger dwelling/servants quarters/granny flat	Formal
Traditional dwelling/hut/structure made of traditional materials	Traditional
Informal dwelling (shack; in backyard)	Informal
Informal dwelling (shack; not in backyard; e.g. in an informal/squatter settlement or on a farm)	Informal
Caravan/tent	Other
Other	Other

Table 27: Baseline residential intervention penetration

Technology (income band)	%
CFLs (low)	60%
CFLs (mid)	90%
CFLs (high)	45%
CFLs (very high)	45%
LED (high)	25%
LED (very high)	25%
Efficient fridge (low)	20%
Efficient fridge (mid)	20%
Efficient fridge (high)	20%
Efficient fridge (very high)	20%
Efficient geyser (mid)	10%
Efficient geyser (high)	20%
Efficient geyser (very high)	30%
SWH (low, mid)	0%
SWH (high)	9%
SWH (very high)	9%

Notes:

- The efficient geyser intervention includes general efficiency measures such as insulation and reduction of set-point temp.
- Savings on existing electric geyser can be as high as 31.5% for a reduction in temp of 10°C.[21] Savings were set as 30% in LEAP.
- A Cape Town electricity savings campaign survey[22] indicated that in the LSM 7-10 bracket (average monthly household income of R10 255.00 or more), 8.6% of respondents had a SWH, 0.8% had a heat pump, and 93.0% had an electric geyser. LSM 7-10 aligns with high and very high income bands in LEAP.

Running LEAP with the old 2007 energy intensity values and the new 2012 household numbers resulted in electricity use higher than actual sales to the residential sector, despite the higher penetration of efficient technologies when compared to the *Energy Scenarios for Cape Town 2011* report's 2007 baseline. All energy intensities that could be affected by behaviour change (i.e. all end-uses except refrigeration) were adjusted downwards until calculated electricity use matched electricity sales. The adjustment factor that resulted in a match between electricity sales and use was 17.29%, i.e. all energy intensity figures (excluding that of refrigeration) were adjusted downwards by 17.29%. In the above-mentioned electricity savings campaign survey, when asked about steps respondents would take to save electricity within next 12 months, 84.7% indicated that they would change their behaviour and 22.3% would install SWHs. Behaviour seems to be the "first port of call." This fact that the LEAP model energy intensity figures had to be adjusted downwards so strongly since the last modelling exercise (despite a higher baseline penetration rate of energy efficiency interventions), indicates that people may indeed be changing their behaviour to save electricity.

[21] "Hot water usage profiling to improve geyser efficiency" by Q. Catherine, J. Wheeler, , R. Wilkinson, G. De Jager

[22] "Electricity Savings Campaign Baseline Survey" by Mthente, Aug 2013

Residential sector paraffin and LPG use was calculated using a bottom-up approach, by using the energy intensity figures per household from the previous LEAP model (2007 baseline). This is why there are discrepancies between the *State of Energy 2015* report and this report's paraffin and LPG figures for the residential sector. The *State of Energy* used a top-down approach to allocate LPG and paraffin use, e.g. a % of total paraffin sales was allocated to the residential sector. LPG and paraffin energy intensity values were adjusted downwards in line with the adjustment factor used for electricity, as it was decided that the behaviour change causing a reduced electricity use would also be implemented across all fuel type usage. Interestingly, the calculated LPG use for the residential sector, given this new adjustment factor, aligns with indications from the LPG industry as to the proportion of total LPG consumed by the residential sector (25% of total, when LEAP model output was 24%).

Through building up an end-use application picture, and using the data on energy per income band, an approximation of the disaggregation of energy per end use application for each income group has been developed.

Table 28: Household energy end use by income band and application

Low income electrified	100%	Low income non-electrified	100%
Lighting	8%	Lighting	17%
Cooking	29%	Cooking	45%
Space heating	9%	Space heating	7%
Water heating	32%	Water heating	31%
Refrigeration	11%		
Other electric	11%		
Medium income electrified	100%	Medium income non-electrified	100%
Lighting	4%	Lighting	22%
Cooking	14%	Cooking	27%
Space heating	9%	Space heating	11%
Water heating	39%	Water heating	40%
Refrigeration	17%		
Other electric	17%		
High income	100%	Very high income	100%
Lighting	3%	Lighting	3%
Cooking	12%	Cooking	13%
Space heating	6%	Space heating	6%
Water heating	41%	Water heating	35%
Refrigeration	17%	Refrigeration	15%
Other Elec	21%	Other Elec	28%

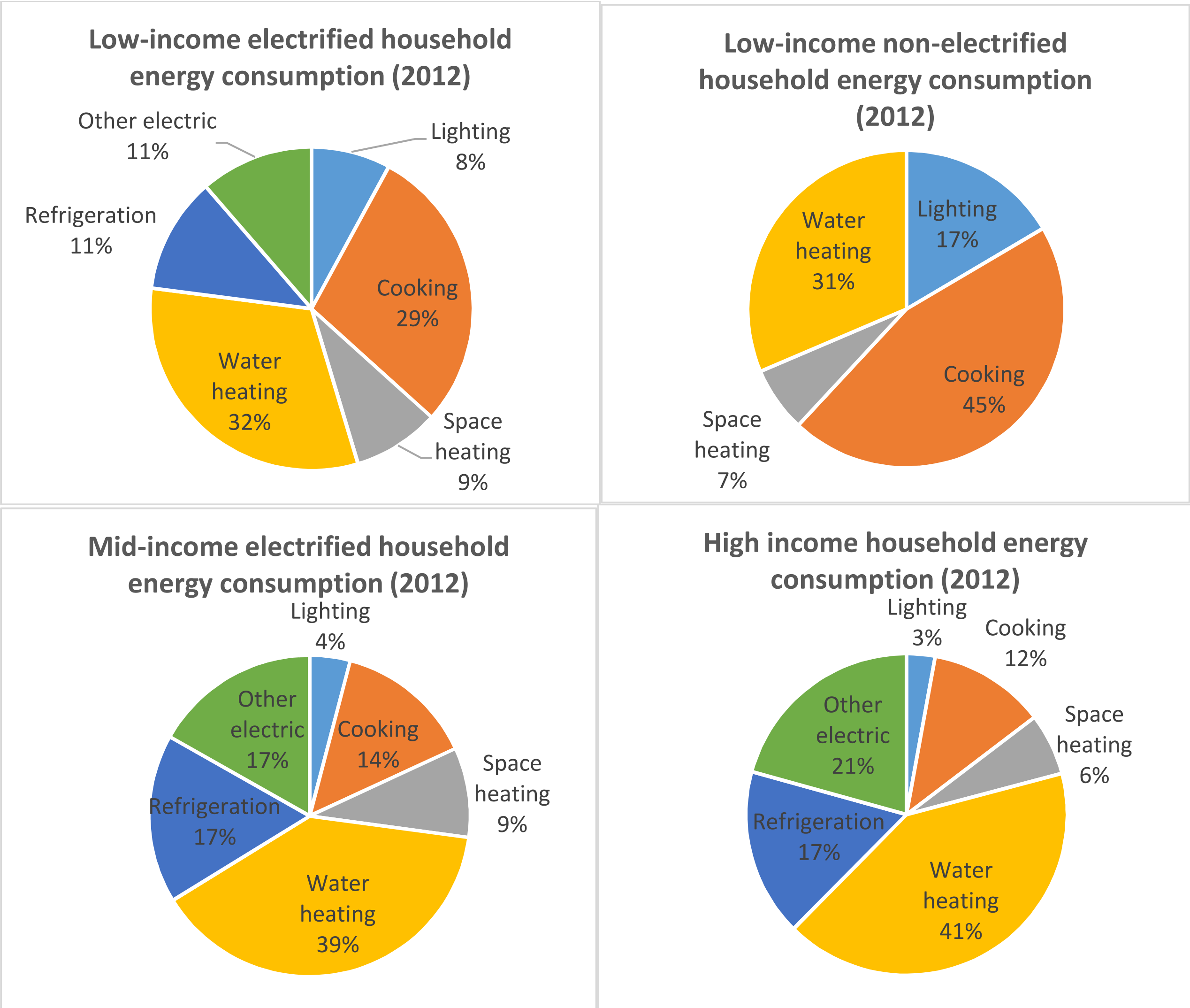


Figure 15: Energy end use application per major household income groupings

Interventions and Costing

Electricity price

Table 29: Electricity price in the residential sector[23]

	c/kWh		ZAR/kWh	ZAR/GJ
Tariff	Excl. VAT	Incl. VAT	Incl. VAT	
Lifeline Block 1	64.93	74.02	0.74	205.61
Lifeline Block 2	89.95	102.54	1.03	284.84
Lifeline Block 3	118.11	134.65	1.35	374.02
Lifeline Block 4	140.18	159.81	1.60	443.90
Lifeline Average	**103.29**	**117.75**	**1.18**	**327.09**
Domestic Block 1	113.2	129.05	1.29	358.47
Domestic Block 2	118.11	134.65	1.35	374.02
Domestic Block 3	118.11	134.65	1.35	374.02
Domestic Block 4	140.18	159.81	1.60	443.90

[23] City of Cape Town: Draft Electricity Tariffs To Be Implemented With Effect From 1 July 2012

Domestic Average	122.40	139.54	1.40	387.60

The *Average Domestic* tariff was used for electricity price in mid- to high-income households. The *Average Lifeline* tariff was used for electricity price in low-income households.

Liquid fuel price

See "liquid fuel price" under *Transport Interventions and Costing* chapter.

Capital cost and lifespan of devices

Table 30: Capital cost and lifespan of devices[24]

Device by income band	ZAR						Lifespan (years)
	Low E	Low NE	Mid E	Mid NE	High	Very high	
LED 5W	N/A	N/A	N/A	N/A	139	139	10
Halogen Downlight 50W	N/A	N/A	N/A	N/A	27	27	2
CFL 9W	23	N/A	23	N/A	23	23	4
Incandescent 60W	6	N/A	6	N/A	6	6	1
Candles	N/A	730	N/A	730	N/A	730	N/A
Elec geyser*	3 000	3 000	6 000	6 000	7 200	8 000	10
Elec geyser insul.*	3 365	3 365	6 365	6 365	7 965	8 765	10
SWH*	7 217	7 217	12 770	12 770	22 528	30 835	20
Fridge	2 000	2 000	4 000	4 000	6 000	10 000	15

* geysers costs inclusive of installation.

Key:

- Elec geyser insul. = elec geyser with insulated hot water pipes, geyser blanket and efficient showerhead
- SWH = Solar water heater with efficient showerhead
- E = Electrified
- NE = Not electrified

Notes:

- Costs of candles = R2/candle x 365 days
- Installation costs excluded in above table
- LEAP cannot work with lifespans <1 year, therefore incandescent lifespan set as 1 year

Table 31: No. of devices per household[25]

Device	Income			
	Low	Mid	High	Very high
Light bulbs	4.11	7.94	11.46	13.61
Water heating	1	1	1	1

[24] Costs sourced from Cape Town or South Africa-based suppliers.
[25] "Annexure B: Technical Report for Energy Scenarios for Cape Town: Exploring the implications of different energy futures for the City of Cape Town up to 2050" by Sustainable Energy Africa

9. Commercial Sector Energy Data

Energy Demand

The main driver of energy demand in the commercial sector was floor area (m²) and sector GVA growth. End use applications of energy in commercial buildings are disaggregated, proportionally, to an m² unit. Floor space expansion closely follows economic trends.[26] This then is the best unit of energy demand for the sector (as households was for the residential sector). The floor area in 2009 for Cape Town's commercial nodes was obtained from the City's Spatial Planning department. This provided the split between retail and office floor space.

Table 32: Commercial floor area by type

Sub-sector	%
Office	73%
Retail	27%
Total	100%

Energy by End-Use

Electricity

Data on electricity intensity and electricity use by end-use has improved since the previous LEAP modelling undertaken for the *State of Energy and Energy Futures 2011* report. In the previous iteration, international data was relied upon, but now Cape Town-specific studies are available.

Table 33: Electricity intensity of commercial sector – ordinary (not efficient) offices[27]

m^2	kWh/m^2
0-2,000	187
2,001-5,000	208
5,001-10,000	216
10,001-20,000	223
20,001-30,000	251
>30,000	255
Average	223

Table 34: Electricity intensity of commercial sector – inefficient retail[28]

Building type	kWh/m^2
Large shopping centre	605
Small shopping centre	337
Average	471

Table 35: Electricity intensity figures used for inefficient office and retail sub-sectors in LEAP

Sub-sector	kWh/m^2

[26] Economic Areas Management Programme ('ECAMP'), City of Cape Town, 2014.
[27] Source: Green Building Council of South Africa
[28] Source: "Energy savings through HVAC retrofits in the commercial sector in SA" by M. Moorlach & A. Hughes, UCT

Office	223
Retail	471

Table 36: Electricity use by end-use in the commercial sector[29]

End-use	%
Lighting	40%
Water heating	2.18%
HVAC	35.82%
Refrigeration	7%
Cooking	0%
Other	15%
Total	100%

The water heating figure in the above table may seem low, but LPG (not electricity) is the main fuel used for water heating in the commercial sector. Likewise, LPG, not electricity, is used for cooking.

Table 37: Electricity savings potential by end-use in the commercial sector[30]

End-use	Savings
HVAC (office)	25%
HVAC (retail)	13%
Lighting	40%
Refrigeration	5%
Water heating	69%

Electricity intensity by end-use was calculated, using the average electricity intensity of each commercial sub-sector (Table 35) and applying the end-use proportional split (Table 36) to these figures. Efficient electricity intensity values were calculated from these figures using the savings potential table (Table 37).

Table 38: Electricity intensity by end-use in the commercial sector

	kWh/m2				Penetration rate of efficient devices	
	Office		Retail			
End-use	Inefficient	Efficient	Inefficient	Efficient	Office	Retail
Lighting	89.20	53.52	188.40	113.04	50%	50%
Water heating	4.86	1.51	10.27	3.18	0%	0%
HVAC	79.88	59.91	168.71	126.53	0%	0%
Refrigeration	15.61	14.83	32.97	31.32	0%	0%
Cooking	0.00	0.00	0.00	0.00	0%	0%
Other	33.45	33.45	70.65	70.65	0%	0%
Total	**223.00**	**163.22**	**471.00**	**344.73**		

[29] Source: "Trends in commercial and Residential building demand in South Africa" presentation by Alison Hughes from ERC/CESAR

[30] Sources: "Analysis Report: Baseline, Energy Savings Potential and Energy Efficiency Programmes in Public Buildings in South Africa" developed by Sustainable Energy Africa for GIZ, February 2012 (lighting savings potential); "Energy savings through HVAC retrofits in the commercial sector in SA" by M. Moorlach and A. Hughes, University of Cape Town (HVAC savings potential); "KZN Industrial Research Report: Eastern Region" presentation by Meryl Govender (Market Research Advisor, Eastern Region, Eskom), March 2009 (refrigeration savings potential); Sustainable Energy Africa (water savings potential).

The floor area was adjusted (keeping the retail-office proportional split) until the resultant electricity use for the commercial sector roughly matched that of the top-down sales to the commercial sector.

Other fuels

Data on liquid fuel and coal use by end-use was very difficult to obtain. Since they only represent 6% of total commercial sector energy use according to the liquid fuel and coal sector allocation under the *Energy Supply* chapter, it was decided to allocate the fuel as a total amount, not split by sub-sector end-use.

Interventions and Costing

Electricity price

Table 39: Electricity price in commercial sector[31]

	c/kWh		ZAR/kWh	ZAR/GJ
Tariff	Excl. VAT	Incl. VAT	Incl. VAT	
SPU 1	103.4	117.88	1.18	327.43
SPU 2	161.68	184.32	1.84	511.99
SPU Average	**132.54**	**151.10**	**1.51**	**419.71**

Cost of electricity efficiency

Data on the capital cost of efficient vs. inefficient technologies was difficult to find, as there is a range of sizes and options for various applications. It was decided to apply a standard cost of 50 cents per kWh, as this was the rebate value of Eskom's Standard Offer Programme whilst it was running. Note: this cost should be applied over the first three years only, but currently is modelled until the model end-year. This cost could not be decreased to zero after 3 years, as some interventions may only be implemented after 2015. This issue applies to the commercial, industrial, agricultural and local government sectors. The residential sector has data per appliance, making this easier to model, e.g. cost for each appliance (efficient vs. inefficient) as opposed to cost per kWh saved.

Liquid fuel price

See "Liquid fuel price" under *Transport Sector Energy Data: Interventions and costing* chapter.

Coal price

See "Coal price" under *Industrial Sector Energy Data: Interventions and costing* chapter

10. Industrial Sector Energy Data

[31] Source: City of Cape Town: Draft Electricity Tariffs To Be Implemented With Effect From 1 July 2012

Energy Demand

The main driver of energy demand in the industrial sector was floor area and GVA growth (as for the commercial sector). The floor area in 2009 for Cape Town's industrial nodes was obtained from the City's Spatial Planning department. This was adjusted upwards to a 2012 value, using the GVA growth factor for the industrial sector (see Business as Usual key assumptions in Table 59).

Energy by End-Use

Electricity

Table 40: Electricity use and savings potential by end-use in the industrial sector[32]

End-use	kWh/m²	Savings Potential	Penetration rate of efficient technology
Compressed Air	4.18%	15%	0%
HVAC	2.31%	15%	0%
HVAC (Ventilation Fans)	2.94%	20%	0%
Lighting	2.84%	40%	50%
Mechanical Equipment	4.64%	15%	0%
Motors (EE potential)	44.98%	5%	10%
Motors (VSD potential)	31.73%	10%	10%
Process Heating	3.74%	5%	0%
Process Steam	0.04%	15%	0%
Pumps & Valves	0.34%	10%	0%
Refrigeration	2.25%	5%	0%
Total	100.00%		

Electricity intensity by end-use was calculated using the above figures and the total electricity sold to the sector.

Other fuels

Data on liquid fuel and coal use by end-use was very difficult to obtain. Liquid fuel and coal was allocated as a total fuel amount to the industrial sector; not split by end-use. Since coal and liquid fuels represent 34% and 23% of total energy use respectively, according to the allocations outlined in the *Energy Supply* chapters, this area requires further research in future iterations of state of energy and energy futures reporting.

Interventions and Costing

Electricity price

Table 41: Electricity price in industrial sector[33]

[32] "KZN Industrial Research Report: Eastern Region" presentation by Meryl Govender (Market Research Advisor, Eastern Region), March 2009. The penetration rates of efficient technologies are assumptions.
[33] City of Cape Town: Draft Electricity Tariffs To Be Implemented With Effect From 1 July 2012

Tariff	c/kWh		ZAR/kWh	ZAR/GJ
	Excl. VAT	Incl. VAT	Incl VAT	
LPU LV	161.31	183.89	1.84	510.82
LPU MV	150.03	171.03	1.71	475.10
LPU Average	**155.67**	**177.46**	**1.77**	**492.96**

LV = Low Voltage
MV = Medium Voltage

An average of the Large Power User tariffs was used in the LEAP model.

Cost of electricity efficiency

Data on the capital cost of efficient vs. inefficient technologies was difficult to find, as there is a range of sizes and options for various applications. It was decided to apply a standard cost of 50 cents per kWh, as this was the rebate value of Eskom's Standard Offer Programme whilst it was running. Note: this cost should be applied over the first three years only, but currently is modelled until the model end-year. This cost could not be decreased to zero after 3 years, as some interventions may only be implemented after 2015. This issue applies to the commercial, industrial, agricultural and local government sectors. The residential sector has data per appliance, making this easier to model, e.g. cost for each appliance (efficient vs. inefficient) as opposed to cost per kWh saved.

Liquid fuel price

See "Liquid fuel price" under *Transport Sector Energy Data: Interventions and Costing* chapter.

Coal Price

Table 42: Coal price

Coal type	ZAR/tonne[34]	USD/tonne	GJ/tonne[35]	ZAR/GJ
ZAR/tonne (Eskom)	200		20.1	9.95
ZAR/tonne (other)	1,128	94	24.3	46.42

11. Agricultural Sector Energy Data

Energy Demand

The total electricity consumed in the agricultural sector was obtained from Eskom (Table 16), whilst liquid fuel use was obtained from DoE (Table 10). In the absence of detailed end-use data, ***the main driver of energy demand for the sector is total energy and sector GVA growth.***

[34] "Stable local coal market" by Charlotte Mathews, 05 June 2014, 06:41 (http://www.financialmail.co.za/moneyinvesting/2014/06/05/stable-local-coal-market). Exchange rate of 12 ZAR/USD used for 2012 "other" coal cost (http://www.x-rates.com/average/?from=ZAR&to=USD&year=2012).

[35] Department of Energy's Draft 2012 Integrated Energy Planning Report: Annexure B - Model Input and Assumptions (Optimisation Model), Published September 2013

Energy by End-Use

Electricity

Table 43: Electricity use by end-use in the agricultural sector

End-use	kWh[36]	Potential savings[37]
Pumping/irrigation	29.0%	10%
Process	10.0%	
Other motive	3.2%	
Materials handling	16.0%	
Lighting	4.0%	40%
Homes & hostels	20.4%	
HVAC	6.4%	15%
Fans	1.5%	20%
Cooling	9.5%	
Total	100.0%	

Other fuels

Data on liquid fuel and coal use by end-use was very difficult to obtain. Liquid fuel use was allocated as a total fuel amount to the agricultural sector; not split by end-use. Liquid fuels represent 0.04% of all energy consumed in the agricultural sector according to the allocations outlined in the *Energy Supply: Liquid Fuel* chapter.

Interventions and Costing

Electricity price

The electricity price was assumed to be the same as in the commercial sector.

Cost of electricity efficiency

Data on the capital cost of efficient vs. inefficient technologies was difficult to find, as there is a range of sizes and options for various applications. It was decided to apply a standard cost of 50 cents per kWh, as this was the rebate value of Eskom's Standard Offer Programme whilst it was running. Note: this cost should be applied over the first three years only, but currently is modelled until the model end-year. This cost could not be decreased to zero after 3 years, as some interventions may only be implemented after 2015. This issue applies to the commercial, industrial, agricultural and local government sectors. The residential sector has data per appliance, making this easier to model, e.g. cost for each appliance (efficient vs. inefficient) as opposed to cost per kWh saved.

Liquid fuel price

[36] "Assumptions and Methodologies in the South African TIMES (SATIM) Energy Model" by ERC Systems Analysis & Planning Group, UCT

[37] "KZN Industrial Research Report: Eastern Region" presentation by Meryl Govender (Market Research Advisor, Eastern Region), March 2009. Assume same savings potentials for agricultural sector in similar end-use applications.

See “Liquid fuel price” under *Transport Sector Energy Data: Interventions and Costing* chapter.

12. Local Government Sector Energy Data

Energy Demand

While disaggregation of local government data is improving at a rapid pace, enabling more detailed modelling of demand interventions, the complexity is such that the main driver of energy demand remains total energy and sector GVA growth. Two dataset on electricity use in the local government sector was available. The top-down recorded sales of electricity to the municipality and actual metered or estimated use of their facilities. Where possible, the more detailed metered data was used in preference to that of the sales data. Liquid fuel use by the City’s fleet was obtained. It is uncertain as to whether this data represents a complete dataset or only represents fleet liquid fuel usage from one department.

Table 44: Electricity use by local government by sub-sector

Sub-sector	kWh
Street lighting (munic)	98,235,794
Street lighting (Eskom)	Not shown
Traffic lighting	1,668,780
WWTW (Eskom-supplied)	49,029,357
WWTW (munic)	76,737,573
Bulk Water Supply (munic)	19,039,860
Pump stations (munic)	44,426,340
Buildings and other (munic & Eskom)	135,114,966

Energy by End-Use

Street lighting

Data was provided by the City on the number, type and wattage of the street lighting stock. The average amount of hours that all the City lamps need to run each day to match that given in Table 44 is 11.3 hours. The total number of lamps was adjusted upwards proportionally until the electricity use equalled that provided by both Eskom and the City.

Table 45: Local government street lighting lamp stock, lifespan and cost[38]

Wattage	No.	Watts (W)	% devices	Lifespan (hrs)	Lifespan (years)	Luminaire & lamp cost
23W LED	0	23	0.00%	60,000	14.5	3,592
33W LED	0	33	0.00%	60,000	14.5	3,596
41W LED	0	41	0.00%	60,000	14.5	2,680

[38] Source of number and Wattage of lamps: Shaun Kemp, Public Lighting Development, City of Cape Town. Source of lifespan and cost of lamps: "Efficient public lighting guide: In support of Municipal Energy Efficiency and Demand Side Management" by Sustainable Energy Africa, 2012.

Wattage	No.	Watts (W)	% devices	Lifespan (hrs)	Lifespan (years)	Luminaire & lamp cost
50W HPS	30	50	0.01%	12,000	2.9	629
50W MH	0	50	0.00%	20,000	4.8	900
55W induction	0	55	0.00%	70,000	17.0	1,538
57W CFL	0	57	0.00%	30,000	7.3	2,791
70W HPS	99,858	70	47.19%	12,000	2.9	900
70W induction	0	70	0.00%	70,000	17.0	1,845
77W LED	0	77	0.00%	60,000	14.5	4,783
80W MV	*57,663*	*80*	*27.25%*	*12,000*	*2.9*	*656*
90W LED	0	90	0.00%	60,000	14.5	4,783
100W HPS	4,377	100	2.07%	16,060	3.9	1,176
120W induction	0	120	0.00%	70,000	17.0	2,650
125W MV	*3,843*	*125*	*1.82%*	*12,000*	*2.9*	*900*
150W HPS	19,145	150	9.05%	16,060	3.9	1,452
150W induction	0	150	0.00%	70,000	17.0	2,950
200W induction	0	200	0.00%	70,000	17.0	3,450
250W induction	0	250	0.00%	70,000	17.0	3,600
250W MV	*21,552*	*250*	*10.18%*	*12,045*	*2.9*	*1,733*
250W HPS	0	250	0.00%	16,060	3.9	1,280
250W MH	*0*	*250*	*0.00%*	*10,000*	*2.4*	*1,504*
400W MV	*3,547*	*400*	*1.68%*	*12,045*	*2.9*	*1,819*
400W MH	*0*	*400*	*0.00%*	*10,000*	*2.4*	*2,052*
400W HPS	0	400	0.00%	12,000	2.9	2,052
600W HPS	64	600	0.03%	Unknown	Unknown	Unknown
1000W HPS	1,494	1,000	0.71%	Unknown	Unknown	Unknown
2000W HPS	42	2,000	0.02%	Unknown	Unknown	Unknown
Total	**211,615**	**7,341**	**100.00%**			

Key

- HPS = High Pressure Sodium
- MV = Mercury Vapour
- MH = Mercury Halide
- LED = Light-Emitting Diode
- CFL = Compact Fluorescent Lamp

Traffic lighting

All traffic lights in Cape Town have been retrofitted with efficient LEDs. It was assumed that each lamp operated for 8hrs/day (24hrs/3 lamps). The number of bulbs was adjusted until electricity use matched that given in Table 44.

Water and wastewater treatment works

Table 46: Electricity use in local government water and wastewater treatment works

Sub-sector (2012)	kWh
WWTW – elec supplied by municipality	76,737,573
WWTW – elec supplied by Eskom	49,029,357
Bulk Water	19,039,860
Pump Stations	44,426,340

Key: WWTW = Wastewater Treatment Works

Table 47: Electricity by end-use in local government WWTW, bulk water provision and pump stations[39]

WWTW, Bulk Water, Pump Stations	kWh
Motors, pumps	85%
Other	15%
Total	100%

A savings potential of 20% was assumed for motors and pumps.[40]

Buildings and facilities

An average of 1,777 kWh/m^2 is recorded across all local government building stock that is metered.[41]

Table 48: Electricity use by end-use in local government buildings and facilities[42]

End-use breakdown per usable m^2	%
HVAC	30%
Lights	40%
Hot Water	5%
Other	25%
Total	**100%**

Table 49: Electricity savings potential by end-use in local government buildings and facilities[43]

End-use	Savings potential
HVAC	25%
Lights	40%
Hot Water	60%

Not all City buildings are metered, therefore floor area was adjusted upwards until calculated electricity use matched actual electricity use.

39 Source: Kevin Samson, City of Cape Town
40 Source: "Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN" by Sustainable Energy Africa. 5-10% savings by improving existing pumps. 3-7% through improvement to new pumping technology (pump technology is generally mature). Gains up to 30% are possible through maintenance improvement and closer matching of pumps to their duties (such as, using variable speed drives).
41 Source: City of Cape Town
42 Source: "Analysis Report: Baseline, Energy Savings Potential and Energy Efficiency Programmes in Public Buildings in South Africa" developed by Sustainable Energy Africa for GIZ, February 2012.
43 "Analysis Report: Baseline, Energy Savings Potential and Energy Efficiency Programmes in Public Buildings in South Africa" developed by Sustainable Energy Africa for GIZ, February 2012 (lighting and HVAC savings figures). Hot water figure is a conservative heat pump savings estimate.

Liquid fuels

Table 50: Liquid fuel use by local government fleet[44]

Fuel	Litres
Diesel	9,999,489
Petrol	5,996,777

Table 51: Local government vehicle fleet savings potential[45]

Measure	%
Fuel efficient tyres	3%
Improved maintenance	15%
Tyre management programme	2%
Reduced mileage	10%
Education campaign	2%
Total efficiency	**32%**

Interventions and Costing

Electricity price

Table 52: Price of electricity for street lighting[46]

	c/kWh		R/100W/burning hr		ZAR/kWh	ZAR/GJ
Tariff	Excl. VAT	Incl. VAT	Excl. VAT	Incl. VAT	Incl VAT	
Street/Traffic Lights	0.0001134	0.000129	0.1134	0.1293	0.0000013	0.00036

Assumed that local government charges its departments at the Eskom Megaflex tariff, i.e. electricity sold at the same amount for what it is bought, at R 0.5224/kWh.[47] The City buys most of its electricity on Eskom's Megaflex tariffs.[48]

Liquid fuel price

See "Liquid fuel price" under *Transport Sector Energy Data: Interventions and Costing* chapter.

13. Transport Sector Energy Data

Energy Demand

Liquid fuel sales were allocated to transport sub-sectors using the sales trade category information (Table 10). In most cases the total fuel amount was allocated to each transport sub-sector without

[44] Source: City of Cape Town
[45] Source: "Modelling Energy Efficiency Potential in Municipal Operations in the Nine Member Cities of the SACN" by Sustainable Energy Africa
[46] *City of Cape Town: Draft Electricity Tariffs To Be Implemented With Effect From 1 July 2012*
[47] *How Much is Megaflex?*, eThekwini Energy Office
[48] Communication with Electricity Department, City of Cape Town.

any further usage breakdown, e.g. the marine, aviation, agriculture, commercial and industrial sub-sectors. Further detailed breakdown is provided for the freight and passenger transport sectors. ***The driver in the freight sector is tonne-km, while the driver of energy demand in the passenger transport sector is passenger-km (pass-km). These are grown on the basis of total metro GVA growth in the case of passenger transport and transport sector GVA growth in non-passenger transport sub-sectors.*** Interestingly, although passenger-km are conventionally driven by population growth, car ownership patterns in South Africa have been found to align more closely with economic growth rates.

Energy by End-Use

Passenger transport

The passenger transport modal split was calculated off the 2011 City of Cape Town Cordon Count. The Cordon Count counts the number of passengers and vehicles passing certain points on main through-routes across the metro. All passengers were summed by mode (excluding heaving vehicles). Some double-counting was unfortunately inevitable. An average trip distance was assigned to each mode.

Table 53: Average passenger trip distance by mode

Mode	Average trip distance	Source
Conventional bus	16 km	ACET Household Travel Survey 2010
MyCiti Bus	16.7 km	Integrated Transport Plan (ITP) 2013-2018
Light vehicles	17.5 km	ITP 2013-2018
Rail	22.8 km	ITP 2013-2018
Cycling	10 km	Assumption
Pedestrian	5 km	Assumption
Metered taxi	17.5 km	Assume same as car
Minibus taxi	16 km	Assume same as conventional bus

The passenger-km was calculated off trip distance, number of passengers and the average occupancy of each vehicles type (occupancy figures were also obtained from the Cordon Count).

Table 54: Passenger transport by mode in Cape Town

Mode	Daily pass-km	% (overall)
Public	**10,743,540**	**35.24%**
Bus	2,249,161	7.38%
GABS	*1,804,272*	*5.92%*
MyCiti	*84,953*	*0.28%*
Private	*359,936*	*1.18%*
Taxis	4,359,873	14.30%
Metered Taxis	*117,985*	*0.39%*
Minibus Taxis	*4,241,888*	*13.91%*
Rail	4,134,506	13.56%
Private	**19,410,055**	**63.66%**
Light Vehicles	19,410,055	63.66%
NMT	**334,690**	**1.10%**

Cyclists	48,280	**0.16%**
Pedestrians	286,410	0.94%
Total	**30,488,285**	**100.00%**

Table 55: Passenger transport energy intensity and occupancy assumptions

Mode	Pass-km (%)	km/lit or km/kWh	lit/100km or kWh/100km	Occupancy Assumed	Occupancy Max	Occupancy %	GJ/lit or GJ/kWh	GJ/pass-km
Private	**63.66%**							
Car diesel	35.00%	16	6.3	1.4	4	35%	0.0377	0.00170
Car petrol	65.00%	10	10.0	1.4	4	35%	0.0332	0.00237
Car diesel efficient	0.00%	17.5	5.7	1.4	4	35%	0.0377	0.00153
Car petrol efficient	0.00%	11.0	9.1	1.4	4	35%	0.0332	0.00215
Car diesel hybrid	0.00%	26.3	3.8	1.4	4	35%	0.0377	0.00102
Car electric	0.00%	4.7	21.3	1.4	4	35%	0.0036	0.00055
Public	**35.24%**							
Minibus	**40.58%**							
Minibus taxi (petrol)	65.00%	8	12.5	6	15	40%	0.0332	0.00069
Minibus taxi (diesel)	35.00%	11.5	8.7	6	15	40%	0.0377	0.00055
Bus	**20.94%**							
Bus (diesel)	96.22%	3	33.3	34	90	38%	0.0377	0.00037
BRT (diesel)	3.78%	3	33.3	45	90	50%	0.0377	0.00028
Rail	**38.48%**	**N/A**	**N/A**	**N/A**	**N/A**	**N/A**	0.0036	**0.00006**
NMT	**1.10%**							
Cyclists	14.43%							
Pedestrians	85.57%							
TOTAL	**100.00%**							

The total number of passenger-km, as well as the percentage diesel/petrol split for cars and minibus taxis were adjusted until calculated petrol and diesel usage matched actual sales as close as possible. The diesel/petrol split for cars and minibus taxis required to balance petrol vs. diesel use with actual figures was 35% diesel/65% petrol. This appears reasonable.

Freight

Table 56: Freight energy assumptions

Fuel	GJ/tonne-km	tonne-km (%)	GJ	tonne-km	tonne-km (%)
Petrol					
Petrol - Road	0.003915	Excl.	42,822	10,939,048	1%
Diesel		100%	1,657,803	727,965,500	99%
Diesel - Road	0.002462	77%	1,380,033	560,533,435	76%
Diesel - Rail	0.001659	23%	277,770	167,432,065	23%

The diesel freight energy intensity figures were obtained from the previous LEAP modelling exercise undertaken in 2011. The petrol energy intensity was calculated by considering the proportional difference between diesel and petrol car energy intensity (km/lit).

The total diesel tonne-km was adjusted until calculated diesel matched actual sales.

Interventions and Costing

Liquid fuel price

Table 57: Liquid fuel price in 2012[49]

Fuel	R/lit	GJ/lit[50]	R/GJ	R/kg	kg/lit
Petrol	11.18	0.0332	337.15		
Diesel	10.51	0.0377	278.90		
Paraffin	7.72	0.0362	213.07		
LPG	10.98	0.0255	429.81	20.33	0.54
Aviation gasoline[51]	18.00	0.032704	550.39		
Jet fuel[52]	6.69	0.0361	185.23		
HFO[53]	6.31	0.0382	165.22		

Liquid fuel price increase over time

Table 58: Liquid fuel price increase over time[54]

	NOMINAL							REAL (2005 ZAR)			
Price	ULP & LRP 93	ULP 95	Petrol	Diesel	LPG	Paraffin		Petrol	Diesel	LPG	Paraffin
Year	Coast c/l	Coast c/l	AVG	Coast c/l	Coast c/kg	Coast c/l	CPI	c/lit	c/lit	c/lit	c/lit
2001	362.00	362.00	362.00	N/A	N/A	229.31	52.40	437.99			277.45
2002	392.00	392.00	392.00	N/A	N/A	251.08	57.20	434.49			278.29
2003	381.33	382.33	381.83	N/A	N/A	227.90	60.50	400.14			238.82
2004	429.92	432.92	431.42	N/A	N/A	266.59	61.40	445.47			275.28
2005	507.17	512.42	509.79	N/A	N/A	353.87	63.40	509.79			353.87
2006	611.75	588.50	600.13	564.83	N/A	427.28	66.40	573.01	539.31		407.98
2007	663.50	653.00	658.25	611.42	N/A	465.53	71.10	586.96	545.20		415.12
2008	886.42	876.42	881.42	919.75	N/A	734.53	79.30	704.69	735.34		587.26
2009	720.42	716.08	718.25	650.61	N/A	454.81	84.60	538.26	487.57		340.84
2010	795.58	802.58	799.08	724.94	1603.33	504.18	88.20	574.40	521.10	1152.51	362.42
2011	962.83	969.33	966.08	906.87	1857.33	666.73	92.60	661.44	620.90	1271.65	456.49
2012	1112.83	1122.58	1117.71	1051.39	2033.42	772.31	97.80	724.57	681.57	1318.19	500.66
2013	1243.42	1255.67	1249.54	1172.90	2181.25	871.99	103.40	766.16	719.16	1337.44	534.66
Average incr. pa	10.8%	10.9%	10.9%	11.0%	10.8%	11.8%	5.8%	4.8%	4.2%	5.1%	5.6%

[49] Average price of liquid fuel at the coast in 2012. Source: Department of Energy: http://www.energy.gov.za/files/energyStats_frame.html

[50] LPG conversion factor (kg/lit) from Afrox Product Reference Manual - Section 5 – LPG. Other conversion factors from LEAP.

[51] Source of fuel price: Comment on April 2013 article: http://www.bdlive.co.za/business/transport/2013/04/18/government-policies-choking-aviation-industry--iata

[52] Source of fuel price: www.pmg.org.za/files/questions/RNW178A-130312.doc

[53] Source of fuel price: http://www.ee.co.za/article/heavy-fuel-oil-cuts-costs-of-own-generation.html (quote: "HFO is approximately 40% cheaper than diesel")

[54] Average price of liquid fuel at the coast. Source: Department of Energy: http://www.energy.gov.za/files/energyStats_frame.html. Source of CPI: StatsSA.

14. Scenarios

Business as Usual (Reference Case)

The Business as Usual scenario takes the current energy consumption (per energy driver unit, e.g. household, floor space, total sector energy or passenger-km) per sector in the city and models what this consumption would look like over time if no other interventions took place. The growth in energy for all sectors save residential is a factor of economic growth; for the residential sector it is a factor of population growth. The key assumptions in the Business as Usual (BAU) Scenario are outlined in the table below.

Table 59: Business as Usual Scenario key assumptions

Assumption	Source
Annual average growth of agricultural sector: 2.90%	Regression analysis on Quantec GVA data (agriculture, forestry and fishing sector) sourced from the City of Cape Town
Annual average growth of industrial sector: 2.19%	Regression analysis on Quantec GVA data (manufacturing sector) sourced from the City of Cape Town
Annual average growth of commercial sector: 4.92%	Regression analysis on Quantec GVA data (wholesale and retail trade; finance, insurance, real estate and business services; and community, social and personal services" sectors) sourced from the City of Cape Town
Annual average growth of local government sector: 2.93%	Regression analysis on Quantec GVA data (general government sector) sourced from the City of Cape Town
Annual average growth of non-passenger transport sector: 2.93%	Regression analysis on Quantec GVA data (transport and storage sector) sourced from the City of Cape Town
Annual average growth of passenger transport sector: 3.40%	Regression analysis on Quantec GVA data (total metro-level) sourced from the City of Cape Town. In SA, the number of registered vehicles has tracked GDP more closely than population.[55] Therefore it was assumed that growth of pass-km follows total metro GVA growth.
Annual average households growth (low-income non-electrified): 0.74%	Population and household projection figures from Western Cape Government 2014[56], StatsSA Census 2011.
Annual average households growth (low-income electrified, mid-, high-, and very high-income): 0.56%	Population and household projection figures from Western Cape Government 2014[57], StatsSA Census 2011.
Electricity supply follows that defined in the IRP 2010 – 2030 Update Report Weathering the Storm Scenario	Department of Energy 2013.
Average annual real increase in petrol prices: 4.8%	Based on real (excludes inflation) price increases from 2001-2013 sourced from Department of Energy.[58]
Average annual real increase in diesel prices: 4.2%	Based on real (excludes inflation) price increases from 2006[59]-2013 sourced from Department of Energy.

55 Source: "Quantifying the energy needs of the transport sector for South Africa: A bottom-up model" by Bruno Merven, Adrian Stone, Alison Hughes and Brett Cohen from ERC, Jun 2012.
56 Received from Karen Small, City of Cape Town Strategic Information
57 Received from Karen Small, City of Cape Town Strategic Information
58 Department of Energy website: Statistics: http://www.energy.gov.za/files/energyStats_frame.html
59 Price data for earlier years for coastal diesel not available

Average annual real increase in paraffin prices: 5.6%	Based on real (excludes inflation) price increases from 2001-2013 sourced from Department of Energy.
Average annual real increase in LPG prices: 5.1%	Based on real (excludes inflation) price increases from 2010[60]-2013 sourced from Department of Energy.
Average annual real increase in jet fuel prices: 5.6%	Set to same as paraffin
Average annual real increase in HFO prices: 4.2%	Set to same as diesel
Average annual real increase in aviation gasoline prices: 4.8%	Set to same as petrol
Average annual real increase in electricity prices: calculated iteratively by considering LEAP supply-side fuel input costs	See "Calculating Supply-Side Data using LEAP" chapter.

Cape Town's electricity supply and power plant fleet capacity was assumed to follow the path set out in the IRP 2010-2030 Update Report Weathering the Storm Scenario (2013). Although this is not the official, cabinet-approved policy (which follows the IRP 2010-2030 Policy-Adjusted Scenario), it is considered by electricity planning experts to represent the "most likely" new build path.[61] An additional scenario has been run, based on figures approximating the current, cabinet-approved new build programme, for purposes of comparison.

Table 60: IRP 2010-2030 Update Report: Weathering the Storm Scenario electricity supply mix

IRP Supply (MWh) Weathering the Storm	**2012**	**2015**	**2020**	**2025**	**2030**	**2040**	**2050**
Pumped Storage	1.2%	2.0%	1.7%	1.8%	1.7%	1.4%	1.3%
Solar PV large-scale	0.0%	0.5%	0.4%	1.1%	3.0%	5.5%	7.7%
Solar Thermal Elec with storage	0.0%	0.2%	0.3%	0.3%	0.3%	4.1%	5.0%
Wind	0.0%	0.9%	0.8%	0.8%	1.4%	3.4%	4.3%
Nuclear	4.2%	3.8%	3.3%	3.4%	3.2%	2.7%	0.0%
Coal	85.1%	83.9%	83.8%	79.5%	70.5%	58.9%	57.1%
CCGT	0.0%	0.0%	0.0%	1.4%	2.7%	4.5%	6.2%
Hydro	3.2%	3.0%	2.6%	4.5%	4.2%	3.5%	3.3%
OCGT	6.2%	5.7%	7.0%	7.1%	13.0%	15.9%	15.2%
Check	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

Renewables (solar and wind)[62] have lower availability than power plants such as coal and nuclear, which is why a higher amount of capacity (MW) is required to produce a similar amount of electricity (MWh) as coal or nuclear power plants. Example:

Table 61: Power plant availability example

[60] Price data for earlier years not available

[61] Pers.com. with Eskom IRP Planning Unit, 2015. The nuclear build programme envisaged in the Policy-Adjusted Scenario, given the lack of finance available, is considered highly unlikely.

[62] Excludes large hydro, as this type of power plant as generally not considered to be "renewable" due to large negative environmental and social consequences (loss of ecosystems through flooding of large areas, as well as displacement of people and disruption or destruction of previous livelihoods).

Plant type	Plant size (MW)	Availability	Hrs available p.a.	Electricity produced (MWh)
Nuclear	100	84%	365*24*84%	735,840
Wind	100	29%	365*24*29%	254,040

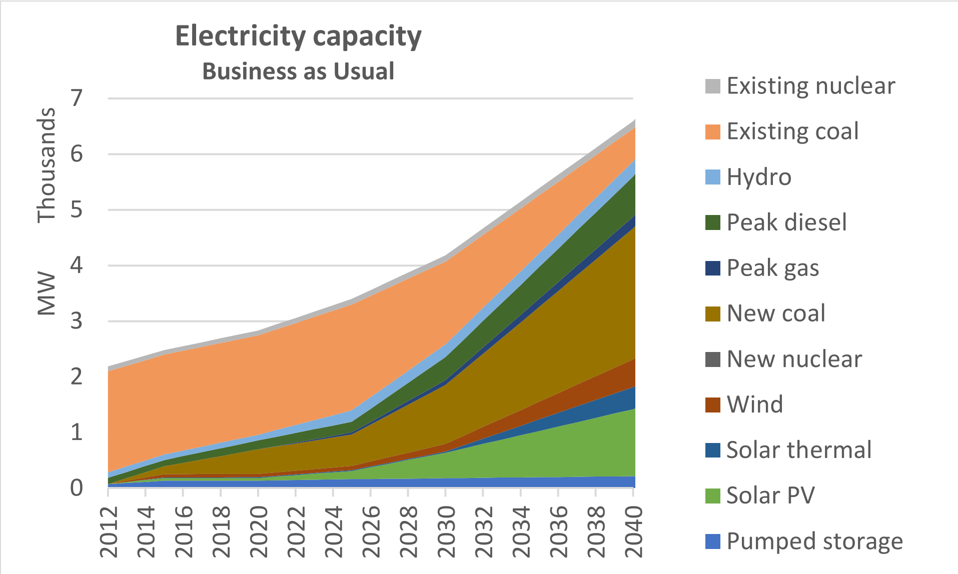


Figure 16: Business as Usual electricity capacity by plant type

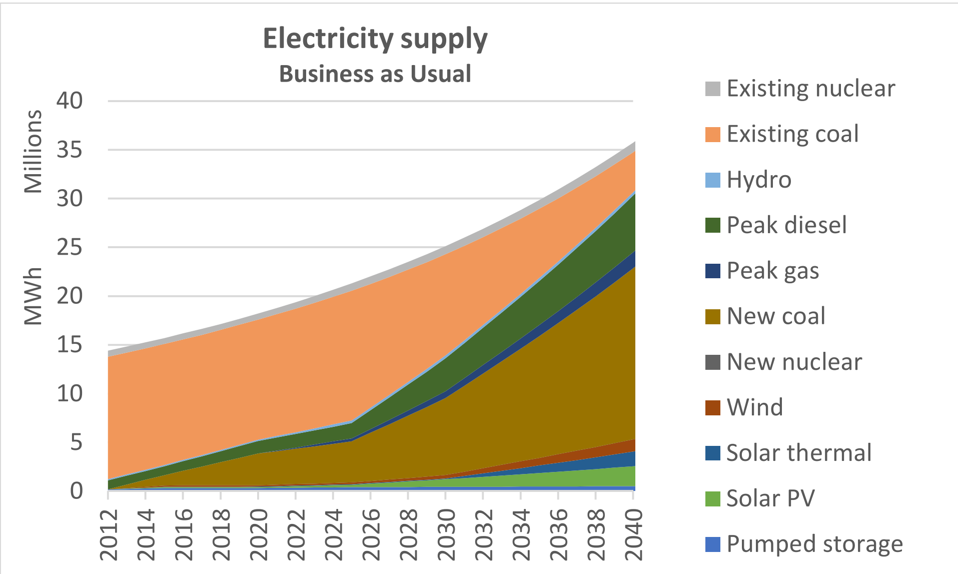


Figure 17: Business as Usual electricity supply by plant type

Despite the introduction of renewables, electricity produced by coal still dominates by 2050.

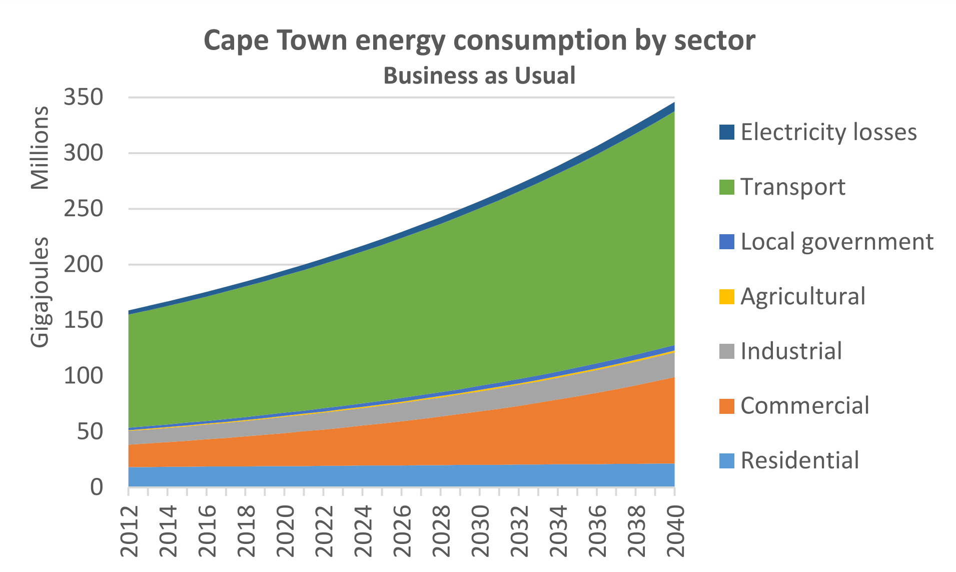


Figure 18: Business as Usual energy demand by sector

Following a Business as Usual Scenario will result in energy consumption more than doubling by 2040 (Figure 18). This may seem unlikely, but comparisons with actual energy consumption growth rates and the previous iteration of LEAP modelling (based on a 2007 baseline) indicate that Cape Town is indeed following a Business as Usual energy consumption path.[63]

The transport sector remains one of the major energy-consuming sectors. The commercial sector becomes more dominant with regards to energy consumption in the future, due to the high economic growth input for this sector when compared to other sectors (see Table 59 on key Business as Usual Scenario drivers).

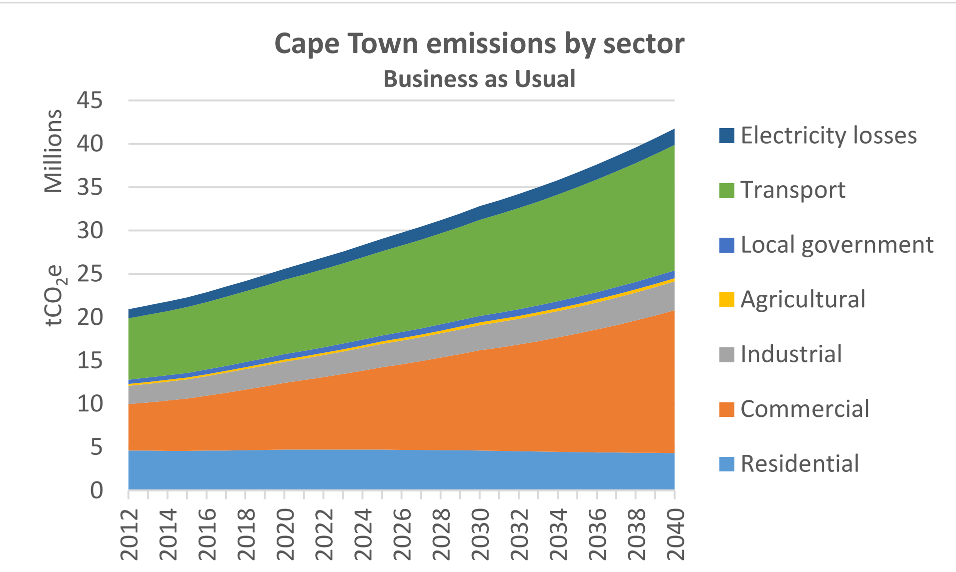


Figure 19: Business as Usual emissions by sector

Emissions more than double on a Business as Usual projection (Figure 19). The commercial sector, due to its high growth rate and heavy reliance on electricity, shifts from contributing 26% of all emissions in 2012 to contributing 39% of all emissions in 2040. The transport sector's proportional contribution to emissions grows slightly from 34% to 35%. All other sectors' proportional

[63] Cape Town State of Energy 2015, SEA

contribution to emissions production decreases over this time period, with the most marked reduction in the residential sector (from 22% to 10%). This is a function of the growth predicted for each sector and the main type of fuel each sector uses. Electricity, the dominant fuel used by the commercial sector, is still relatively "carbon-dirty" even with the introduction of renewables into the electricity supply mix. This is why, along with the sector's high economic growth rate, the commercial sector contributes disproportionately to emissions production by 2040.

Table 62: Relative contribution of sectors to emissions 2012 to 2040

All sectors (tCO_2e)	2012%	2040%
Residential	22%	10%
Commercial	26%	39%
Industrial	10%	8%
Agricultural	1%	1%
Local Government	2%	2%
Transport	34%	35%
Electricity Losses	5%	4%

Figure 18 and Figure 19 demonstrates how an energy efficiency focus may differ depending on end-goals. If the major goal is to reduce only energy consumption, the focus would be primarily on the transport sector. If the focus, on the other hand, is on emissions reduction, the commercial sector may be seen as the major focus area. It must be noted though that all sectors are important when tackling emissions and energy consumption reduction. Even the most aggressive interventions, when limited to one sector, will still not have the same scale of impact as addressing all sectors as a whole.

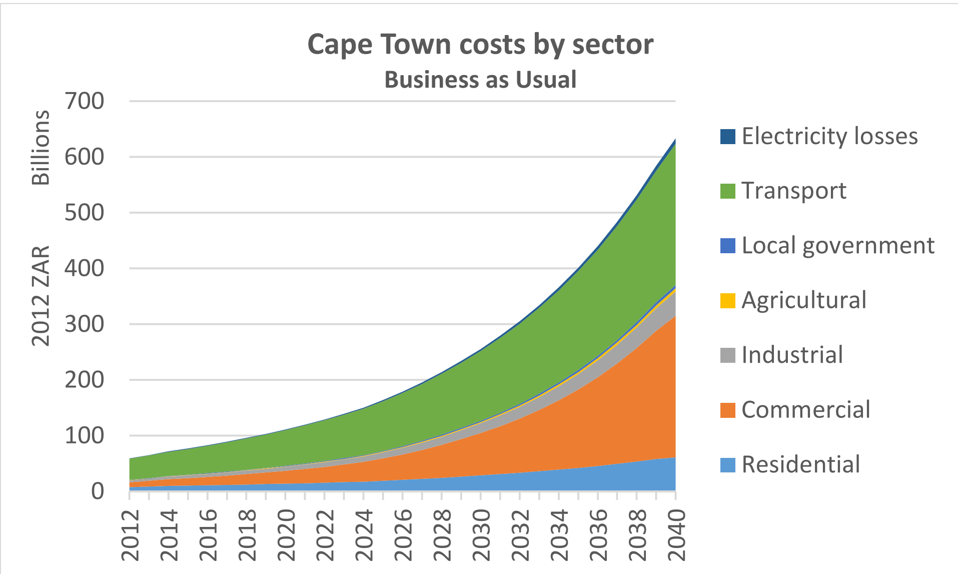


Figure 20: Business as Usual costs by sector

Energy-related costs climb steeply towards 2040 (Figure 20). Electricity costs, in particular, are pushed up by the new power plant build required to meet a Business as Usual Scenario energy demand. The high electricity price increase is the reason why the commercial sector shows a large increase in associated energy costs (vs. the transport sector, which consumes largely liquid fuel; not electricity).

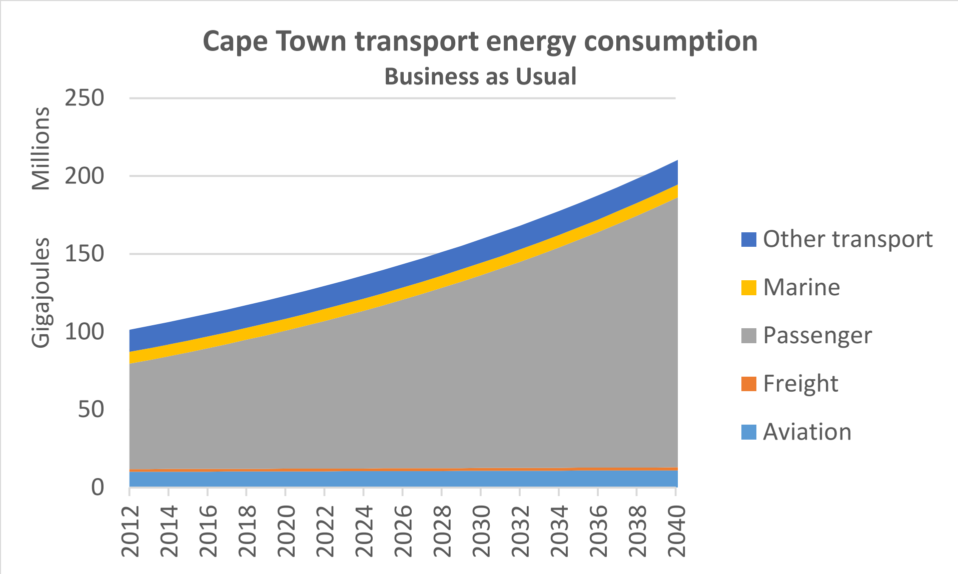


Figure 21: Business as Usual transport sector energy demand

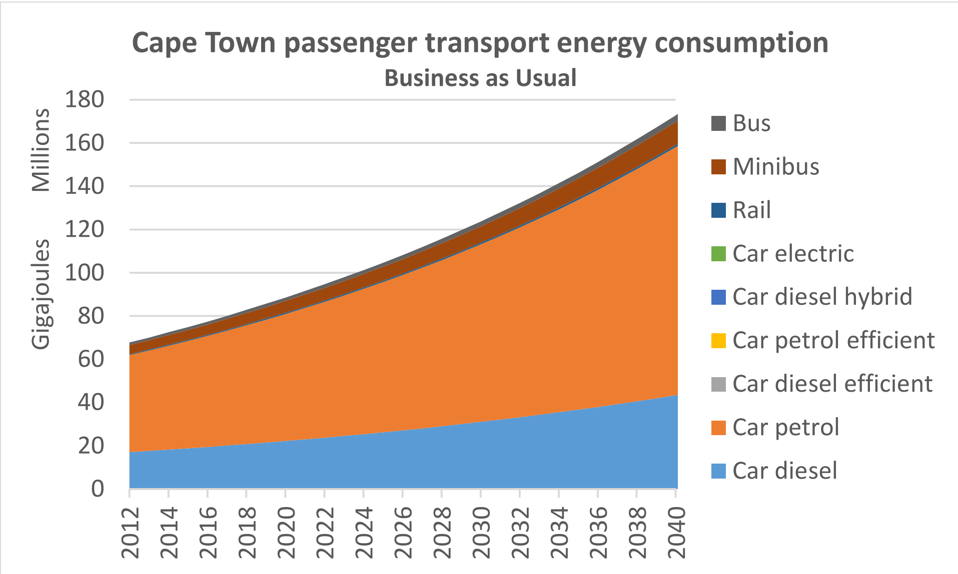


Figure 22: Business as Usual passenger transport sector energy demand

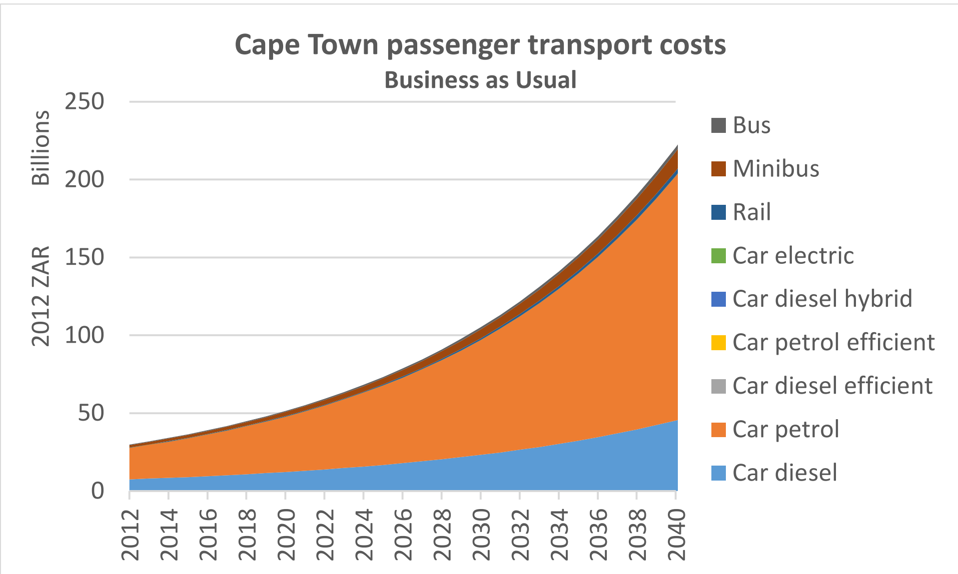


Figure 23: Business as Usual passenger transport sector costs

As has been discussed previously, the transport sector dominates energy consumption in Cape Town (Figure 18). Energy consumption within the transport sector is primarily by the passenger transport sector (Figure 21), which in turn is dominated by private passenger transport (Figure 22), i.e. people driving around in cars. The costs associated with private passenger transport are very high, as this is an extremely inefficient way of moving people when compared to public transport. It also annexes most of the available road-space.

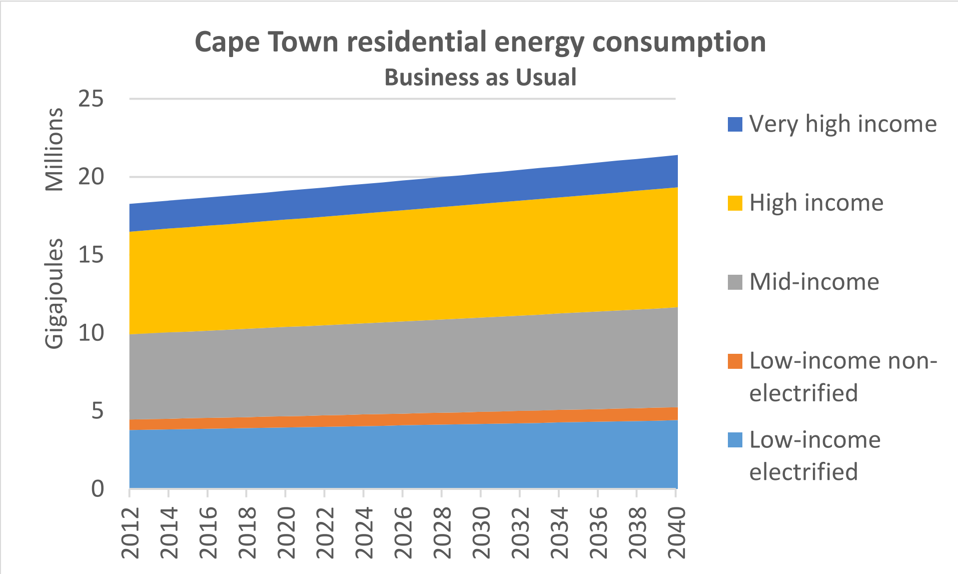


Figure 24: Business as Usual residential sector energy demand

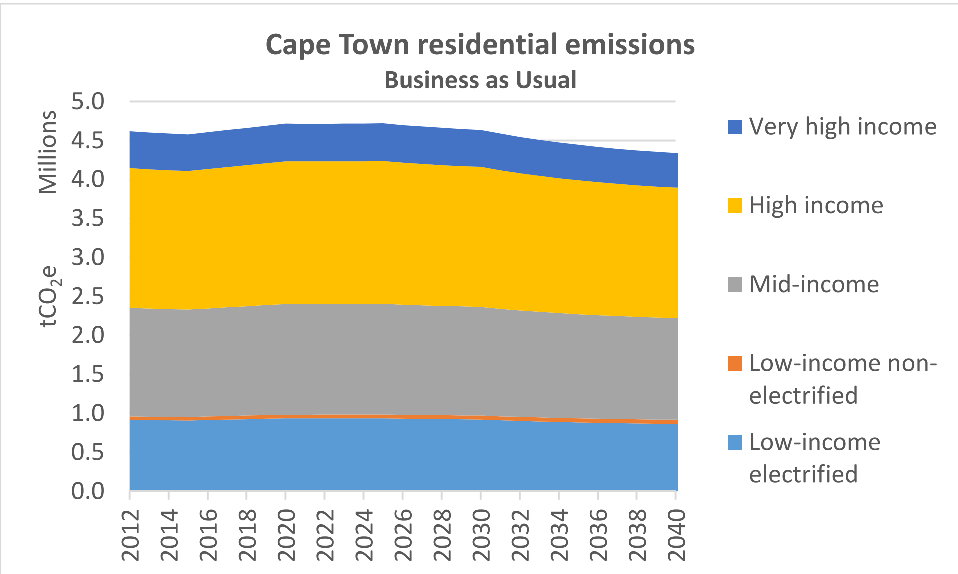


Figure 25: Business as Usual residential sector emissions

The energy consumption in the residential sector does not grow as rapidly as some of the other sectors. This is because projections predict a decline in the rate of population growth.[64] Detailed analysis of data also indicates growth across household types to be at a relatively similar rate. (0.56% in formal dwellings and 0.79% in informal dwellings: see Table 18 and Table 21). Emissions production declines in absolute terms due to (1) the relatively slow growth of the residential sector, and (2) some "decarbonisation" of the electricity through the introduction of renewables.

[64] Western Cape Government 2014 projections (received from Karen Small, City of Cape Town Strategic Information)

Comparison with Business as Usual from the 2011 report

The Business as Usual (BAU) Scenario of the latest LEAP model (2012 baseline year) was compared with the BAU Scenario of the model created for the previous Energy Futures 2011 report (2007 baseline year).[65]

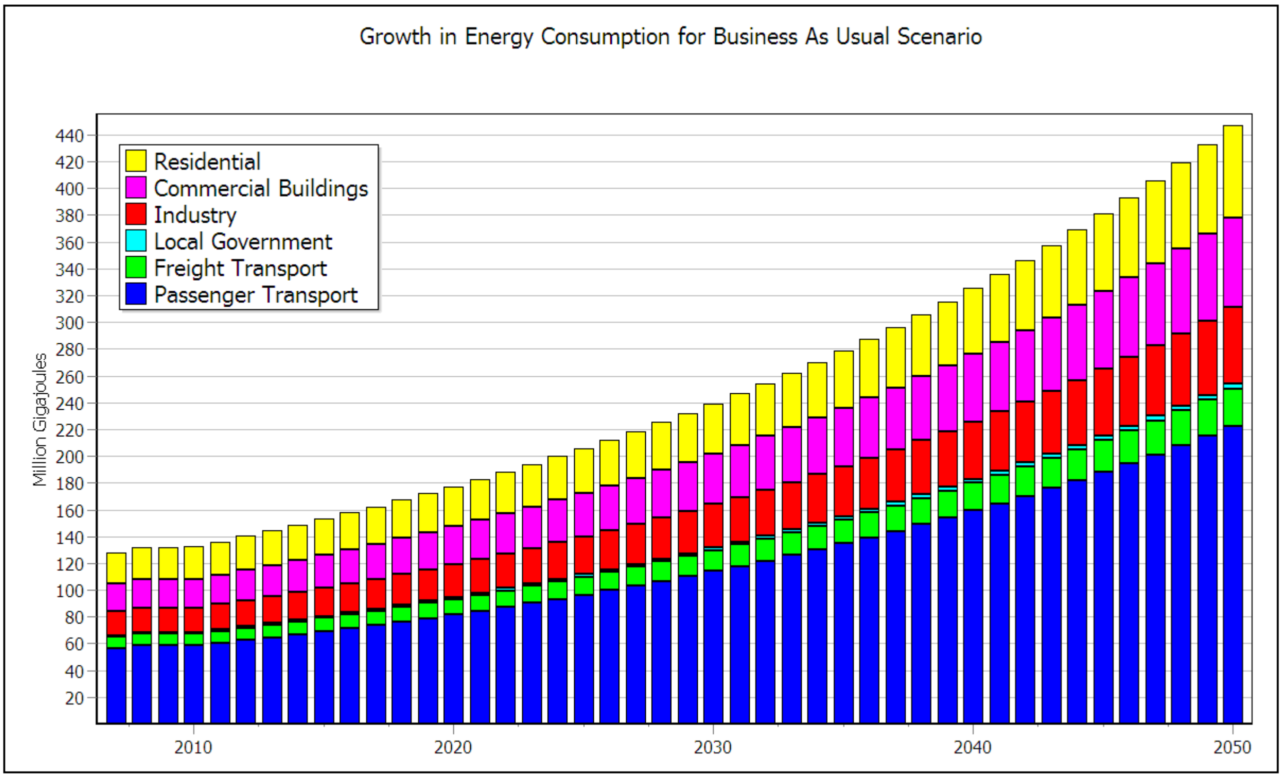


Figure 26: Business as Usual energy demand by sector from 2007 baseline

[65] Energy Scenarios for Cape Town - Exploring the Implications of Different Energy Futures for the City up to 2050, Aug 2011

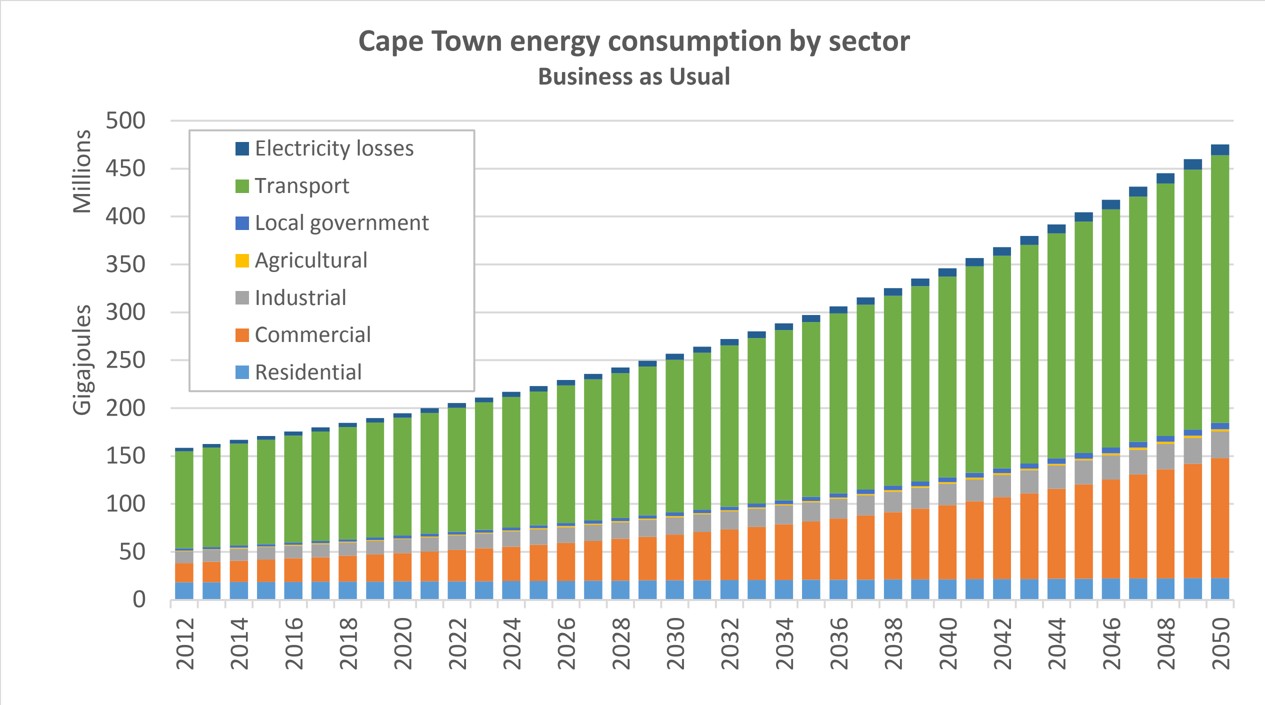


Figure 27: Business as Usual energy demand by sector from 2012 baseline

The industrial sector is smaller in the newer model, as 70% of the sales on the City's Large Power User tariff (previously assigned solely to the industrial sector) was assigned to the commercial sector in the newer model.[66] The transport sector is proportionally larger in the newer model due to the inclusion of the aviation and international marine fuels (this data was not available in the previous model).

Table 63: Comparison of growth drivers in old vs. new model Business as Usual scenarios

Old LEAP model	New LEAP model
Growth in formal households: 4%	Growth in low-income electrified, mid-, high- and very-high-income households: 0.56%
Growth in informal households: 13% p.a. 2007-2010, 8% p.a. onwards	Growth in low-income non-electrified households: 0.74%
Growth in passenger transport sector: 3.4%	Growth in passenger transport sector: 3.40%
Growth in energy consumption: 2.9%	Growth in agricultural sector: 2.90% Growth in commercial sector: 4.92% Growth in local government sector: 2.93% Growth in industrial sector: 2.19% Growth in transport (non-passenger) sector: 2.93%

Table 64: Comparison of old vs. new model Business as Usual scenarios

GJ (mill)	2007	2012	2015	2020	2030	2040	2050
2007 BAU	128	140	153	178	240	328	447
2012 BAU	N/A	159	171	195	257	346	475
2007 vs. 2012 BAU (difference)	N/A	13.6%	11.8%	9.6%	7.1%	5.5%	6.3%
2007 BAU average growth p.a.	N/A	1.8%	3.0%	3.1%	3.0%	3.2%	3.1%

[66] For more detail, see chapter 7: Energy Supply Data.

2012 BAU average growth p.a.	N/A	N/A	2.5%	2.7%	2.8%	3.0%	3.2%

The newer model shows higher energy consumption levels for all years when compared to the older model. However, the annual average growth rates of both models are relatively similar. Differences between the models are a function of:

a) Improved data collection, e.g. the older model did not include aviation or international marine fuels. Thus the later model works off a larger base quantity.
b) The dramatic change in City population growth predictions. New predictions are based on a very detailed report done for the City and Province by Price Waterhouse Cooper and this has a sizeable impact on the model.
c) Much more detailed local economic data, with a longer data time period, allows for a more refined economic forecast per sector, using regression analysis. The later model thus has a much higher commercial growth rate, but slightly lower rates of growth in the other economic sectors.

The two models start to converge over time and the average annual growth rates of both models are relatively similar. This indicates that the LEAP model outputs are relatively robust.

Comparison with Western Cape energy futures modelling report

PDG undertook climate mitigation scenarios modelling[67] for the Department of Environmental Affairs and Development Planning of the Western Cape Government. A comparison with this model shows similar mitigation scenarios, and similar energy and emissions growth rates for a reference/business as usual scenario, as well as a low-carbon/energy efficiency scenario.

	Cape Town model	Western Cape model
Business as Usual / Reference Case average annual energy consumption growth (2012-2040)	2.8%	2.5%
Business as Usual / Reference Case average annual emissions production growth (2012-2040)	2.5%	2.3%
Energy efficiency and cleaner electricity supply scenario[68] average annual energy consumption growth (2012-2040)	1.6%	1.3%
Energy efficiency and cleaner electricity supply scenario average annual emissions production growth (2012-2040)	0.7%	0.9%

The broad-brush conclusions were also similar. Both models showed that (1) even with aggressive energy efficiency and cleaner electricity interventions, emissions still increase though the rate of this increase decreases; (2) the largest emissions reduction gains identified are in the electricity supply sector; and (3) the largest energy reduction gains are in the passenger transport sector.

The fact that these models align very well, indicates the robustness of the models, i.e. if they were showing very different results and interventions focus areas, it would cast doubt on the assumptions behind both the models.

[67] Western Cape Climate Change Mitigation Scenarios exercise for the energy sector, Mar 2015
[68] Comparing the Cape Town GSOL scenario with the Western Cape APMF scenario.

Sensitivity Test: Economic Growth

Table 65: Economic Growth Scenarios key assumptions

Scenario	Assumption
BAU High Growth Scenario	All the GVA growth factors used in the BAU Scenario were multiplied by 1.3
BAU Low Growth Scenario	All the GVA growth factors used in the BAU Scenario were multiplied by 0.7

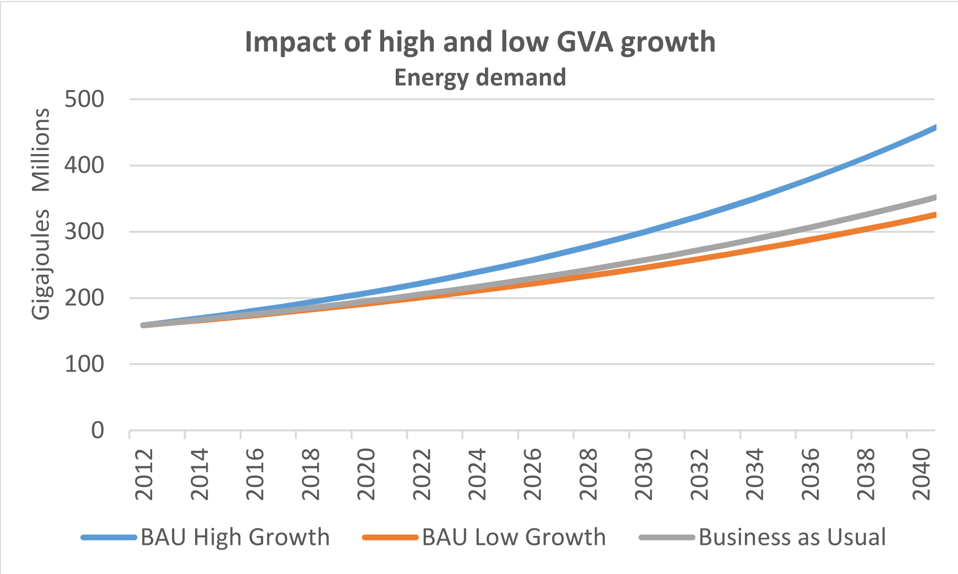


Figure 28: Impact of high and low economic growth on energy demand

Energy consumption is sensitive to economic growth, e.g. in the past, electricity sales tracked economic growth closely.[69] The current limit on electricity consumption nationally through load-shedding is having a large economic impact on the country.

Cape Town has recently (2007 onwards) experienced a decoupling in electricity sales from metro-level GVA growth. Aside from the 2008 economic recession, economic growth has been positive, while electricity sales are now below those levels seen in 2007. This cannot be ascribed purely to economic impact, as GVA is growing, but may be a result of fuel switching (especially in the industrial sector) and electricity efficiency (as a result of the large electricity tariff increases since 2008).[70]

Sensitivity Test: Population Growth

Table 66: Population Growth Scenarios key assumptions

Scenario	Assumption
Business as Usual (BAU)	Population grows to 4.6 million by 2040 (0.68% pa)
BAU High Population	Population grows to 5.3 million by 2040 (1.21% pa)

The model is not very sensitive to a higher population growth, as the growth factors for the other sectors still dwarf that in the residential sector, e.g. the driver of energy demand in the commercial sector is sectoral GVA contribution, which grows at 4.92%.

[69] The original IRP based electricity demand projections purely on economic growth forecasts
[70] State of Energy in Cape Town 2015

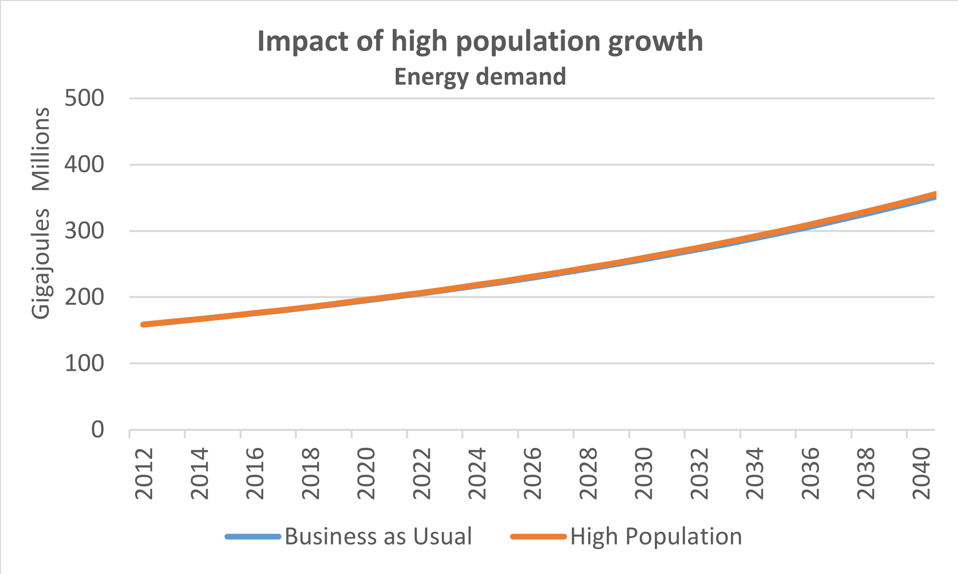


Figure 29: Impact of high population growth on energy demand

Electricity Efficiency Scenario

Table 67: Electricity Efficiency Scenarios key assumptions

Scenario	Assumption
Agricultural Scenario	• All lighting efficient by 2025 • 90% of pumps, irrigation, HVAC, fans efficient by 2040
Commercial Scenario	• All lighting efficient by 2025 • 90% of HVAC and refrigeration efficient by 2040 • 47% of water heating efficient by 2040 (40% in 2035, 20% in 2025)
Industrial Scenario	• All lighting efficient by 2025 • 90% of all other systems (HVAC, motors, mechanical equipment, refrigeration, etc.) efficient by 2040
Local Government Scenario	• All lighting (buildings and street) efficient by 2025 • 80% water heating efficient by 2040 (70% efficient by 2035, 50% by 2025) • 90% of HVAC and motors/pumps efficient by 2040 • All traffic lighting already efficient in baseline[71]
Residential Scenario	• 96% efficient lighting by 2040 in high- to very high-income households • 100% efficient lighting by 2025 in mid-income households • 90% efficient lighting in low-income households by 2025, 100% by 2040 • By 2040, 25% efficient water heating in low-income electrified households, 20% in low-income non-electrified households, 50% in mid-income households, 75% in high- and very high-income households • 89% of all fridges efficient by 2040

A detailed breakdown of the level of intervention per five year time period is attached as an annexure.

[71] Source: City of Cape Town

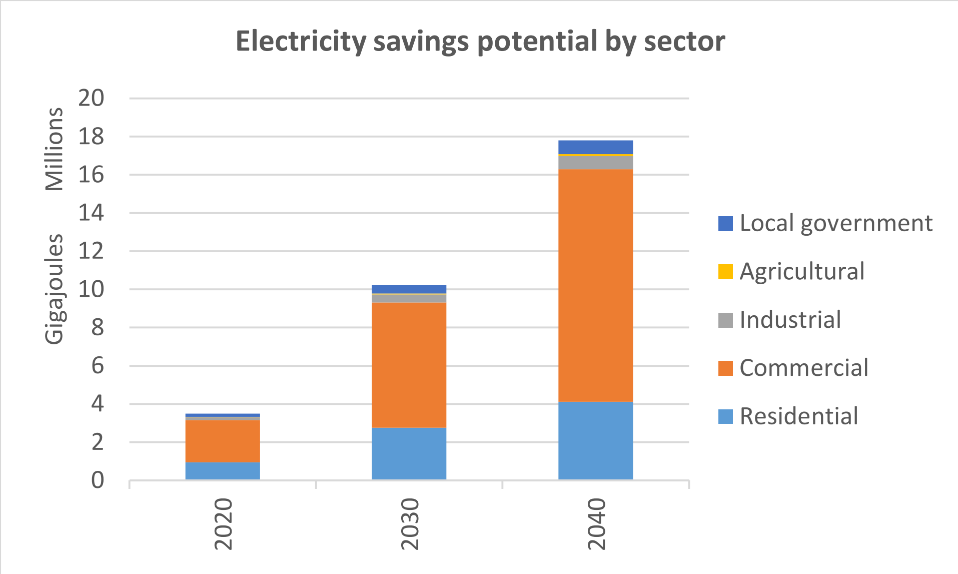


Figure 30: Electricity savings potential by sector (cumulative)

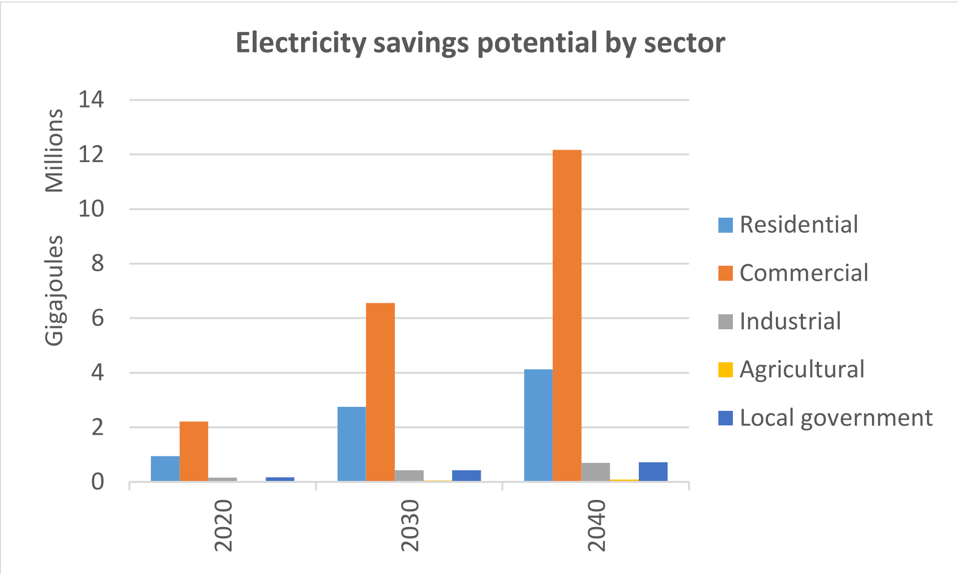
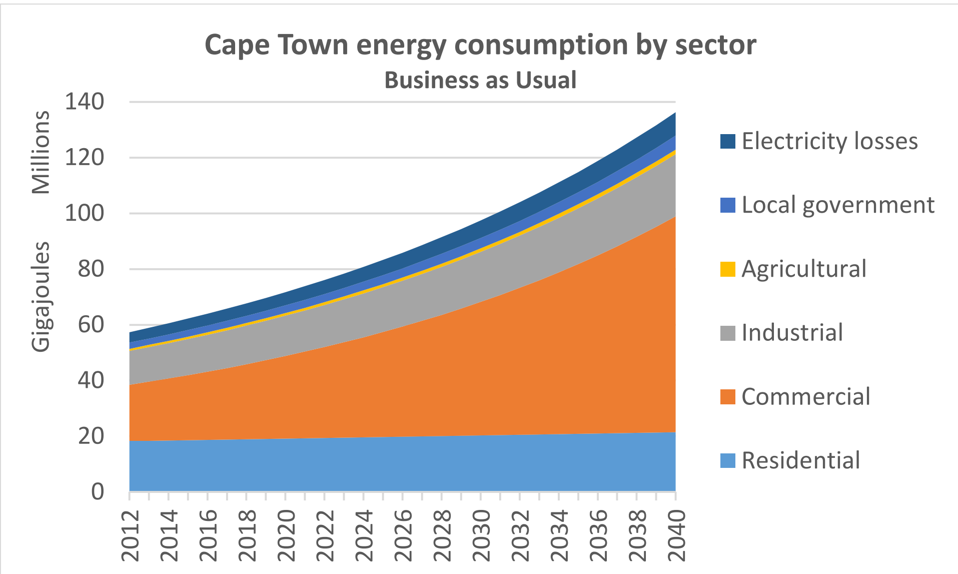


Figure 31: Electricity savings potential by sector (non-cumulative)



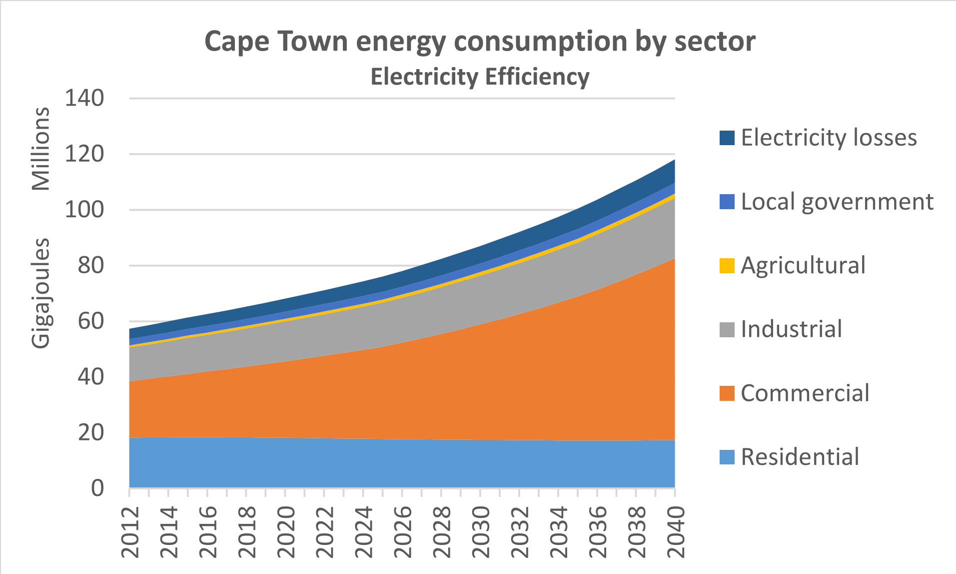


Figure 32: Impact of electricity efficiency on energy demand in the built environment (excludes transport sector)

The commercial sector represents the largest electricity savings potential, followed by the residential sector. Efficiency in the residential sector is important from a peak electricity load perspective, as this sector is the major contributor towards peak electricity use in the country. The residential sector uses about 17% of the total electricity generated in South Africa. From 7am to 10am in the morning, and 5pm to 9pm in the evening (periods of peak demand in South Africa), the residential sector's demand is up to 35% of the total national demand required.[72]

The City has taken initiative in promoting both residential and commercial sector efficiency. Its residential electricity efficiency campaign focused on information dissemination on steps to reduce electricity use via various forms of media (bill inserts, posters, leaflets, etc.). The City also endorses solar water heater (SWH) installers, as part of a mass SWH rollout programme that offers various SWH financing option in order to avoid the large up-front capital costs these systems pose.

The City launched the Energy Efficiency Forum, which provides owners and managers of offices, shopping centres, hotels and other commercial and public buildings with practical knowledge on energy efficiency solutions, and serves as a platform for collective action and shared learning. Regular forum meetings offer case studies of energy efficiency retrofits and updates on financing options, policy issues and training opportunities. Heightened energy efficiency awareness, as a result of this forum, may well be one of the reasons that the greatest up-take of the National Business Initiative's Private Sector Energy Efficiency programme[73] was in the Western Cape.

Transport Efficiency Scenario

Table 68: Transport Efficiency Scenarios key assumptions

Scenario	Assumption

[72] "Residential Time-of-Use tariff: Statistical evaluation of the domestic customer load response to the pricing signals" presentation by Vashna Singh, Eskom

[73] This programme offers energy efficiency funding to companies.

Efficient Vehicles Scenario	• Private (car) passenger-km by 2040: 3% conventional diesel, 5% conventional petrol, 25% efficient diesel, 46% efficient petrol, 11% diesel hybrid and 10% electric. • 90% of all buses and minibuses are efficient by 2040.
Transport Behaviour Scenario	• Occupancy of private vehicles increases from 1.4 in 2012 to 1.8 in 2040
Passenger Modal Shift Scenario	• 10% modal shift from private to public transport by 2035, increase at same rate until 2040, i.e. pass-km by public vehicles (vs. private): 35% in 2012, 45% in 2035, 47% in 2040. • Modal shift occurs in tandem with occupancy increase in non-rail public transport: 5% by 2035, 6% by 2040
Bus Rapid Transit (BRT) Scenario	• 38% of all bus pass-km by BRT by 2040
Freight Modal Shift Scenario	• Road-to-rail freight modal shift: 23% rail in 2012, 30% in 2025, 34% in 2035, 36% in 2040

The figure below shows typical city patterns relating to modal share and GDP. Transport experts note that modal shifts in cities with an entrenched 50% private modal share and low densities, as Cape Town has, are extremely difficult to achieve. This intervention rate has been slightly reduced over the 2007 LEAP model. However, the importance of shifting the trajectory of Cape Town from a high oil-consuming, "North American pattern" of transport development is well illustrated here, and captured in the interventions above.

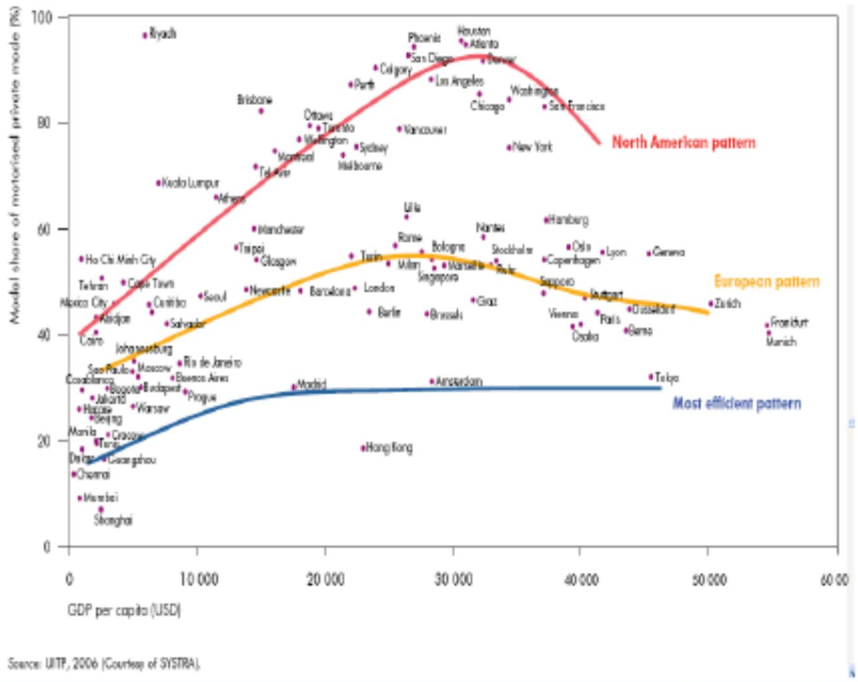


Figure 3: Mode share, GDP and city patterns
Source: http://www.uitp.org/advocacy/climate_change.cfm, accessed 1 Sept 2011

The Scenarios displayed below are non-cumulative and are considered individually. Unlike the electricity efficiency scenarios, the impact of implementing more than one of the transport scenarios simultaneously, does not necessarily result in the sum of their individual impacts, e.g. shifting more people onto public transport will decrease the energy efficiency impact of efficient private vehicles.

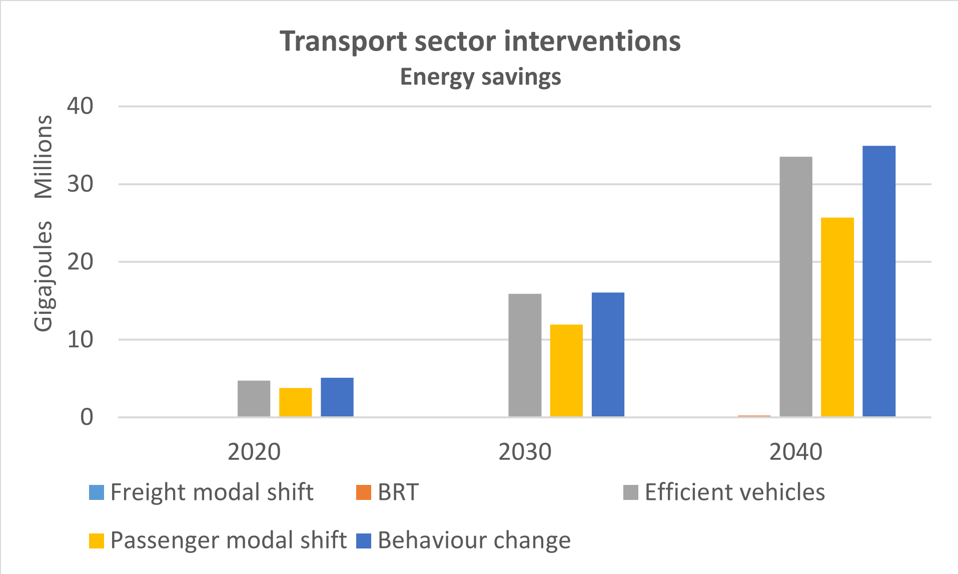


Figure 33: Energy savings potential of transport interventions

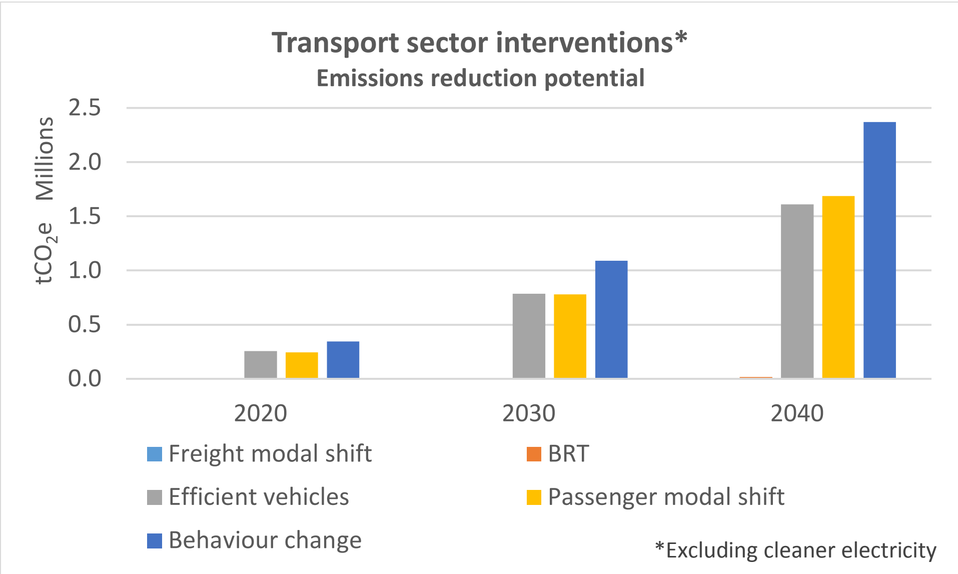


Figure 34: Emissions reduction potential of transport interventions

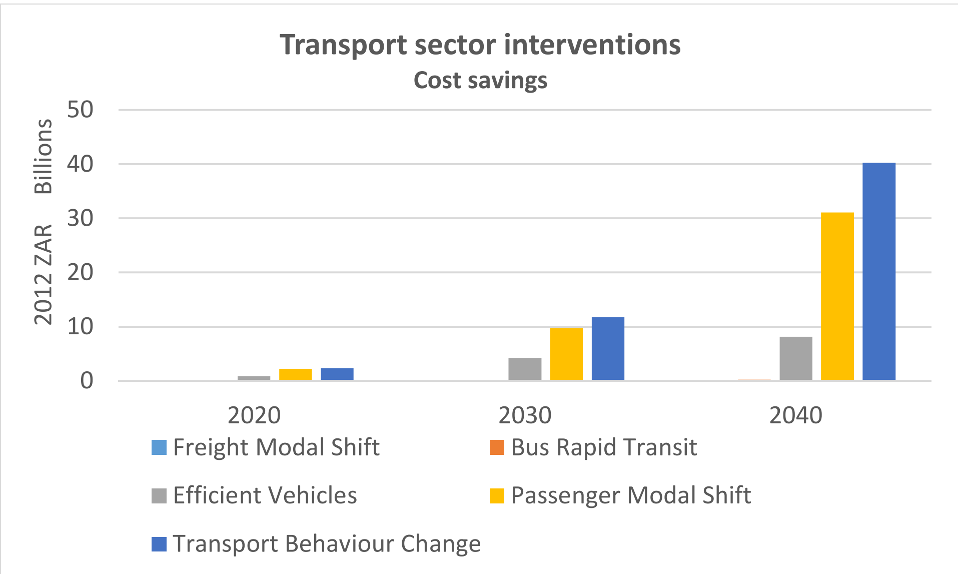


Figure 35: Costs savings potential of transport interventions

The scenario that individually demonstrates the largest savings in energy, emissions and costs is that of transport behaviour change. Private passenger transport (pass-km by car) is responsible for such a huge proportion of energy consumption, emissions production and costs that any technological or behavioural improvement in efficiency in this sector results in large savings. It is for this same reason that the scenario with the next-largest energy savings impact is that concerning vehicle efficiency (although this focuses on both public and private vehicle efficiency).

The results showing that behaviour change in the private passenger transport sector has a large impact (even larger than that of a modal shift) are encouraging, as this is something that the City could potentially affect through behaviour campaigns. The City has already taken steps in this direction, through the initiation of its Travel SMART programme. Originally aimed at reducing the trips travelled by its own staff, the City's Travel SMART programme was extended as a pilot project to a number of large employers in the central city to assist them to create a mind-shift among their own staff and provide information – and, where possible, options - to encourage the use of more sustainable ways of travelling to and from work. This programme has the potential to be scaled up.

A behaviour change campaign should not replace any drive to shift people over to public transport or to provide a quality public transport service, integrated across public transport modes. Private transport takes up an unfair share of the road-space, which is in essence a public open space that should be shared by all. Congestion caused mainly through the use of cars represents a large loss of productive time and money. The majority of residents within Cape Town also cannot afford to travel by car. The focus should shift from spending taxpayer money on ever-widening roads that cater to the upper-income bracket in cars, to the provision of public transport for all.

Indications are also that the energy savings impact of a modal shift to public transport is underestimated. In LEAP, modal shift is modelled by considering a straight shift in passenger-km from private to public transport. Yet indications are that when people do shift to public transport, the amount of kilometres they travel reduces. In other words, as the use of public transport increases linearly the car passenger-km decrease exponentially. [74] This is due to a phenomenon called transit leverage, whereby 1 pass-km of public transport use replaces between 5 and 7 pass-km in a car due to:

- more direct travel (especially in trains)
- trip chaining (doing various other things like shopping or service visits associated with a commute)
- giving up one car in a household (a common occurrence that reduces many solo trips)
- living or working nearer to public transport, often induced by transit-oriented development

Transit leverage is not as pronounced in relation to buses as they do not have the same direct speed (unless BRTs are being used) and they don't facilitate land use change as easily.

The BRT Scenario's energy savings are not large, as this scenario was modelled purely as a shift of people who already were in conventional buses to BRT buses, which are slightly more efficient due

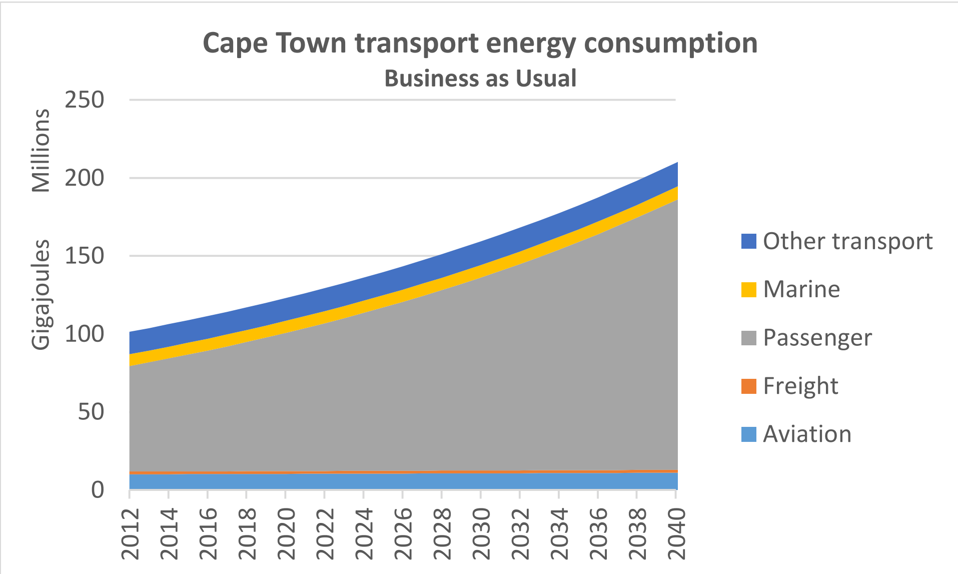
[74] Newman, Peter and Kenworthy, Jeff. 2011. Evaluating the Transport Sector's Contribution to Greenhouse Gas Emissions and Energy Consumption, in Salter, R. and Dhar, S. and Newman, P. (ed), Technologies for Climate Change Mitigation - Transport Sector. pp. 7-23. Denmark: UNEP Riso Centre on Energy, Climate and Sustainable.

to higher occupancy levels. This scenario may be combined with other scenarios, e.g. it is actually a mechanism to encourage modal shift, which has one of the biggest energy savings impacts. It must be noted that BRT infrastructure costs were not included in the BRT Scenario, because infrastructure costs were not included for the other scenarios, e.g. fixing pot-holes, widening roads, providing parking was not applied to car-focused scenarios. It is extremely difficult to obtain this data in a "Rands per pass-km" format, which is how the costing in this LEAP model is set up. It was therefore decided to exclude infrastructure costs for all transport-related scenarios. Vehicle capital costs were included.

The energy savings impact of the freight scenario is small, as the baseline energy consumption by the freight sector was small. This is a result of allocating only the fuel used by trucks when fuelling up in the metro area, i.e. excludes all fuel-ups on the complete route, which may fall mainly outside the metro area.

When considering scenario costs, the Efficient Vehicles Scenario is more expensive than any other scenarios, as it includes the cost of the new, more efficient, vehicles. Electric and hybrid vehicles currently sell at higher prices when compared to cars of a similar size running on conventional fuels.

The Passenger Modal Shift Scenario results in larger emissions reductions by 2040 than the Efficient Vehicles Scenario, mainly because the penetration rate of efficient diesel/petrol vehicles is set to stabilise after 2035, while some modal shift still does occur from this date onwards. See Table 68: Transport Efficiency Scenarios key assumptions.



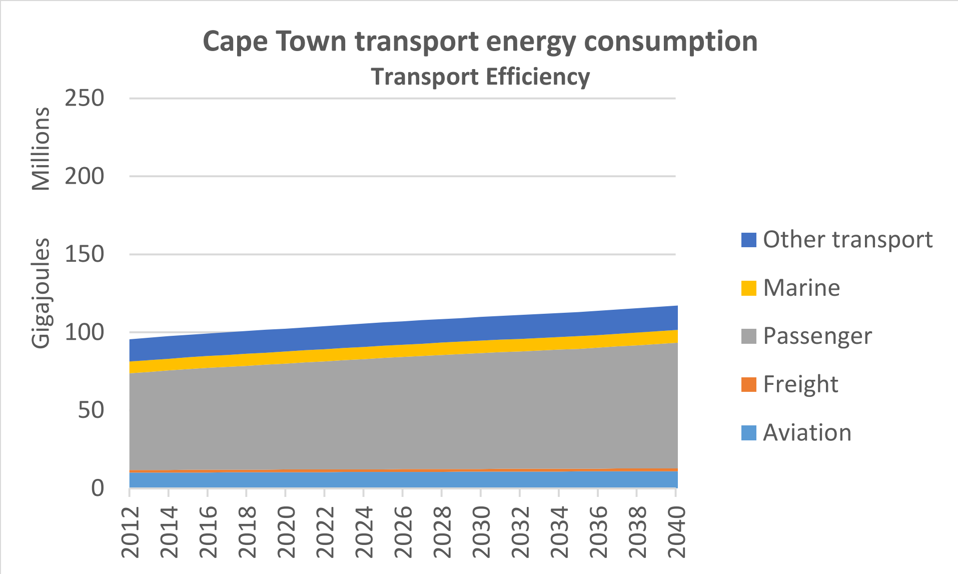


Figure 36: Impact of transport efficiency on energy demand in the transport sector

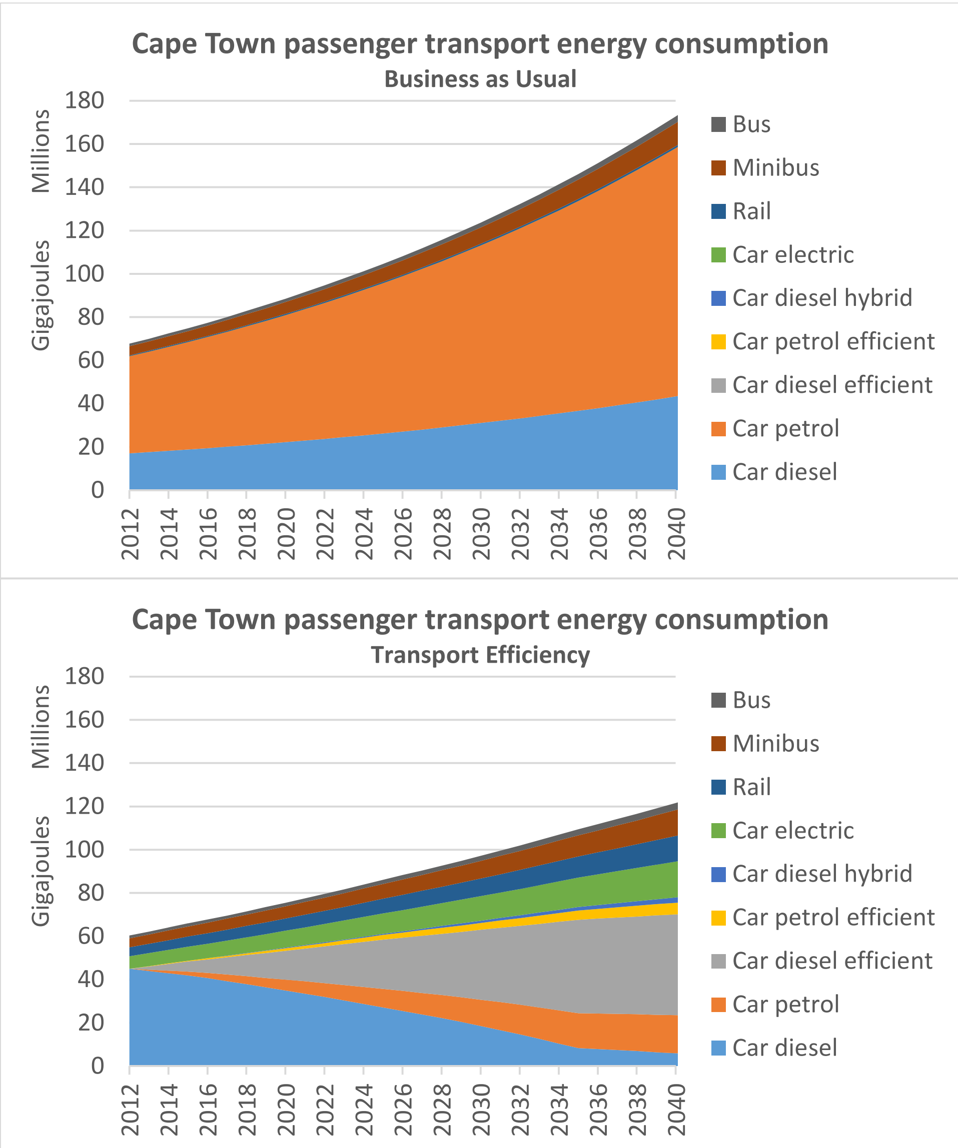


Figure 37: Impact of transport efficiency on energy demand in the passenger transport sector

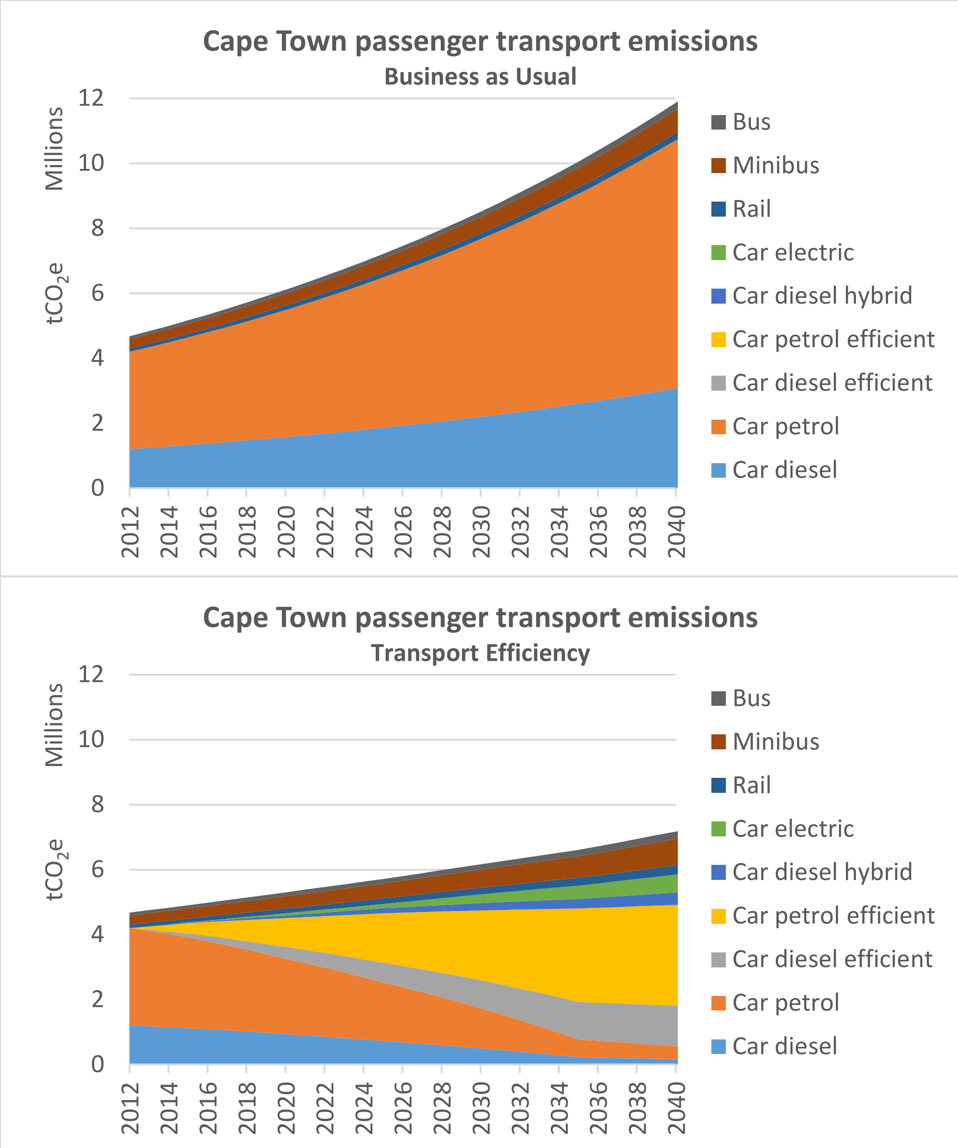


Figure 38: Impact of transport efficiency on emissions in the passenger transport sector

Combined Electricity and Transport Efficiency Scenario

Table 69: Electricity and Transport Efficiency Scenarios key assumptions

Scenario	Assumption
Electricity Efficiency Scenario	• Includes all scenarios discussed in the *Electricity Efficiency Scenario Outputs* chapter.
Transport Efficiency Scenario	• Includes all scenarios discussed in the *Transport Efficiency Scenario Outputs* chapter.

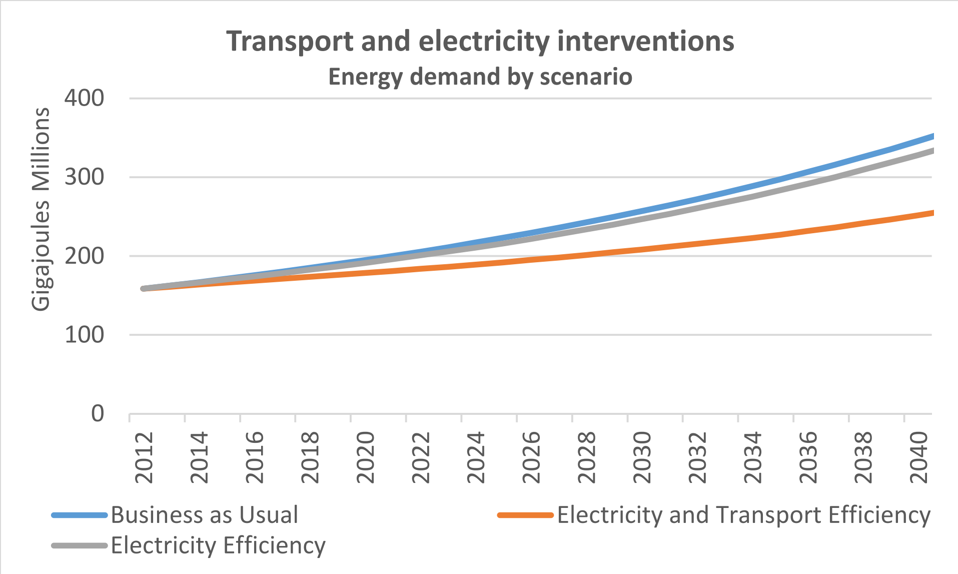


Figure 39: Impact of electricity and transport efficiency on energy demand

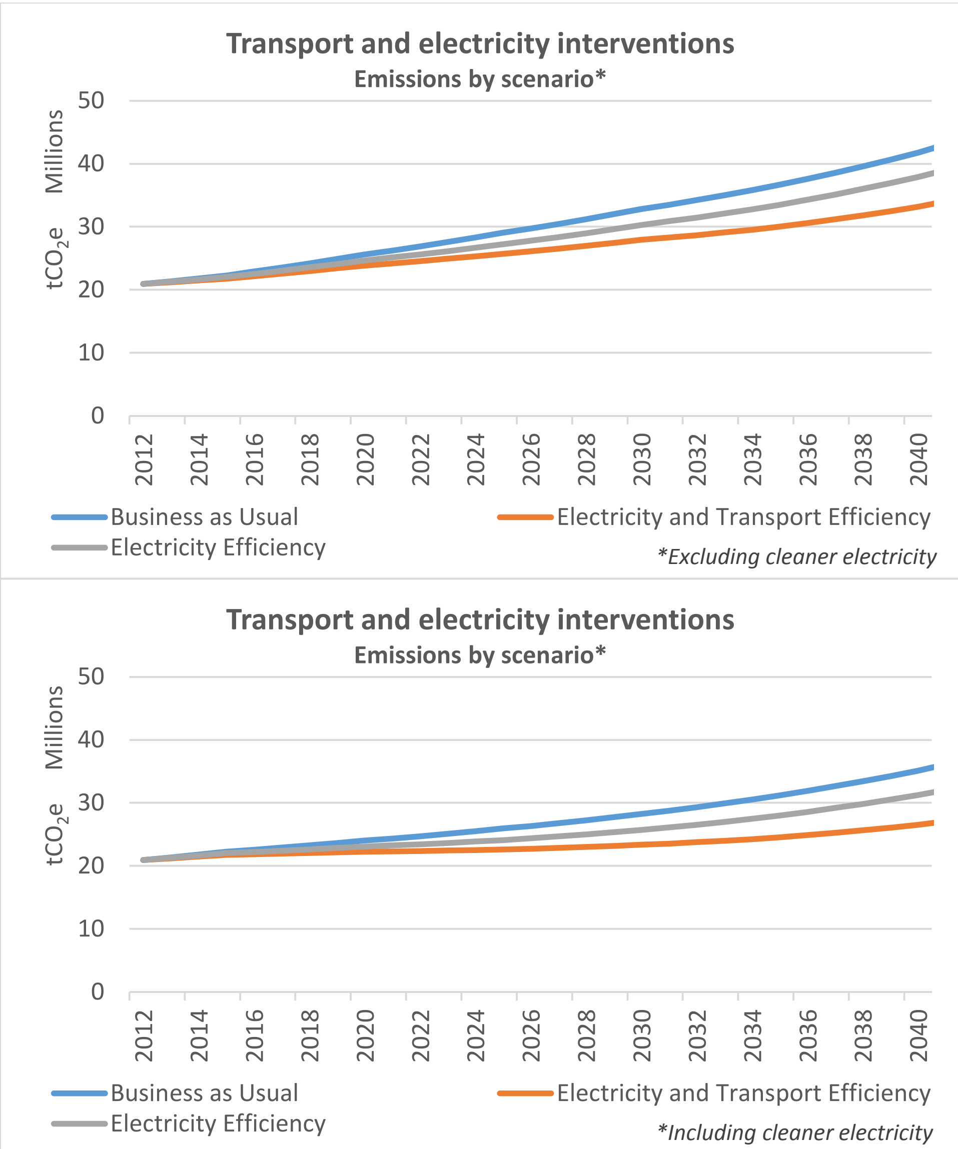


Figure 40: Impact of electricity and transport efficiency on emissions

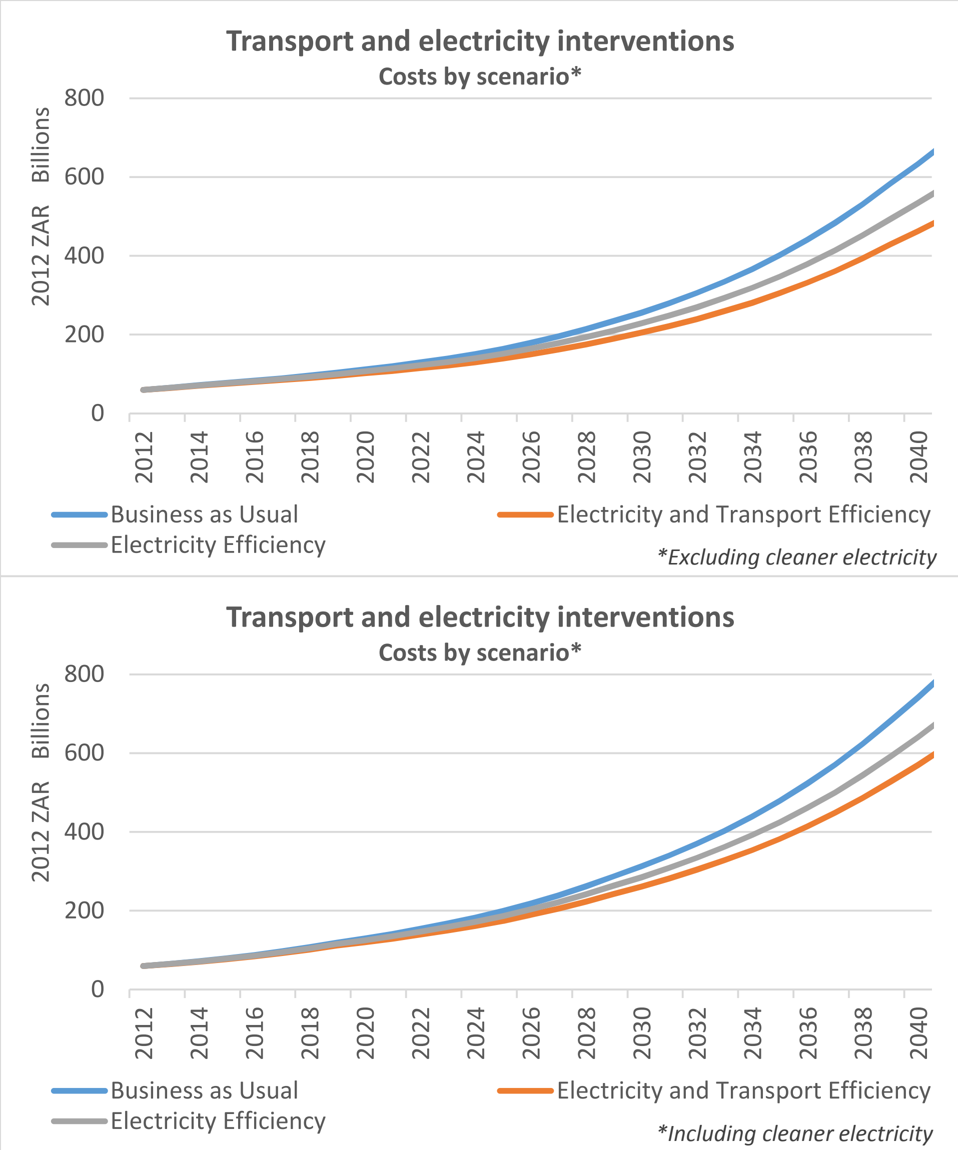


Figure 41: Impact of electricity and transport efficiency on costs

Larger energy and emissions savings are realised through transport efficiency interventions if no supply-side (cleaner electricity) interventions take place concurrently. This is due to the fact that a measure of electricity efficiency has already been achieved (the City's electricity sales in 2014/15 are below that in 2007/08), whilst transport energy consumption has remained inefficient. [75]

Relatively higher emissions savings per unit energy are achieved through electricity efficiency interventions due to South Africa's electricity supply continuing to be relatively carbon intensive (most electricity will still be produced by coal-fired power plants in 2040).[76] However, the energy savings realised from the transport sector are potentially so great that the emissions savings for the transport sector will also trump the emissions savings potential from electricity efficiency interventions. It must be noted that this situation changes if supply-side (i.e. lower-carbon electricity) interventions are also implemented. This will increase the amount of emissions savings that can be realised through electricity efficiency interventions to slightly higher than that realisable by the transport sector. The cleaner electricity used in the above graphs include embedded solar PV

[75] Cape Town State of Energy 2015
[76] Following the "Weathering the Storm" scenario in the IRP 2013 update

and local large-scale generation (renewables and gas). Detail on the supply-side scenarios are covered in the following chapters.

It is sobering that even with aggressive electricity and transport efficiency measures, the emissions trajectory is upwards after 2030; in contrast with what has been set out in the Cabinet-endorsed national emissions Peak, Plateau, Decline trajectory.

A more detailed picture of the energy savings impacts are provided in the graphs below.

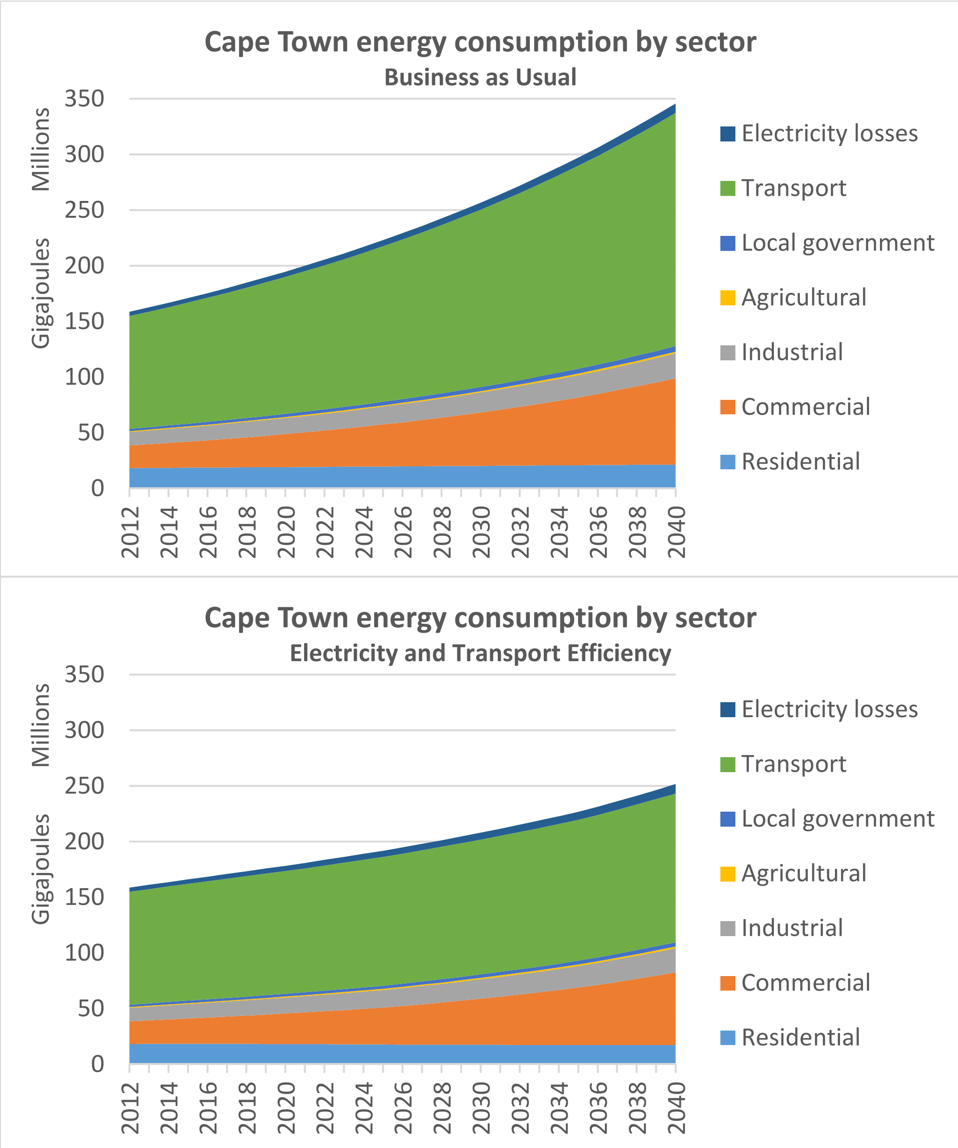


Figure 42: Impact of electricity and transport efficiency on energy demand by sector

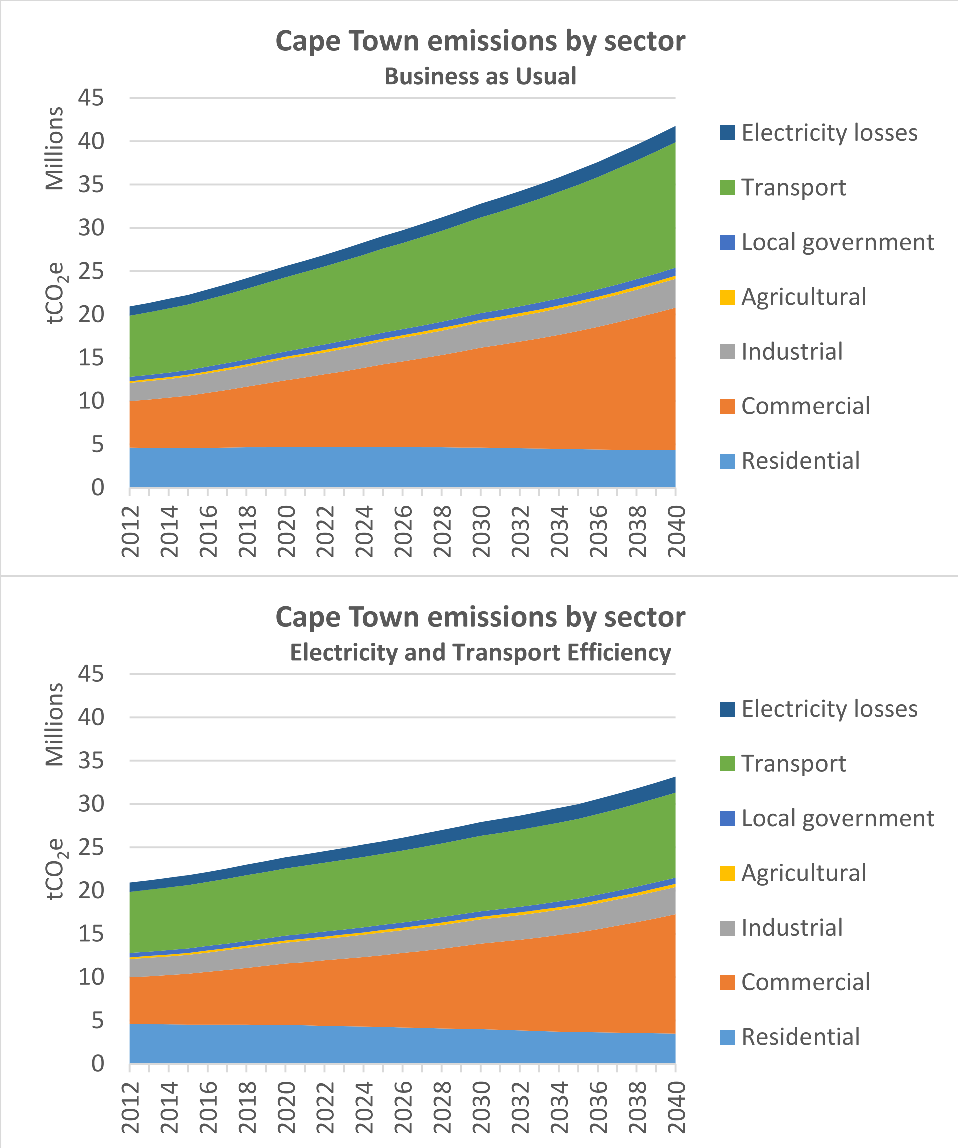


Figure 43: Impact of electricity and transport efficiency on emissions by sector

Supply-Side Scenarios: Cleaner Electricity

Table 70: Cleaner electricity supply scenarios key assumptions

Scenario	Assumption
ETE Local Generation (GEN)	• All demand side efficiencies in place (as in ETE Scenario) and, in addition, local generation of 300MW CCGT, 50MW large-scale solar PV and 50MW wind by 2020. Same amount of capacity added every 5 years thereafter: 900MW CCGT, 150MW large-scale PV, 150MW wind by 2030; and 1 500MW CCGT, 250MW large-scale PV, 250MW wind by 2040.
Solar PV	• ETE with embedded solar PV in 50% of high (2kW) and very high income (3kw) households by 2040 (10% by 2020; 30% by 2030), and supplying 15% of electricity needs in commercial and industrial sectors by 2040.
GEN Solar PV	• GEN with embedded solar PV in 50% of high and very high income households by 2040, and supplying 15% of electricity needs in commercial and industrial sectors.

The renewable and cleaner electricity scenarios (Solar PV and GEN Solar PV) are both modelled off an efficient scenario (ETE – Electricity and Transport Efficiency), as it is cheaper to first save electricity rather than build new plants, i.e. it is assumed that this would be the first port-of-call rather than implementing renewable/cleaner energy first without any efficiency interventions. The ETE scenario's electricity supply mix is that of the IRP 2013 Update's *Weathering the Storm* Scenario.

Table 71: Supply-side scenarios electricity mix (MWh)

IRP Weathering the Storm	**2012**	**2015**	**2020**	**2025**	**2030**	**2040**	**2050**
Solar PV Embedded	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CCGT local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wind local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pumped Storage	1.2%	2.0%	1.7%	1.8%	1.7%	1.4%	1.3%
Solar PV large-scale	0.0%	0.5%	0.4%	1.1%	3.0%	5.5%	7.7%
CSP	0.0%	0.2%	0.3%	0.3%	0.3%	4.1%	5.0%
Wind	0.0%	0.9%	0.8%	0.8%	1.4%	3.4%	4.3%
New Nuclear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
New Coal	0.0%	6.5%	17.5%	19.1%	30.5%	47.8%	56.5%
CCGT	0.0%	0.0%	0.0%	1.4%	2.7%	4.5%	6.2%
OCGT	6.2%	5.7%	7.0%	7.1%	13.0%	15.9%	15.2%
Hydro	3.2%	3.0%	2.6%	4.5%	4.2%	3.5%	3.3%
Existing Base	85.1%	77.4%	66.4%	60.4%	40.1%	11.1%	0.6%
Existing Nuclear	4.2%	3.8%	3.3%	3.4%	3.2%	2.7%	0.0%
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**
GEN Solar PV	**2012**	**2015**	**2020**	**2025**	**2030**	**2040**	**2050**
Solar PV embedded	0.0%	0.0%	2.1%	4.2%	6.9%	10.8%	14.7%
CCGT Local	0.0%	0.0%	13.3%	23.7%	30.6%	36.7%	35.5%
Solar Local	0.0%	0.0%	0.5%	0.8%	1.1%	1.3%	1.3%
Wind Local	0.0%	0.0%	0.7%	1.3%	1.6%	2.0%	1.9%
Pumped Storage	1.2%	2.0%	1.5%	1.3%	1.0%	0.7%	0.6%
Solar PV large-scale	0.0%	0.5%	0.4%	0.8%	1.8%	2.7%	3.6%
CSP	0.0%	0.2%	0.2%	0.2%	0.2%	2.0%	2.4%
Wind	0.0%	0.9%	0.7%	0.6%	0.8%	1.7%	2.0%
New Nuclear	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
New Coal	0.0%	6.5%	14.6%	13.4%	18.2%	23.6%	26.4%
CCGT	0.0%	0.0%	0.0%	1.0%	1.6%	2.2%	2.9%
OCGT	6.2%	5.7%	5.8%	5.0%	7.8%	7.8%	7.1%
Hydro	3.2%	3.0%	2.2%	3.1%	2.5%	1.7%	1.5%
Existing Base	85.1%	77.4%	55.4%	42.2%	23.9%	5.5%	0.3%
Existing Nuclear	4.2%	3.8%	2.8%	2.4%	1.9%	1.3%	0.0%
Total	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

The City has plans on the table to procure 300MW of gas, 50MW of large-scale PV and 50MW of wind power.[77] There are considerations that this might go up to some 800MW of gas production. Based on this intention the ETE Local Generation Scenario has been developed to explore the impact

[77] Pers. com. A. Janisch, ERMD, City of Cape Town: Official letter of intent from City to War Room, IPP office going out soon for 300MW CCGT. IPP office indicates that 50MW PV at blended Eskom purchase price with 6% escalation being offered at the moment. Inclusion of 50MW wind considered appropriate.

of the production already under consideration, and the extension of that production over time to a fairly “heavy gas” future. This builds on the efficiency scenario, i.e. this electricity supply mix is modelled on top of the scenario that already includes all demand-side interventions (ETE - Electricity and Transport Efficiency).

The Solar PV Scenario considers the impact of embedded rooftop solar PV. Embedded solar PV refers to solar PV installed on residential, commercial or industrial buildings’ rooftops. There is a limit as to the amount of embedded solar PV that can be installed on one transformer. Current experience and workings indicate anything over 25% of electricity demand may result in voltage fluctuations outside of an allowable range. The Solar PV scenario drew on detailed modelling of uptake (based on the Rogers estimation curve)[78] and matched this with grid limits. This looks at embedded solar PV in 50% of high and very high income households in 2040, based on a 2kW system in high-income and 3kW system in very high-income households. In the commercial and industrial sectors it looks at supplying 15% of the electricity needs of each sector through rooftop PV installations by 2040.

The GEN Solar PV Scenario considers the impacts of embedded rooftop solar PV in addition to the local cleaner and renewable energy production of the ETE Local Generation Scenario.

Table 72: Local generation and embedded PV (GEN Solar PV): local generation supply as portion of total capacity and total supply under the ETE demand scenario profile

	2012	2015	2020	2025	2030	2040
ETE total demand (MWh)	**14,415,661**	**15,426,852**	**17,248,042**	**19,346,806**	**22,443,303**	**31,262,319**
Local CCGT (%)	0%	0%	14%	24%	31%	37%
Local wind (%)	0%	0%	1%	1%	2%	2%
Local large-scale solar PV (%)	0%	0%	0%	1%	1%	1%
Embedded Solar PV (%)	0%	0%	2%	4%	7%	11%
ETE total capacity (MW)	**2,185**	**2,441**	**2,853**	**3,457**	**4,378**	**6,891**
Local CCGT (%)	0%	0%	11%	17%	21%	22%
Local wind (%)	0%	0%	2%	3%	3%	4%
Local large-scale solar PV (%)	0%	0%	2%	3%	3%	4%
Embedded Solar PV (%)	0%	0%	8%	14%	22%	30%

Local Generation proves to be extremely cost effective (Figure 45). The large component of gas offsets the more costly large-scale PV and wind. Due to solar PV and wind’s lower availability when compared to conventional electricity power plants such as coal, gas and nuclear, a high amount of system capacity is required (see Figure 47). This is particularly evident in the case of embedded, rooftop PV. Here a large capacity of rooftop PV is required to supply the 15% of all commercial and industrial needs and this can be seen to push the costs up.

It must be noted that implementing solar PV *along with electricity efficiency* measures (the GEN Solar PV Scenario builds on the Electricity efficiency interventions of the ETE Scenario), is cheaper than to implement embedded solar PV when no efficiency gains have been realised. It is always cheaper to save electricity than to generate more electricity for what may be inefficient uses. The GEN Solar PV without the efficiency interventions would show higher costs than that in BAU, making it critical that the two are implemented in unison.

[78] Sustainable Energy Africa: Revenue Impact Tool, 2014.

It must also be noted that costs outputs from LEAP does not indicate who pays. The costs of embedded solar PV, in this case, is borne by private and business users in the residential, commercial and industrial sectors. The cost (and/or indeed cost savings) of increased gas and renewables in the national electricity mix is borne by all. In the local mix it is borne by all recipients of City distribution.

The emissions for both Local Generation and GEN Solar PV Scenarios are progressively lower, because more electricity is being obtained from a renewable source (Figure 44).

It may be more efficient, cost-wise, to implement larger-scale clean energy and renewable development at a city-scale level (economies of scale) as opposed to small-scale embedded generation (SSEG), in order to bring down electricity emission. However, the private investment in renewable energy offered by SSEG is still worth pursuing in order to meet local emissions reduction goals.

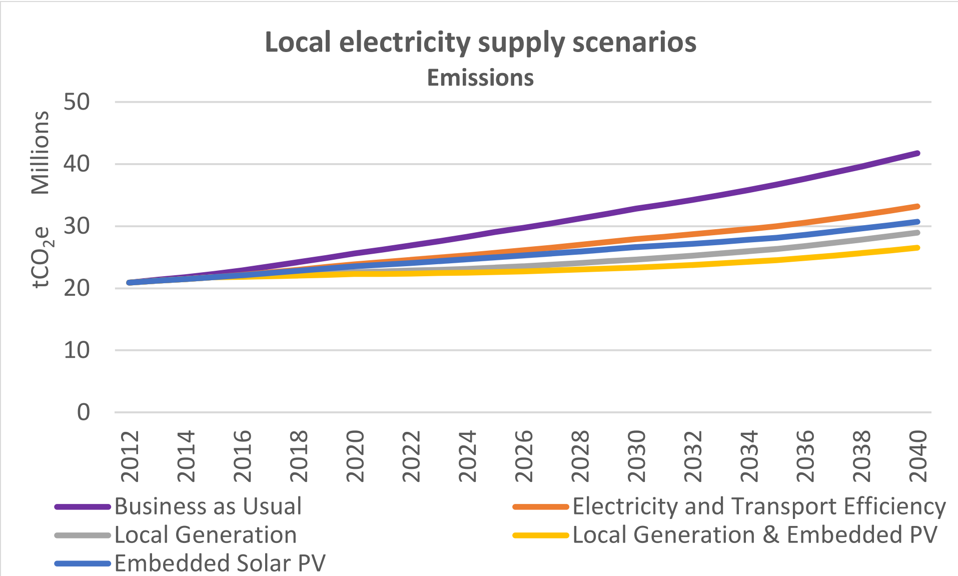


Figure 44: Impact of Local Generation, Solar PV and GEN Solar PV on emissions off an ETE baseline

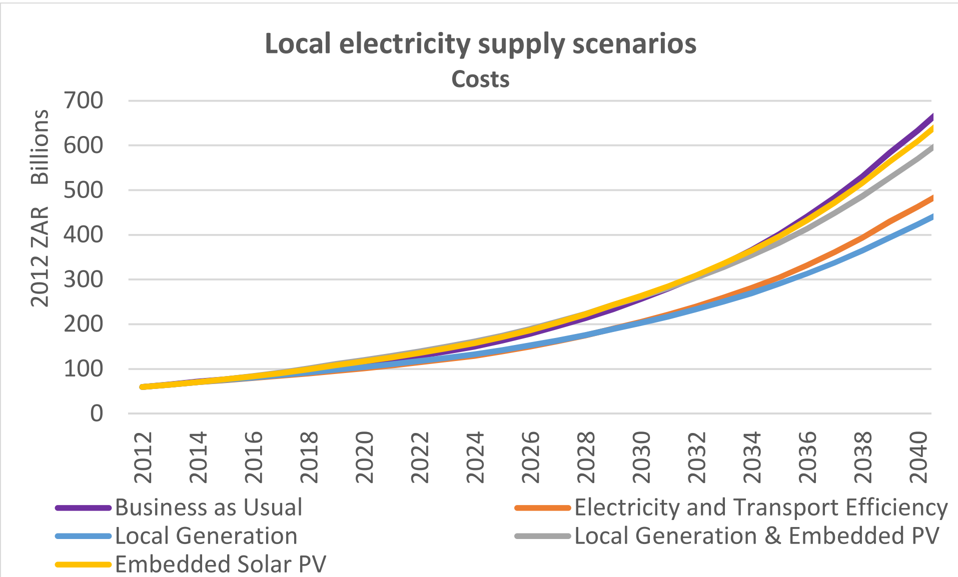


Figure 45: Impact of local gas, PV and wind generation, and embedded solar PV on costs

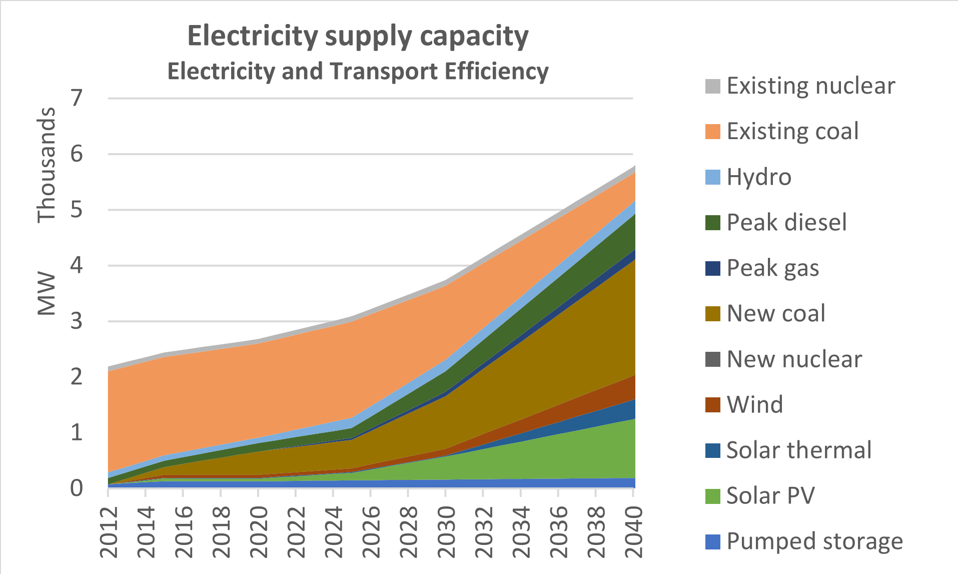


Figure 46: Electricity capacity (MW) of Electricity and Transport Efficiency (ETE) Scenario

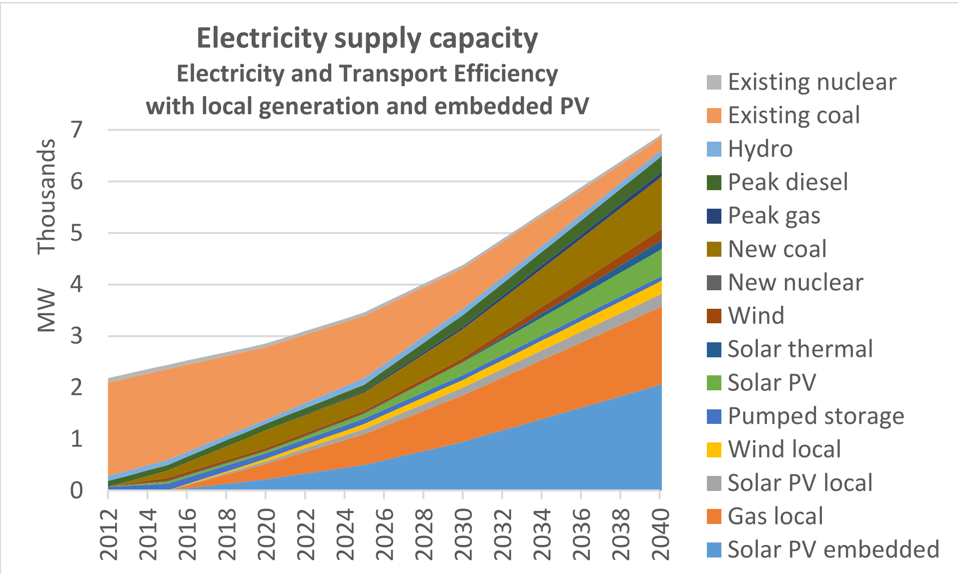


Figure 47: Electricity capacity (MW) of GEN Solar PV Scenario (local generation and embedded solar PV)

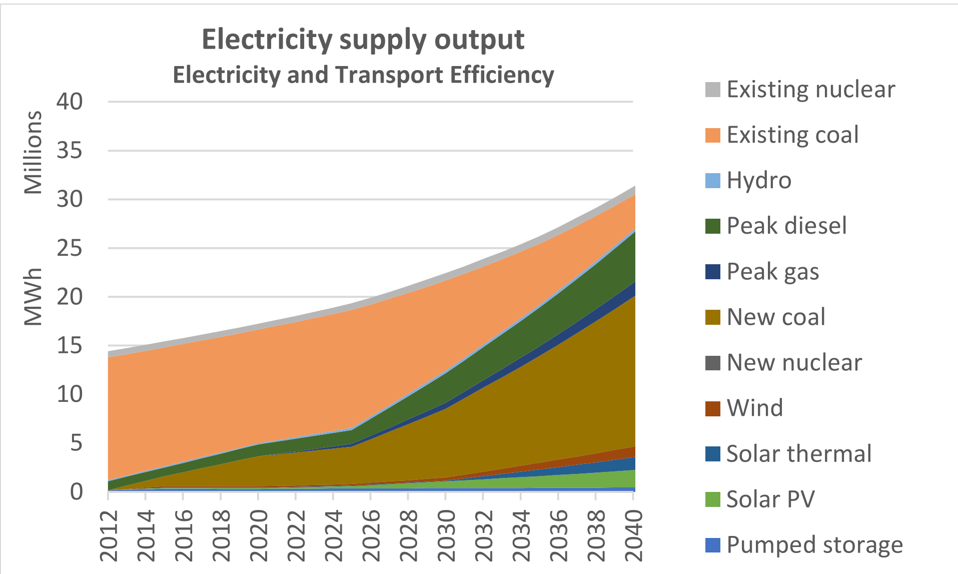


Figure 48: Electricity supply (MWh) of Electricity and Transport Efficiency (ETE) Scenario

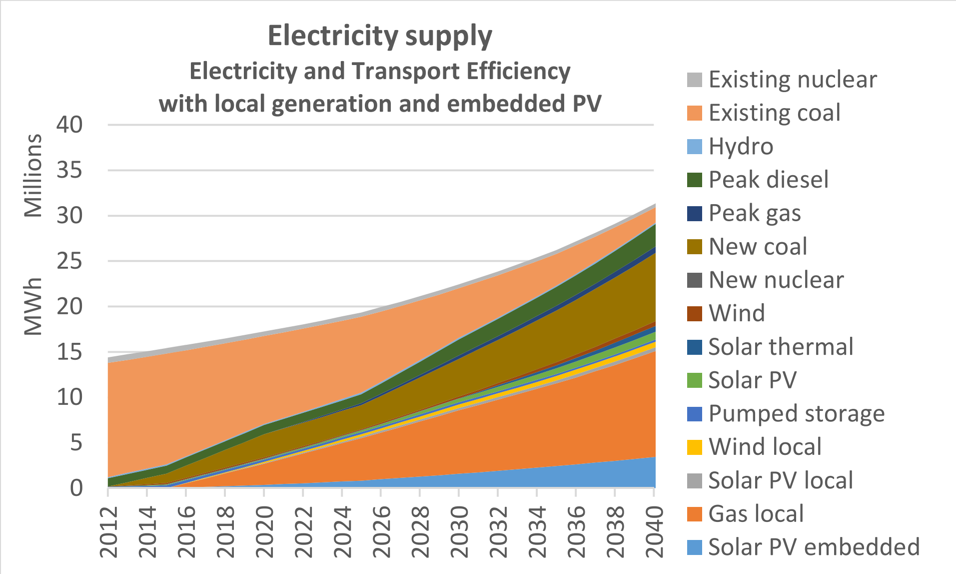


Figure 49: Electricity supply (MWh) of GEN Solar PV Scenario (local generation and embedded solar PV)

Supply-Side Scenario: Fuel Switching

Given the Local Generation scenario envisages substantial gas resources coming into the Cape Town area, the possibility of fuel switching from electricity or coal to gas for process heating and process steam within industry arises. In order to ascertain whether it was worthwhile to actually undertake a scenario that explored fuel switching, the industrial sector process heating was explored. Results indicate that in terms of electricity, 1.6% of end use is for thermal (process heating and process steam); in terms of coal this is higher at around 21%. These are large figures within industry; however, the industrial sector is small within Cape Town, with electricity and coal use for thermal purposes in industry representing 0.1% and 1.6% respectively of total metro energy consumption. Thus, the availability of gas would potentially impact substantially on coal use, but minimally on electricity use, and certainly would not substantially alter the city's energy picture. This is important to consider, but a separate scenario has not been undertaken.

Table 73: Proportion of coal and electricity used for thermal heating in industry

Total energy used by industrial sector for thermal/heat (2012)	GJ	% of total industrial energy	% of total CCT energy
Electricity (thermal)	197 035	1.6%	0.1%
Coal (thermal)	2 527 094	20.8%	1.6%

Supply-Side Scenario: IRP Base Case

The IRP Scenario models what Business as Usual would look like if electricity supply is in line with the IRP 2013 Update Report Base Case Step 5 Scenario, as this scenario very closely reflects the cabinet-endorsed IRP 2011 Policy-Adjusted Scenario, but includes updates such as a revised demand projection and technology costs. The IRP 2013 Update provided better data for modelling purposes, which is why the IRP Scenario was based on this report.

Table 74: Electricity supply mix in IRP Base Case Scenario

IRP Base Case Step 5	2012	2015	2020	2025	2030	2040	2050
Solar PV Embedded	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CCGT local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Solar local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Wind local	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Pumped Storage	1.2%	2.0%	1.7%	1.6%	1.4%	1.1%	1.1%
Solar PV large-scale	0.0%	0.5%	0.5%	1.9%	3.3%	5.1%	6.3%
CSP	0.0%	0.2%	0.3%	0.3%	2.5%	3.4%	4.6%
Wind	0.0%	0.9%	0.8%	1.1%	2.2%	3.5%	4.0%
New Nuclear	0.0%	0.0%	0.0%	2.7%	7.1%	13.1%	13.9%
New Coal	0.0%	6.5%	17.5%	18.7%	25.0%	39.3%	44.9%
CCGT	0.0%	0.0%	0.0%	5.1%	5.6%	6.3%	7.5%
OCGT	6.2%	5.7%	6.9%	6.5%	12.7%	14.2%	14.8%
Hydro	3.2%	3.0%	2.6%	4.1%	3.6%	2.8%	2.6%
Existing Base	85.1%	77.4%	66.3%	54.9%	33.8%	9.0%	0.5%
Existing Nuclear	4.2%	3.8%	3.3%	3.1%	2.7%	2.2%	0.0%
TOTAL	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**	**100.0%**

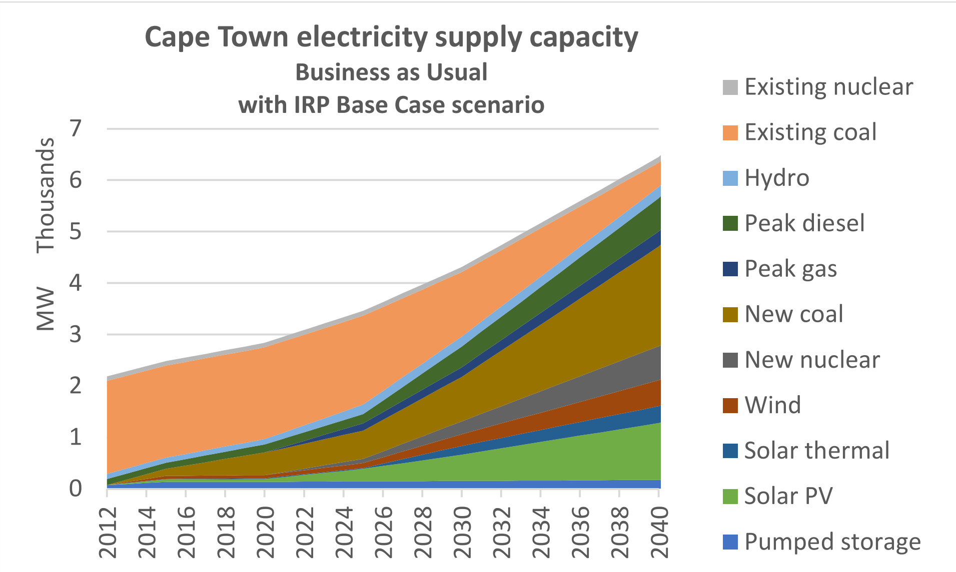


Figure 50: IRP Scenario electricity capacity (MW)

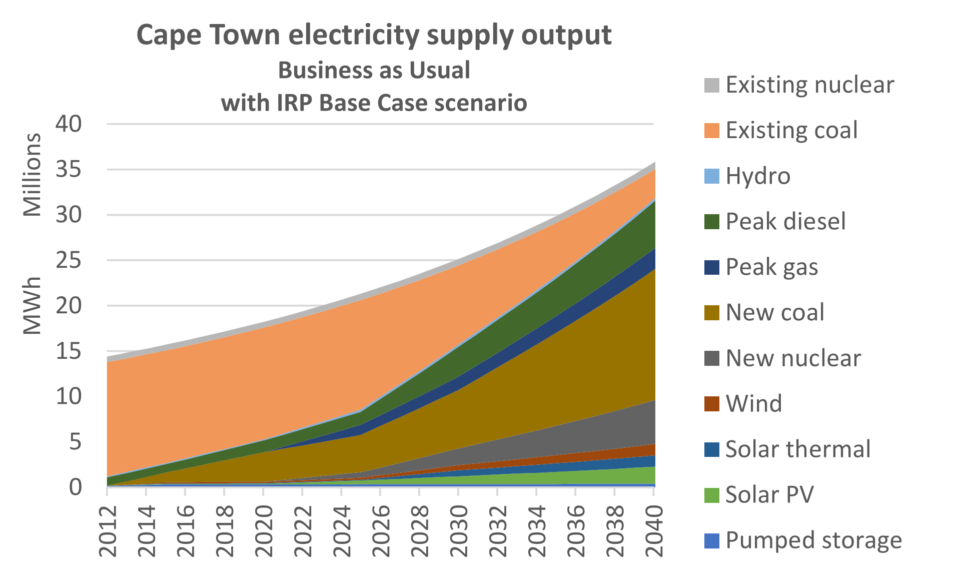


Figure 51: IRP Scenario electricity supplt (MWh)

Emissions in the IRP Scenario are lower than in the BAU Scenario post 2020 (Figure 52). This is due to the provision for a nuclear build to come on line after 2020 in the IRP Scenario. Nuclear energy has zero emissions associated with it. However, the nuclear build component renders the IRP Scenario more costly (Figure 53). Following an energy efficient and cleaner electricity supply-side scenario (GEN Solar PV) results in lower costs and emissions than both BAU and IRP. Given, the IRP supply mix will bring down the emissions of GEN Solar PV even further, but it will push up the costs to be even higher than BAU despite the savings gains through energy efficiency.

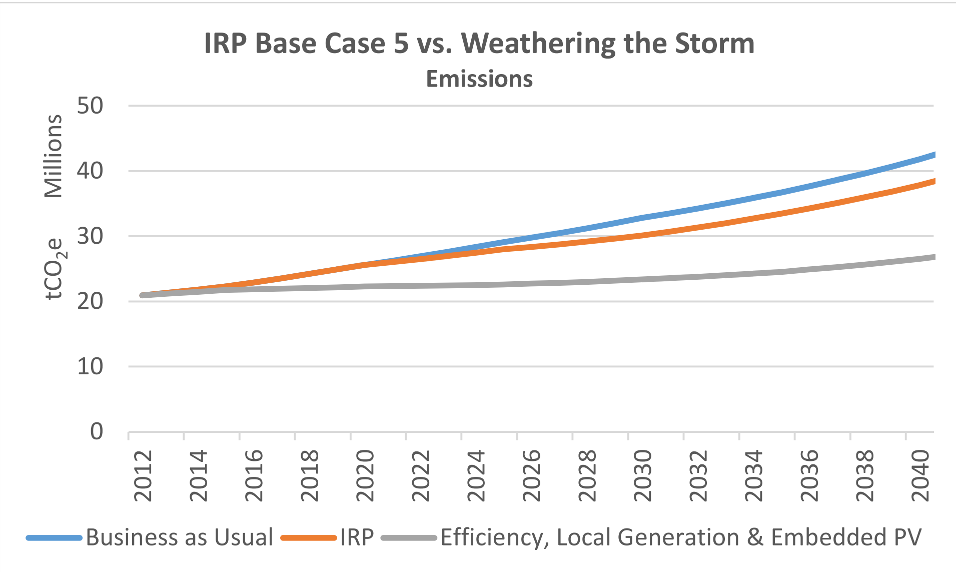


Figure 52: Impact of IRP Scenario on emissions

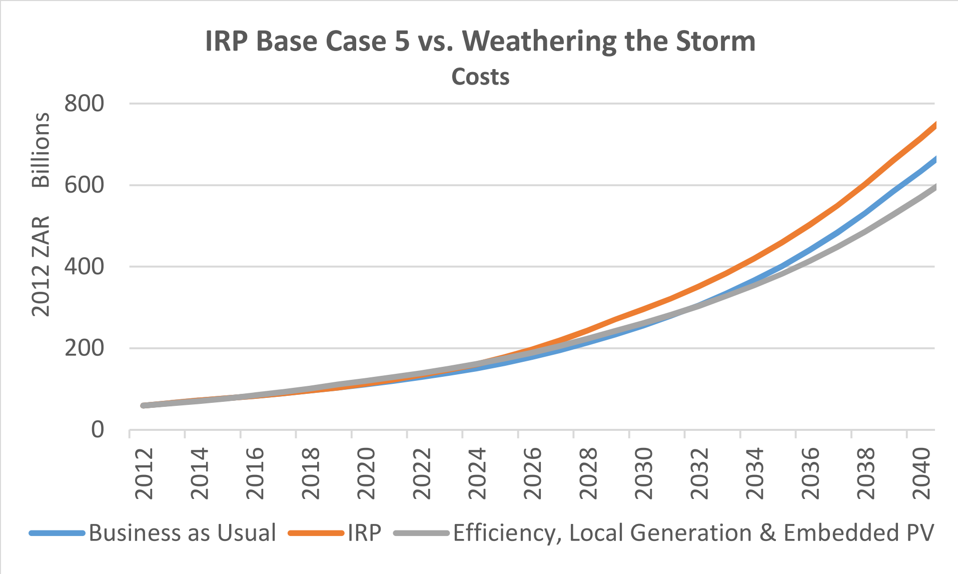


Figure 53: Impact of IRP Scenario on costs

Carbon Tax Scenarios

Table 75: Carbon Tax Scenarios key assumptions

Scenario	Assumption
BAU Carbon Tax Scenario	• Business as Usual Scenario with a carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025[79]
ETE Carbon Tax Scenario	• Electricity and Transport Efficiency Scenario with a carbon tax of R40/tonne in 2015 increasing gradually to R47/tonne in 2019 before the more rapid escalation to R117/tonne in 2025
Solar PV Carbon Tax Scenario	• Embedded Solar PV with carbon tax of R40/ton in 2015 increasing gradually to R47/ton in 2019 before the more rapid escalation to R117/ton in 2025.
Local Generation Carbon Tax Scenario	• Local Generation (gas, wind, large-scale PV) with carbon tax of R40/ton in 2015 increasing gradually to R47/ton in 2019 before the more rapid escalation to R117/ton in 2025.
Solar and Local Gen Carbon Tax Scenario	• Local Generation and embedded Solar PV with carbon tax of R40/ton in 2015 increasing gradually to R47/ton in 2019 before the more rapid escalation to R117/ton in 2025.

An energy efficient scenario is more resilient in the face of the implementation of a carbon tax than an inefficient BAU scenario (Figure 54). The total scenario cost of an energy efficient and cleaner electricity scenario with a carbon tax is lower by 2040 than that of Business as Usual without a carbon tax (Figure 55).

[79] Based on assumption used in IRP 2013 update

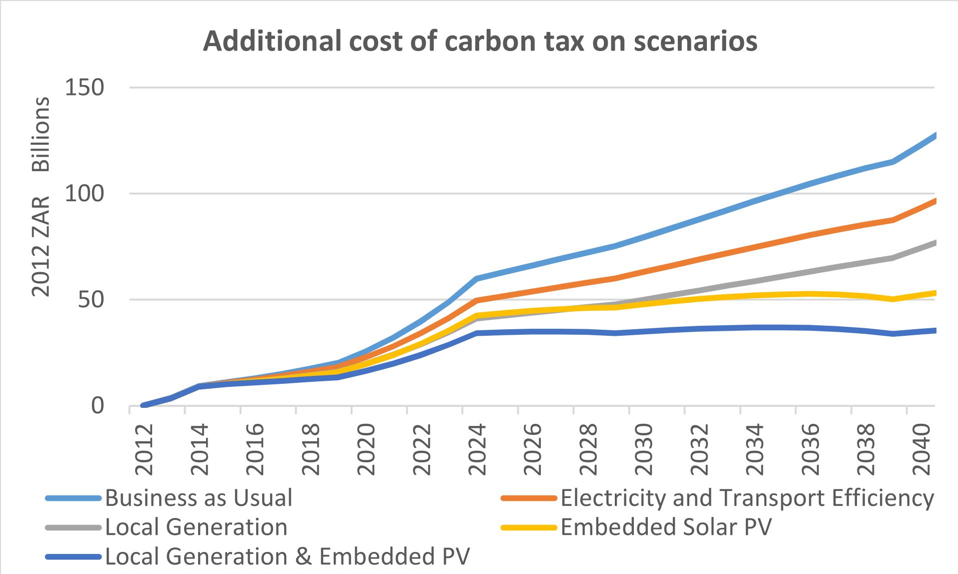


Figure 54: Additional costs of a carbon tax on scenarios

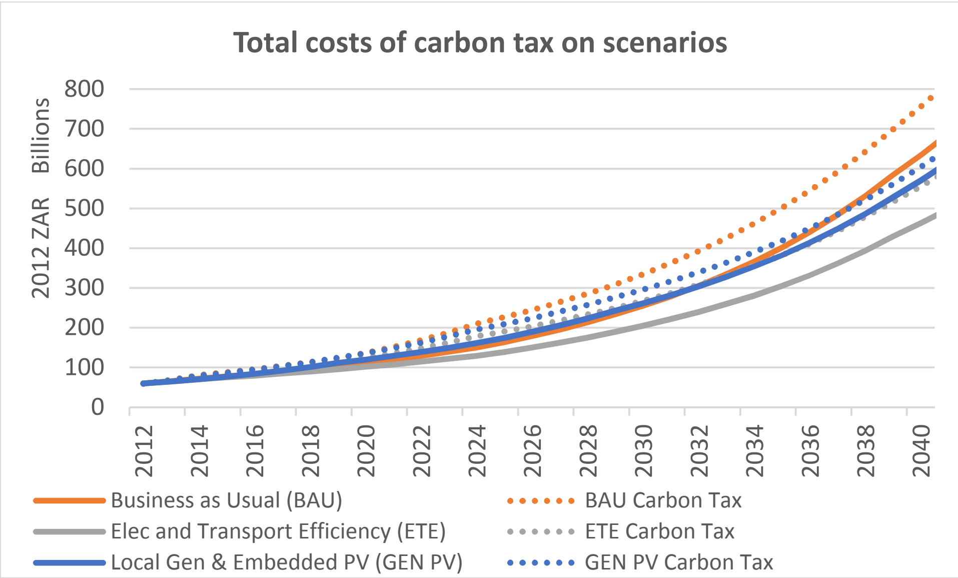


Figure 55: Total scenario costs impact of a carbon tax

Peak Oil Scenarios

Table 76: Peak Oil Scenarios key assumptions

Scenario	Assumption
BAU Peak Oil Scenario	• Business as Usual Scenario with annual liquid fuel price increases 5% above the current real increase rate[80]
ETE Peak Oil Scenario	• Electricity and Transport Efficiency Scenario with annual liquid fuel price increases 5% above the current real increase rate

Peak oil is the point in time when the global production of oil reaches its maximum rate, after which production will gradually decline. This will result in liquid fuel price instability and shocks.

[80] The real average annual increase of liquid fuels range between 4.2% and 5.6% depending on the fuel type.

The financial impact of an additional average annual increase of 5% on liquid fuel prices is untenable no matter which way you look at it. The impact will be severe and will require a paradigm shift when it comes to how our cities work.

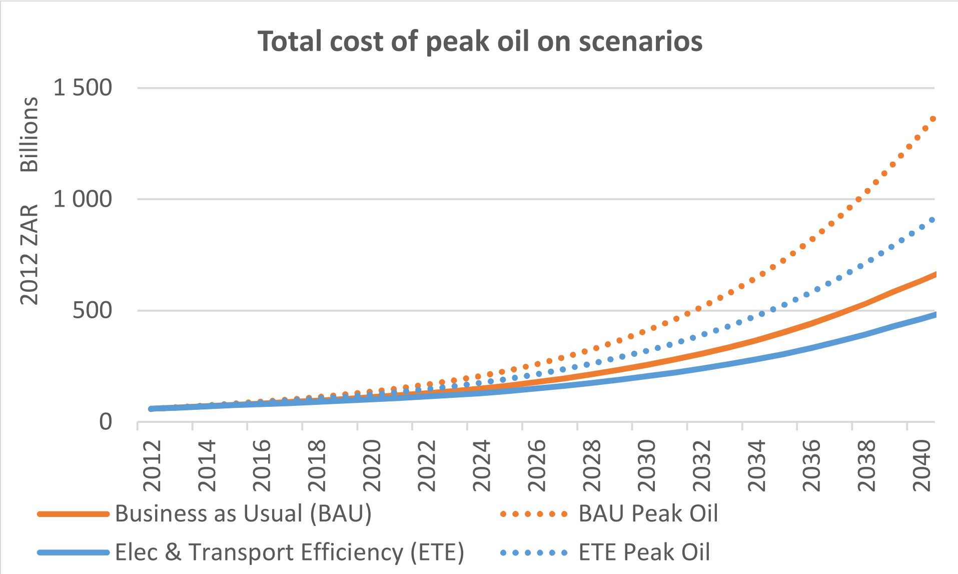


Figure 56: Impact of peak oil on costs

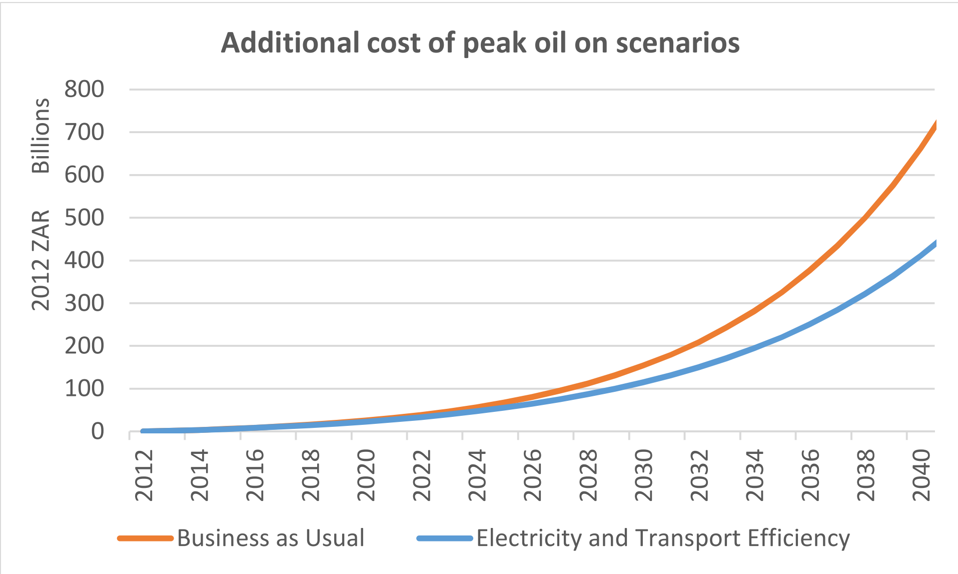


Figure 57: Additional costs of peak oil

Scenarios Comparison Summary

Energy Demand

The scenarios with the largest energy savings impact are the transport sector efficiency scenarios, in particular the following interventions: (1) increased car occupancy (Transport Behaviour Scenario), (2) the introduction of more efficient vehicles (Efficient Vehicles Scenario), and (3) passenger transport modal shift from private to public transport (Passenger Modal Shift Scenario). Electricity efficiency in the commercial and residential sectors also have substantial energy savings potential.

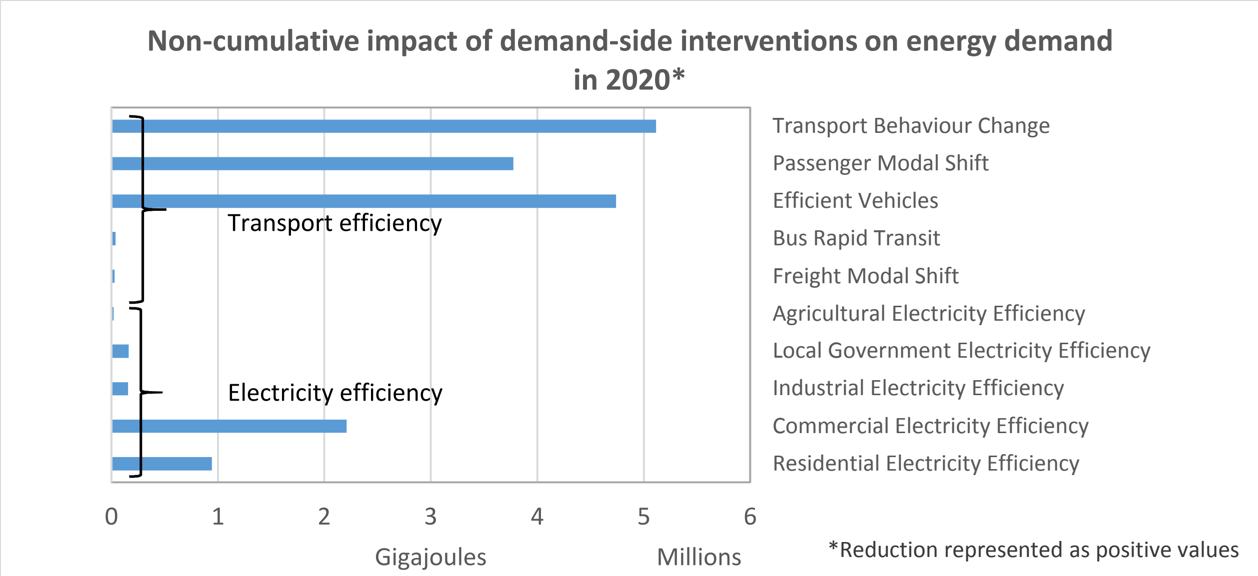


Figure 58: Impact of sustainable energy scenarios on energy demand by 2020

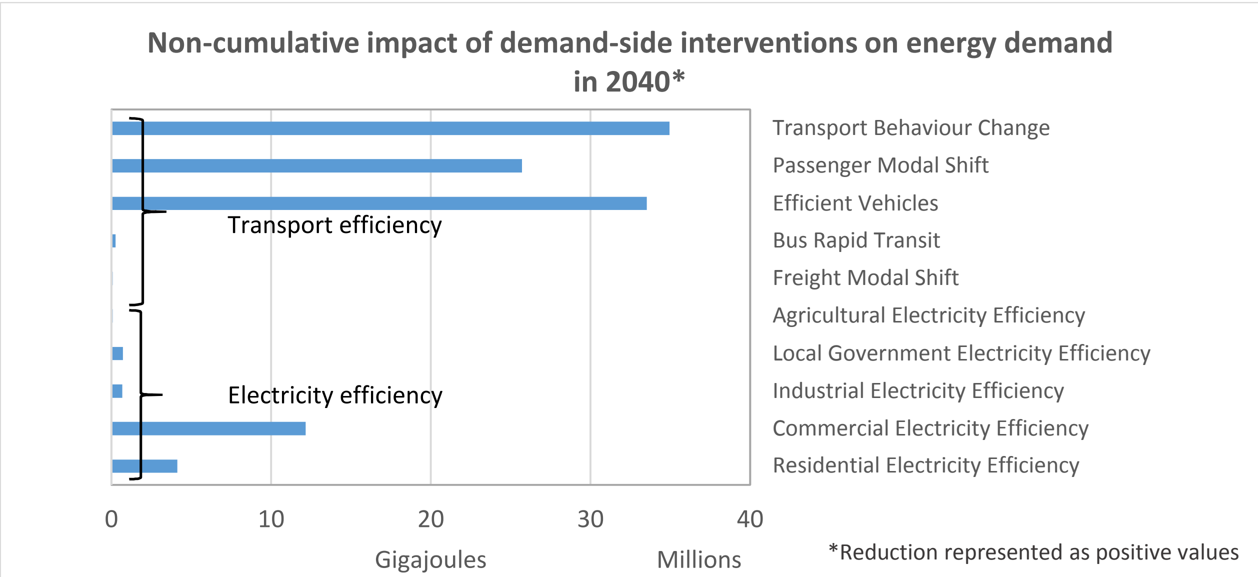


Figure 59: Impact of sustainable energy scenarios on energy demand by 2040

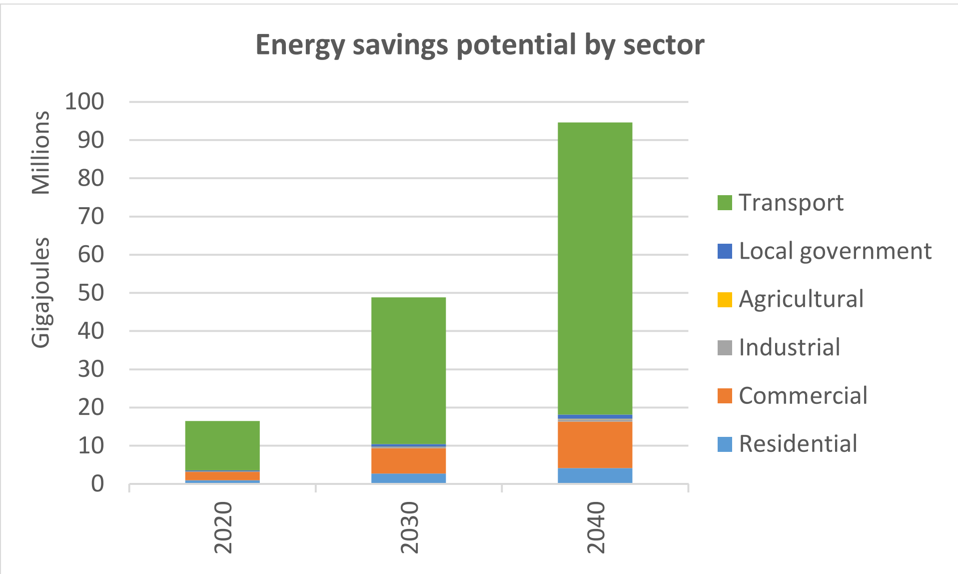


Figure 60: Impact of sustainable energy scenarios on energy demand over time

Emissions

When considering energy efficiency interventions off a Business as Usual scenario electricity supply mix, the highest reduction impact interventions are (1) electricity efficiency in the commercial sector (Commercial Sector Electricity Efficiency scenario) and (2) an increase in car occupancy (Transport Behaviour scenario). A passenger transport modal shift from private to public transport (Passenger Modal Shift scenario) takes longer to implement, which is why emissions reductions are initially less than that of an Efficient Vehicles scenario, but overtakes it by 2040.

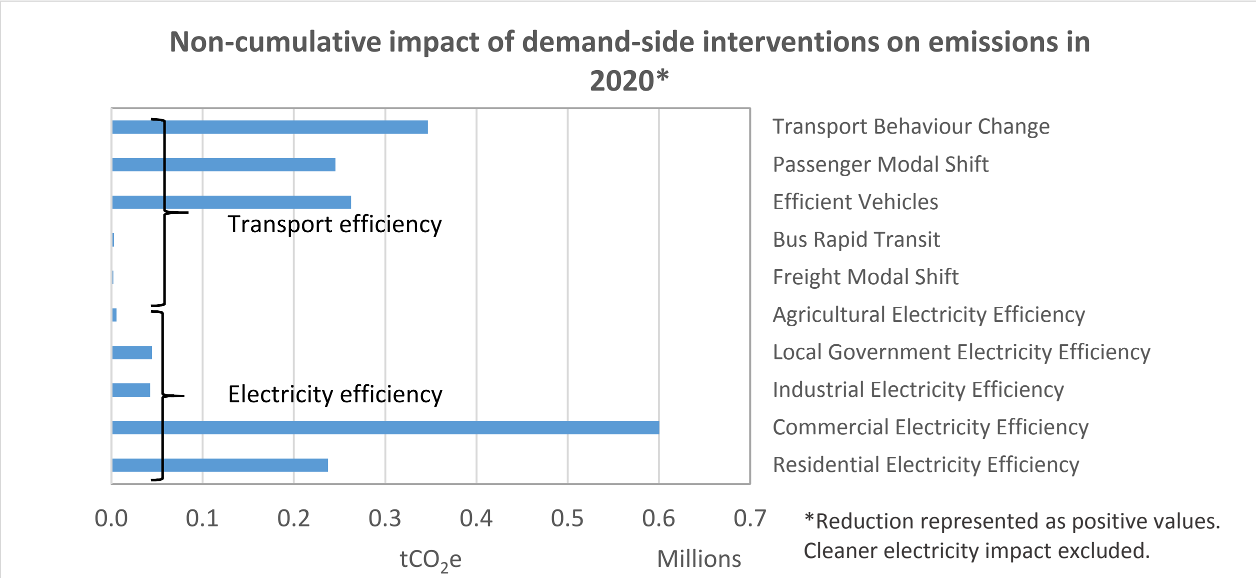


Figure 61: Impact of sustainable energy scenarios on emissions by 2020 (excluding cleaner electricity)

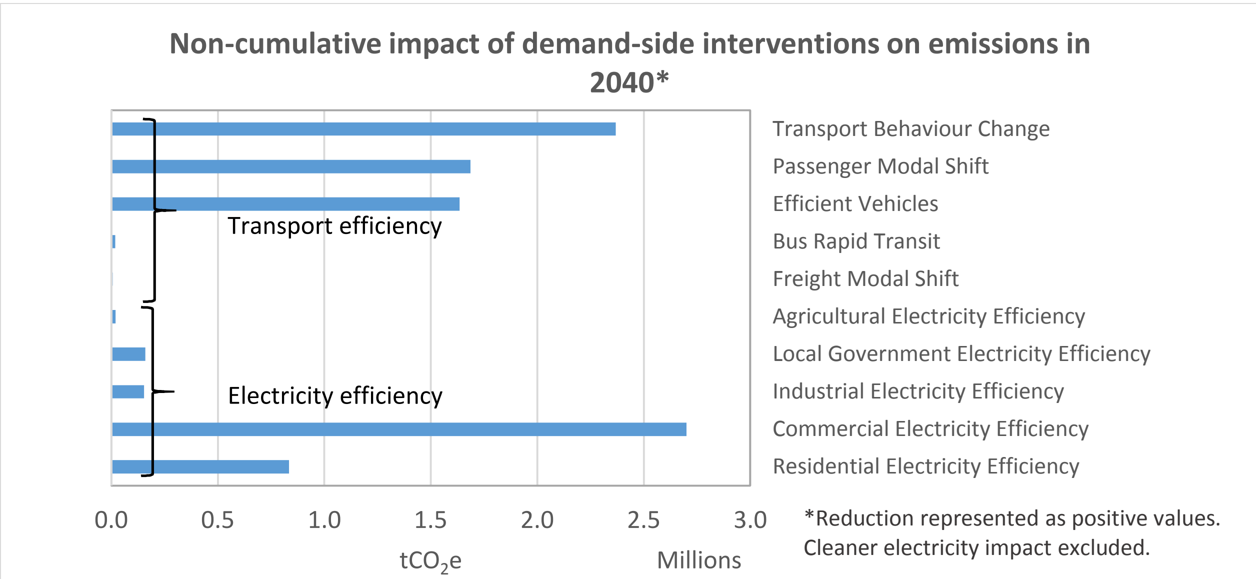


Figure 62: Impact of sustainable energy scenarios on emissions by 2040 (excluding cleaner electricity)

When including cleaner electricity (local gas, large-scale solar PV and wind, and embedded solar PV), the emissions reduction potential of electricity efficiency interventions is even higher. All passenger transport efficiency interventions are combined in the graphs below.[81]

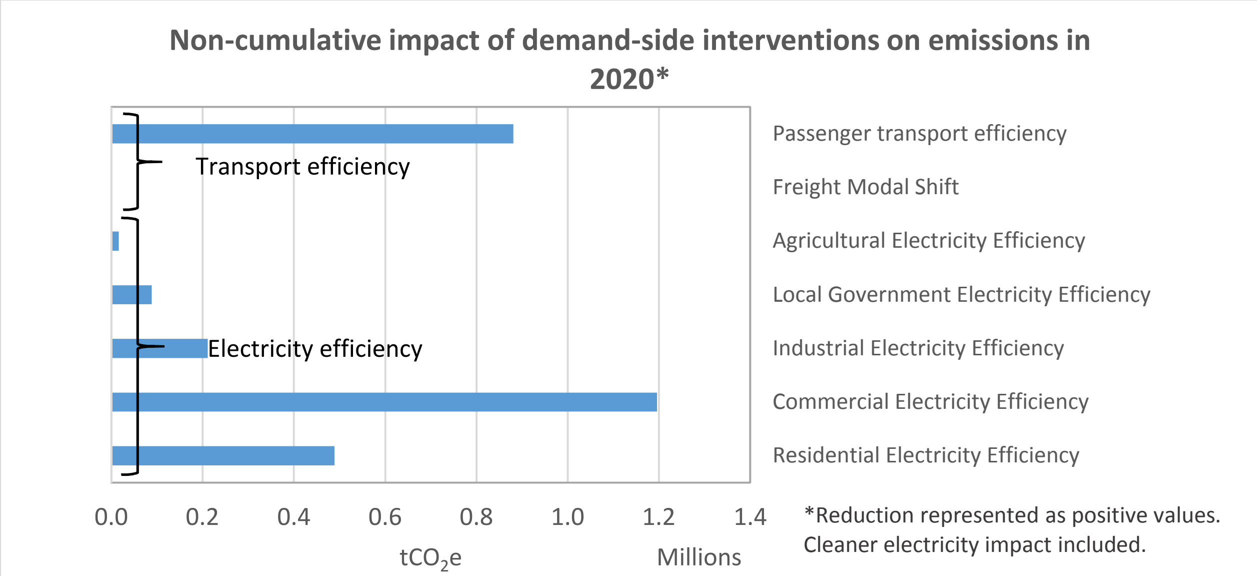


Figure 63: Impact of sustainable energy scenarios on emissions by 2020 (including cleaner electricity)

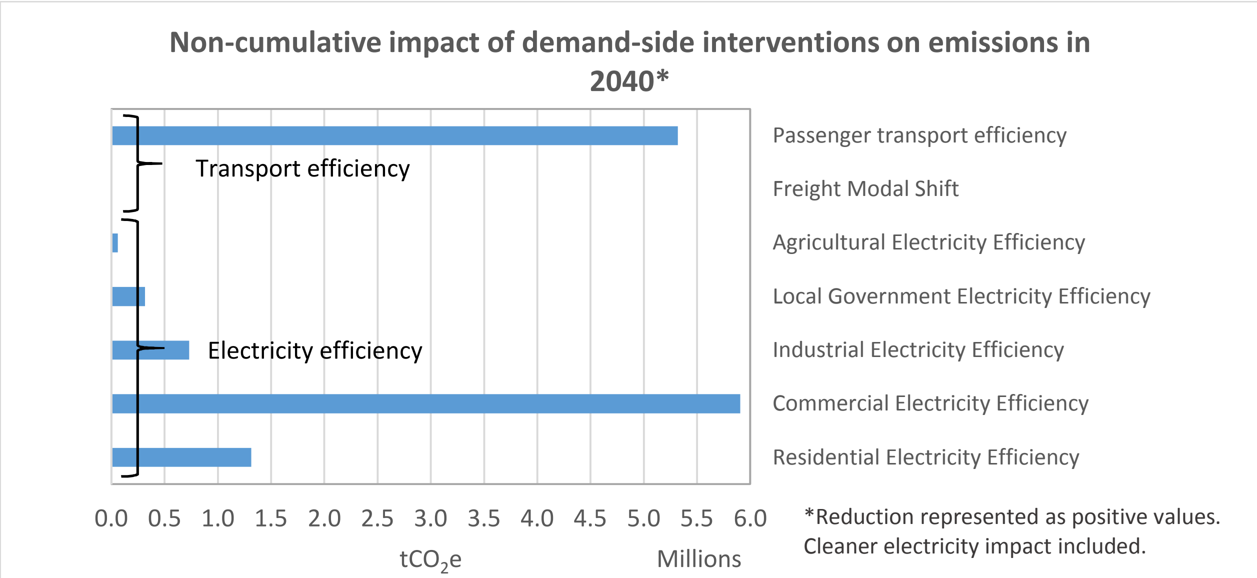


Figure 64: Impact of sustainable energy scenarios on emissions by 2040 (including cleaner electricity)

[81] Due to model set-up, it was difficult to disaggregate individual transport interventions' emissions impacts, as these had been modelled individually off Business as Usual only, rather than GEN Solar PV (the scenario that included cleaner electricity)

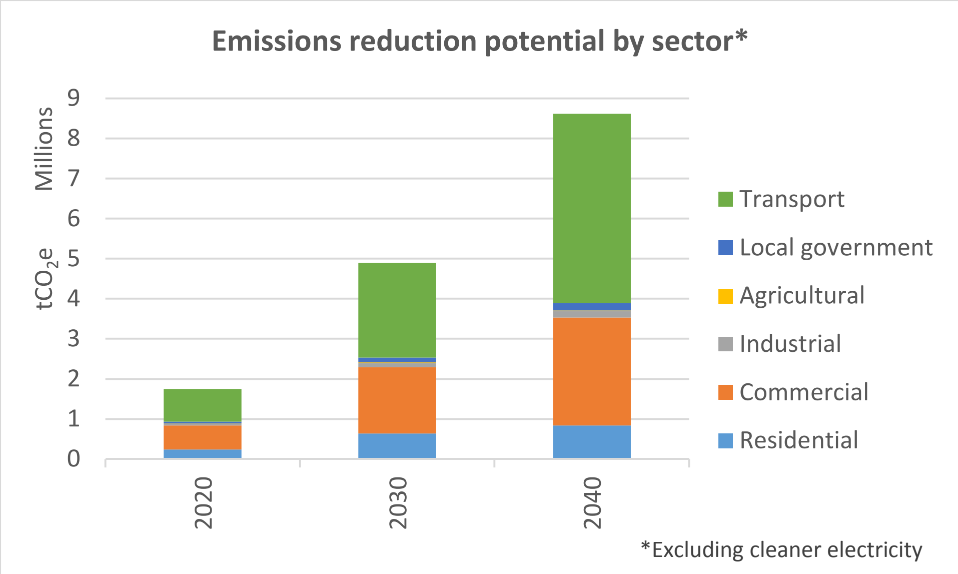


Figure 65: Impact of sustainable energy scenarios on emissions over time (excluding cleaner electricity)

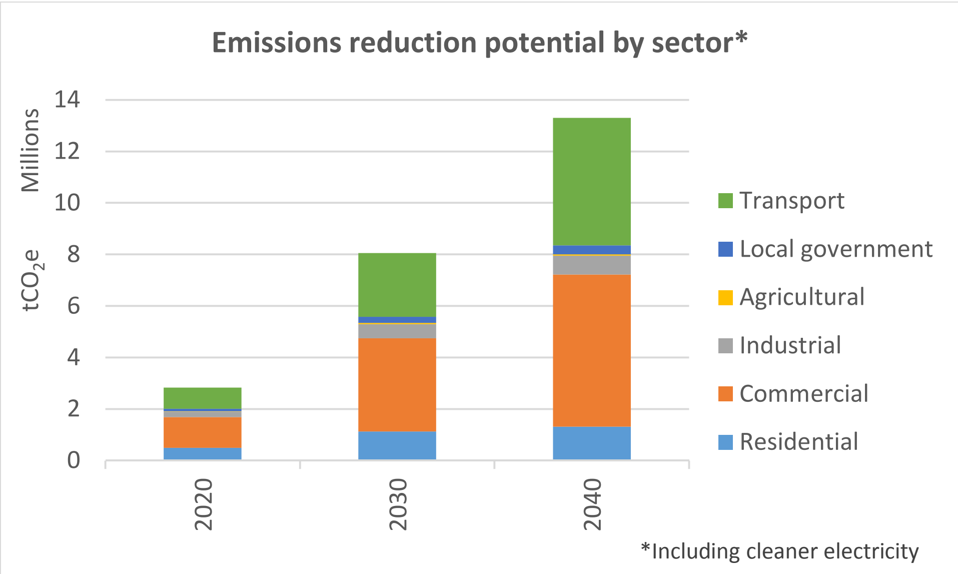


Figure 66: Impact of sustainable energy scenarios on emissions over time (including cleaner electricity)

The Cabinet-endorsed Peak, Plateau, Decline (PPD) emissions pathway, outlining the country's national emissions commitment, was set by applying the national PPD emissions upper and lower limits' growth rates to that of Cape Town's emissions from 2012 onwards.

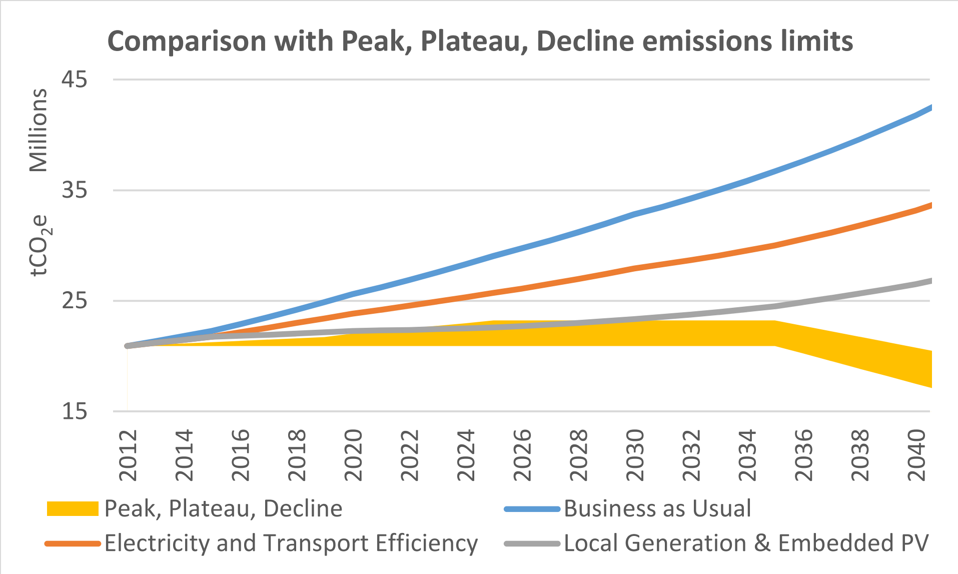


Figure 67: Scenarios vs. Peak, Plateau, Decline emissions pathway (2012-2040)

Current trajectories (BAU) are headed on a growth path that is entirely at odds with the mitigation commitments pathway of national government. Despite aggressive energy efficiency implementation, and a greater contribution to the national grid of renewables, the emissions trajectory for the *Electricity and Transport Efficiency* scenario still climbs above the bounds of the upper limit of the PPD emissions pathway. Emission intensity (emissions per unit of economy produced) will decrease as a result of energy efficiency (Figure 68), but emissions cannot be expected to decline in absolute terms if the economy remains largely reliant on fossil fuels, the key drivers of energy use (and hence emissions production) are economic, and the economy is forecast to grow.

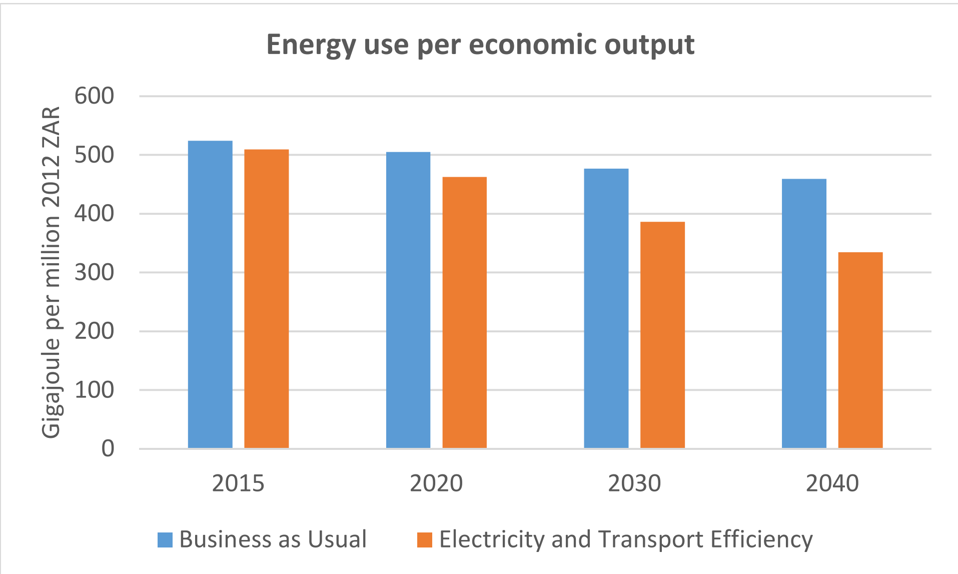


Figure 68: Energy use per economic unit over time

The *Local Gen and Embedded Solar PV* scenario provide the only scenario that aligns well with the limits of the PPD emissions pathway. This is an exciting indication. Although this begins to climb again after 2035, where the PPD pathways require an absolute decline, this is in part because of the nature of modelling, where efficiency interventions achieve 100% penetration in the model, whereas 'real life' at this point would in all likelihood present new (unknown today) efficiency opportunities and technologies at this point.

Costs

A positive cost value in the graphs below represents savings, whilst a negative value represents costs. The largest savings are realised by electricity efficiency in the commercial and residential sectors, an increase in car occupancy (Transport Behaviour Scenario) and a modal shift of passengers from private to public transport (note: does not include infrastructure costs).

By 2040 the investment in local generation is producing sizeable savings. The embedded small-scale rooftop solar PV remains costly (Figure 70).

The costs of a carbon tax are almost as severe as the impact of peak oil in the short term, ***but peak oil costs dwarf all others in the long term*** (Figure 70). The impacts of both a carbon tax and peak oil are less severe when implemented on an energy efficient scenario than when implemented on a Business as Usual scenario.

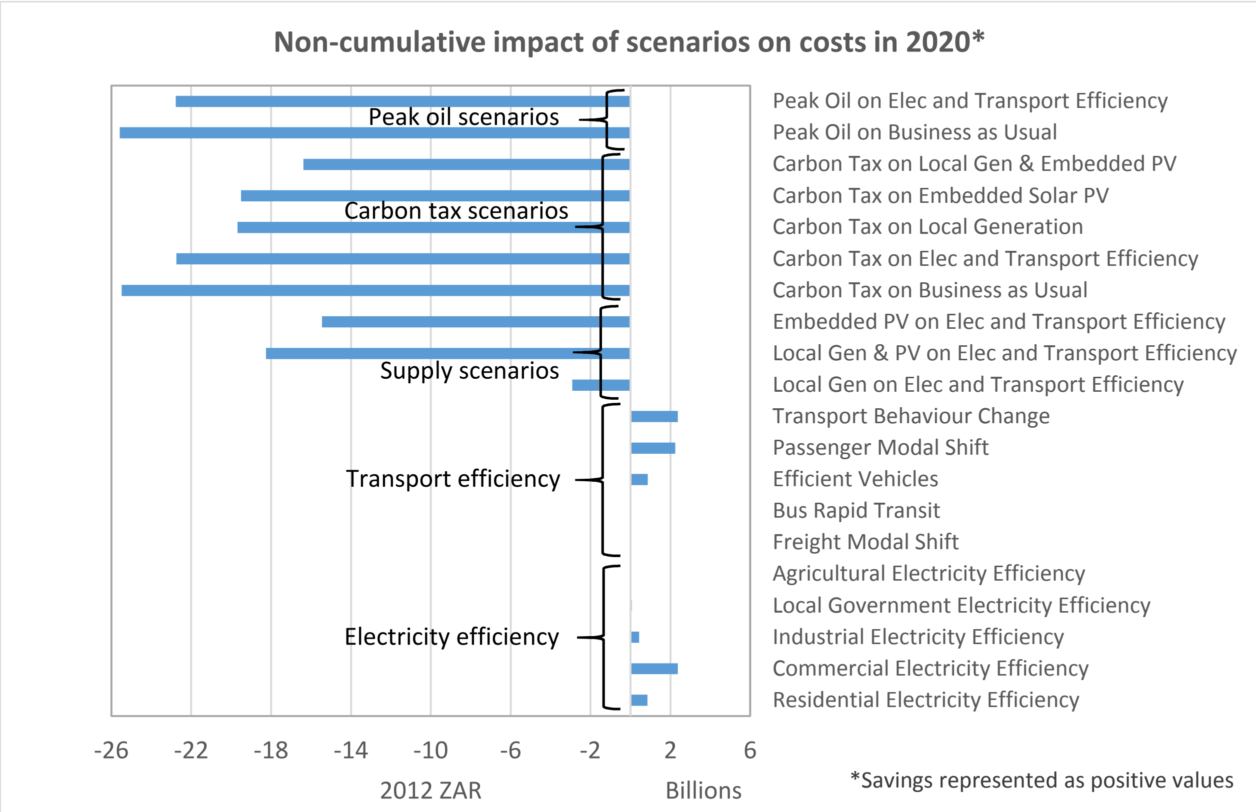


Figure 69: Impact of scenarios on costs by 2020

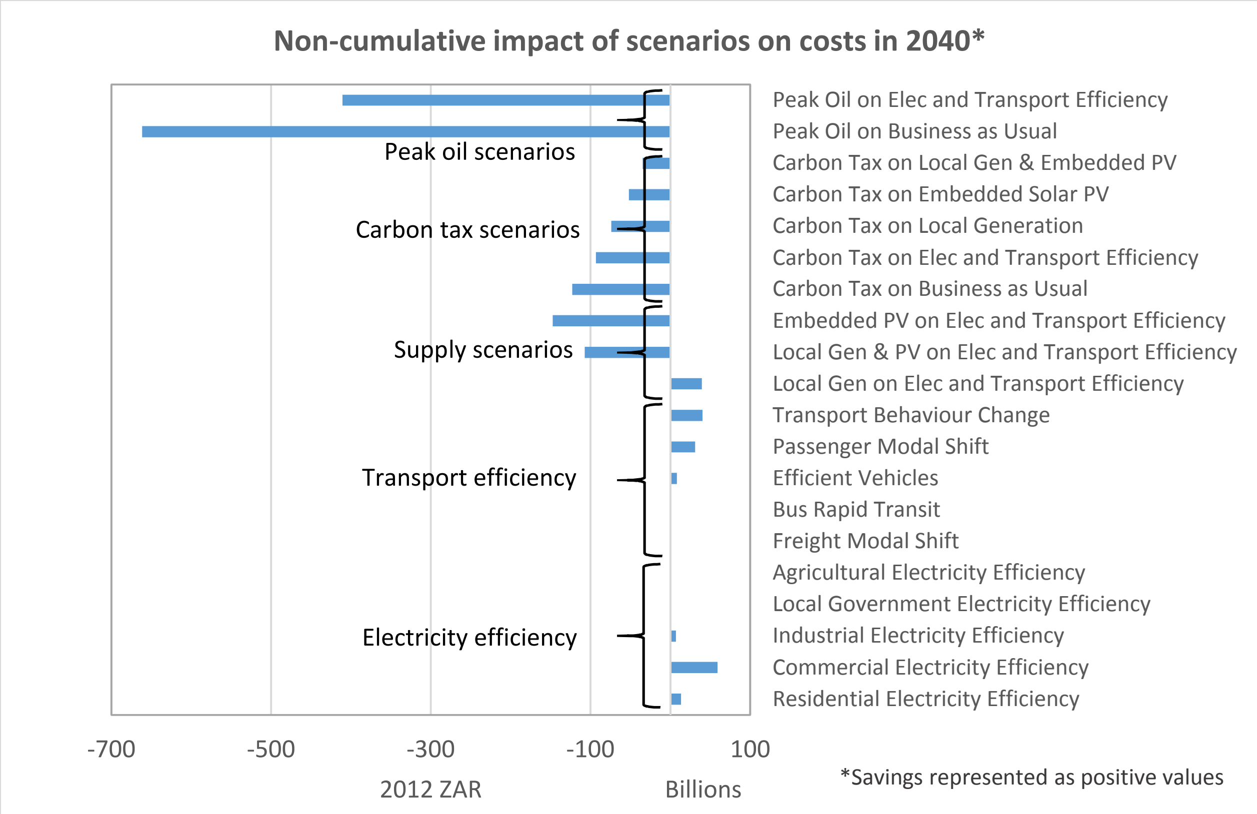


Figure 70: Impact of scenarios on costs by 2040

The largest cost savings per unit energy reduced consumption is in the industrial sector, followed by the agricultural and commercial sectors (Figure 71).

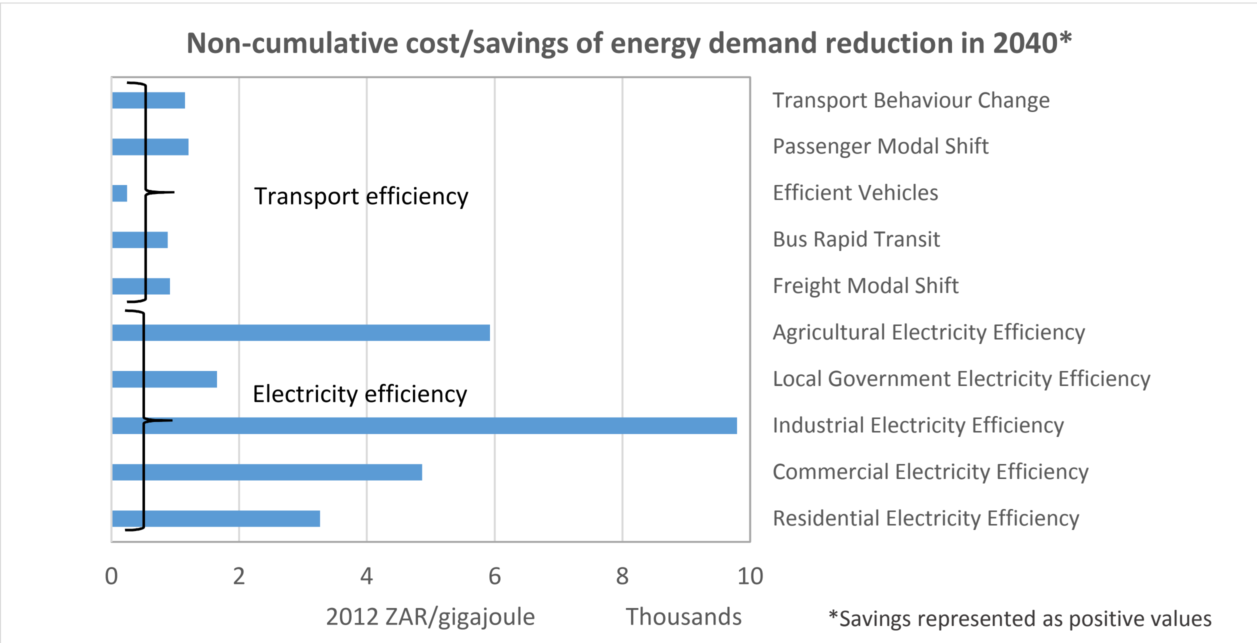


Figure 71: Savings/cost per unit energy reduced by 2040

Most interventions provide monetary savings per unit emissions reduced, but embedded solar PV remains costly (Figure 72). It must be stated that this is generally a voluntary cost borne by customers who decide to install these systems, though this may currently be in response to electricity insecurity as a result of load-shedding.

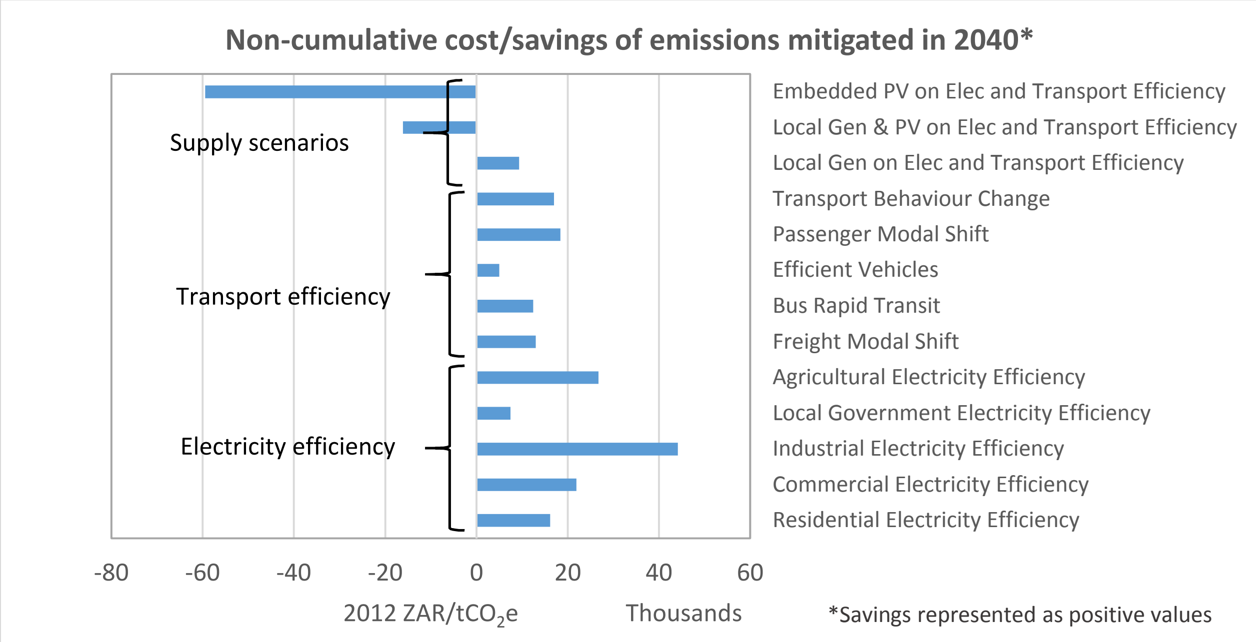


Figure 72: Savings/cost per unit emissions reduced by 2040

Energy-related costs per household increase substantially over time as a result of above-inflation increases in electricity and liquid fuel prices. Energy efficiency drops the cost per household. Local generation and embedded solar PV increases costs yet again, solely as a function of the costs of embedded PV (local generation drops costs). Again, the costs of embedded solar PV will be borne by high-income users who decide to install these systems, whilst the savings of energy efficiency and local generation will be felt across the board.

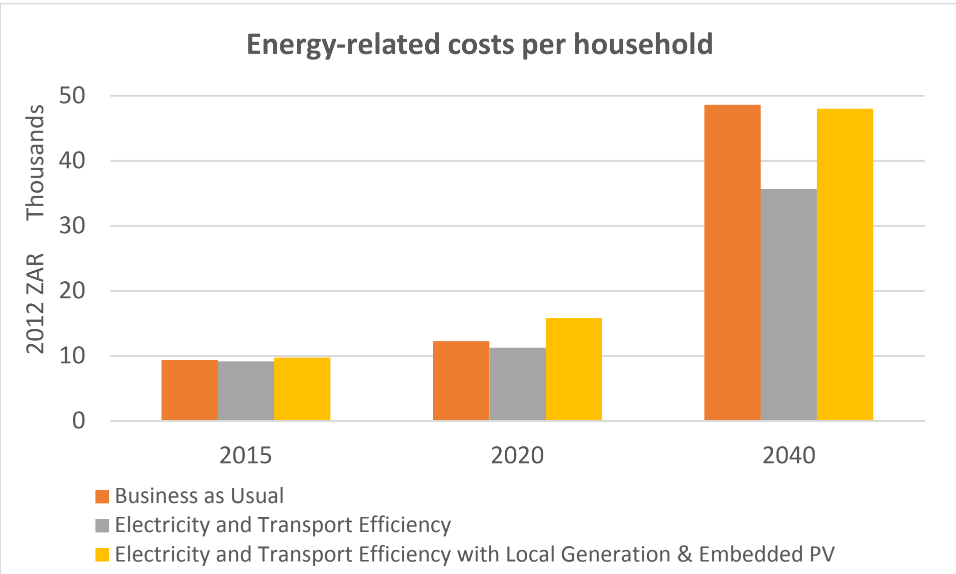


Figure 73: Energy-related costs per household

Energy, emissions and cost savings per intervention per sector

Costs in the exercise comprise of:

- Technology cost, where available (SWH, conventional electric geyser, light bulbs, vehicle capital costs, etc.). Where not available, Eskom Standard Offer value (R/kWh) has been used to cost the intervention.
- Energy source costs (R/GJ). It must be noted that the costs are not directly comparable. Electricity price differs between BAU and ETE, affecting savings. Therefore savings are not only made up of electricity saved, but partly as a function of the different electricity costs as well. Each intervention affects the amount of electricity supplied to the scenario, which affects supply-side costs, which in turn affect demand side-costs.

Residential sector

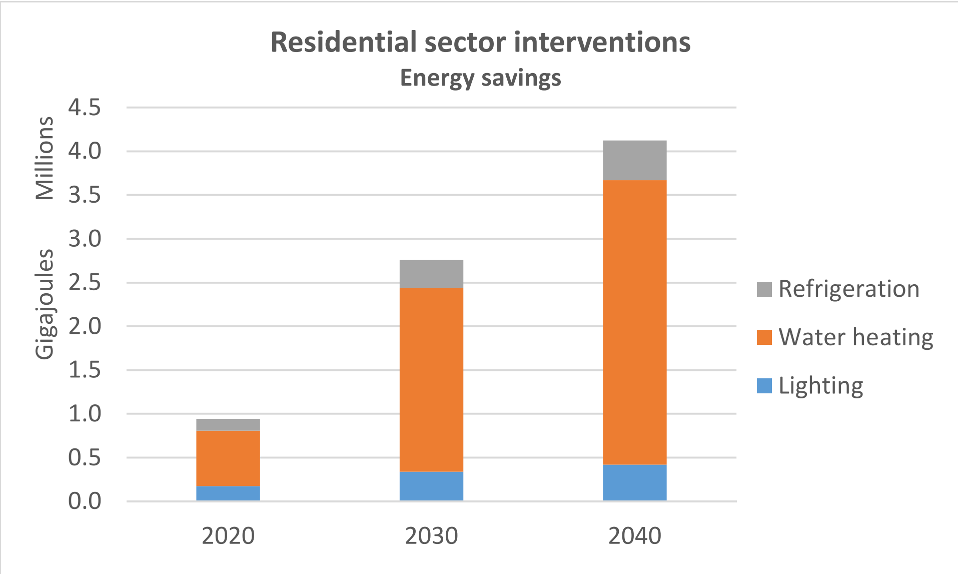
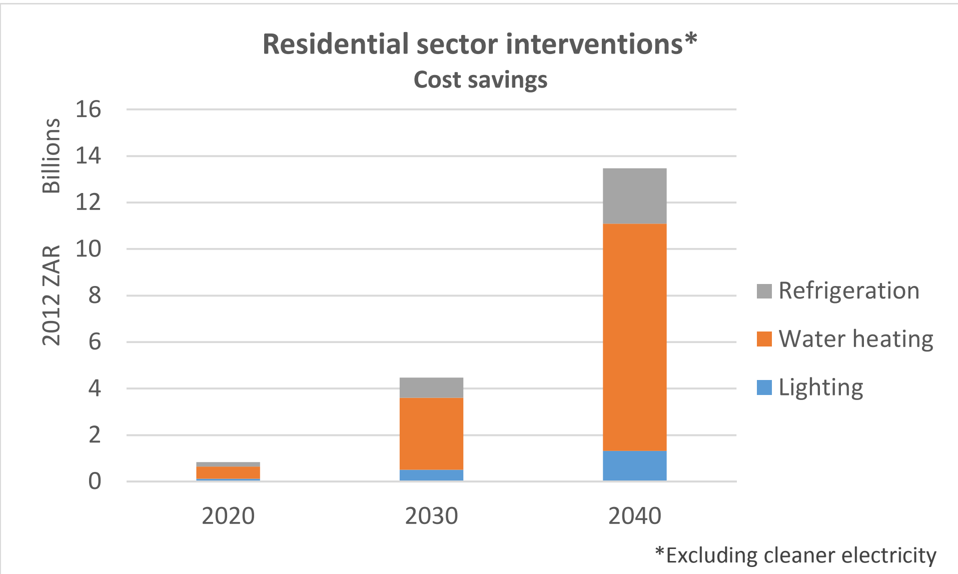


Figure 74: Energy savings off BAU per intervention in the residential sector



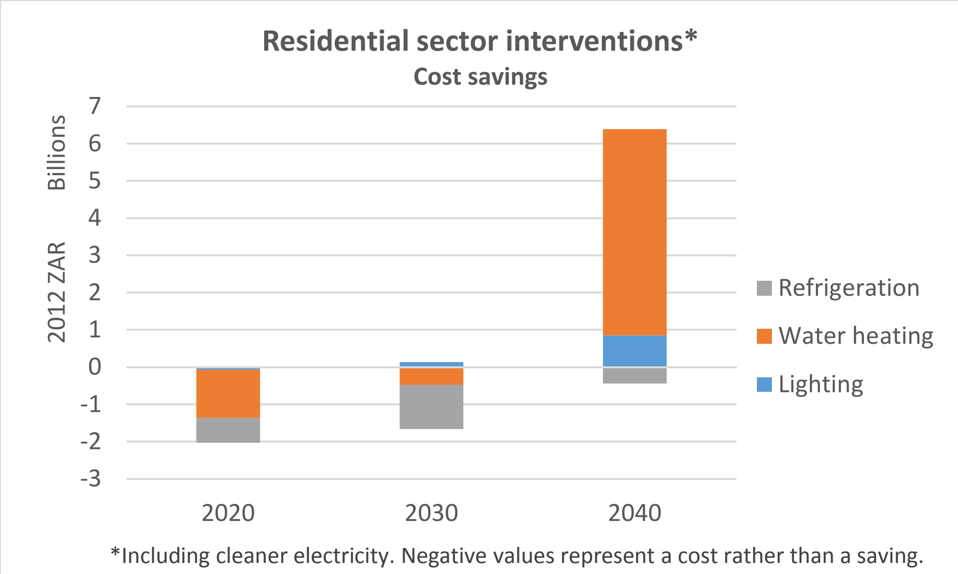


Figure 75: Cost savings off BAU per intervention in the residential sector

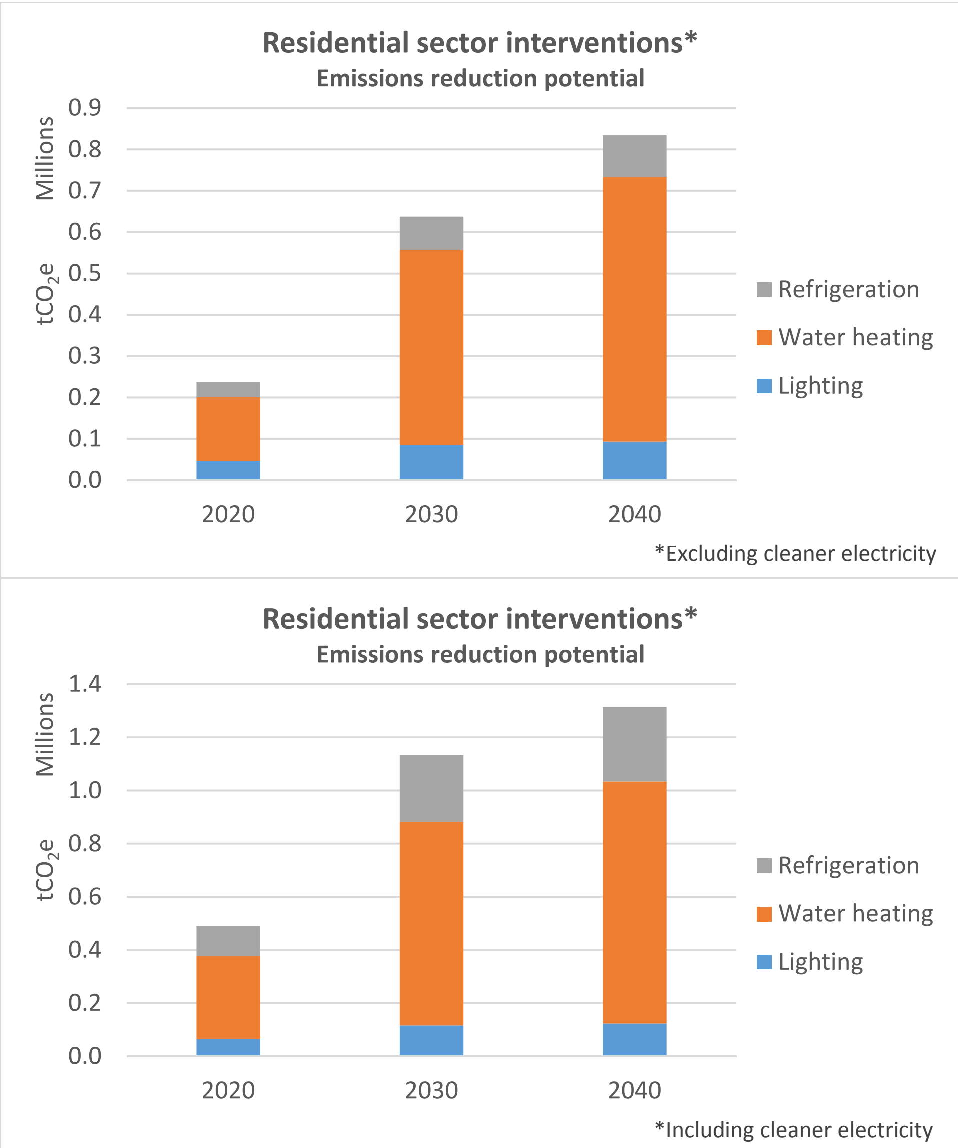


Figure 76: Emissions savings off BAU per intervention in the residential sector

Commercial sector

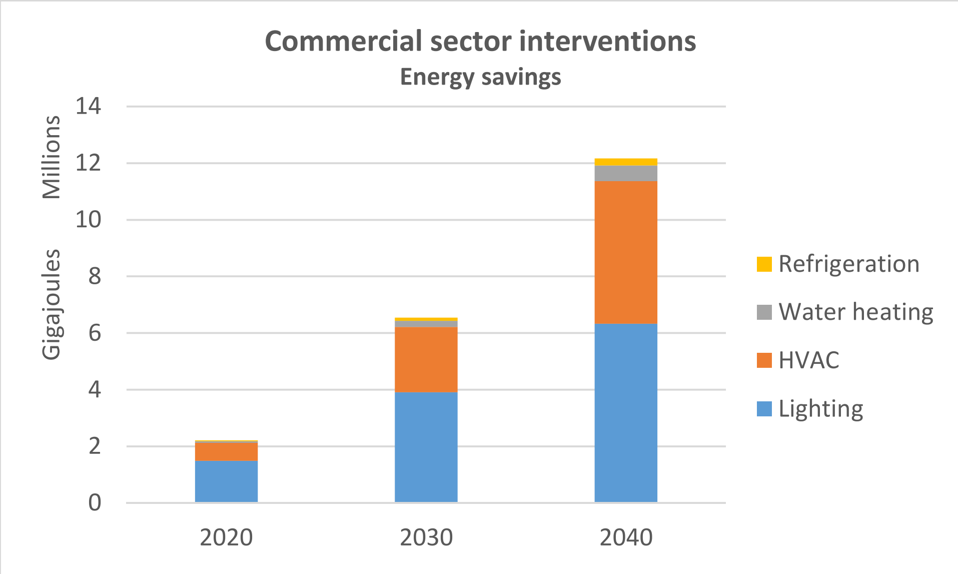


Figure 77: Energy savings off BAU per intervention in the commercial sector

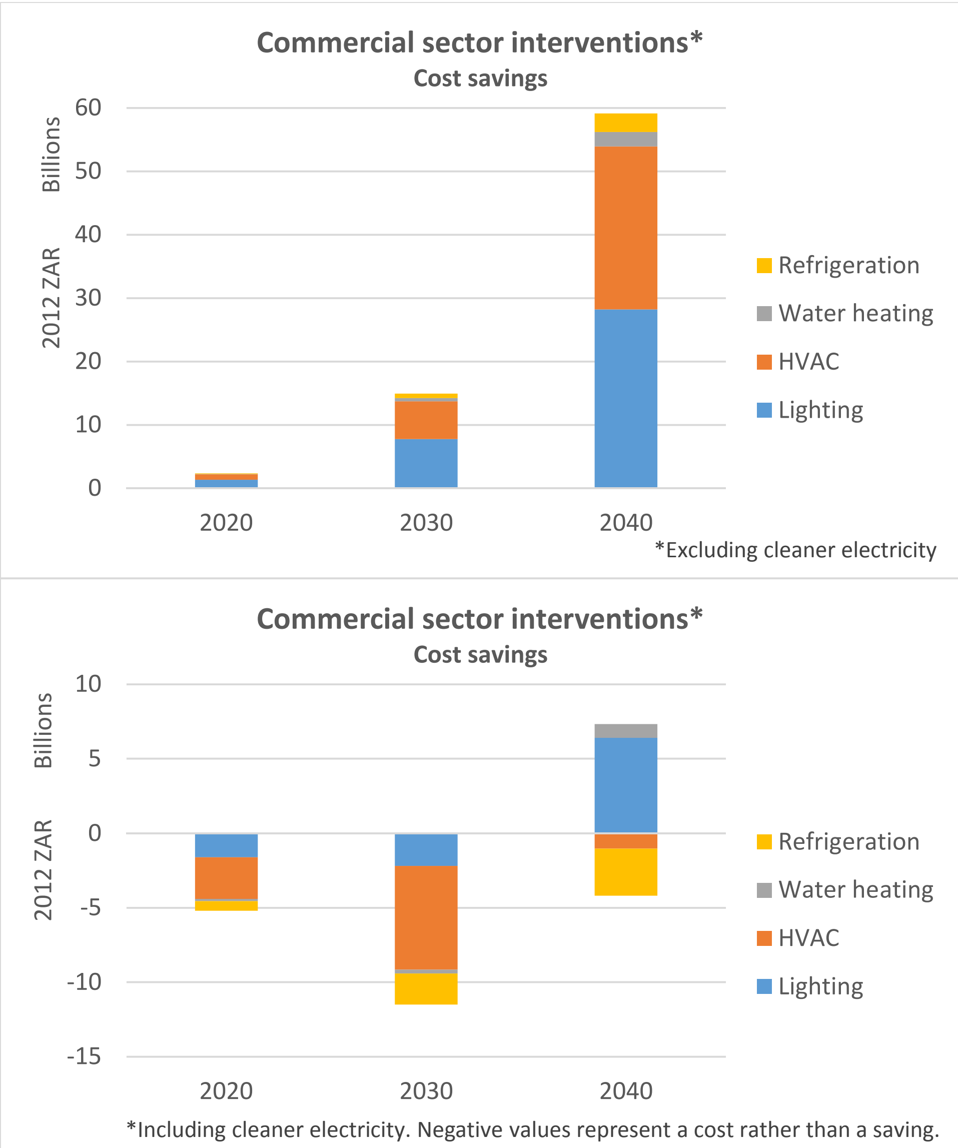
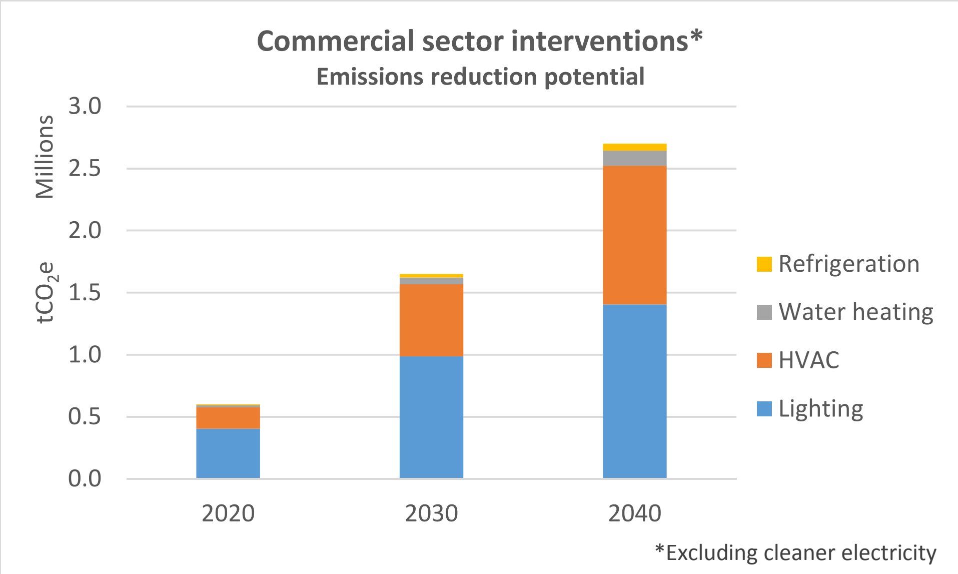


Figure 78: Cost savings off BAU per intervention in the commercial sector



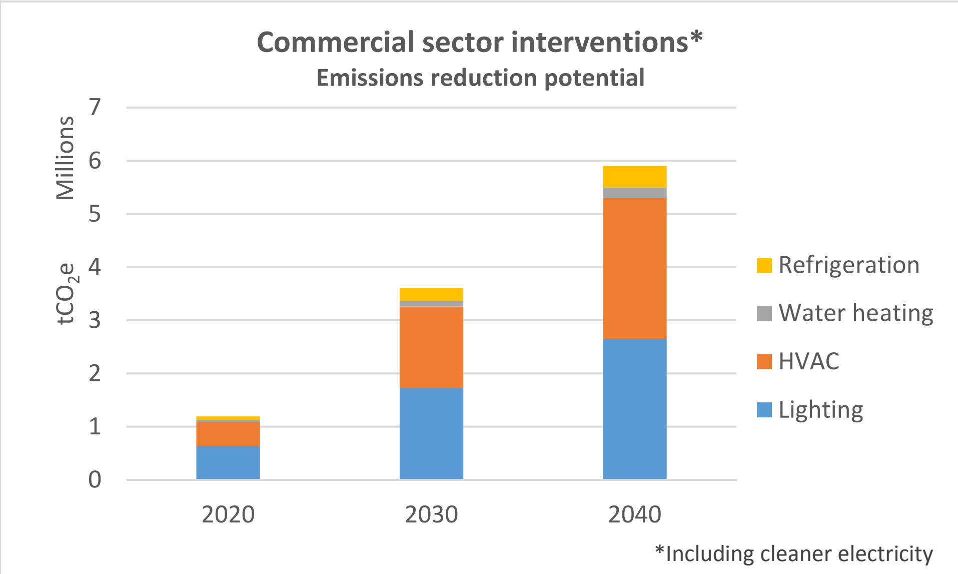


Figure 79: Emissions savings off BAU per intervention in the commercial sector

Industrial sector

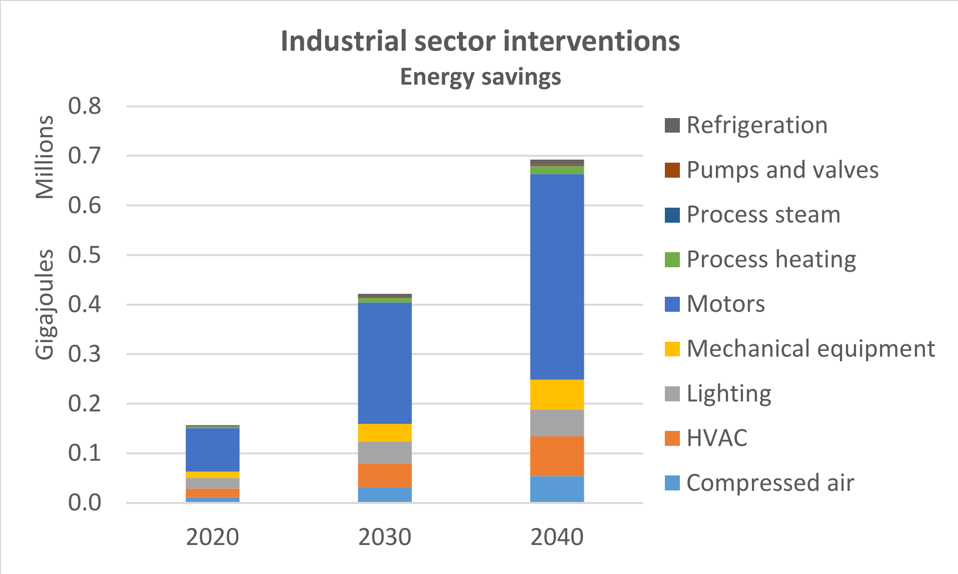


Figure 80: Energy savings off BAU per intervention in the industrial sector

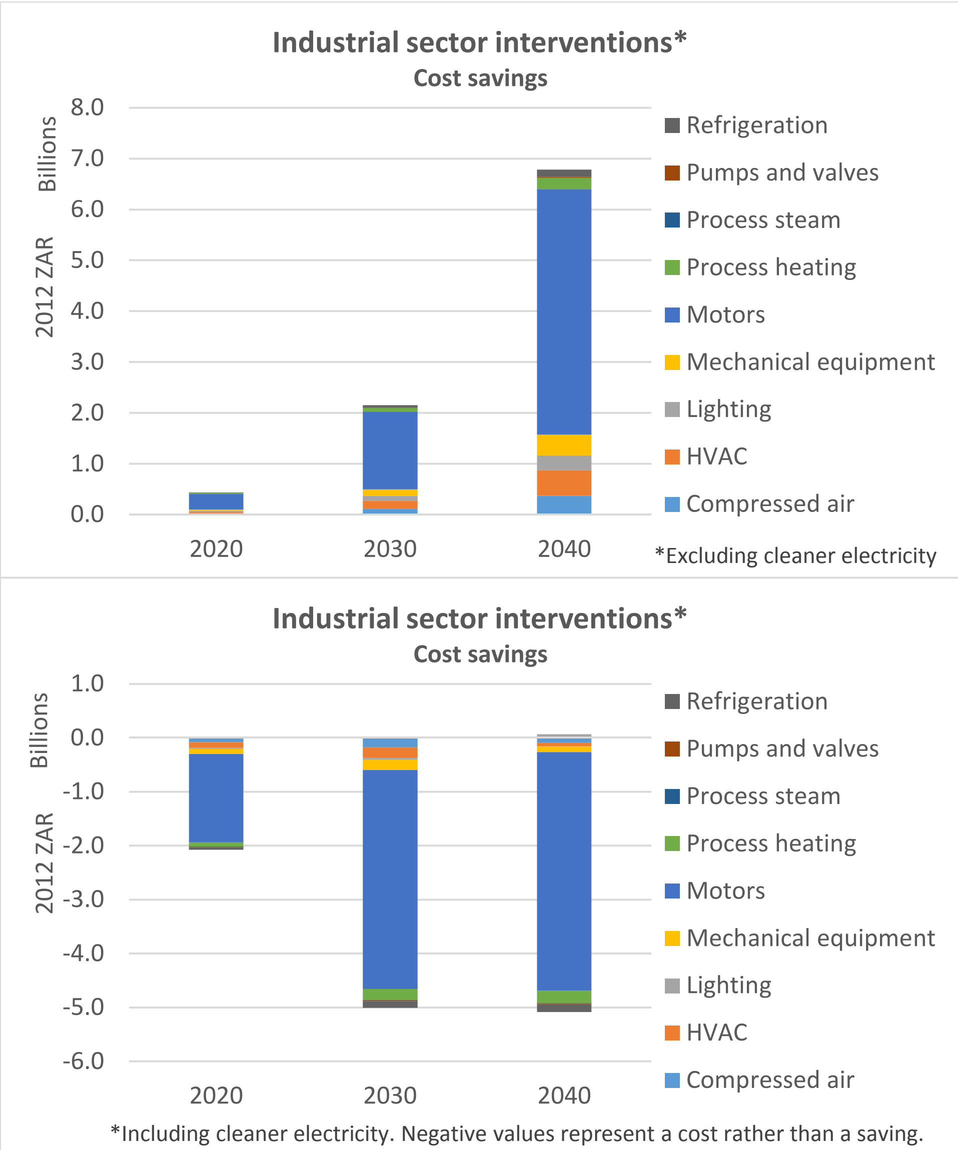
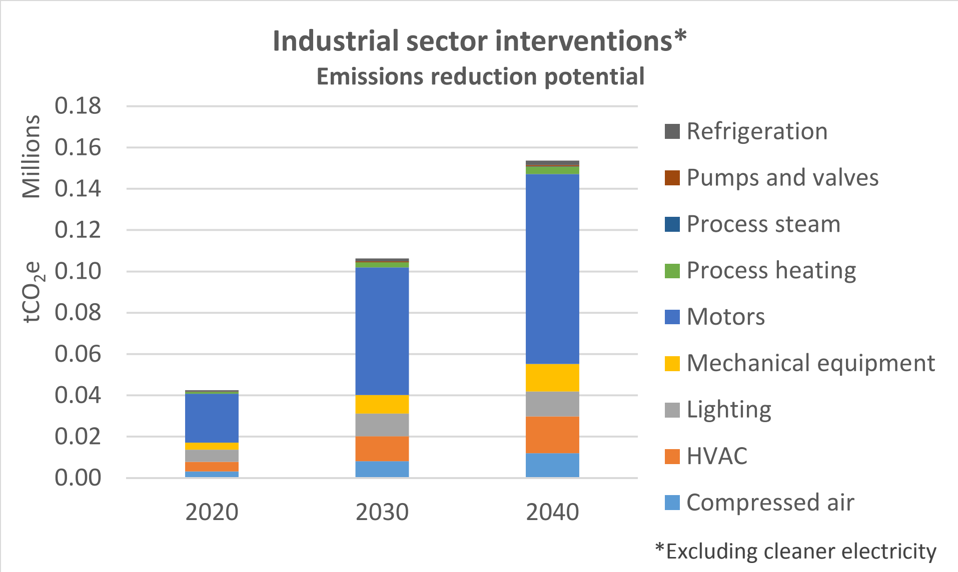


Figure 81: Cost savings off BAU per intervention in the industrial sector



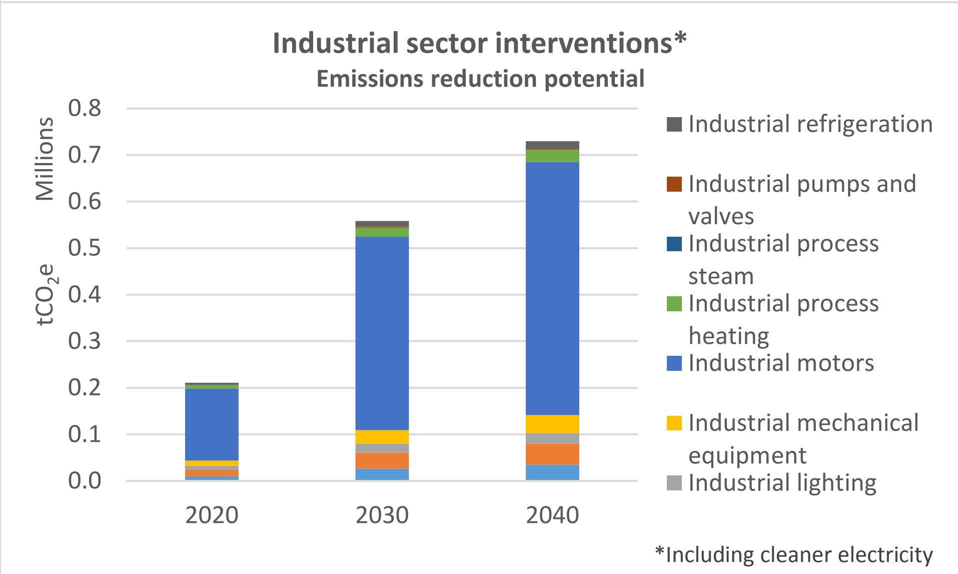


Figure 82: Emissions savings off BAU per intervention in the industrial sector

Agriculture sector

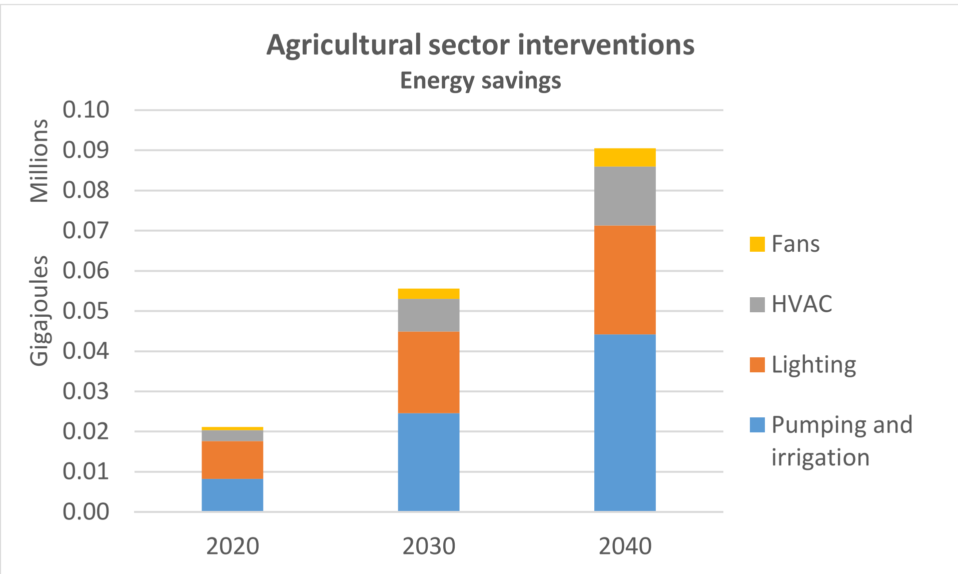


Figure 83: Energy savings off BAU per intervention in the agricultural sector

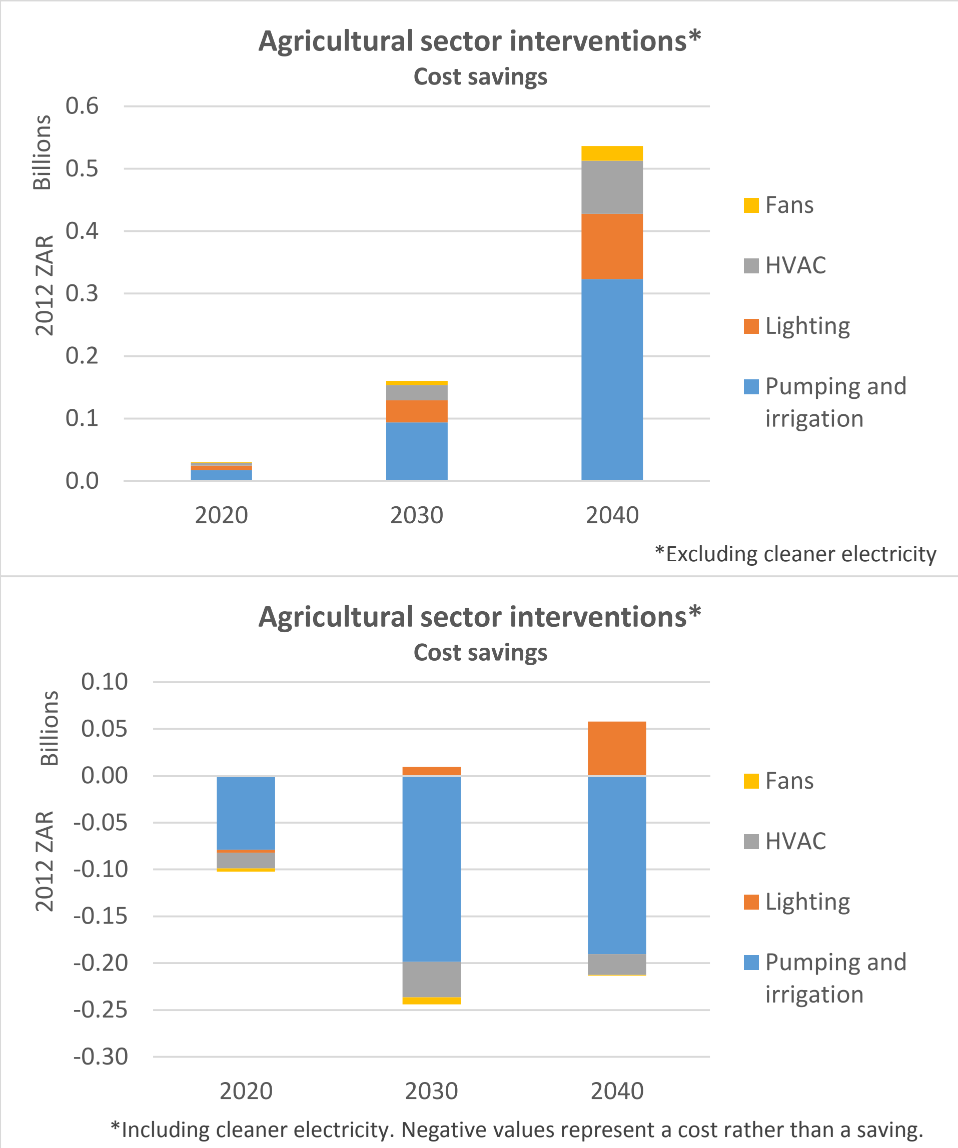
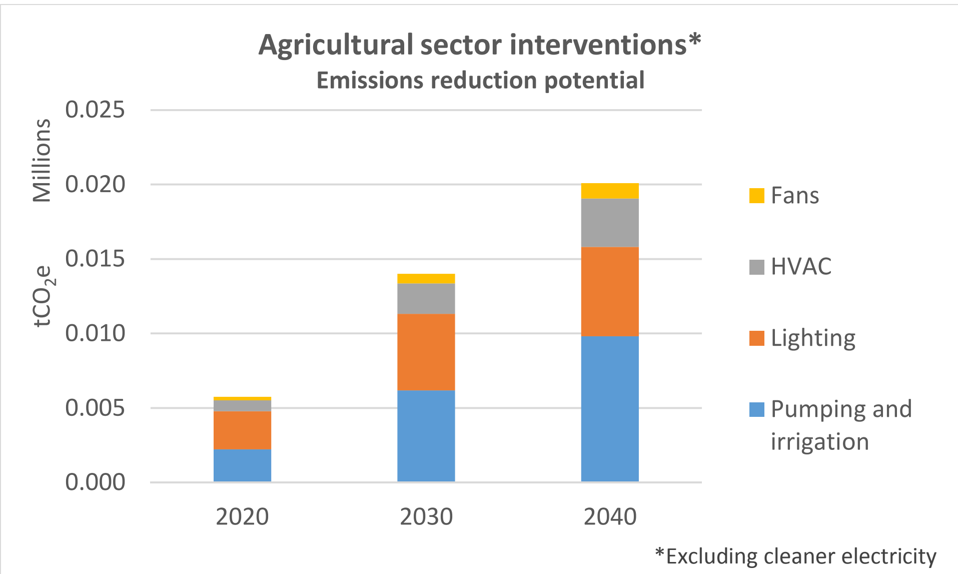


Figure 84: Cost savings off BAU per intervention in the agricultural sector



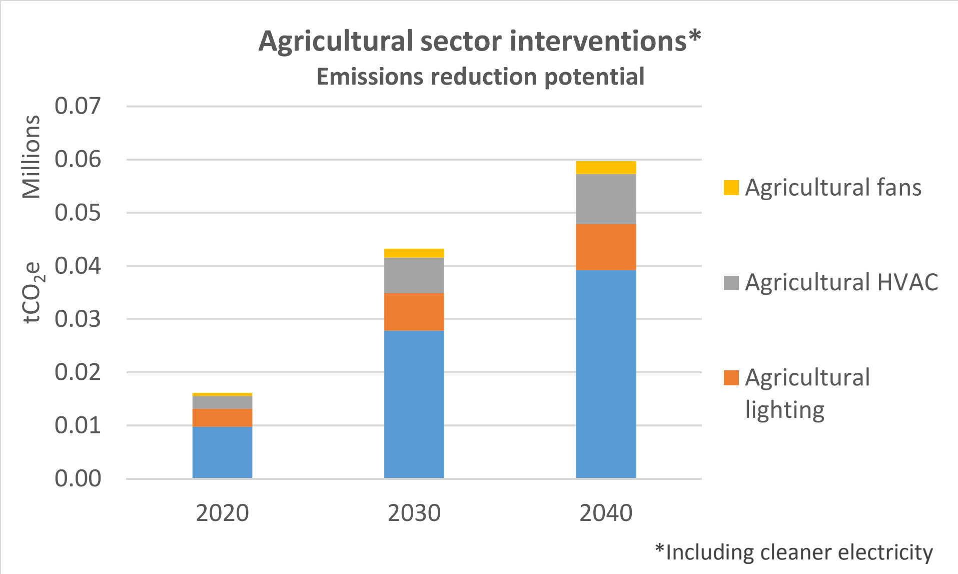


Figure 85: Emissions savings off BAU per intervention in the agricultural sector

Local Government sector

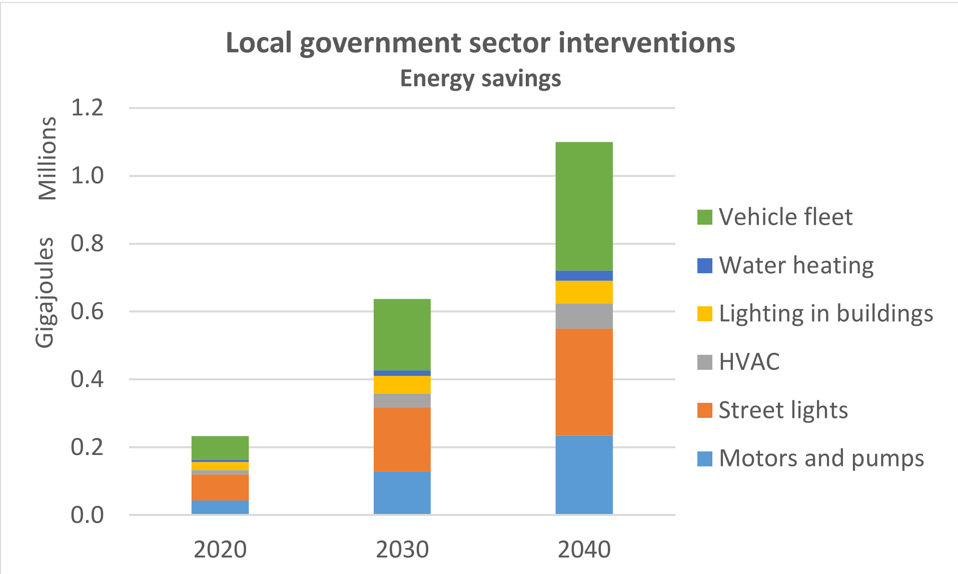
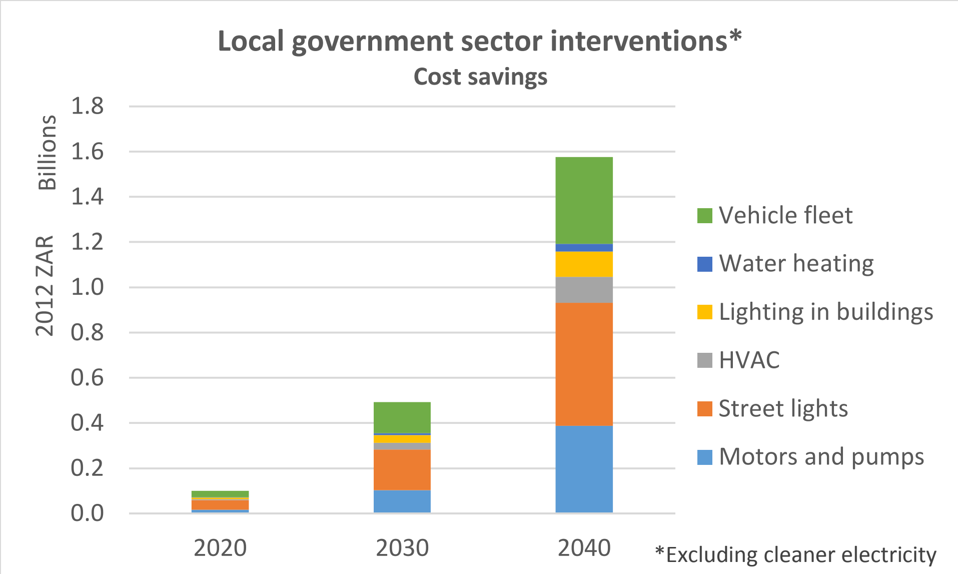


Figure 86: Energy savings off BAU per intervention in the local government sector



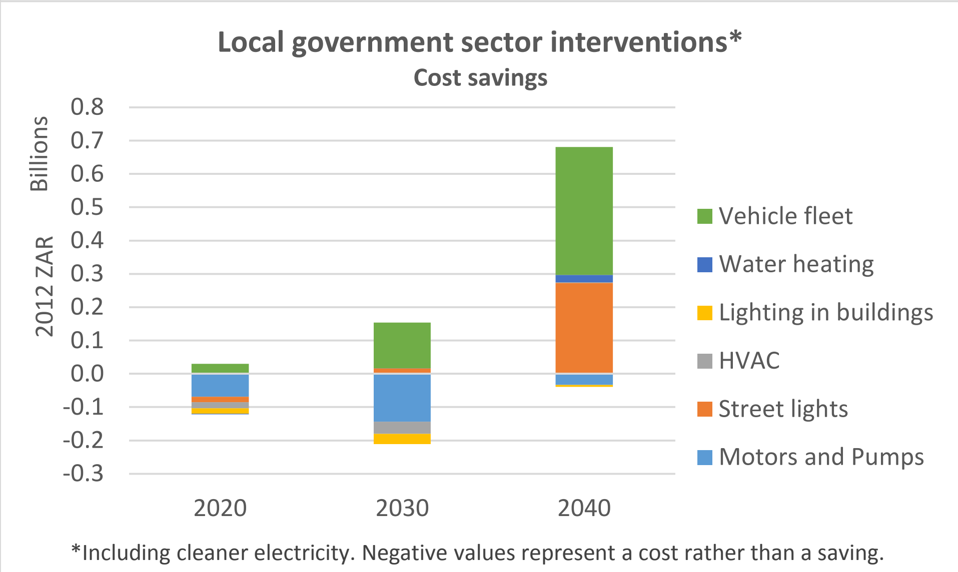
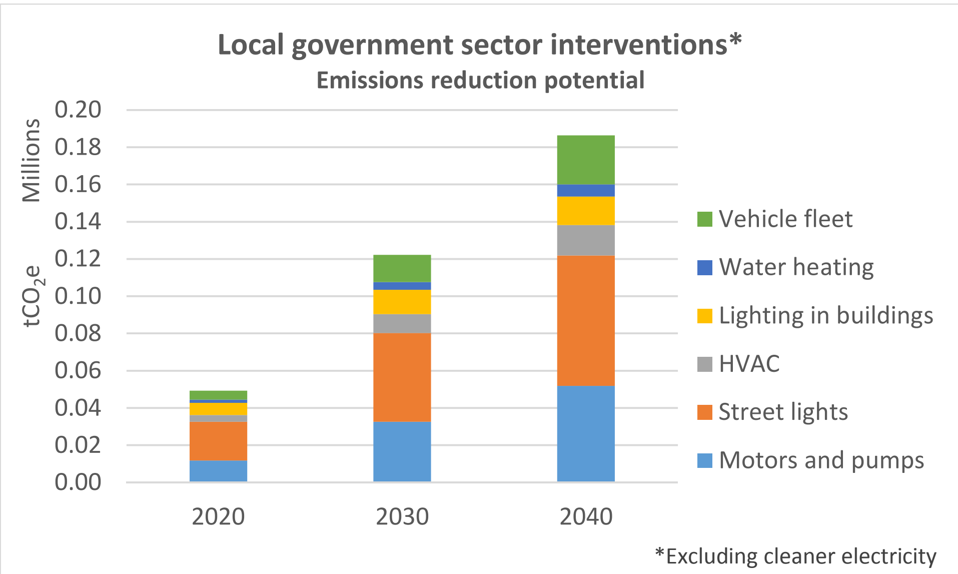


Figure 87: Cost savings off BAU per intervention in the local government sector



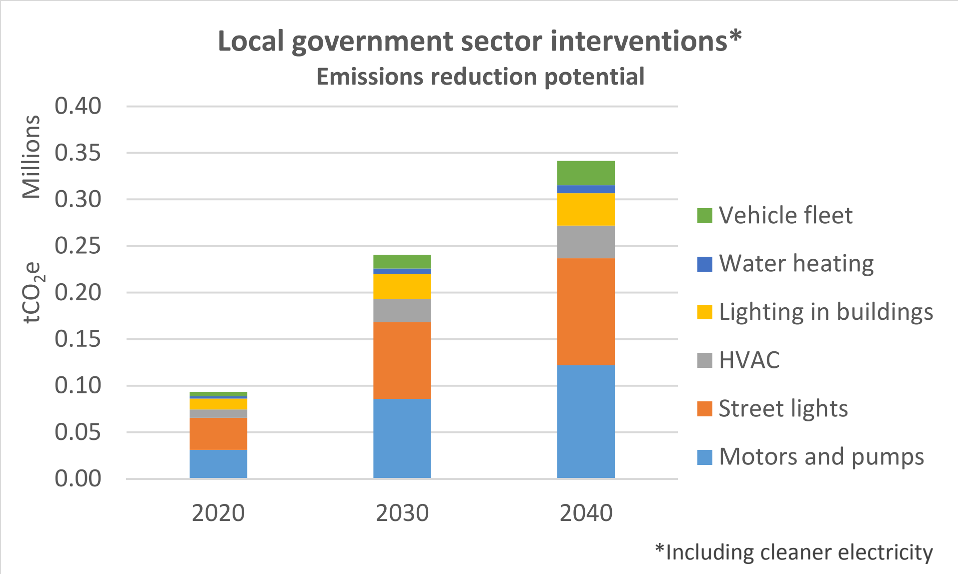


Figure 88: Emissions savings off BAU per intervention in the local government sector

Transport sector

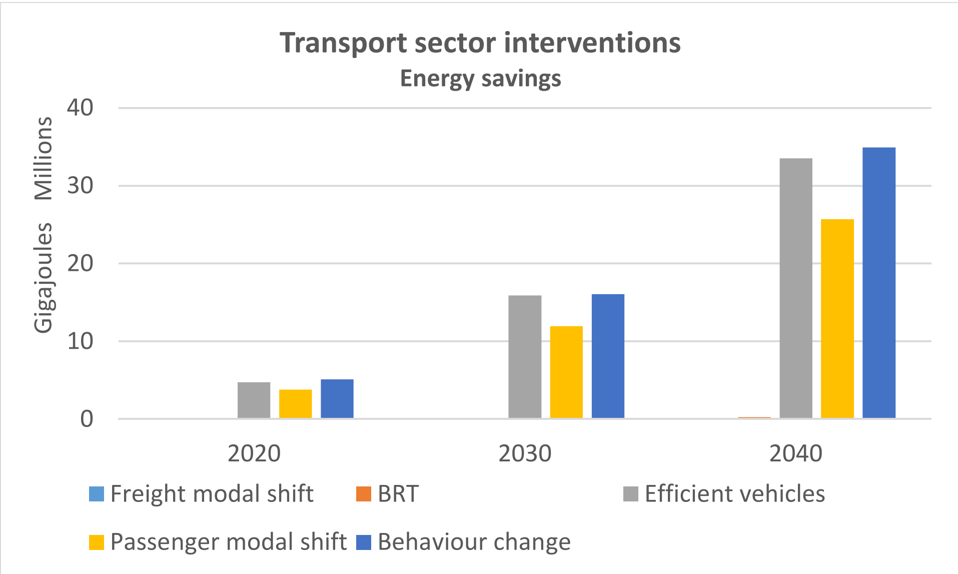


Figure 89: Energy savings off BAU per intervention in the transport sector

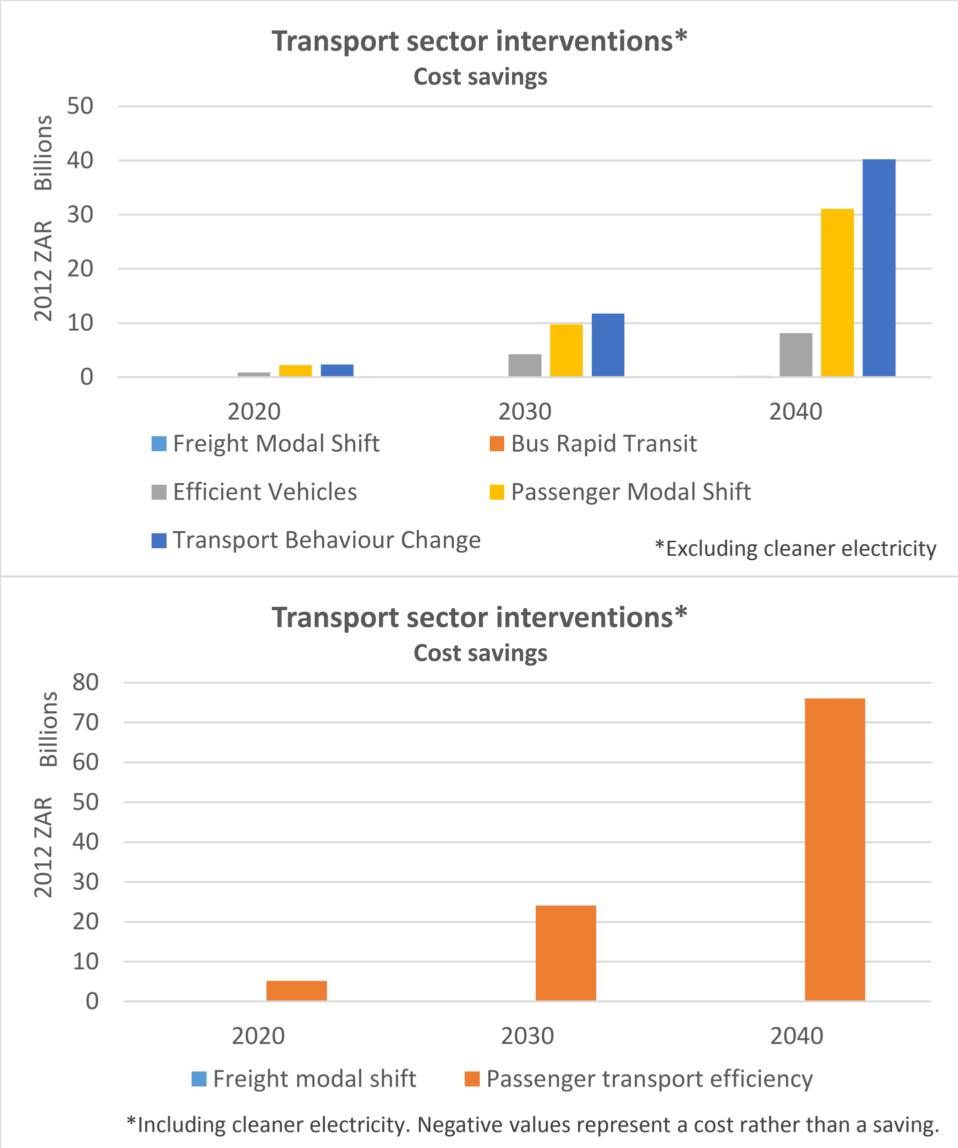
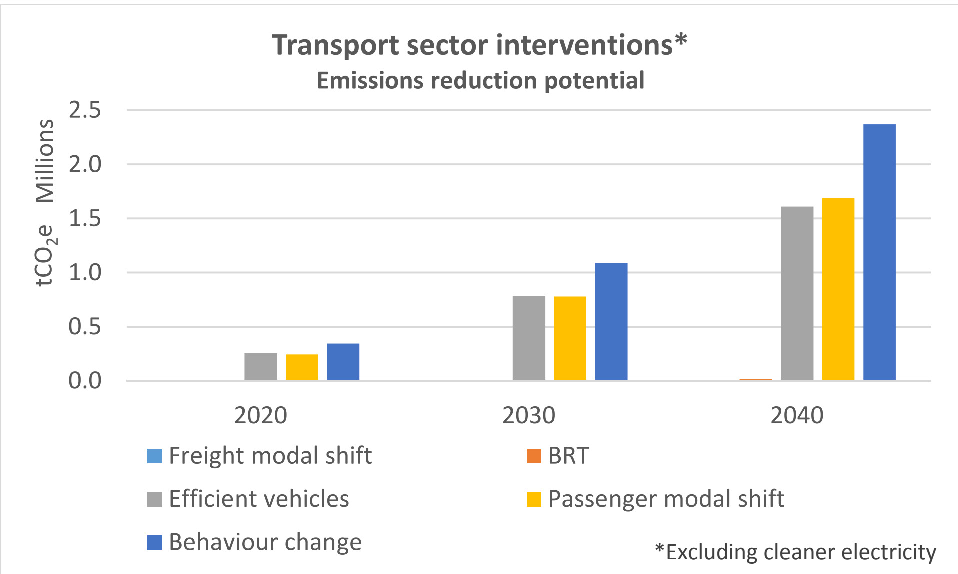


Figure 90: Cost savings off BAU per intervention in the transport sector



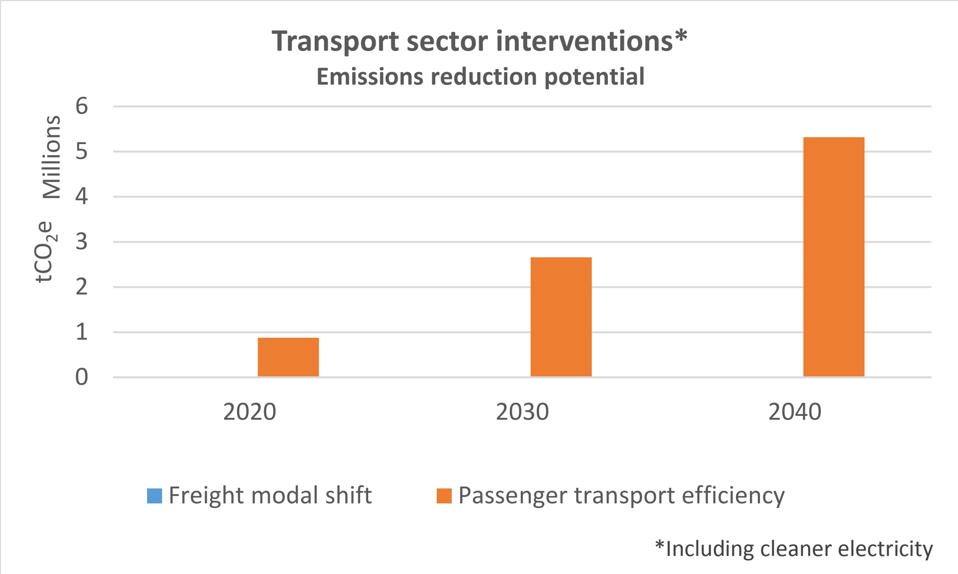


Figure 91: Emissions savings off BAU per intervention in the transport sector

Annexure 1: Detailed breakdown of efficiency interventions over 5-year periods 2012 – 2050

Sector/Sub-Sector	2012	2015	2020	2025	2030	2035	2040	2045	2050
Residential	2012	2015	2020	2025	2030	2035	2040	2045	2050
CFL (low-inc)	60%	67%	78%	90%	95%	100%	100%	100%	100%
CFL (mid-inc)	90%	92%	96%	100%	100%	100%	100%	100%	100%
CFL (high-inc)	45%	44%	42%	40%	32%	24%	16%	8%	0%
CFL (very high-inc)	45%	44%	42%	40%	32%	24%	16%	8%	0%
LED (high-inc)	25%	31%	40%	50%	60%	70%	80%	90%	100%
LED (very high-inc)	25%	31%	40%	50%	60%	70%	80%	90%	100%
SWH (low-inc elec)	0%	0%	5%	10%	15%	20%	25%	28%	30%
SWH (low-inc non elec)	0%	0%	5%	9%	15%	20%	20%	25%	30%
SWH (mid-inc elec)	0%	0%	9%	20%	30%	40%	50%	60%	70%
SWH (mid-inc non-elec)	0%	0%	9%	20%	30%	40%	50%	60%	70%
SWH (high-inc)	9%	9%	23%	40%	55%	65%	75%	83%	90%
SWH (very high-inc)	9%	9%	23%	40%	55%	65%	75%	83%	90%
Geyser Insulated (mid-inc)	10%	13%	17%	21%	26%	30%	30%	30%	30%
Geyser Insulated (high-inc)	20%	22%	25%	28%	32%	35%	25%	18%	10%
Geyser Insulated (very high-inc)	30%	31%	32%	33%	34%	35%	25%	18%	10%
Efficient Fridge (low)	20%	28%	43%	57%	71%	85%	89%	93%	96%
Efficient Fridge (mid)	20%	28%	43%	57%	71%	85%	89%	93%	96%
Efficient Fridge (high)	20%	28%	43%	57%	71%	85%	89%	93%	96%
Efficient Fridge (very high)	20%	28%	43%	57%	71%	85%	89%	93%	96%
Commercial	2012	2015	2020	2025	2030	2035	2040	2045	2050
Efficient Lighting	50%	62%	81%	100%	100%	100%	100%	100%	100%
Efficient HVAC	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Water Heating	0%	5%	12%	20%	30%	40%	47%	53%	60%
Efficient Refrigeration	0%	11%	30%	48%	67%	85%	90%	95%	100%
Industrial	2012	2015	2020	2025	2030	2035	2040	2045	2050
Efficient Machine Drives/Motors	10%	20%	36%	52%	69%	85%	90%	95%	100%
Efficient HVAC	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Lighting	50%	62%	81%	100%	100%	100%	100%	100%	100%
Efficient Compressed Air	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Ventilation Fans	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Mechanical Equipment	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Process Heating/Steam	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Pumps and Valves	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Refrigeration	0%	11%	30%	48%	67%	85%	90%	95%	100%
Agricultural	2012	2015	2020	2025	2030	2035	2040	2045	2050
Efficient Pumps/Irrigation	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Lighting	0%	62%	81%	100%	100%	100%	100%	100%	100%
Efficient HVAC	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Fans	0%	11%	30%	48%	67%	85%	90%	95%	100%
Local Government	2012	2015	2020	2025	2030	2035	2040	2045	2050
Buildings: Efficient Lighting	65%	73%	87%	100%	100%	100%	100%	100%	100%
Buildings: Efficient HVAC	10%	20%	36%	52%	69%	85%	90%	95%	100%
Buildings: Efficient Water Heating	0%	12%	31%	50%	60%	70%	80%	90%	100%
WWTW: Efficient Motors/Pumps	0%	11%	30%	48%	67%	85%	90%	95%	100%
Bulk Water: Efficient Motors/Pumps	0%	11%	30%	48%	67%	85%	90%	95%	100%
Pump Stations: Efficient Motors/Pumps	0%	11%	30%	48%	67%	85%	90%	95%	100%
Efficient Street Lighting	59%	68%	84%	100%	100%	100%	100%	100%	100%
Efficient Traffic Lighting	100%	100%	100%	100%	100%	100%	100%	100%	100%

Vehicle Fleet: Efficient Diesel	0%	11%	30%	48%	67%	85%	90%	95%	100%
Vehicle Fleet: Efficient Petrol	0%	11%	30%	48%	67%	85%	90%	95%	100%
Transport	2012	2015	2020	2025	2030	2035	2040	2045	2050
Freight: tonne-km by rail (vs road)	23%	24%	27%	30%	32%	34%	36%	38%	40%
Public transport share of all pass-km (incl. public, private, NMT)	35%	37%	39%	41%	43%	45%	47%	49%	51%
Share of private passenger pass-km: conventional diesel	35%	31%	23%	17%	10%	4%	3%	1%	0%
Share of private passenger pass-km: conventional petrol	65%	57%	44%	31%	19%	8%	5%	2%	0%
Share of private passenger pass-km: efficient diesel	0%	4%	10%	15%	20%	25%	25%	25%	25%
Share of private passenger pass-km: efficient petrol	0%	7%	18%	29%	38%	46%	46%	46%	46%
Share of private passenger pass-km: diesel hybrid	0%	1%	4%	6%	8%	10%	11%	13%	15%
Share of private passenger pass-km: electric	0%	0%	1%	3%	5%	8%	10%	13%	15%
Efficient diesel/petrol (vs conventional diesel/petrol)	0%	11%	30%	48%	67%	85%	90%	95%	100%
Share of minibus pass-km by efficient minibuses (vs. conventional)	0%	11%	30%	48%	67%	85%	90%	95%	100%
Share of conventional bus pass-km by efficient buses (vs. conventional)	0%	11%	30%	48%	67%	85%	90%	95%	100%
Share of bus pass-km by BRT	4%	7%	14%	20%	26%	32%	38%	44%	50%
Passenger: Private: Occupancy	1.40	1.45	1.53	1.61	1.68	1.76	1.84	1.92	2.00

Annexure 2: Detailed breakdown of supply side interventions over 5-year periods 2012 – 2050

Sector	kW
Residential high-income	2
Residential very high-income	3
Commercial/Industrial	12
Industrial	400
Solar capacity	19.4%

Residential

Variables	2012	2015	2020	2025	2030	2040
Solar PV penetration	0.0%	0.0%	10.0%	20.0%	30.0%	50.0%
No. of households (high-income)	220 705	224 434	230 789	237 323	244 043	258 059
No. of households (very high-income)	53 126	54 024	55 553	57 126	58 744	62 118
No. of systems (2 kW)	0	0	23 079	47 465	73 213	129 030
No. of systems (3 kW)	0	0	5 555	11 425	17 623	31 059
Capacity (MW)	0	0	63	129	199	351
Electricity (MWh)	0	0	106 765	219 576	338 691	596 905
CCT elec demand (MWh)	4 464 972	4 429 464	4 364 749	4 292 818	4 233 897	4 207 328
Elec provided by solar (check)	0%	0%	2%	5%	8%	14%

Commercial

Variables	2012	2015	2020	2025	2030	2040
Elec demand of scenario	5 267 916	5 903 254	7 121 819	8 566 980	10 685 482	16 835 506
Elec supplied by solar PV (%)	0.0%	0.0%	3.0%	6.0%	10.0%	15.0%
Elec supplied by solar PV (MWh)	0	0	213 655	514 019	1 068 548	2 525 326
Capacity (MW)	0	0	126	302	629	1 486
No. of systems	0	0	10 447	25 205	52 397	123 831

Industrial

Variables	2012	2015	2020	2025	2030	2040
Elec demand of scenario	1 431 712	1 513 183	1 659 051	1 818 489	1 997 362	2 433 640
Elec supplied by solar PV (%)	0.0%	0.0%	3.0%	6.0%	10.0%	15.0%
Elec supplied by solar PV (MWh)	0	0	49 772	109 109	199 736	365 046
Capacity (MW)	0	0	29	64	118	215
No. of systems	0	0	73	161	294	537

Total

Residential, Commercial, Industrial	2012	2015	2020	2025	2030	2040
MWh	**0**	**0**	**370 191**	**842 704**	**1 606 975**	**3 487 276**
MW	0	0	218	496	946	2052