POLOKWANE LEAP MODEL TECHNICAL REPORT

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SAMSET
Supporting Sub-Saharan Africa's Municipalities with Sustainable Energy Transitions




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1.DOCUMENT OVERVIEW

This is the technical documentation for the development, data, and methodology of the Polokwane City energy systems model which forms part of the Supporting Sub Saharan African Municipalities with Sustainable Energy Transitions (SAMSET) project. The SAMSET project is in collaboration with Sustainable Energy Africa, the University of Uganda Martyrs, the University of Ghana, University of Durham and University College London. SAMSET is co-funded by aid from the UK Department for International Development, the Engineering and Physical Science Research Council and the Department for Energy and Climate Change.

The model is developed on the Stockholm Environment Agency's Long range Energy Alternatives Planning System (LEAP) platform. LEAP is essentially an accounting-type simulation model, although other uses and features have emerged as the product has developed. The rationale for the selection of LEAP as a tool for the SAMSET project has been documented in project outputs (Tait, McCall, & Stone, 2014) and the LEAP software tool itself is well documented by SEI (http://www.energycommunity.org). The low learning curve, the free licence of use and the large amount of support online for problems and questions relating to LEAP were chief among the reasons for its use in this project. For the SAMSET project, LEAP is used to create a bottom-up, data-driven picture of Polokwane's energy system on the supply and demand sides, projecting a reference case into the future. Scenarios are then developed which project how municipal driven interventions may alter the path of this reference case, reducing energy consumption and mitigating CO_2 emissions.

The model was created largely from the data collected and collated by Aurecon's (2013) State of Energy (SoE) report with the addition of new sources and information gathered by the ERC and SAMSET partners.

2.GENERAL BACKGROUND AND METHODOLOGY

Sources of data for the model

The majority of the data for the model was obtained from Aurecon (2013) and their SoE report. The report was the starting point for much of this work and formed part of the initial scope of the SAMSET projects. Where data was lacking for the model, data from the ERC's national energy systems model: South African TIMES model (SATIM) was used. Other sources of data and information come from public access documents and reports and are cited as such in the methodologies.

Model background

The general form of a LEAP model involves firstly the division of the energy demand side into typical economic sectors:

- transport;
- municipal services;
- households/residential;
- industry;

- commercial;
- agriculture.

Secondly, supply sectors need to be defined under the node 'Transformation' typically but not exclusively as follows:

- transmission and distribution;
- electricity production;
- oil refining;
- charcoal production.

In order to build a model, data must be collected for the demand-side sectors that captures the levels of output and energy intensity of producing that output by technology and/or energy carrier for each of the typical services required in that sector, for instance lighting, heating, passenger transport or production of steel. An example is given in the figure below.

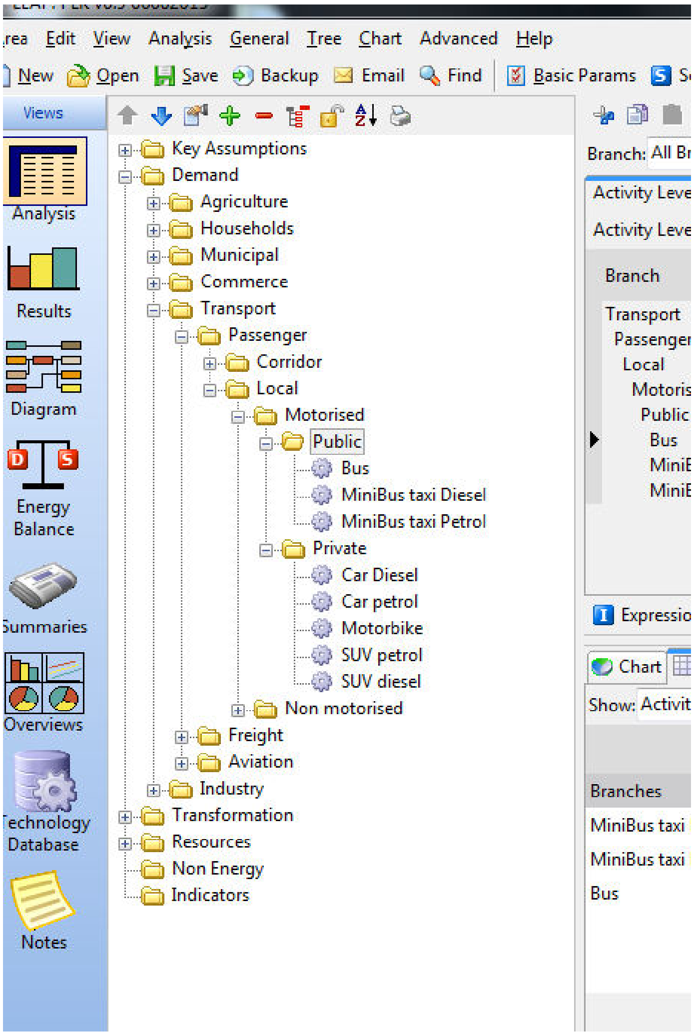

Figure 1: Example of the tree structure in LEAP which aids in categorising the sectors and subsectors of a model down to individual technologies. Here the level goes down to the share of private cars which are diesel or petrol and so on.

It is important to understand that an energy service – heating, for instance – may be supplied by many technologies, which may use different energy carriers (fuels) such as coal, diesel or electricity. A combination of a technology and energy carrier will have distinct energy efficiency and emissions, with important implications for sustainability. An important feature of a useful energy systems model is therefore that, while we want to capture the actual technologies and energy carriers used to supply services today, which we define as the base year, we want to be able to simulate switching to other technologies and energy carriers in the future to evaluate the impact on sustainability.

The general mathematical form by which the energy consumption of the services in a sector is calculated is a simple accounting formula outlined in a general but not overly mathematically formal way below for the sake of communicating across disciplines. For simplicity's sake we will assume that a technology may be either a different means of doing the same thing (for example travelling by bus or by car) but also using a different energy carrier / fuel (for example travelling using a petrol fuelled car or electric car).

For a given year in the time horizon of the model:

Energy consumption of a sector = the sum of all the energy consumptions of services required by the sector

Where, if:

E_S = the energy consumed by a service in a given year

θ_i = share of service supplied by technology i

η_i = the energy intensity (equivalent to efficiency) of technology I in units of energy required per units output for example MJ/[passenger km] or GJ/[ton steel]

O_S = the output of a service required in a given year in physical units for example, passenger km of passenger transport, tons of steel or GJ of heating

$E_S = \sum (\theta_i X \eta_i X O_S)$

This simple structure offers considerable advantages in developing scenarios of shifts to new technologies because the modeller can easily change the relative shares θ_I of technologies that supply a service at a given future output O_S, and the impact on emissions and energy consumption can be quickly assessed. Technologies that have no share of service provision in the base year, say electric cars, can be readily assigned a growing share in a scenario of the future. The given future output is readily projected in LEAP which provide a spreadsheet like formula builder for generating time series of parameters such that an output O_S such as residential heating or tons of steel can be linked to a driver such as population or gross domestic product . GDP itself can be set up as a global assumption accessible to all sectors in the tree structure of the model and defined as a geometric progression relative to time such that it grows at a fixed percentage, of say 2%, per annum for the time horizon of the model. More elaborate representations, including step changes and linear interpolation between defined points are equally possible using the formula builder giving the modeller considerable flexibility in implementing the views of stakeholders or other forms of data. An example of this flexibility is demonstrated in Figure 2, where the shares of individual technologies are set easily by the user and LEAP instantly shows the graphic representation of this change.

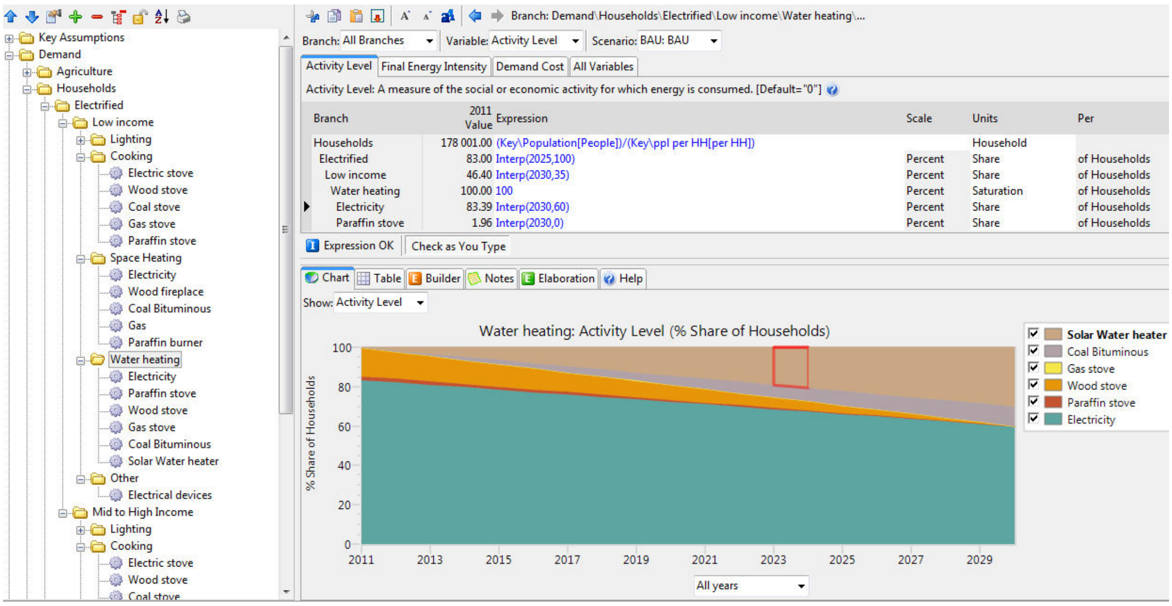

Figure 2: A screen shot of the LEAP interface showing the change in water heating technologies for low-income households through to 2030

LEAP has a financial framework and, if the costs of technologies are known, the impact on net present value of supplying that service can equally be quickly assessed. The disadvantage of this simplistic representation is that the share of a technology may be changed faster than is practical in the real world, given the technical life and age distribution of exiting devices. LEAP does allow for devices to be vintaged and technical change to be managed by a stock model, but this is much more data-intensive and not suitable for most cases where sectors have been represented in the SAMSET project due to data gaps. Some attention needs to be paid, therefore, to keeping rates of change within a conservatively realistic window.

For a bottom-up model to be reliable, the assumed activity levels and energy intensities used in services need to be calibrated so that the total energy consumed in the model in the base year, which we define as an historical year, say 2010, agrees with the total energy known to have been supplied to the system in that year. This total energy data typically comes from recorded total electricity sales and petroleum fuel sales obtained from the major utilities. Acquiring this data and validating it is therefore an important first step in the modelling process.

In the model developed for Polokwane all fuels sold within the municipality are assumed to be consumed within the boundary and thus count toward the city's emissions levels, although it should be noted that a significant portion of petrol and diesel sold within Polokwane is combusted on the road outside of the boundary. In this framework we adopt the methodology of accounting for those energy and emissions which are consumed and combusted on the road outside of Polokwane.

The LEAP model was created to represent all major sectors of Polokwane as a bottom-up simulation model, and this was calibrated with known fuel sales (mainly liquid fuels and electricity) within the municipal boundary. The main drivers for this model are population, and economic growth (one local, and one regional).

The base year for this model is 2011, as most of the statistics and data overlap in this year. Much of the data in this model and report is taken from the SoE report developed for the City of Polokwane by Aurecon Consulting

3. KEY GLOBAL ASSUMPTIONS IN THE MODEL

As discussed above, drivers of the output of energy services are key to generating scenarios, including a baseline – often called a Reference case or Business as usual (BAU) case to distinguish it from scenarios where active intervention towards some goal like sustainability is assumed. Typical drivers of energy service demand are **GDP** and **population** and the ratio between them which reflects **average income**.

Consumption of goods with respect to income is generally not linear and therefore, if significant income disparities exist, it is good practice to divide the population into income groups if the data allows typically low, medium and high. Also, as discussed above, calibration is a key step in model development and therefore supply side data collection is crucial. It is therefore key to developing global assumptions for the model to understand the drivers of demand and the total supply of energy to be calibrated against. These are discussed below, with respect to Polokwane, in their respective sections.

3.1 POPULATION

The population of Polokwane in 2011 was 628 999, up from 581 802 in 2006, as indicated in Table 1.

Table 1: Polokwane population and growth rates

Year	Population	Growth
2006	581 802	2.30%
2007	594 022	2.10%
2008	605 693	2.00%
2009	616 223	1.70%
2010	626 085	1.60%
2011	628 999	0.50%

Aurecon (2013); Statistics South Africa (2011)

3.2 ECONOMY

According to the Aurecon report, the gross value added (the GDP of a city) by the city's economy was in the region of R20.8bn in 2011, if the trend continues as indicated in the table below.

Table 2: Polokwane GVA

Locality	GVA Per Year (R'000)				
	2006	2007	2008	2009	2010
Limpopo	105 182 819	110 144 266	112 843 902	110 733 494	114 195 479
Capricorn District	25 883 933	27 786 229	29 265 085	29 241 423	30 034 266
Polokwane	16 907 304	18 275 484	19 332 495	19 335 633	19 911 605

Aurecon (2013)

The national GDP of South Africa grew at an annual average of 2.92% between 2005 and 2014 (Statistics SA, 2011). Data for Polokwane's GVA between 2007 and 2010 (see Table 2) indicate an average growth rate of 2.93%. The relation between the two economic indicators is shown in Figure 3. Only in 2009 does a linear correlation deviate, when the national economy is seen to shrink. However, it should be noted that Polokwane was one of the host cities for the 2010 Soccer World Cup and that this may have prevented the local Polokwane economy from shrinking during the 2009 economic recession. It is for these reasons that it is assumed that the economy of Polokwane will follow the growth trends of the national economy in general.

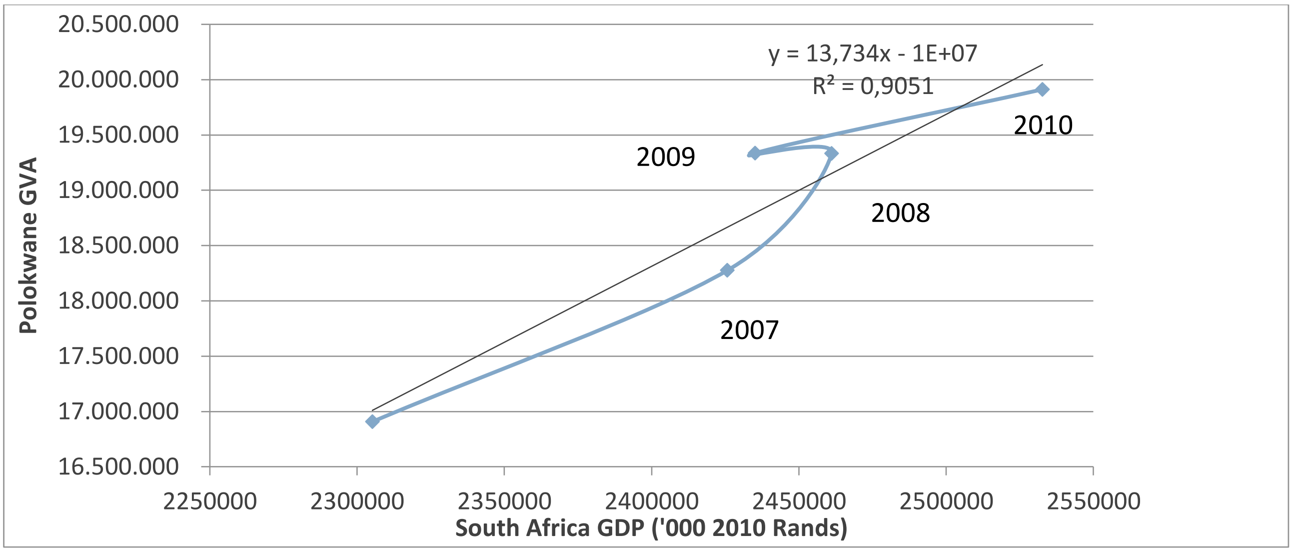

Figure 3: Polokwane GVA versus the national GDP showing an almost linear relation save for economic recessions (2009)

4. FUEL SUPPLY DATA FOR POLOKWANE

Much of the data used in this methodology comes from the SoE report, and the energy balance there is given below. In this work, data on fuel consumptions was obtained from other sources as well and included with the Aurecon SoE data – in some cases there were minor discrepancies (often relating to boundaries) while some differences were much larger.

Table 3: Energy demand (GJ) by sector as indicated in the SoE report

	Electricity	Diesel	Petrol	Wood	Coal	LPG	Total	% of total
Households	1 767 330			92 298	1 741 392	39 969	3 640 990	23%
Commerce and industry	1 485 677	41 757			4 394 179	302 630	6 224 244	39%
Local authority	81 763	23 724	18 033				123 520	1%
Transport		2 085 467	3 943 503				6 028 971	38%
Agriculture	1 620						1 620	0.01%
Total	3 336 390	2 150 949	3 961 536	92 299	6 135 571	342 600	16 019 345	100%
% of total	21%	13%	25%	1%	38%	2%	100%	

Below are data for some of the major fuels sold and consumed in the municipality, and all the data collated in this work is summarised at the end of this section.

4.1 LIQUID FUELS

The total liquid fuels supplied to Polokwane was estimated using fuel sales data collected from the South African Oil and Petroleum Industry Association (SAPIA), and disaggregated by product and the relevant magisterial district (Polokwane). Magisterial district and municipal boundaries do not align perfectly, and the municipal boundary of Polokwane includes the greater part of the Polokwane magisterial district but also two residential townships, Seshego and Thabamoopo, adjoining the central town, that fall into magisterial districts of the same name. A percentage of the fuel consumption in each magisterial district that is likely consumed in the municipal boundary was therefore assumed as shown in Table 4.

Table 4: Total liquid fuel supplies to Polokwane adjusted for municipality boundary overlaps (in kilolitres)

Magisterial districts and their fuel allocations to Polokwane	Jet fuel	Avgas	Diesel	HFO	LPG	Paraffin	Petrol	Grand total
Polokwane (Pietersburg) (south of tropic of Capricorn) @ 90%, jet fuel, aviation, furnace oil @ 100%	120	177	69 587	1 682	392	2 410	101 892	176 261
Seshego @ 80%	-	-	445	-	-	-	4 281	4 726
Thabamoopo @ 80%	-	-	2 546	-	-	43	13 561	16 149
Total Polokwane Municipality	120	177	72 578	1 682	392	2 453	119 734	197 136

4.2 ELECTRICITY

The SoE report provided NERSA and Eskom sales data for Polokwane by customer group, as given below.

Table 5: Eskom electricity sales data for Polokwane

	No. of consumers	Estimated consumption (MWh)
Domestic consumers	47 035	226 097
Commercial	3 220	48 300
Manufacturing / industrial	3	900
Agricultural	75	450

Source: Aurecon (2013)

Table 6: NERSA sales submissions for electricity for Polokwane

	No. of consumers	Consumption (MWh)
Domestic (pre-paid)	32 867	157 987
Domestic (conventional)	21 132	106 841
Agriculture	-	-
Mining and quarrying	-	-
Manufacturing / industrial	888	314 049
Commercial	3 216	49 439
Transport		
General		
Re-distributors		
Electricity department own use	1	706
Street lighting	1	14 737
Municipal own use (excl. Electricity department)	1	7 269
Totals	58 106	651 028

Source: Aurecon (2013)

During this modelling work and correspondence with the SAMSET partners in Polokwane the municipal electricity accounts were obtained (see Table 7). The wheeled account is electricity going to Eskom customers who are connected to the municipality network, and does not necessarily indicate consumers within the municipality boundary.

Table 7: Polokwane municipality electricity purchases (kWh)

Municipality	2011	2012	2013	2014
With wheeling	890 026 462	890 279 189	883 394 060	903 378 287
Without wheeling	824 324 421	826 198 945	825 366 975	834 201 850
Wheeled amount	65 702 041	64 080 244	58 027 085	69 176 437

Source: Polokwane Municipality correspondence with SAMSET team

The NERSA sales for Polokwane Municipality show a 20% difference and the reason has not been resolved (see 12 for further discussion). In this methodology we use the municipal sales without wheeling as the electricity purchases for Polokwane Municipal electricity users. This total consumption is then split by sectors using the distribution in Table 6 (NERSA data).

Table 8: Adjusted electricity consumption (MWh) by sector for Polokwane in 2011 combining municipal and Eskom data

	NERSA submissions data adjusted to match Polokwane accounts	Aurecon source - Unadjusted	
Sector	**NERSA submissions**	**Eskom sales**	**Total**
Domestic (pre-paid)	200 041	226 097	426 138
Domestic (conventional)	135 281		135 281
Agriculture		450	450
Mining and quarrying			
Manufacturing / industrial	397 645	900	398 545
Commercial	62 599	48 300	110 899
Transport			
General			
Re-distributors			
Electricity department own use	894		894
Street lighting	18 660		18 660
Municipal own use (excl. Electricity Dept)	9 204		9 204
Total	**824 324**	**275 747**	**1 100 071**

4.3 COAL

The Aurecon report provided data for coal consumption by industry (including the smelters) and for HHs (although this number has been revised down by a factor of 1000 based on data received from Aurecon at a later stage in the report development).

Table 9: Coal consumption data for 2011

Sector	Unit	Quantity
Industry	Tonnes/year	158 064
Households	GJ/year	1 741

Source: Aurecon (2013)

Further data for coal consumption was obtained from the Air Quality Management plan report by Rautenbach et al (2006); see Table 10.

Table 10: The air quality management coal consumption in industry and commerce in 2006

Industry	Use in	tonnes/year
Coca cola	Boilers	1 560
Enterprise	Boilers	5 000
Sasko	Boilers	480
SAB	Boilers	6 480
Other	Boilers	1 220
Commerce		
Dry cleaners	Boilers	1 494
Hospital	Boilers	1 296
Schools	Boilers	120

4.4 CHARCOAL

A news article by *Business Day Live* on the use of charcoal in Polokwane (Radebe, 2011) as well as a dated report by the Department of Water and Forestry (2004) indicated large amounts of charcoal were being used by the silicon smelter in Polokwane (see Table 11).

Table 11: The use of charcoal in Polokwane

Source	Year	Charcoal use (tonnes/year)
Business Day Live (Radebe, 2011)	2011	85 000
Roundwood supply report (DoWF, 2004)	2004	120 000

4.5 FUELS CONSUMPTION DATA SUMMARISED

All the sources of fuels data for Polokwane collated during this work are presented below. This combines with new data not in the Aurecon report. These numbers are used to calibrate the model in each sector (where there is sufficient detail).

Table 12: Fuels supply data collected from various sources and used to inform the LEAP model

Fuel	Quantity	Units	Year	Source of data	Sector
Avgas	177 420	Litres	2011	SAPIA	Transport
Jet fuel	120 021	Litres	2011	SAPIA	Transport
Diesel	71 897 927*	Litres	2011	SAPIA	Transport (assumed)
Petrol	119 266 125*	Litres	2011	SAPIA	Transport (assumed)
HFO	1 681 770	Litres	2011	SAPIA	Unknown
LPG	391 893	Litres	2011	SAPIA	Mixed
Paraffin	2 453 071	Litres	2011	SAPIA	Households (assumed)
Diesel	680 000	Litres	2011	Aurecon SOE	Municipality
Petrol	468 000	Litres	2011	Aurecon SOE	Municipality
Coal	2 910	Tonnes	2006	AQM 2006	Commerce
Coal	14 740	Tonnes	2006	AQM 2006	Industry
Coal	140 414*	Tonnes	2011	Aurecon SOE	Heavy industry
Coal	1 741	GJ	2011	Aurecon SOE (adjusted for numeric error)	Households
Wood	92 299	GJ	2011	Aurecon SOE	Households
Electricity	561 419	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Households
Electricity	398 545	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Industry

Fuel	Quantity	Units	Year	Source of data	Sector
Electricity	110 899	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Commerce
Electricity	450	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Agriculture
Electricity	9 204	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Municipal
Electricity	18 660	MWh	2011	Aurecon (Eskom and NERSA sources) + Municipality	Municipal
Electricity	894	MWh	2012	Aurecon (Eskom and NERSA sources) + Municipality	Municipal
Charcoal	120 000	tonnes	2011	BDlive news article + DoWF Roundwood supply report	Industry
Note: * These are numbers which relate to other numbers in the table (coal supplied to Polokwane from Aurecon data will presumably include the coal consumption in small industries from the AQM report) and are made to be consistent to the total supply data provided					

4.6 FUEL SUPPLY AND GENERATION

All liquid fuels are assumed to be generated outside of the boundary of Polokwane, this assumption extending to include wood and coal sources.

Electricity generation

The supply of electricity to the city of Polokwane comes from the national grid. The electricity supply going into the future is assumed to follow the IRP2010 Policy adjusted scenario (see Figure 4). Current numbers for new REIPPP wind and solar power have been included in the LEAP model and make up part of the policy adjusted scenario's new build.

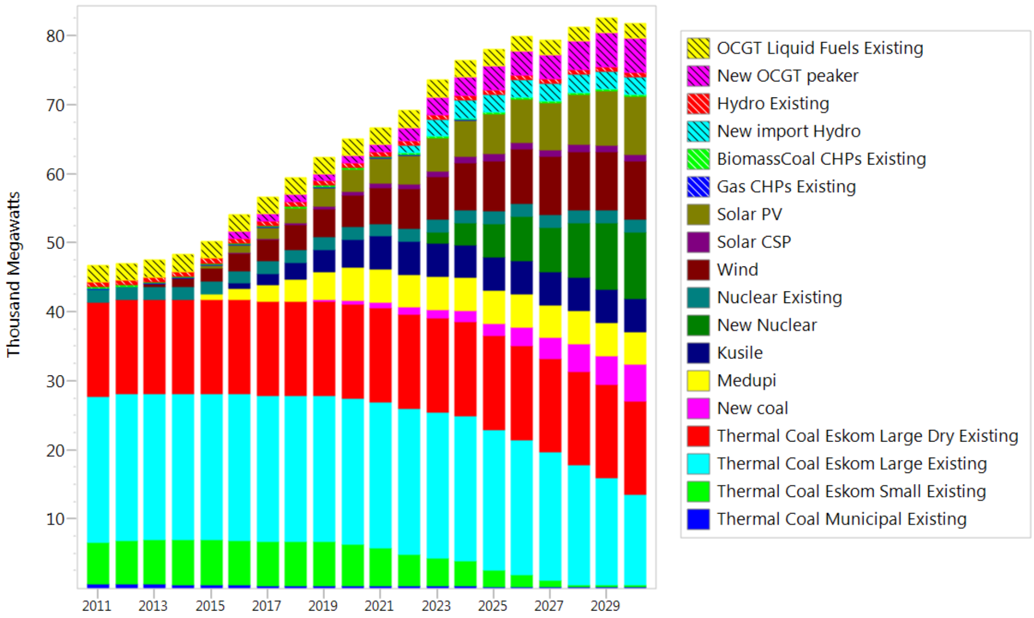

Figure 4: The national electricity generation supply system capacity under the IRP2010 Policy adjusted scenario

5.TRANSPORT SECTOR

Polokwane is situated on a fairly busy transport corridor for both freight and passenger transport. This will add to the challenge of balancing supply (of fuel) to demand (of transportation).This also adds to the complexity of scenario development, as outside factors will affect the liquid fuel demands within the municipal boundary. Data for the total number of registered vehicles in Polokwane city was available from eNATIS (Electronic National Administration Traffic Information System). One issue with this data is the aggregation of vehicle types such as 'light passenger less than 12 persons', and 'light load GVM 3500kg or less'. The latter may include utility pick-up trucks ('bakkies'), sport utility vehicles (SUVs) or larger-bodied light trucks and vans which in general would be used for transporting freight only, whereas SUVs are generally used for passenger transport and bakkies could be used for either. This further complicated the data issues around transportation, and assumptions were made during methodology to address this.

5.1 PASSENGER TRANSPORT

This subsector comprises the transport of people around and in the city, as well as along the corridors, mainly the N1 highway used by people transiting through Polokwane. The data available to this study was supplied from Aurecon's initial SOE report, and liquid fuel supply-side data from SAPIA combined with the eNATIS[1] vehicle registration data. The passenger vehicle population by type was estimated from both eNATIS data on registered vehicles and data provided by Aurecon (mainly bus and minibus count in Polokwane

[1] Electronic National Administration Traffic Information System – live vehicle population statistics for Polokwane. Available at http://www.enatis.com/.

for local use and for long distance travel). The table below shows the data for the number and type of vehicles within Polokwane in the year 2011.

Table 13: eNATIS vehicle count of registered vehicles in Polokwane

Year	Month	Heavy load GVM>3500kg not equipped to draw	Heavy load GVM> 3500kg – equip to draw	Light load GVM 3500kg or less	Heavy passenger 12 or more persons	Light passenger less than 12 persons	Mini -bus	Motor cycle	Special vehicle
2011	Sept	2 439	3 917	34 611	1 278	48 655	3 139	2 106	3 361

It should be noted this is data for the number of registered vehicles in Polokwane and does not necessarily indicate the number of vehicles which are used within the boundary – a large number of these may also be being used outside of the municipal boundary, and likewise vehicles registered elsewhere and used within Polokwane would not be reflected in this data.

Aurecon's data provided the number of buses being used within the city, as well as the number of taxi's being used (160 buses, and 1 225 minibuses). For long-distance travel, Aurecon's data had a total of 218 long distance bus arrivals per day, and 178 long-distance taxis arriving per day. These would be used to meet the corridor passenger transportation demand.

The modal share of passenger transport is given in the table below. The data indicates that the majority of people use walking as their mode of transportation. What is not clear is whether there are combined/mixed modes here – walking then taking a bus, for example. What will become clear is that, despite walking being the main mode of transportation in trip terms, when considering the distances involved, walking demand does not compare to any of the other modes in passenger-km terms.

Table 14: The mode share for Polokwane commuters as given by the integrated transport plan (Siyazi-Khosa Joint Venture, 2007)

Mode of travel	% of total trips
Bus	6.58%
Minibus taxi	9.69%
Train	0.30%
Car (driver)	7.46%
Car (passenger)	7.25%
Motorcycle	0.32%
Bicycle	0.55%
Foot	67.48%
Other	0.36%
Total	100%

Due to the fact that Polokwane is a corridor route, the passenger demand is split into 'local' and 'corridor' sections, as the economic drivers for these were assumed to differ – with local passenger transport demand assumed to be population driven, while corridor transport demand was assumed to be driven by growth in the regional economy (the national economy was used as a proxy).

5.1.1 LOCAL PASSENGER TRANSPORT METHODOLOGY

The steps in the methodology employed here to calculate the total local pass-km supplied by each vehicle type and their effective MJ/pass-km efficiency are summarised below:

- Make an assumption on % of vehicles registered in Polokwane but are not used here.
- Make an assumption about SUVs/bakkies that are used for passenger transport and not freight transport (using a bakkie for construction etc).
- Use a % split between diesel and petrol for each vehicle type – using national numbers.
- Use data from Aurecon on what modes of transport people use for work/school, and use some assumptions about number of days and trips per day for transport for each mode and the distance travelled to get an estimate of total passenger-km demand.
- Use the passenger-km and mode split to get total pass-km for each vehicle type.
- Use an estimate of vehicle occupancy to get total veh-km per year.
- Check the total annual average mileage (km travelled) assumed for each vehicle type calibrating against the estimate of passenger-km demand.
- Adjust the veh-km accordingly to a known approximate average of the typical vehicle may travel in a year, if the adjustment required is not unreasonable.
- Adjust the total passenger-km demand accordingly with this calibration.
- Use the vehicle L/100km efficiency and the vehicle-km travelled to get a total fuel consumed for each vehicle type.
- Adjust the average occupancy and average annual mileage for each vehicle type to calibrate the calculated fuel demand of the vehicle population with the estimated supply side statistics for gasoline and diesel.

- The final MJ/pass-km for each vehicle can now be determined and will be entered as the assumed energy intensity in the LEAP model as per Equation 1 above.

A summary of assumptions for calculating the local passenger transport demand is tabulated, as in Table 15 and the assumptions for active and inactive vehicles in Polokwane are shown in Table 16.

Table 15: Assumptions to determine initial (before calibration) total pass-km for Polokwane by mode

	Avg. km/ trip*	Population using this mode on average**	Avg. number of trips per day	Days of the year using transport	Total pass-km/yr.	Motor-ised %	Non-motorised %
Bus	10.0	6.58%	2	280	231 773 552	13.7	
Minibus taxi	14.6	10.05%	2	320	590 001 062	34.9	
Car	14.0	14.71%	2	320	829 030 746	49.0	
Motorcycle	15.0	0.32%	2	320	19 322 849	1.1	
Bakkie/SUV	14.0	0.36%	2	320	20 288 992	1.2	
Bicycle	5.2	0.55%	2	320	11 439 395		2
Foot	2.2	67.48%	2	320	588 568 622		98
		100.0%				100	100
Total motorised					1 690 417 201		
Total non-motorised					600 008 017		
Total local passenger					2 290 425 217		

* Based on assumptions on travel time and average travel speeds by each mode

** Taken from Table 13.

Table 16: Assumption on the inactive vehicles in Polokwane – the portion of vehicles registered in Polokwane but not used within the city boundaries

	Bus	Private car	Minibus	Motorbike	LCV (bakkie/ pick-up truck)
Diesel	0%	20%	5%	0%	20%
Petrol		20%	5%	0%	20%
For passenger*					20%

* This is the number of Bakkies/LCV vehicles used for passenger transport; the remainder is used in freight (for construction etc).

The split of vehicle population by fuel type is taken from the SATIM methodology. See Table 17. The total vehicles used in Polokwane for local passenger transport is shown in Table 18.

Table 17: Vehicle split by fuel type based on national sales data (Merven et al, 2012)

	Bus	Private car	Minibus	Motorbike	Other	LCV (bakkie)
Diesel	100%	6%	1%	0%	67%	43%
Petrol		94%	99%	100%	33%	57%

Table 18: The vehicle count for Polokwane after assumptions for passenger transport in the municipality

	Bus*	Private car	Minibus*	Motorbike	LCV (bakkie)
Diesel	160	2 393	12	-	2 381
Petrol	-	36 531	1 152	2 106	3 157
* This is Aurecon data.					

The total pass-km serviced by each vehicle by each fuel type is determined using the number of vehicles (above) and using the passenger-km in Table 14. This was then converted to vehicle-km travelled per year for each vehicle type and sense-checked against common numbers or assumptions and adjusted only if the mileages were far off the mark. The resulting analysis of mode shift and passenger transport demand as well as the calibration of vehicle km to fit an average statistic gives the total share of pass-km by vehicle type (Table 19):

Table 19: The motorised pass-km share by mode after adjustments

	Bus	Private car	Minibus	Motorbike	Other	LCV (bakkie)
Diesel	9.8%	2.3%	0.5%	0.0%	0.0%	3.3%
Petrol	0.0%	34.4%	44.6%	0.8%	0.0%	4.4%

The occupancy of each vehicle is taken from the SATIM methodology (national numbers) and influences the efficiency of each vehicle as much as the fuel efficiency does (Table 20):

Table 20: Vehicle occupancies used in the passenger transport sector

	Bus	Private car	Minibus	Motorbike	Other	LCV (bakkie)
People/vehicle	25	1.4	12	1	1.4	1.4

The vehicle efficiencies in MJ/pass-km are calculated based on the L/100km fuel economy for the vehicle types and then working out fuel consumption based on the L/100km and the total vehicle km (from the transport analysis) travelled by each vehicle (Table 21).

Table 21: The fuel economies (L/100km) for each vehicle type used in this analysis – taken from SATIM numbers

	Bus	Private car	Minibus	Motorbike	Other	LCV (bakkie)
Diesel	31.2	7.5	11.4		7.5	11.5
Petrol		8.3	13.5	5.2	8.3	13.0

The BRT buses are assumed to be 15% more efficient in fuel than the regular buses in this model – making the fuel efficiency of the BRT's 0.38 MJ/Pass-km or just a little more than the minibus taxis. The effective MJ/pass-km efficiencies for each vehicle is calculated based on the total pass-km derived in this analysis and the total fuel consumed for each, the result is given in the table below.

Table 22: The vehicle efficiency in MJ/pass-km by vehicle for local passenger transport

	Bus	BRT	Private car	Minibus	Motorbike	LCV (bakkie)
Diesel	0.45	0.38	1.92	0.34		2.94
Petrol			1.90	0.36	1.67	2.98

5.1.2 CORRIDOR PASSENGER TRANSPORT METHODOLOGY

This section describes the passenger transport requirements along the corridor – through Polokwane, but where vehicles require fuel within the boundary. The total pass-km going through the corridor was estimated using the known number of bus departures/arrivals per day. Using the size of the fuel tanks for the long distance buses and the taxis, and assuming that they only fill up 80% of it when they stop, as well as an assumption on the number of days a year these operate, the total fuel consumption on the corridor for public transport could be estimated (see Table 23).

Table 23: Calculating total fuel consumed for passenger transport along the corridor

	Vehicles*	Tank (L)	% of tank filled **	GJ/tank	Number of days/year**	Total GJ
Long distance bus	43	300	80%	8.6	300	110 837
Long distance taxis – diesel	2	86	80%	2.5	300	1 293
Long distance taxis – petrol	173	86	80%	2.5	300	114 786

* Number of vehicles comes from Aurecon's data for long distance buses and taxis.

** These are assumptions.

Using assumed average occupancy for buses as 50 people, and for taxis 16 people,[2] an assumption of 300 days a year of operations, the total passenger-km demand on the corridor is estimated at 717.4 million passenger-km. Using the total fuel consumption, the efficiency of the vehicles was estimated to be 0.34 MJ/pass-km for the bus, and 0.29 for the long distance taxi. An assumption was made that 20% of all corridor passenger transport involved private vehicles, which equates to 179 million passenger-km. For calibration means (in terms of fuel consumption), some extra fuel for petrol was left over at the end of the analysis for transport of passenger *and* freight (discussed in the next section).

Table 24: Assumptions and calculations of private passenger corridor demand

	% split	Occupancy	L/100km	MJ/km	MJ/ pass-km	Pass-km	Total GJ
Private – diesel	4	2.5	7.5	2.685	1.074	5 071 116	7 705
Private – petrol	96	2.5	8.3	2.664	1.065	77 428 884	183 499

5.1.3 AVIATION

Polokwane has its own small airfield located within the city boundary. The fuel supply data from SAPIA indicated jet fuel consumption and aviation gasoline consumption, reasonable to assume these were used at the local airfield. The total fuel consumption for aviation is given in the table below.

Table 25: Fuel supply to the airfield in Polokwane in 2011

Fuel	Litres
Jet fuel	120 021
Aviation gasoline	177 420

5.1.4 COSTING

To account for cost impacts in the scenarios, cost data from SATIM (ERC) was used to calculate the annualised cost per passenger-km (the end use) (Table 26).

[2] It is assumed that long distance buses (and cars) are more likely to have a higher occupancy for the long trip to be more economical (for buses at least) while travelling long distance in a private car is more likely to have more than one person.

Table 26: Vehicle capital cost data taken from SATIM and calculated cost per passenger vehicle

Vehicle	Capital cost – 2011 rands	Life (years)	Annualised R/pass.km per vehicle (8% discount rate)
SUV diesel	600 495	10	3.18
SUV petrol	579 378	10	3.07
Car diesel	202 883	10	1.59
Car petrol	176 420	10	1.39
Hybrid	360 132	10	2.83
Electric	412 888	10	3.24
Bus	538 230	15	0.05
Minibus diesel	373 771	15	0.06
Minibus petrol	299 017	15	0.04
BRT bus	538 230	15	0.79

5.2 FREIGHT TRANSPORT

The approach here was to calculate corridor demand first then the local city freight, as this was assumed to be less than the corridor freight demand. Aurecon data gave a vehicle count at several stations around the municipality for freight. However, only the N1 route data could be used to avoid double counting. The registration database could not be used for freight as easily since there would be a lot of trucks registered elsewhere and being used through Polokwane and vice versa. The figure below shows the counting stations in the survey.

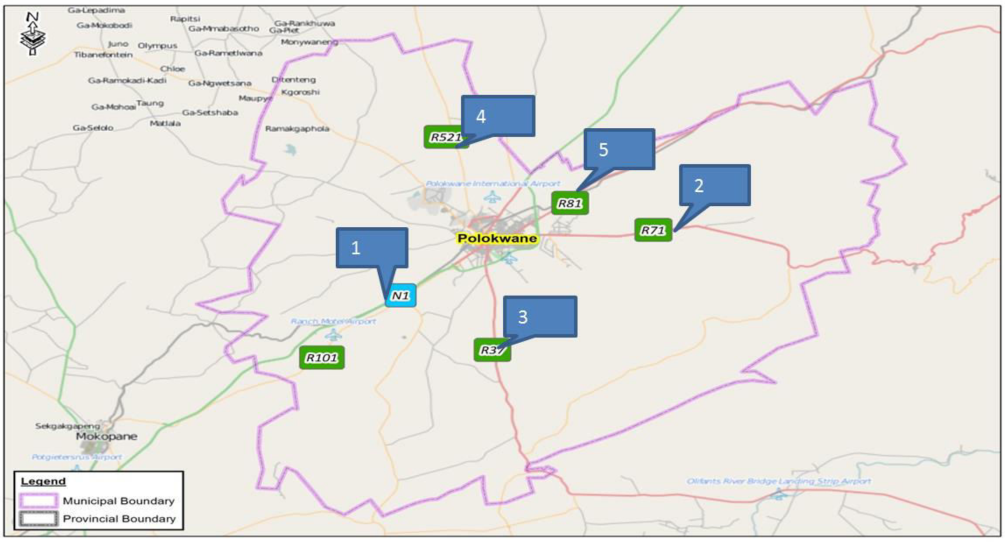

Figure 5: The location of the counting stations for the freight/truck count survey

Source: Aurecon (2013)

Only one data point could be used from this survey, however, since there would inherently be double counting if more than one data point were used – some vehicles would pass through two points. The data point for the N1 (point number 1 in the figure) counting station was used – the main corridor and the tally was 2335 trucks – 55.1% were 'long heavy vehicles', 22.8% were 'medium heavy vehicles', and 22.1% were 'short heavy vehicles'.

Table 27: Vehicle counting data for Polokwane key corridor roads

Road section	Route	Distance of section (km)	Avg daily trucks at counting station	Vehicle kilometres			
				All HV	Short HV	Medium HV	Long HV
1	N1	52	2 335	121 403	26 838	27 703	66 875
2	R 71	45	1 083	48 727	28 774	14 412	5 540
3	R 37	37	824	30 505	16 282	4 695	9 527
4	R 521	28.5	876	24 951	7 962	5 862	11 127
5	R 81	27.5	719	19 779	7 278	4 697	7 812
			Total Veh-km =	245 367	87 136	57 371	100 883

Source: Aurecon (2013)

5.2.1 CORRIDOR FREIGHT

The corridor freight is split into road and rail.

5.2.1.1 Road freight

The steps in the methodology for calculating the corridor freight can be summarised as follows:

- The number of heavy, medium and light vehicles recorded by the N1 counting station (Aurecon, 2013) is assumed to represent the total frequency of corridor trips by road vehicles.
- A frequency of refuelling and the average quantity filled (based on typical fuel tank sizes) is assumed.
- Calculate the total fuel consumed by each vehicle type using these assumptions.
- Assuming typical average truck fuel efficiencies (MJ/ton-km) calculate the total ton-km for each vehicle type from the fuel consumed by each from the above step.

The counting station on the N1, recorded a total of 2 335 heavy, medium, and light trucks passing through on an average day. An assumption was made that 85% of this traffic is corridor traffic – leaving a total of 1 985 trucks passing through the counting station assumed to be corridor freight.

Table 28: The general assumptions and calculations for corridor fuel consumption by vehicle type (grey-shaded cells are assumptions)

Vehicle type	Split *	% traffic which fill up	% are diesel	Nett Vehicle count*	GJ Diesel fill up/day	GJ petrol fill up/ day	Days/ year	Total diesel – GJ	Total Petrol – GJ
HCV	55.1%	75%	100%	1093	2936		300	880 657	-
MCV	22.8%	50%	60%	453	292	174.5	300	87 557	58 371
LCV	22.1%	50%	43%	439	152	180.6	300	45 592	54 190

* This is based on the vehicle count for counting station 1 from Table 27

Using the total fuel used by each truck type, and vehicle efficiency in MJ/ton-km (from SATIM methodology), the total ton-km can be estimated for the corridor freight. Table 33 shows the final calculated freight demand for Polokwane's corridor.

5.2.1.2 Rail freight

The 'Feasibility study on rail development in Limpopo province 2006' (LTE Consulting, 2006) report indicated there was a total of 227.8 million ton-km of rail freight on the Polokwane–Groenbult route. Assuming the locomotives are diesel-fuelled, and using SATIM numbers for diesel rail freight of 0.23 MJ/ton-km, the total diesel consumed on this route would be 52 394 GJ per year. This data should be reviewed in future data collection iterations, however, as there may be more freight than this travelling by rail through Polokwane.

5.2.2 LOCAL FREIGHT

Local freight was estimated using the 'LCV' vehicle registration count and the remaining fuel balance from the previous transport sections in the following method:

- Calculate the LCV freight contribution from the LCV vehicle count left over from the passenger section.
- Tally remaining fuel for calibration of the model (next section).

The remaining LCV count from the eNATIS data after allocation to passenger travel use is assumed to be active in local road freight. Again, using the same assumption as in the passenger section on the number of inactive LCV's in the city, and using the diesel/petrol split with an assumption of the total capacity of each vehicle (on average about 0.3 tonnes), the total ton-km by LCVs in Polokwane can be determined. The LCV freight calculation summary is given in the table below.

Table 29: Local freight data and assumptions for Polokwane

	Split	Inactive here	No. of vehicles.*	Capacity (tons)	Mileage (km/yr**)	Ton-km	L/ 100km	Fuel (L)	Fuel – GJ	MJ/ ton-km
Diesel	43%	20%	9 525	0.3	20 097	57 427 899	11.5	22 014 028	788 102	13.72
Petrol	57%	20%	12 626	0.3	20 097	76 125 355	13.0	32 987 654	1 058 904	13.91

* Vehicle count comes from the number of LCVs not used for passenger transport in the passenger section.

** The mileage is an assumption and is used to calculate the total ton-km using the average capacity assumption.

Using the SAPIA data provided for the total fuel supplied to the city, the remaining diesel and petrol left over after accounting for all other transport demand as discussed above is assumed to be used for local freight provided by MCVs and HCVs in Polokwane.

5.3 CALIBRATION

In this analysis and the assumptions made, the remaining fuel left was on the order of 10% for diesel and petrol fuel quantities (see Table 30).

Table 30: Fuel remaining after transport model calculations

	GJ of fuel remaining	% of all fuel supplied fuel
Diesel	224 619	8.73
Petrol	428 293	11.2

To calibrate the model to the total fuel supplied to Polokwane, it is assumed, with the large uncertainty around the extent of the corridor transport, the remaining fuel be allocated there. To 'even out' the fuel that is left over, 200 000 GJ of petrol is allocated to the corridor passenger private transport, while the remaining 228 293 GJ of petrol and the remaining diesel (table above) are used for local freight transport (below). Using an assumption that the majority of local freight (apart from LCVs which are already accounted for above) is through MCVs and then a smaller quantity in HCVs, the total freight then is calculated using typical fuel efficiencies (see Table 31).

Table 31: Calculating the remaining local freight using the balance of fuel remaining.

	% fuel split	MJ/ton-km*	Diesel ton-km	Petrol ton-km
HCV	10%	1.2	1 306 793	
MCV – D	90%	4.6	2 991 869	
MCV – P	100%	4.6		80 955 671

* Taken from ERC's SATIM model input data.

5.4 SUMMARY OF TRANSPORT

This section presents summary tables of the transport methodology section for input into the model.

5.4.1 PASSENGER

Table 32: Summary total passenger demand for Polokwane for 2011

	Pass-km	Share
Passenger total	3 700 555 914	100.0%
Corridor	1 084 455 617	29.3%
Local	2 616 100 297	70.7%

Table 33: Summary corridor passenger transport demand and detail for Polokwane in 2011

Corridor total	1 084 455 617	Pass-km	
Corridor – public	66%	of total	
		% share	MJ/pass-km
	Bus	45.0%	0.34
	Minibus – D	0.7%	0.25
	Minibus – P	54.3%	0.29
Corridor – private	34%	of total	
		% share	MJ/pass-km
	Diesel	2%	1.074
	Petrol	98%	1.066

Table 34: Summary local passenger demand and detail for Polokwane in 2011

Local passenger	2 616 100 297	Pass-km	
Motorised	2 016 092 281	77.1%	of local passenger
Public	54.8%		of motorised
Vehicle type	Share	MJ/pass-km	
Bus	18%	0.45	
Minibus – D	1%	0.34	
Minibus – P	81%	0.36	
Private	45%		of motorised
Vehicle type	Share	MJ/pass-km	
car diesel	5%	1.92	
car gas	76%	1.90	
motorbike	2%	1.67	
LCV gas	7%	2.94	
LCV diesel	10%	2.98	
Non-motorised	600 008 017	22.9%	of local passenger
Walking		98.1%	of non-motorised
Bicycle		1.9%	of non-motorised

5.4.2 FREIGHT

The overall freight demand for Polokwane in 2011 is given in Table 35.

Table 35: Summary total freight demand for Polokwane in 2011

Subsector	Tonne-km	Share
Freight total	1 275 948 681	
Corridor	1 031 583 010	80.8%
Local	244 365 671	19.2%

The breakdown of each freight group is given in the tables below for HCVs, and medium and light commercial vehicles of both petrol and diesel type.

Table 36: Summary corridor freight breakdown for Polokwane in 2011

Corridor road	803 783 010	Ton-km
Vehicle	**Share of freight**	**MJ/ton-km**
HCV	94.78%	1.16
MCV – D	2.25%	4.56
MCV – P	1.26%	4.56
LCV – D	0.95%	5.6
LCV – P	0.76%	8.4

Table 37: Summary local freight breakdown for Polokwane in 2011

Local		244 365 671	Ton-km
Vehicle	**Share of freight**	**Ton-km split**	**MJ/ton-km**
HCV	7.92%	19 363 724	1.16
MCV – D	18.14%	44 332 737	4.56
MCV – P	19.28%	47 115 955	4.85
LCV – D	23.50%	57 427 899	13.72
LCV – P	31.15%	76 125 355	13.91

6. MUNICIPAL SECTOR

This section details the municipality's use of energy within the city. This includes its service vehicle fleet for the city, traffic and street lights, water systems and general municipality building energy use.

6.1 DATA

Most of the data for the municipality comes from Aurecon (2013) and is indicated in Table 38.

Table 38: The total fuel supply (in GJ) to the municipality's operations in Polokwane in 2011

	Street lighting	Miscel-laneous	Water / sewerage	Transport	Totals
Electricity	53 053	2 542	26 168	-	81 763
Diesel	-	-	-	23 724	23 724
Petrol	-	-	-	18 033	18 033
Totals	53 053	2 542	26 168	41 757	123 520
Share	43.0%	2.1%	21.2%	33.8%	100.0%

Source: Aurecon (2013)

6.2 TRANSPORT

This section comprises the municipality's fleet of vehicles for operations, ranging from garbage trucks to general utility vehicles. All liquid fuels allocated to the municipality are allocated to this section. Without a vehicle count for the municipality's operations, only the total fuel consumed can be incorporated into the model. This would still show the contribution to the overall energy picture of the city, and would indeed be expected to grow in consumption with the growth of the population of the city – the number of services grows proportionally.

6.3 LIGHTING

This section comprises the public street lighting and traffic lights in Polokwane. From the Aurecon data for the SoE draft report the total energy consumption for all public lighting was split into public street lights and traffic lights. The number of LED traffic lights replaced was taken from Botes et. al. (2014), and also confirmed through communication with the municipal SAMSET partners. The document stated that 1096 traffic lights were replaced in 2010/2011 with LED lights and this made up 44% of all traffic lights. The remainder were replaced the year after. The wattages used were taken from 'Efficient public lighting guide' (SEA, 2012). Note that the report indicated 'traffic signal head', and it is not clear as to whether this indicates individual lights in the traffic signals or the whole traffic signal (three bulbs per head – red, amber and green). This methodology assumes that this is 1091 traffic heads (each of which have three bulbs) and one bulb operates at a time.

Table 39: Traffic lights in Polokwane in 2011

Traffic light	Number of devices*	Watts per bulb	kWh/yr.
Incandescent	1 091	75	716 727
LED	1 400	5	61 320
Total	2 491		778 047

Source: Botes. et. al. (2014)

The street lights were then calculated as the balance of the total energy reported by the SoE (53 053 GJ) after deducting the above traffic light contribution (see Table 40). The number of lamps was also reported in the SALGA report (Botes et al., 2014), at 12 757 of 70W HPS lamps. They replaced the original mercury vapour (MV) 125W lamps with these lamps by 2012.

Table 40: Street lamps in Polokwane in 2011

Total energy consumed		13 958 953	kWh
Total number of 70W lamps:		12 757	Lamps
Total energy consumed	@ 12hrs a day	3 911 296	kWh
Total energy per 70W bulb		306.6	kWh
Total energy left for all 125W bulbs		10 047 657	kWh
Total energy per 125W bulb		547.5	kWh/year

Source: Botes et al.(2014)

6.4 WATER SYSTEMS

The waste water systems in Polokwane consumed a total of 26 168 GJ of electricity in 2011. According to discussions with the engineers with Polokwane municipality, the waste water systems have been retrofitted with variable speed drives, but these were not as yet fully optimised (by 2015). It is believed once the systems are optimised for the VSDs that a savings of 50% can be achieved.

6.5 OTHER

The remaining allocation of electricity – the 'Miscellaneous' group in Table 36 is allocated to general municipal buildings and includes the 'electricity department own use'.

7.HOUSEHOLD SECTOR

7.1 OVERVIEW

This sector is one of the more challenging sectors to represent in a model due to the diverse number of different energy uses in the household (HH) and met with many different technologies, as well as the compounding effect of HH behaviours varying between income groups and electrification.

The HH sector in this model is split into electrified and non-electrified HHs. The proportion of HHs that are electrified is based on the proportion of HHs which use electricity for lighting – and this data is derived from the national census 2011 for Polokwane. It is assumed that HHs that have electricity will use it first for lighting before being used for other end use services. These two categories are further split into two income groups; low income, and mid to high income HHs. With the lack of sufficient data on energy use in HHs in Polokwane, only these two income groups where used, as splitting the groups into low, medium, and high income groups would create more uncertainty than would have benefit been gained, but this approach still keeps the resolution of the HH subsectors that would be useful for keeping information about socio-economic development. Using the census 2011 data, the HH sector is split into three income groups (see Table 41). The groupings have been aligned with the same income groupings as ERC's SATIM model data for households.

Table 41: Income grouping of households in Polokwane

Census category R/month	Lower annual R/year	Annual upper R/year	Group*	Share of all HHs in Polokwane
None	0	0	Low-income	13.8%
R1–R400	12	4 800	Low-income	4.8%
R401–R800	4 801	9 600	Low-income	8.5%
R801–R1 600	9 601	19 200	Low-income	19.3%
R1 601–R3 200	19 201	38 400	Mid-income	19.7%
R3 201–R6 400	38 401	76 800	Mid-income	11.7%
R6 401–R12 800	76 801	153 600	High-income	8.1%
R12 801–R25 600	153 601	307 200	High-income	7.2%
R25 601–R51 200	307 201	614 400	High-income	4.6%
R51 201–R102 400	614 401	1 228 800	High-income	1.6%
R102 401–R204 800	1 228 801	2 457 600	High-income	0.4%
R204 801 or more	204 801		High-income	0.3%
* The groupings have been aligned with the same income groupings as ERC's SATIM model data for households.				

Source: Statistics South Africa, Census 2011

The share of the HH income groupings have been changing over the last 10 years in Polokwane. The HH income grouping definition (see first column of table above) for the national census has not changed since 2001 – that is, the income categories were in nominal prices, but in order to obtain the population for 2001 income groups that would correspond to the 2011 rands used for the 2011 census an adjustment to the 2001 income brackets is done using the Consumer Price Index (CPI) for the years 2001 and 2011. For 2001 the CPI was 52.4 (where CPI = 100 in the 2012), and for 2011 the CPI was 92.6 (Statistics South Africa, 2015). Thus a person earning R4 800 in 2001 was equivalently earning R8 482 (R4800 x 92.6/52.4) in 2011 rands. Using this adjustment, many people in the R1–4800 bracket fall into the R4801–9600 bracket. This adjustment was applied to all income groupings for the 2001 census and compared to the populations for the 2011 census.

Table 42: Household count by income group for the 2001 (adjusted for inflation) and 2011 censuses

Income group	2001	2011	Growth over 10 years	Annual growth
Low-income	72 506	82 554	14%	1.31%
Mid-income	32 147	55 847	74%	5.68%
High-income	20 194	39 590	96%	6.96%
All	124 847	177 991	43%	3.61%

According to the census data, Polokwane's mid-to-high-income groups have been growing at more than 5.6% per year, while low-income groups have increased at just over 1.3% per year.

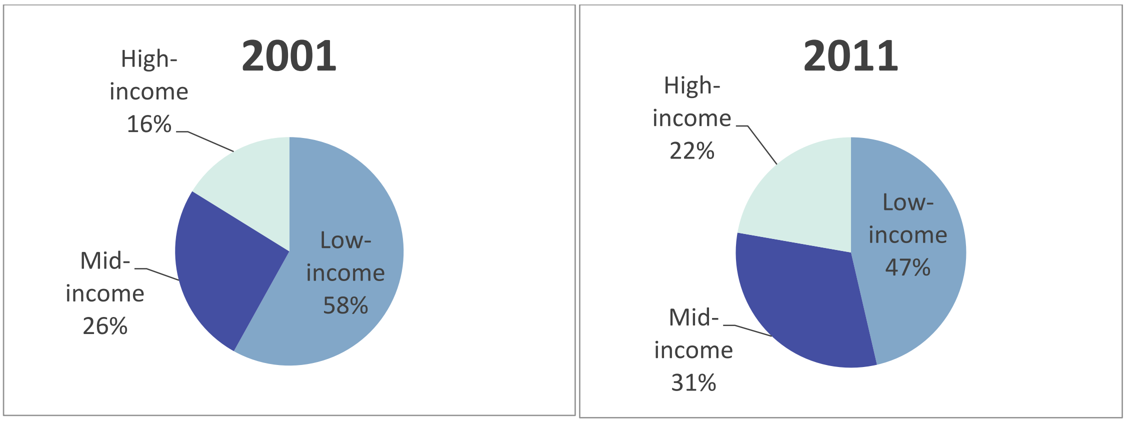

Figure 6: The comparison of HH income groups between 2001 and 2011 census data for Polokwane

Note that low income is an annual income of R0–R19 200, middle income is R19 201–R76 800 and high income anything above R76 800. Inflation has been accounted for in this comparison.

7.2 DATA

The methodology employed in this study to represent the HH sector in LEAP is to use a bottom-up end use analysis to determine the total shares of each fuel and technologies used by HHs to meet their needs. This is then calibrated to the known overall fuel consumption from data – such as the known electricity sales to HHs in Polokwane.

Sources of data in this study are national statistics (mainly the Census and Community Survey 2007 by Statistics South Africa), and the Aurecon Report which includes municipal accounts and distributor accounts. Data was also adopted from the SATIM models and methodologies (ERC, n.d) for various end use technologies in the bottom up analysis used in this methodology.

HH fuel source for the lighting, cooking and space heating, from data from the Census 2011 is presented in Table 41. In this methodology water-heating is assumed to follow a similar profile for cooking: the assumption here is that low-income HHs that do not have a water-heater (a geyser) would most likely use their stove to heat required water.

Table 43: Census 2011 data for household energy use by end use for Polokwane

		Electrified households		Non-electrified households	
End use	**Energy carrier**	**Low**	**Mid-to-high**	**Low**	**Mid-to-high**
Lighting	Electricity	77%	88%	0%	0%
	Gas	0%	0%	1%	1%
	Paraffin	2%	1%	9%	11%
	Wood	0%	0%	0%	0%
	Coal	0%	0%	0%	0%
	Animal dung	0%	0%	0%	0%
	Solar	1%	1%	3%	5%
	Other	0%	0%	0%	0%
	None	0%	0%	1%	1%
	Unspecified	0%	0%	0%	0%
	Candles	20%	10%	86%	82%
Cooking	Electricity	82%	87%	1%	3%
	Gas	1%	2%	5%	11%
	Paraffin	2%	1%	60%	59%
	Wood	14%	10%	33%	27%
	Coal	0%	0%	0%	0%
	Animal dung	0%	0%	0%	0%
	Solar	0%	0%	0%	0%
	Other	0%	0%	0%	0%
	None	0%	0%	0%	0%
	Unspecified	0%	0%	0%	0%
	Candles	0%	0%	0%	0%
Heating	Electricity	68%	76%	1%	2%
	Gas	1%	1%	2%	4%
	Paraffin	1%	1%	26%	26%
	Wood	17%	12%	42%	35%

End use	Energy carrier	Electrified households Low	Electrified households Mid-to-high	Non-electrified households Low	Non-electrified households Mid-to-high
	Coal	0%	0%	0%	0%
	Animal dung	0%	0%	0%	0%
	Solar	0%	0%	0%	0%
	Other	0%	0%	0%	0%
	None	13%	10%	28%	31%
	Unspecified	0%	0%	0%	0%
	Candles	0%	0%	0%	0%

Source: Statistics South Africa, Census 2011

The Aurecon data provided total energy consumed for fuels in the residential sector of Polokwane. Paraffin was not included in the report, but SAPIA magisterial data for paraffin sales into Polokwane was used. It was assumed that the majority of paraffin (2.7 million litres in 2011) was used for household use with a small amount for the commercial sector.

Table 44: Initial household energy consumption total before bottom-up analysis

Fuel	GJ/annum	Source
Electricity	2 021 109	Aurecon – Eskom and municipal accounts
Wood	92 299	Aurecon estimation
Coal	1 741	Aurecon estimation
Gas	39 969	Aurecon estimation
Paraffin	84 078	SAPIA data
Total	2 222 172	

Number checking and further rationale for bottom-up analysis

LPG

The LPG usage that Aurecon reported (39 969 GJ) was found to be too high. When converting the total GJ per HH into litres, each HH would be consuming 226L per year. Converting this into the number of 9kg LPG bottles, this equates to 13.6 x 9kg bottles per year for cooking, and heating. With this result, it is concluded here that this LPG consumption is too high, and instead, a bottom-up end-use analysis is done to provide an estimate, provided also that this estimate falls reasonably within the total LPG sales data for Polokwane.

Wood

The Aurecon report provided an intensity of 83.75kg of wood per year per HH. This translates to about 6.9kg per month of wood. Using data from SATIM of rural HHs in Mpumalanga, the average HH would consume between 150kg and 230kg per month on just cooking, if the main source of fuel for cooking is wood. If the HH consumed various fuels, the wood consumption drops to about 100kg per month. Given that this is for rural HHs, where tradition would play a larger role in cooking habits and wood consumption, it stands to reason that the assumption of just 7kg per month is still too low even for a rural setting in Polokwane. In this analysis, a bottom-up analysis was done using various assumptions on HH usage per end use and per income category to provide a total energy consumption of wood. Various sources of information and surveys were used to guide the assumptions.

Coal

The Aurecon report made an assumption of 10kg per month for consumption. As with wood and LPG, a bottom-up end-use analysis is done to estimate the total coal consumption for all HHs.

Electricity

The Aurecon report provided detail about electricity sales from the municipality to domestic consumers (both prepaid, and billed) as well as those supplied by Eskom through NERSA sales forms. Using this known electricity consumption number, the bottom-up end-use approach was calibrated to meet this total demand for electricity by adjusting operating hours or number of devices per HH and so on until the total HH electricity consumption matched the known electricity sales. Any information about electricity use (such as data from the Census, or from Aurecon's report) was inserted into the calculations of the end-use fuel consumptions.

Paraffin

The sales of paraffin to Polokwane were obtained using SAPIA data and adjusted to compensate for the boundary overlaps of the districts within Polokwane. It is assumed that the majority of paraffin is used by HHs, and so in the bottom-up analysis paraffin need only be below the total fuel consumption in Polokwane – it is known that a small amount of paraffin is being used in the commercial sector, from information in the AQM (2006).

7.3 HOUSEHOLD ENERGY CONSUMPTION METHODOLOGY

As stated above, a bottom-up analysis of each end-use (cooking, lighting, heating, water-heating, and 'other') as well as each fuel associated with that end-use – based on the Census data, was carried out in order to determine energy-intensity values. This approach involves using known efficiencies for typical HH appliances such as stoves or geysers, while making assumptions on the overall use by each HH – how much hot water is needed by the HH on a daily basis and so on. These assumptions were adjusted staying within reasonable limits in order to calibrate to a known energy consumption value – in this case electricity, paraffin and LPG which are known quantities sold within Polokwane. Wood and coal were not calibrated to meet a top-level fuel demand.

The bottom-up end-use analysis was carried out by starting with the total useful energy required and converting this to final energy using efficiency numbers for common technologies used in HHs (like electric stoves). This final energy consumption is then adjusted for the scale – such as the number of hours a day that a heater may be used and the number of days a year that the heater is needed etc. The tables below indicate the total energy consumption for the HH sector after this bottom up analysis is completed.

Table 45: The total fuel allocation for the household sector in Polokwane in 2011 in this methodology

Fuel	GJ/annum	Comment
Electricity	2 037 724	Calibrated to Aurecon data
Wood	443 036	Much higher than Aurecon data
Coal	5 694	Higher than Aurecon data
Gas/LPG	7 998	Lower than Aurecon data
Paraffin	83 621	Marginally higher than SAPIA number
Total	2 542 989	

The total energy consumed by each fuel for each end use was also used and sense-checked[3] while completing the bottom up analysis (see Table 46).

Table 46: Total energy consumption (in GJ) by end-use and by fuel

	Lighting	Heating	Water- heating	Cooking	Other
Electricity	381 731	210 828	1 143 848	164 303	137 014
Gas	271	2 252	1 486	3 989	
Paraffin	13 288	4 216	41 852	24 266	
Wood	-	141 848	170 257	96 397	
Coal	-	3 007	1 389	748	
Total	395 396	362 150	1 360 392	289 704	

The total energy intensity values for each end use for the household sector as a result of this methodology are presented in Table 47.

[3] Such as checking that the resulting numbers show typical HH energy consumption behaviours such as water-heating being the main/majority electricity consumer in electrified households.

Table 47: Household energy intensity values in MJ/household per year for each end-use and fuel

		Electrified		Non electrified	
End-use	Fuel	Low-income	Mid-to-high	Low-income	Mid-to-high
Cooking	Electricity	1 860	867	0	0
	Gas	1 322	590	1 322	590
	Paraffin	1 493	667	1 493	667
	Wood	4 629	2 066	4 629	2 066
	Coal	6 172	2 755	6 172	2 755
	Animal dung	0	0	0	0
	Solar	926	413	926	413
Water heating	Electricity	3 713	13 268	0	0
	Gas	1 474	4 010	1 474	4 010
	Paraffin	1 902	2 283	1 902	2 283
	Wood	5 897	7 076	5 897	7 076
	Coal	7 862	9 435	7 862	9 435
	Solar	1 179	10 614	1 179	10 614
Heating	Electricity	1 261	2 523	0	0
	Gas	916	916	916	916
	Paraffin	336	671	336	671
	Wood	3 577	5 366	3 577	5 366
	Coal	6 570	9 855	6 570	9 855
Lighting	Electricity	1 343	4 456	0	0
	Gas	621	621	621	621
	Paraffin	2 483	2 483	2 483	2 483
	Solar	39	70	39	70
	Candles	540	720	540	720
Other	Electricity	679	1 721	0	0

7.4 COSTING

The costs associated with interventions in the scenarios, presented in the sections later, are given in Table 48. These are the capital costs associated with the energy efficiency scenarios, and do not include the fuel costs – the fuel costs are presented in the BAU scenario section.

Table 48: Cost of devices for household scenario interventions adapted from SEA report for the Cape Town LEAP model

	2011 rands per device		Lifespan (years)
	Low-income	Mid-to-high income	
LED 5W		139	10
CFL 9W	23	23	4
Incandescent 60W	6	6	1
Candles*	1 080	1 480	
Elec geyser	3 000	6 000	10
Elec geyser with blanket	3 365	6 365	10
SWH	5 101	14 431	20
Gas lamp	260	260	10
Paraffin lamp	50	50	10
Gas heater	1 100	1 100	10

* These are annual numbers based on 540 and 720 candles used on average per HH respectively and at R2 per candle.

8. INDUSTRY SECTOR

There are two industrial smelters within the boundary of the city that are supplied by Eskom and are large energy users. There are also several other industries located within the boundary of Polokwane such as a Coca-Cola plant, Sasko, and Enterprise (Aurecon, 2011).

Data issues

The data from Aurecon on Eskom electricity (900MWh) is far too low to be used for the smelters. The Anglo platinum smelter has a 68MW furnace (van Maneen, 2008) which, if used at 80% capacity factor, would consume 476 544 MWh per year. Because of this discrepancy the Aurecon data for industry electricity consumption is used for industry not including smelters –i.e. the Aurecon electricity in industry is assigned to general industry in Polokwane. The other smelter is the Silicon smelter producing metallic silicon with 3 x 48MVA furnaces (Ferro Atlantica, 2015) and would consume energy on a comparable scale to the Anglo smelter.

8.1 METHODOLOGY

The industrial sector is split into heavy industry and 'other' industry, where heavy industry represents the smelters, and 'other' will represent the 'smaller' industries such as the Coca-Cola plant, Sasko and all other industries in Polokwane. This is done since the smelters are just two companies and are largely out of the influence of the municipality, and with these subsector categories we are able to explore scenarios where the municipality has influence over, and thus is more relevant to, city planners and decision-makers.

Most of the information for the industrial sector is supply-side, with little to no information on demand-side consumption. There is some information on demand-side consumption for the Anglo smelters in the way of some technical papers available online (van Maneen, 2006; 2008; De Clerk, 2012), while there is some information on the Silicon smelters website (see Ferro Atlantica, n.d) on total maximum output of the plant as well as the total maximum power consumption in their furnaces. Information is also gathered, where available, from various online reports and articles, and this is merged with the data from Aurecon to form a data set of fuel consumption in industry in Polokwane. The fuel consumption data for all industries in Polokwane is collated, and broad assumptions on where these are consumed are made – such as 'process heating'.

8.2 DATA

The Air Quality Management report (AQM) by Rautenbach et al. (2006) has a list of 'minor sources' for emissions in Polokwane for industries. While the smelters were included in the 'major sources' part of the table, there was no data provided. The table does provide a good representation of coal and, to a degree, paraffin and diesel consumption in the rest of industry in Polokwane, but no electricity consumption. For industry, the AQM provided some fuel consumption for the year 2006 for the factories/manufacturers in Polokwane. mainly for coal consumption. Table 49 is taken from the AQM.

Table 49: Fuel consumption for Polokwane's smaller industries in 2006

	Entity	Fuel	Use	Tonnes/year	Comment
Industries – larger companies	Coca-Cola	Coal	Boilers	1 560	
	Enterprise	Coal	Boilers	5 000	
	Sasko	Coal	Boilers	480	
	SAB	Coal	Boilers	6 480	
Other industries or manufacturing		Polyfuel	Boilers	438 000	Unknown units/fuel
		Coal	Boilers	1 220	

Source: AQM (Rautenbach et. al., 2006)

The AQM collected data from many businesses or industries in Polokwane, as indicated in Figure 7 below, but many of the data points are grouped into the commercial sector – mainly the schools, dry cleaners, clinics and hospitals etc.

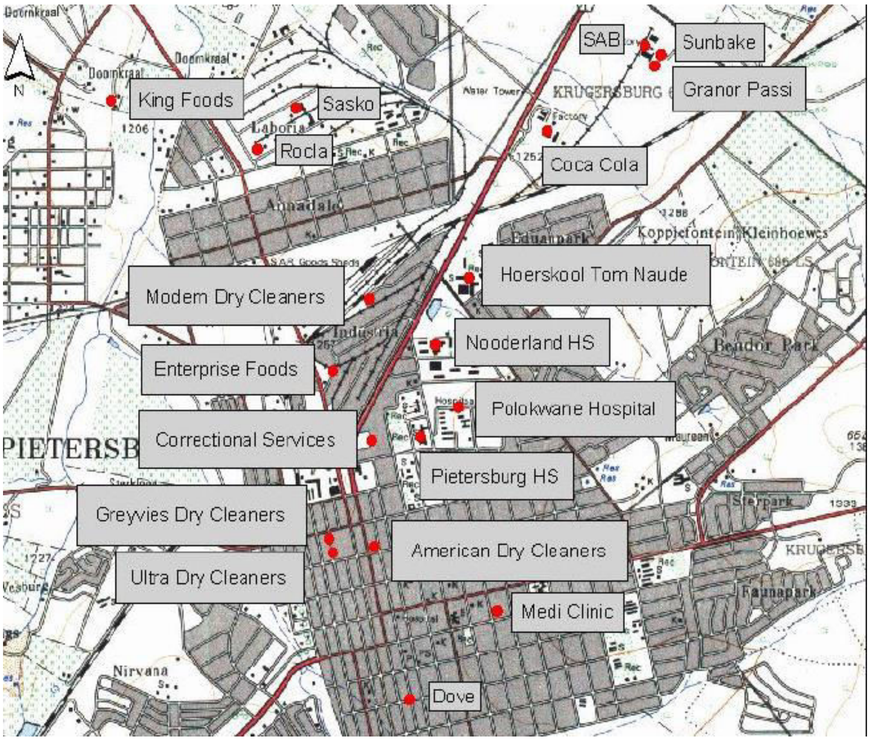

Figure 7: Map of all the commercial and industrial locations where fuel consumption was collected for the study – not including the two smelters

Electricity

Heavy industry

The electricity consumption for the large industries – the two smelters – is determined from what is published online and using some assumptions on operating factors. For the Silicon smelter, we use the electricity energy intensity of 13 MWh/tonne from Xakalashe (2011) and their production value for 2008 of 51 800 of Si metal (International Business Publications, 2014) which is 95% of their maximum capacity. For the Anglo smelter, we use the rated capacity available from van Maneen (2006, and 2008) of 68MW which is designed for 90% capacity factor operation, but we assume that the actual was 75% which is less in 2011, relative to its maximum in 2010, based on the total South African Platinum group metals production profile published by Statistics South Africa (2015b).

Other industry

Electricity for all other industries in Polokwane is taken from the Aurecon report and adjusted for data received by the Municipality.

Coal

The coal for heavy industry is data from the Aurecon report and is thought to be reliable, based on communication from Aurecon as well as a check with Anglo Platinum's sustainability report and the sulphur emissions from their Polokwane plant. The Anglo Platinum smelter has two coal-fired flash dryers to dry the concentrate before being fed into the furnace (van Maneen, 2006). It is assumed that all coal consumed at this smelter is for the dryer. The coal consumption data from the AQM is used for the 'other' industries and is used for heating. The AQM indicated that the coal was used in boilers, but it is common for boilers to be used for generating heat for industrial use.

LPG

Most LPG is consumed within the residential sector. The residential sector consumption was calculated bottom-up, and the remaining fuel was assumed to be used in commerce – assuming this to be for cooking in restaurants. Without data on industrial LPG consumption, in this model none is consumed within industry.

Diesel

Consumption here is assumed to be for transportation. The data for diesel in industry comes from Aurecon's data, and was indicated that the Anglo Platinum smelter, Sasko, Coca-Cola, and Enterprise factories used diesel. However, this is not included in the model in this sector and is assumed to be consumed within freight in the transport sector.

Charcoal

The Silicon smelter in Polokwane uses charcoal as a reducing agent in their works. In 2004, it was reported that the silicon smelter used 90% of industrial charcoal in South Africa – about 85 000 tonnes (DoWF, 2004). A news report in 2011 about local charcoal suppliers for the smelter indicated the smelter consumed about 120 000 tonnes per year for reducing (Radebe, 2011). In this methodology, we adopt the 120 000 tonnes per year as the total charcoal consumption for industry.

Heavy fuel oil - HFO

The AQM data indicated some HFO use in dry cleaners (commercial sector), but only on the order of 5% of all the HFO assigned to Polokwane from the SAPIA data. Here, the remaining (95%) is assumed to be consumed in 'other industries' for heating purposes. It is possible this is consumed by the brick factories in Polokwane.

The total fuel consumed in the industries in Polokwane is summarised in Table 50.

Table 50: Industry energy consumption in Polokwane in 2011 (in GJ)

Industry	Electricity	Coal	Charcoal	HFO
Other	1 434 763	397 980		63 079
Heavy	4 050 379	3 791 173	3 240 000	
Total	5 485 142	4 189 153	3 240 000	63 079

8.3 HEAVY INDUSTRY OUTPUT

In this methodology, it was attempted to estimate the total production output from the smelters in order to have a handle on growth assumptions and scenarios. Using numbers for energy intensity by Warner et al. (2007) and the published numbers for Polokwane smelter capacity (see Ferro Atlantica, n.d) the combined total output for both smelters is estimated to be 70 474 tonnes. Using the fuel consumption data and assumptions on the use of those energy sources, Table 51 lists the end uses for industry and their associated energy intensities.

Table 51: Energy end-use intensity values for industry in Polokwane in 2011

End use	Fuel	Fuel consumed	Units	Intensity	Units
Heavy industry					
Heating	Coal	3 791 173	GJ/year	53.8	GJ/tonne
	Electricity	3 082 473	GJ/year	43.7	GJ/tonne
Other	Electricity	967 906	GJ/year	13.7	GJ/tonne
	Charcoal	120 000	tonnes/year	1.7	t/tonnes
Other industry					
Heating	Coal	397 980	GJ/year		
	LPG	-	GJ/year		
	HFO	1 608 770	L/year	22.8	L/tonne
Other	Electricity	1 434 763	GJ/year		

9. COMMERCIAL SECTOR

This sector comprises shopping malls, shops, office blocks and office spaces, hospitals, schools, and banks, etc.

9.1 DATA

Electricity data for the commercial sector comes from the adjusted Aurecon data and the municipality data (see Table 8 and section 4.2). The AQM (2006) data has coal, paraffin, and diesel consumption for dry cleaners, car service centres, hospitals and schools and indicates the fuel was used for heating (space heating, and process heating) and incinerators. LPG usage was given by Aurecon but for the total supplied to the city. Here it was assumed that remainder of LPG fuel after residential bottom up analysis was used in the commercial sector. We assume that LPG usage is most likely used for cooking and for space heating.

9.2 METHODOLOGY

The total fuel allocations to the commercial sector from the data sources are given in Table 52. Using this national average for electricity to floorspace intensity (331 kWh/m^2) from the SATIM model (Energy Research Centre, nd) and the total electricity sold to commercial entities in Polokwane (110 899 MWh), the total floorspace in Polokwane is calculated to be 335 204m^2.

Table 52: Fuel consumption in the commercial sector of Polokwane in 2011

Fuel	Quantity	Units	Year	Source	Comment
Electricity	110 899	MWh	2011	Municipality	
LPG	3 808	Litres	2011	SAPIA	Remainder of LPG after residential sector bottom up analysis
Coal	2 910*	Tonnes	2006	AQM	Used for space heating and incinerators in hospitals/schools/dry cleaners
HFO	73 000*	Litres	2006	AQM	Used for boilers
Diesel	20 800*	Litres	2006	AQM	Used for incinerators
Paraffin	14 600*	Litres	2006	AQM	Used for boilers

* This data is from the AQM which was dated 2006. Coal usage could be assumed reasonable to not change greatly (unless there is technology switching) in hospitals and schools. HFO was used by dry cleaners presumably for process heating (drying clothes or heating the water for cleaning). Diesel use was for incinerators at the medi-clinic and is also reasonable to assume (Google search indicates they are still there) this has not changed in 5 years. Paraffin is used for boilers at the local Supa Quick. It is assumed that these numbers are approximately equal to the fuel consumption in 2011.

End-use services

Using the SATIM fuel consumption share splits by end-use, the fuels allocated to the commercial sector were split over the end-uses – distributing the total energy consumption over the various end uses, then using the floor space from above, the intensities for each fuel and end-use was calculated. Process heating was added as an end-use in this model since the AQM data showed there were several incinerators being used in the area and boilers providing heat not used for space-heating. This would normally go under the 'other' category of end-uses, but since there was some representation of process heating from the AQM data, it was warranted to have this end-use. The results of these steps are given in the two tables below.

Table 53: Fuel consumption by end use for the commercial sector for Polokwane in 2011

	Lighting	Space-heating	Water-heating	Cooling & ventilation	Refriger-ation	Cooking	Process heating	Other	Unit
Electricity	41 675	5 374	3 638	33 260	7 864	403		18 686	MWh
Coal		26 766					51 809		GJ
HFO							2 862		GJ
Paraffin							503		GJ
Diesel							744		GJ
LPG			79.7			8.9			GJ

Table 54: Energy intensities by fuel for each end-use in the commercial sector in Polokwane in 2011

	Lighting	Space-heating	Water-heating	Cooling & ventilation	Refriger-ation	Cook-ing	Process heating	Other	Unit
Electricity	124.33	16.03	10.85	99.22	23.46	1.20		55.75	kWh/m^2
Coal		0.08					0.15		GJ/m^2
HFO							8.54		MJ/m^2
Paraffin							1.50		MJ/m^2
Diesel							2.22		MJ/m^2
LPG			0.24			0.03			MJ/m^2

10. AGRICULTURE SECTOR

The Eskom data, provided by Aurecon, on electricity supplied to sectors within Polokwane shows about 432MWh of electricity going to agriculture. Using SATIM numbers to split the electricity end uses to irrigation, processing, and 'other', the following table shows the representation of the agriculture sector in Polokwane.

Table 55: Agriculture sector in Polokwane

Electricity	1 556	GJ
Irrigation	491	32%
Processing	413	27%
Other	652	42%
Diesel	1 006	GJ
Transport*	985	98%
Irrigation	21	2%
Petrol*	87.3	
Transport	87.3	100%

*It is known that the agriculture sector would be consuming diesel and petrol for tractors and other vehicles, but this fuel consumption is assumed to reside in the transportation sector freight section.

11. SCENARIOS

This section details and outlines various scenarios to explore what Polokwane future energy consumption may looks like given certain assumptions and constraints. The Business-as-usual scenario is discussed first and alternate scenarios built on top of it are presented.

11.1 BUSINESS-AS-USUAL (BAU)

This scenario represents the current trajectory of the city of Polokwane and includes planned new developments (and those come into effect since 2011 the base year) which are foreseeable. This will include all developments which are expected to take place in the next few years.

11.1.1 GENERAL

The population growth averages at a rate of 1.58% since 2007 (Aurecon and see Table 1). In the BAU scenario, it is assumed this population growth rate remains through to 2030.

The local economy of Polokwane growth rate is assumed to follow national growth rates. Historically since 2004 South Africa's average growth rate has been 2.94%. Using the Aurecon data for Polokwane's GDP, it was found that there is a strong relation between national and municipal, except when there is negative growth rate (recession).

The GDP projection to 2030 used in this scenario is the 'Weathering the storm' national GDP scenario used in the IRP2010 update draft document (see Figure 8).

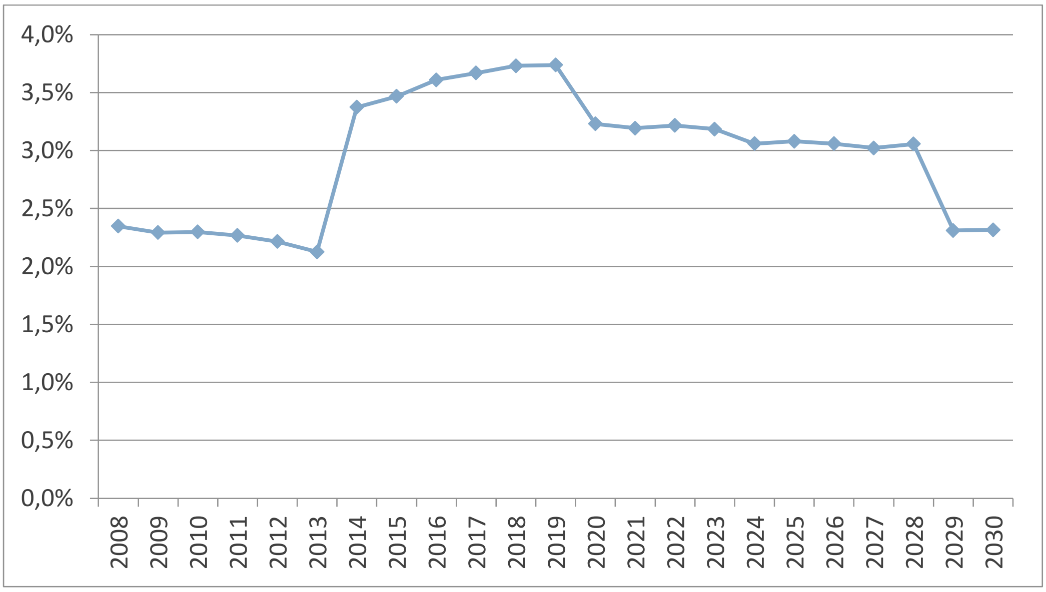

Figure 8: National GDP projection scenario 'Weathering the storm' as given in the IRP2010 update (2013) draft

It is assumed that the economy growth rate for Polokwane will follow this trend and in this scenario the numbers in Table 56 (taken from 'Weathering the storm') are used as the economic projection.

Table 56: Polokwane local economy (GVA) numbers used for the BAU scenario

	Growth rate - 'Weathering the storm'	Polokwane inferred GVA '000 Rands
2011	2.3%	20 873 130
2012	2.2%	21 335 540
2013	2.1%	21 788 865
2014	3.4%	22 523 984
2015	3.5%	23 305 045
2016	3.6%	24 146 228
2017	3.7%	25 032 150
2018	3.7%	25 965 970
2019	3.7%	26 936 238
2020	3.2%	27 806 121
2021	3.2%	28 693 948
2022	3.2%	29 616 922
2023	3.2%	30 560 166
2024	3.1%	31 494 921
2025	3.1%	32 464 741
2026	3.1%	33 457 750
2027	3.0%	34 468 478
2028	3.1%	35 521 977
2029	2.3%	36 342 438
2030	2.3%	37 184 082

11.1.2 MUNICIPAL AUTHORITY

Traffic lights were all replaced to LED lights by 2012 (Botes et. al., 2014); as for the street lights, the mercury vapour lamps were replaced with lower wattage (75W) HPS lamps. The municipal water system saw a replacement of the motors with variable speed drives implemented by 2014, with an average energy reduction of 42% as indicated by Polokwane municipal engineers (communication with the SAMSET team).

11.1.3 INDUSTRY

11.1.3.1 Heavy industry

Heavy industry (the two smelters) produces largely for the national and international market. Their output is assumed to remain as is except for some expansion on their furnace; from discussions with municipal officials, it has been indicated that an additional furnace (or at least an expansion) has been planned for the smelters. This expansion to Anglo is planned to be in the region of an additional 10MW of power. However, it is unknown whether this will change the overall energy intensity of the smelters. An assumption is made that this will only increase the overall output of the smelter and not change the overall energy intensity. For now, it is assumed that the first phase will occur in 2017 and the last phase will be in 2019. Production remains constant between 2011 and 2016, and increases in 2017 based on the first phase of expansion and again in 2019 by the third phase of expansion for the smelters. The energy intensities are assumed to remain as is, and these expansions are assumed to increase output capacity.

11.1.3.2 Other industries

For the rest of industry in Polokwane – made up of Sasko, Coca Cola, and Enterprise and other smaller industries and factories in Polokwane, the growth of the sector is assumed to follow the local economy growth trajectories which itself is simply the same trend as the national economic growth rate.

11.1.4 TRANSPORT

11.1.4.1 Freight

Local freight is assumed to follow local industry (not the smelters) growth, which itself follows the national GDP growth trends. And the split between vehicle types is assumed to remain the same as the base year.

Corridor freight would follow regional and national growth levels due to cross-border trade between Zimbabwe, Mozambique and, to a degree, Botswana. Some consultation with transportation and logistics experts[4] indicates that the region between Gauteng and the Beit Bridge crossing on the Zimbabwe/South Africa had a freight growth of 2.6% through to 2030. In this scenario, 2.6% is used as the growth through to 2030. In the BAU scenario, the split between the types of vehicles used is assumed to remain the same as in the base year.

11.1.4.2 Passenger

Corridor transport

Corridor passenger growth is assumed to follow local economy growth (which itself is tracking national growth numbers). It is assumed that corridor passenger mode split remains the same throughout.

Local transport

A first pass through the methodology for this model used GDP per capita as the driver for the passenger-km demand and then a share split for public and private demand were imposed on the model exogenously. However, after testing scenarios of population increase it became clear that this driver (GDP per capita) would not adequately capture these socio-economic changes – the demand for passenger-km dropped with an increase in population. Therefore we derived an alternative formulation of the GDP per capita driver for passenger transport demand – one which keeps the GDP per capita (or general wealth of the populace) as the key component to transport demand but doesn't allow for a net drop in transport demand with increased population (which would not be observed in reality). This is outlined below:

[4] Communication with the Logistics team at Stellenbosch University.

Private passenger demand is directly proportional to motorisation (vehicles per thousand people), and motorisation (M) is proportional to GDP per capita[5] and can be written as some linear function of GDP per capita:

$$M \approx k\left(\frac{GDP}{Pop}\right)$$

Where k is a constant to calibrate the base year values (in the year 2011 of the model).

The number of cars (private four-wheel cars) is then:

$$cars = M \times population \times 1000$$

Again, this is calibrated to the base year value for Polokwane (this is 44 462 vehicles of the four-wheel private vehicles after accounting for those which are not used in Polokwane – see transport section)

Then the population that is motorised (privately) is:

$$mpop = Occupancy \times cars$$

Where occupancy is again calibrated to the base year values – due to the inherent assumptions in the model for occupancy for private vehicles in determining the base year passenger-km demand, this comes out to be 1.42 People per vehicle.

And thus;

$$Private\ pass.km\ demand = Occupancy \times avg\ mileage \times cars$$

Where *avg mileage* is the weighted average of four-wheel private vehicles (private cars and the LCVs/bakkies assumptions) from the analysis in the transport section of this report.

The population of non-private car motorisation is then:

$$NCAP = Population - mpop$$

And the passenger-km demand for public transport is assumed to be linearly linked to the non-private car populace:

$$pass.km\ public\ = x \times NCAP$$

Where *x* is used to calibrate to the base year values in the transport model.

With this formulation for passenger-km for both private and public transport, a handle is kept for population and for wealth of the municipality, while just an increase in population (without an increase in GDP) results in an increase in public transportation demand but not private transportation demand.

The vehicle type split for private vehicles is assumed not to change to 2030.

[5] This relation is a Weibull or Gompertz relation which is an 'S-curve', but at low levels of saturation (of cars/1000 people) it can be assumed to be linear and not exponential. This is an underlying assumption in this transport model methodology.

For the public transportation shares by vehicle type, it is assumed that the BRT system will make up 15% of public transportation usage between its opening in 2016 to 2020. It is also assumed that this grows to 25% by 2030.

The following table indicates the assumed public transportation share by vehicle type for this scenario.

Table 57: The percentage share of public transportation by vehicle type in Polokwane for the BAU scenario

	2011	2015	2020	2030
Buses	17.83	17.83	12.83	10.83
Mini diesel	0.82	0.82	0.82	0.82
Mini petrol	81.35	81.35	71.35	63.35
BRT[6]	0.00	0.00	15.00	25.00

Table 58: The transportation assumptions and characteristics summary for the BAU scenario

Sector/subsector	Element	BAU scenario	Comment
Transport passenger local	Private pass-km demand	Driven by GDP per captia and motorisation	
Transport passenger local	Public pass-km demand	Driven by population of Polokwane and population with cars (above)	
Transport Passenger local	Public vehicle shares	Minibuses 81% to 71% by 2020, 63% by 2030. Buses 17.8% to 12.8% 2015 to 2020, 10.8% by 2030. BRT 15% by 2020, 25% by 2030	The BRT is an assumption, then assumed this share is taken mainly from Minibuses and some from buses.
Transport Passenger local	Non-motorised transport demand for pass-km	Growth is linked to motorised demand	The level of NMT is linked to the levels of the motorised transport and the share of NMT in the base year.
Transport passenger local	Private vehicle shares	Do not change from base year	Assumption.
Transport passenger corridor	Public and private vehicle shares	Do not change from base year	Assumption.

11.1.5 COMMERCE

The commercial sector driver in this model is the floor-space of commercial activities. The base year floor-space was estimated based on the total electricity consumption for the commercial sector and dividing by the national average electricity intensity (kWh/m^2)

[6] This assumption is thought to be an optimistic one.

taken from SATIM. The floor-space projection into the future is assumed to be directly proportional to the growth of the local economy – i.e. more economic activity, more floor-space.

All new buildings are to be compliant with the SANS1004 building codes. The codes stipulate that energy consumption in buildings not exceed specified intensity levels as indicated in the table below.

Table 59: Maximum annual energy consumption per building classification as stated in the SANS 204 building regulation

1	2	3	4	5	6	7	8
Classification of occupancy of building	Description of building	Maximum energy consumption[ab]					
		Climatic zone[c]					
		1	**2**	**3**	**4**	**5**	**6**
A1	Entertainment and public assembly	420	400	440	39	40	42
A2	Theatrical and indoor sport	420	400	440	39	40	42
A3	Places of instruction	420	400	440	39	40	42
A4	Worship	120	115	125	11	11	12
F1	Large shop	240	245	260	24	26	25
G1	Offices	200	190	210	18	19	20
H1	Hotel	650	600	585	60	62	63

[a] The annual consumption per square metre shall be based on the sum of the monthly consumption of 12 consecutive months.

[b] Non-electrical consumption, such as fossil fuels, shall be accounted for on a non-renewable primary energy thermal equivalence basis by converting mega joules to kilowatt hours.

The current average energy (all fuels) consumption in kWh/m^2 for all end-uses and fuels in Polokwane is 399 kWh/m^2. Using the above table the average energy consumption of a SANS204 building would be 328 kWh/m^2 – adjusted using SATIM distribution for each category of commercial space. This equates to a total of 17.9% reduction of new buildings compared to existing/old buildings as compared to the base year intensities.[7]

Using the floor-space growth rate to work out the total new added floorspace and weighting this to the overall stock of floor-space (new + old) and applying the reduction in energy intensities, the slowly changing average energy intensity of buildings is calculated to 2030.

Table 60: The commercial sector floor-space overall energy intensity reduction

	2015	2020	2025	2030
% new floor space to base year floor space	4.4%	9.1%	14.0%	19.1%
Overall (all commerce) energy intensity reduction	99.22%	98.38%	97.51%	96.59%

[7] It should be noted that this number is highly dependent on the actual floorspace in Polokwane, while in this methodology the floorspace is an estimate.

11.1.6 HOUSEHOLDS

The total number of HHs is projected using the population projection and the number of persons per HH. Over 10 years the HH density dropped from 4.1 to 3.5 people per HH. In this scenario it is assumed that by 2030 the density will drop further to 3 people per HH.

Table 61: Number of households compared with population. Data is from Census

	Households	Population	People/HH
2001	124 847	508 277	4.1
2011	178 001	628 999	3.5

The national target for universal electricity access is 2025, and in this scenario it is assumed that by 2025 all HHs have access to electricity.

Figure 6 from the HH section shows the change in the income grouping of all HHs in Polokwane between 2001 and 2011, and this is presented in the table below:

Table 62: Total household count by income group, data comes from the Census for 2001 and 2011, the groupings for 2001 are adjusted for inflation

Income group	2001	2011
Low-income	72 506	82 554
Mid-income	32 147	55 847
High-income	20 194	39 590
All	124 847	177 991

It is reasonable to assume there will continue to be a shift in income groups as time progresses, in the BAU it is assumed that the same level of change occurs between 2011 and 2030. The new income band split for 2030 is indicated in the figure below.

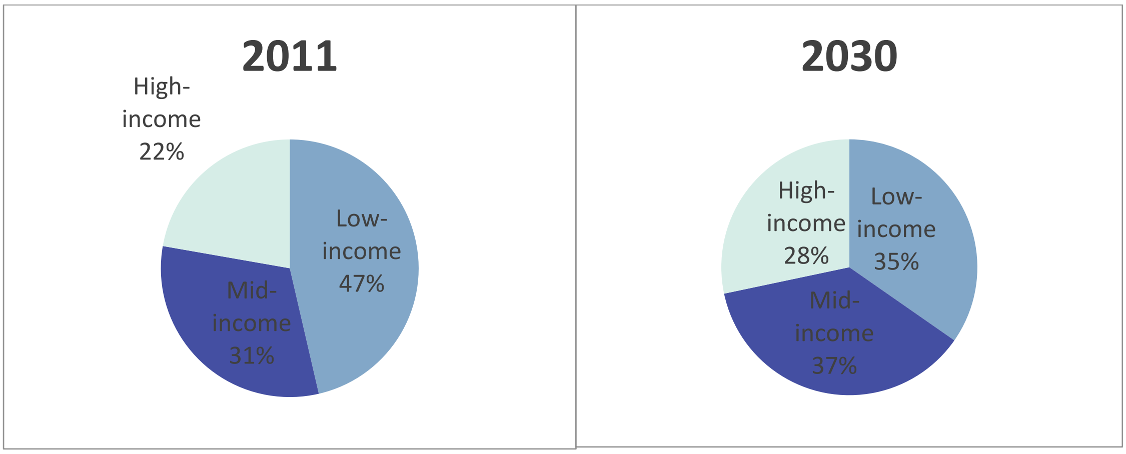

Figure 9: The income band split between low-, middle- and high-income groups in Polokwane for 2030

End-use fuel shares

Using data from the census 2001 and 2011 data sets on HH fuel usage for lighting, cooking and space heating, the change in fuel usage for end uses was estimated, as in Tables 63–65:

Table 63: The change in fuel usage for lighting, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Candles	Solar	Other	None
Low-income	21.0%	0.0%	-4.0%	-17.4%	0.4%	-0.3%	0.2%
Mid-income	6.1%	-0.2%	-1.9%	-4.4%	0.4%	-0.2%	0.2%
High-income	0.5%	-0.1%	-0.3%	-0.4%	0.4%	-0.2%	0.1%

Table 64: The absolute change in fuel usage for cooking, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Wood	Coal	Dung	Solar	Other	None
Electrified									
	29.9%	-0.6%	-15.7%	-12.0%	-0.6%	-0.5%	-0.2%	-0.3%	0.1%
Mid-income	2.3%	-0.9%	-7.0%	6.4%	-0.4%	-0.2%	-0.2%	-0.1%	0.1%
High-income	-1.6%	2.3%	-1.0%	0.5%	-0.1%	0.0%	-0.2%	0.1%	0.1%
Non-electrified									
Low-income		1.5%	9.3%	-8.7%	-1.1%	-1.2%	-0.1%	-0.4%	0.5%
Mid-income		-3.0%	2.8%	3.3%	-2.0%	-0.9%	-0.1%	-0.3%	0.3%
High-income		9.1%	-2.5%	-2.0%	-2.4%	-2.3%	-0.4%	-0.5%	0.4%

Table 65: The absolute change in fuel usage for heating, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Wood	Coal	Dung	Solar	Other	None
Electrified									
Low-income	13.2%	0.1%	-8.3%	-13.3%	-1.8%	-0.4%	-0.1%	-2.8%	13.3%
Mid-income	-11.2%	-0.1%	-3.6%	6.8%	-1.8%	-0.1%	0.0%	-2.3%	12.2%
High-income	-6.6%	1.4%	-0.5%	1.1%	-0.4%	0.0%	0.0%	-1.2%	6.2%

Non-electrified									
Low-income		0.4%	-16.1%	-5.5%	-2.6%	-0.6%	0.0%	-3.4%	27.5%
Mid-income		-2.5%	-25.0%	6.0%	-4.8%	-0.2%	-0.1%	-3.9%	30.1%
High-income		-2.1%	-24.0%	1.1%	-6.4%	-1.0%	0.3%	-3.7%	35.2%

Generally, electricity usage increased the most compared to other fuel sources. In this methodology, it may not be wise to use the numbers indicated in the tables above for HH fuel switching, but the general trend of fuel shifting is used – i.e. more uptake of electricity compared to other fuels.

Keeping these numbers in mind and the general trend to cleaner fuels, the following end-use fuel changes were used for this scenario.

The assumed changes for fuels in the household sector:

Lighting: All electrified HH's use CFLs by 2020, with only 1% using solar and 1% using incandescent. Non-electrified HHs shift toward more solar powered devices – a total of 10% by 2020 (up from 2.8% in the base year) and candles and paraffin shares at 85% and 5%.

Generally, the *cooking and space heating* end uses are assumed to move away from dirty fuels (such as coal, paraffin and wood, which are hazardous to health and pose a fire risk). Using the data from the tables above, the following assumptions on HH end-use fuel-shifting RE made.

Cooking: for electrified HHs:

85% of low income users use electricity, with gas making up 10% and wood 5% (down from 14%) by 2030.

90% of mid to high income users use electricity and 10% use gas by 2030.

For non-electrified HHs:

(The data shows a general increase in paraffin use.)

50% of low-income HHs still use paraffin (down from 61%), with wood at 25% (down from 33%) and gas at 25% (up from 5%) by 2025.

15% of mid-to-high income users use wood by 2025, paraffin usage drops to 25% (down from 49%) and gas makes up 60% by 2025.

Space heating: for electrified HHs:

80% of low-income HHs use electricity, with 10% using gas and 10% using wood for space heating by 2030.

85% of mid-to-high income HHs use electricity by 2030 (down from 87% today) and gas makes up 15% by 2030 (up from 1.85%)

For non-electrified HHs:

Wood use remains constant at 60%, paraffin usage drops to 25% (down from 37%), with gas making up 15% (up from 2.9%) by 2025 for low-income HHs.

For mid-to-high income – wood usage increases to 50%, paraffin drops to 15%, and gas increases from 6% to 35% of mid-to-high income HHs by 2025.

Water heating: for electrified HHs:

30% of low-income HHs have solar water heaters by 2030, 60% of HHs use electric geysers, and 10% use gas (this is a combination of gas geysers and gas stoves for low income).

20% of mid-to-high income HHs use solar-electric geysers by 2030, 5% use gas, and the remaining 75% use electric geysers.

For non-electrified HHs

30% of low-income HHs use solar water-heaters by 2025, 25% use gas (from their stove), 30% use paraffin (from the stove), and 15% use wood (also from their stove).

40% of mid-to-high income HHs use solar water-heaters by 2025, 30% use gas (from their stove), 15% use wood, and another15% use paraffin (their stoves).

11.1.7 FUEL COSTS AND COSTING IN THE MODEL

The electricity price path for this scenario is used to infer the changes to electricity tariffs for Polokwane going forward (see Figure 10). The costs for diesel and petrol are assumed to track the changes in crude oil prices going into the future. The World economic outlook of 2013 published by the IEA is used for the price of crude going to 2030 in this scenario (see Table 66).

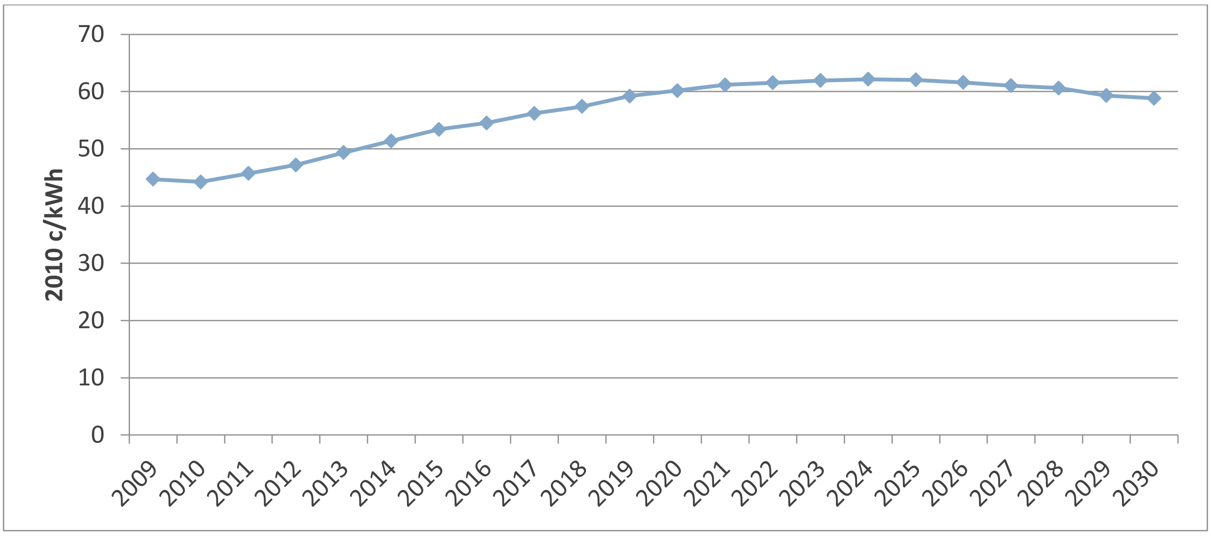

Figure 10: The electricity cost of supply trajectory for the Policy adjusted scenario from the IRP2010

Table 66: WEO 2013 crude oil import cost projections (2012 USD (real))

	2011	2015	2020	2025	2030	2035
$/barrel	107.6	113	120	127	136	145

The price of inland diesel, petrol, paraffin and LPG (given in the table below for 2011 and 2015 from DoE website) are assumed to grow at the same rate as the crude oil price.

Table 67: The current cost of liquid fuels in Polokwane – data sourced from DoE website fuel price publications and Aurecon report

	2011	2015
Petrol (c/L)	996.58	1237.4
Diesel (c/L)	925.62	1078.4
Paraffin (c/L)	700.68	734.9
LPG (R/kg)	23.45	

Costing in the model

In this work, costing is calculated on the demand side – where fuel is consumed to meet an end-use. The demand-side costs include an annualised cost for the device/technology based on an 8% discount rate and the assumed life of the technology plus the cost of the fuel (section above). Only technologies in branches where scenarios have an affect are the investment costs of the technologies included (plus the fuel costs), while branches which are not affected by scenarios in this report have only the fuel cost component included (such as the agriculture sector). The transport corridor branch does not have any costs included since this would be costs not incurred by Polokwane.

11.1.8 SCENARIO RESULTS

The BAU scenario is run in LEAP and gives the overall picture shown below of the energy consumption for the city by each sector. Industry and transport are the two largest energy consumers in the city. Noticeably is the slight bump around 2019 where the smelters expand their operating capacity. Figure 11 and Figure 12 show the results for Polokwane with and without the smelters included.

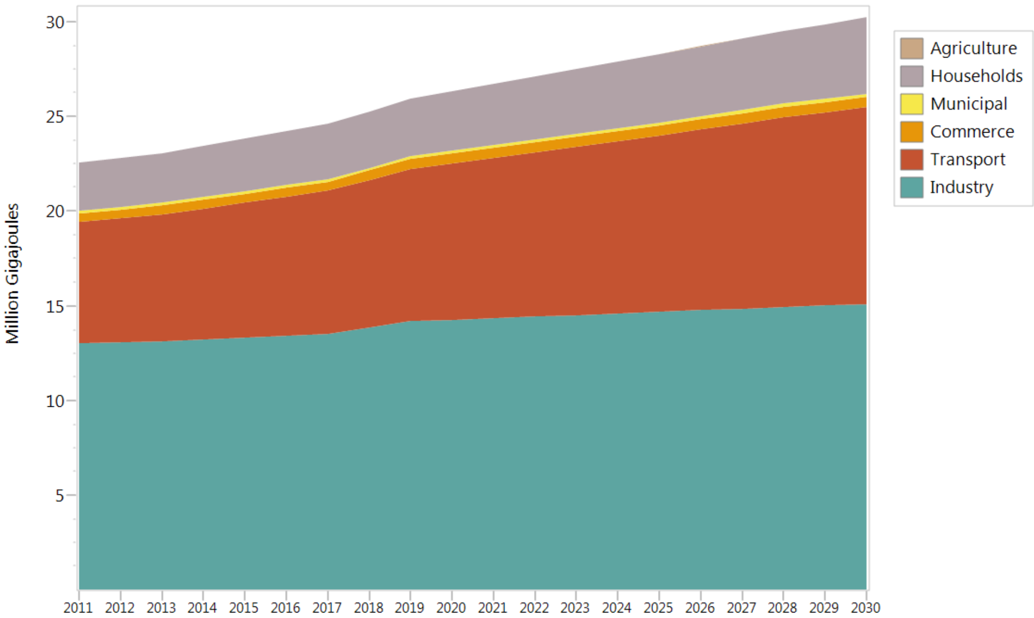

Figure 11: The projected energy consumption for Polokwane through to 2030 for the BAU scenario (Smelters included)

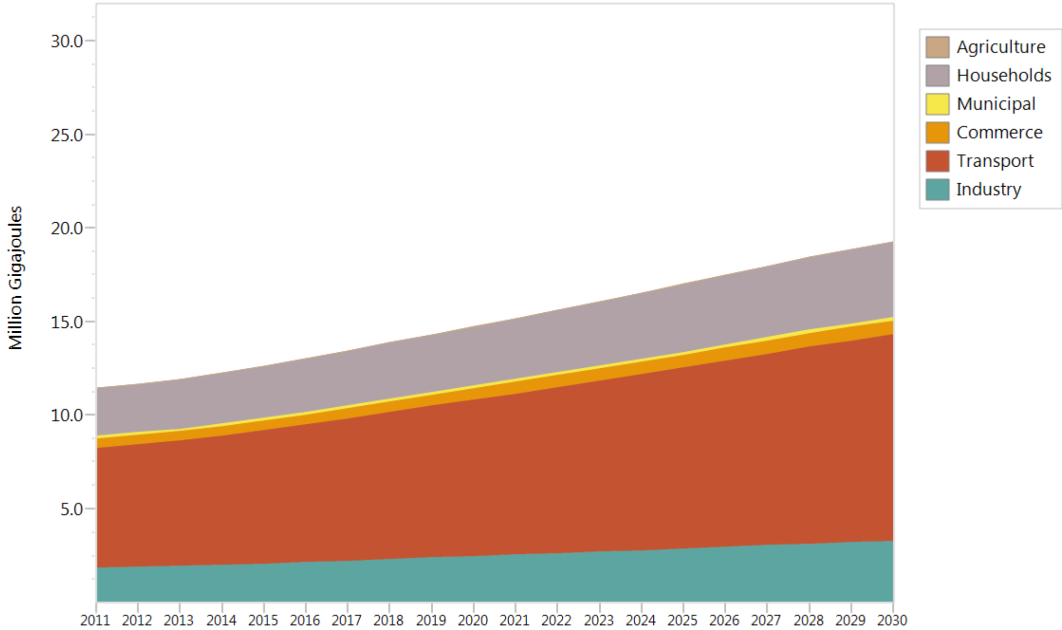

Figure 12: The BAU scenario where the two smelters have been excluded

Looking at the pie charts below, if one includes the smelters, the share of energy consumption for industry is almost 60% of all of Polokwane and this reduces to just less than half of all energy consumed in Polokwane by 2030. Without the smelters, however, transport is the largest energy consumer in the municipality.

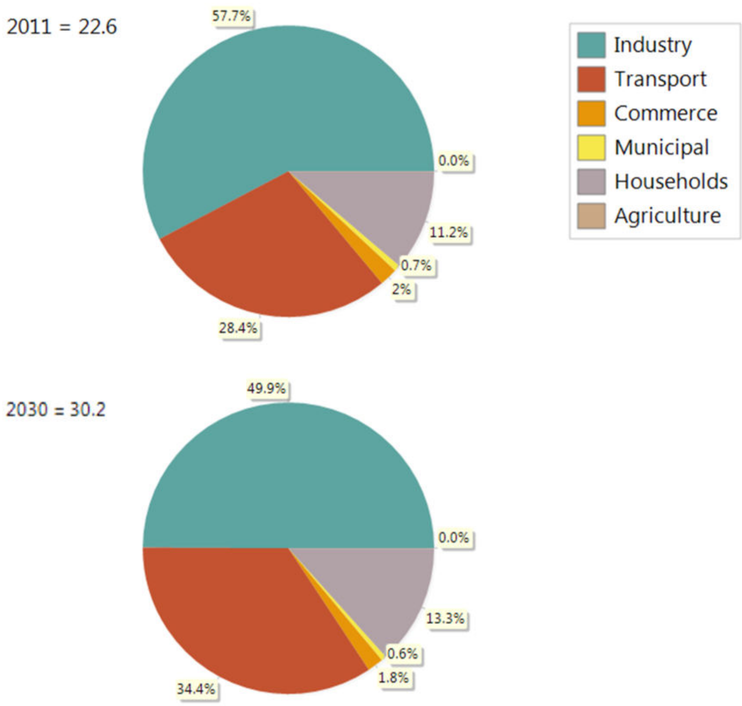

Figure 13: The share of energy consumption by each sector in Polokwane for the base year and end year showing the overall change in energy profile – smelters included.

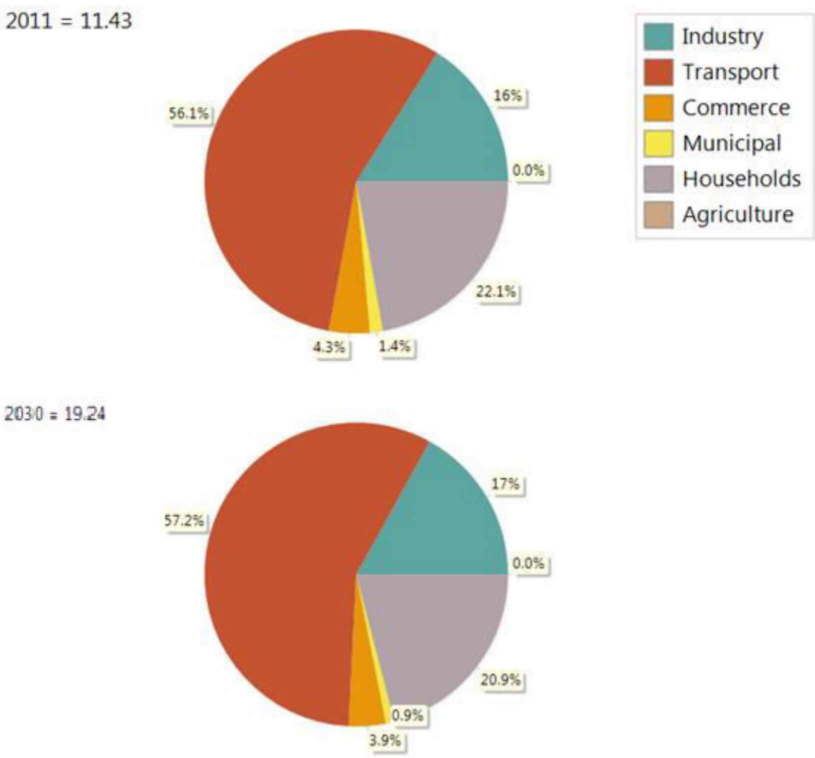

Figure 14: The energy share by sector for 2011 and 2030 in Polokwane where the smelters have been excluded

The increase in non-industry energy consumption shares in the model where smelters are included is a result of the industries generally not expanding much (save for an expansion in 2017 through to 2019) between 2011 and 2030, while the other sectors grow at roughly 2.7% pa on average. As indicated in the pie charts without smelters included, the shares of the subsectors are roughly the same as the base year.

The main source of fuel for Polokwane remains electricity going into the future with diesel and petrol making up a significant portion as well, as the following series of graphs shows. Petrol consumption, however, is mainly in passenger transport and mainly for local residents.

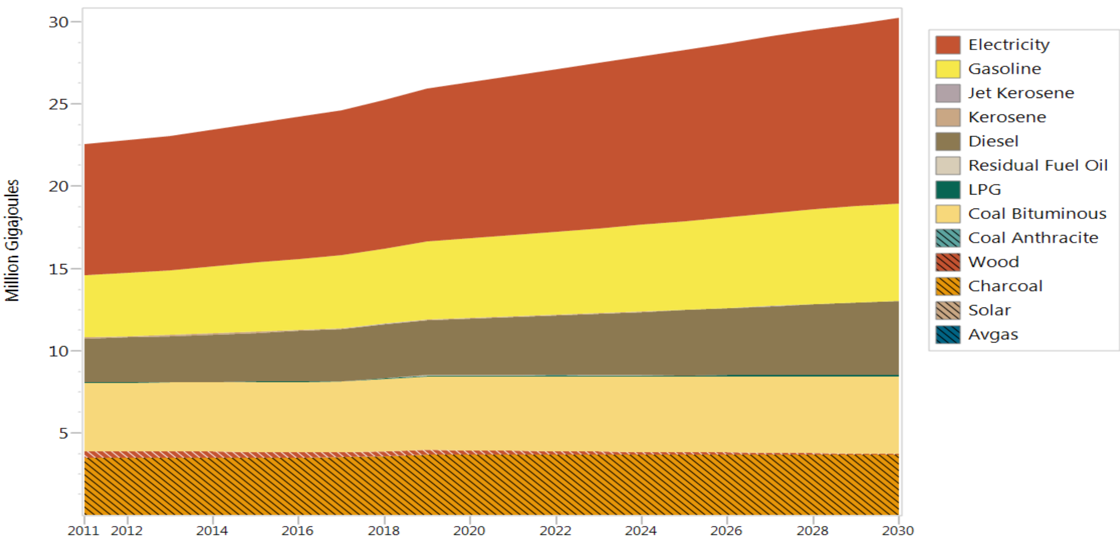

Figure 15: Energy consumption by fuel type for Polokwane in the BAU scenario, smelters included

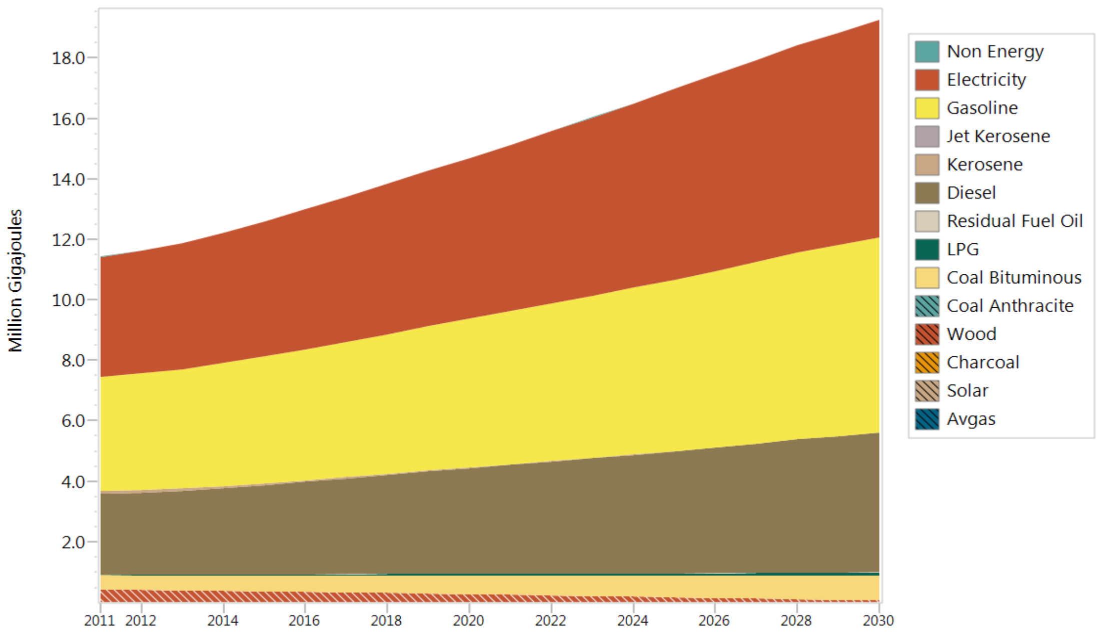

Figure 16: The fuel consumption in Polokwane for the BAU scenario where the smelters have been excluded

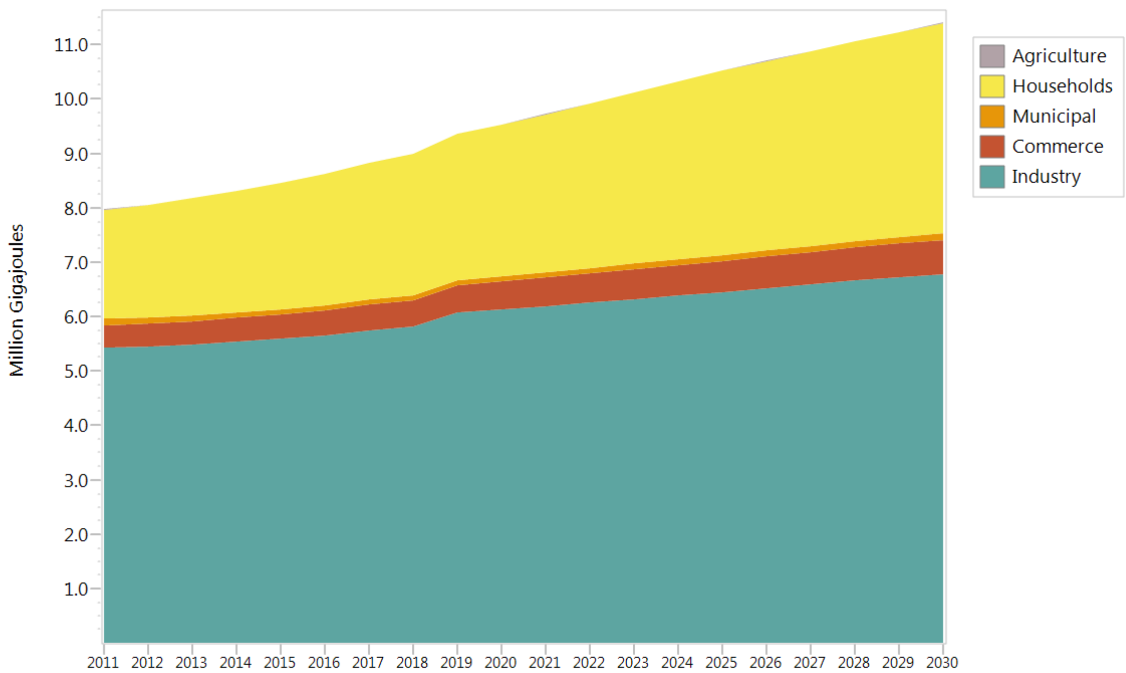

Figure 17: The total electricity consumption by sector for Polokwane in the BAU scenario – smelters included

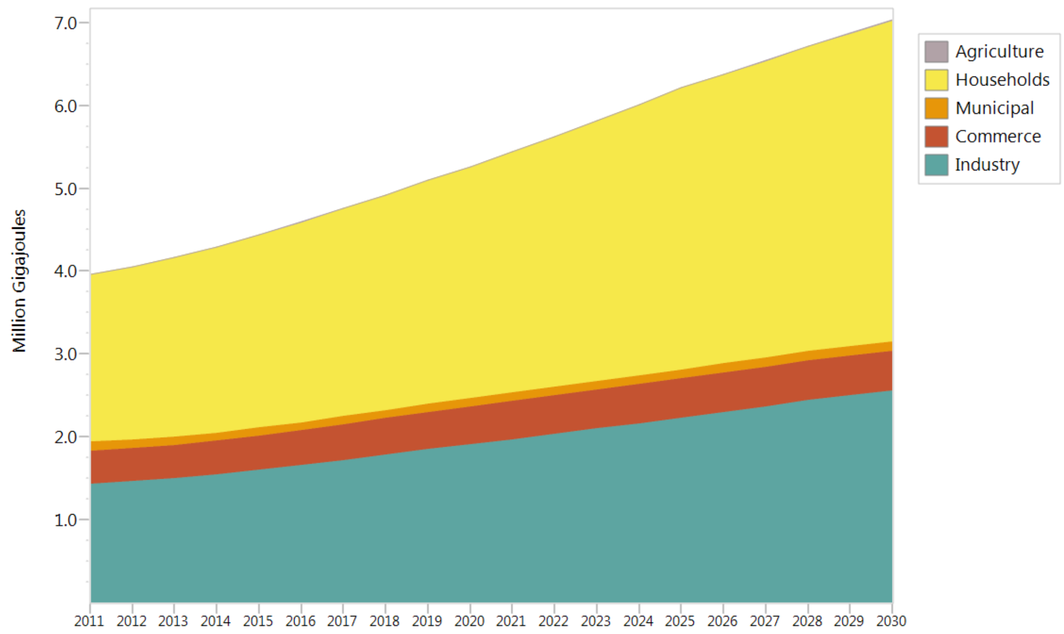

Figure 18: Electricity consumption in Polokwane BAU where the smelters have been excluded

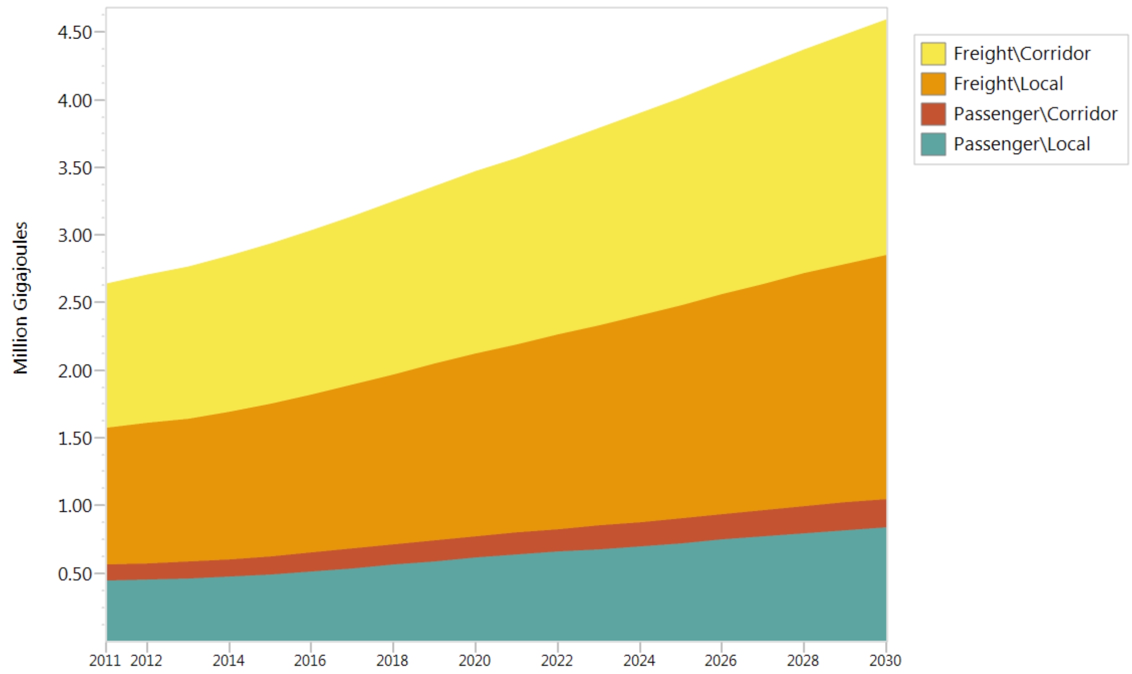

Figure 19: Diesel consumption in Polokwane by the subsectors for the BAU scenario

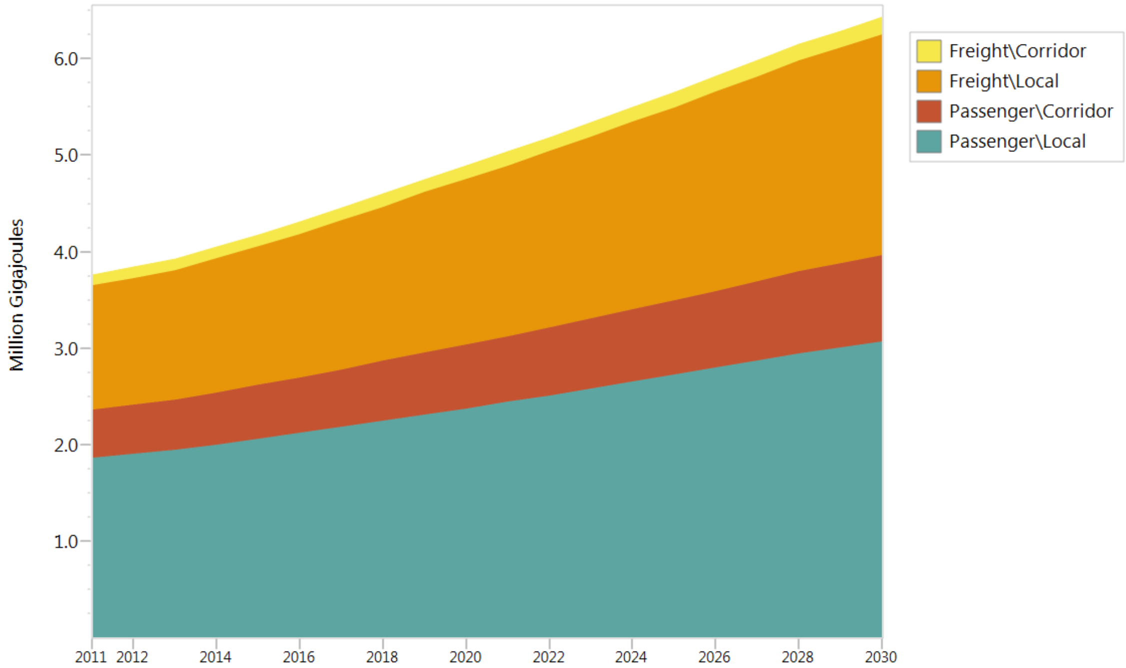

Figure 20: Petrol consumption in Polokwane for the BAU scenario

The change in share of the transport sector fuel consumption is very little by 2030 (Figure 21), and most of the passenger fuel consumption is in the private sector (Figure 22)

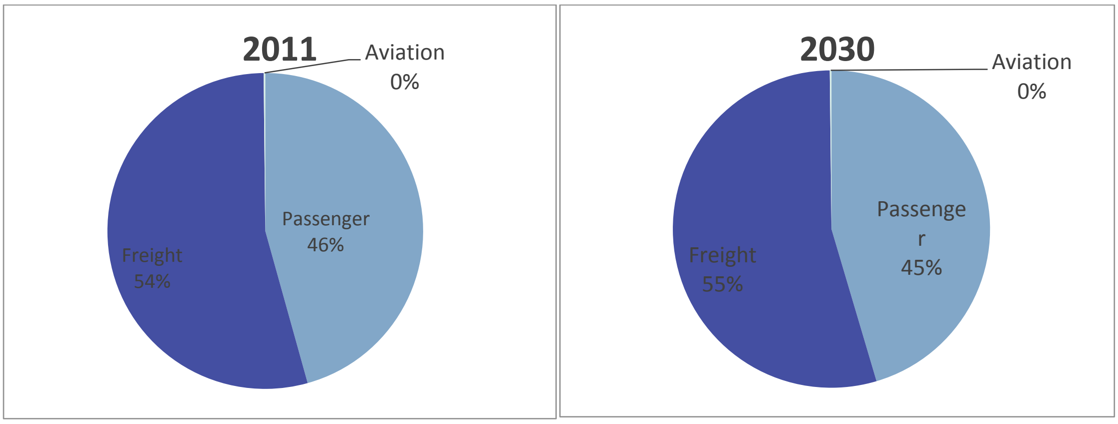

Figure 21: Transport sector energy consumption by subsector

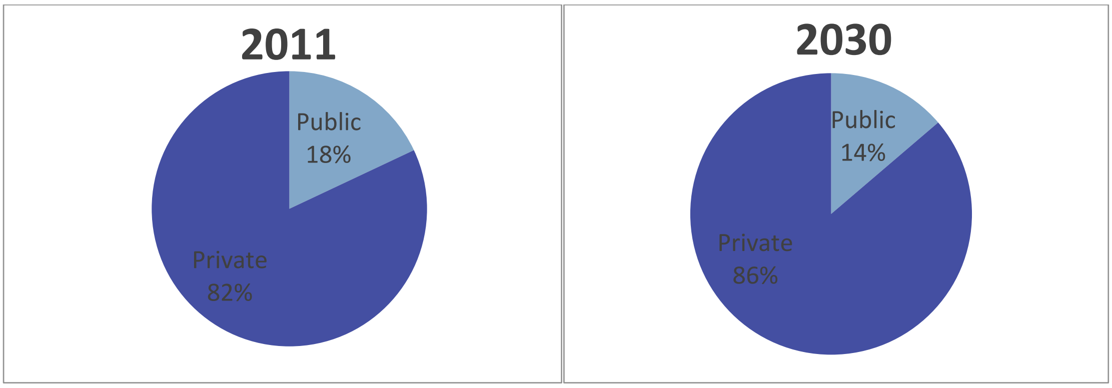

Figure 22: Passenger transport for the BAU scenario showing the total energy consumption split for private and public transport

The majority of petrol consumed in the city is for light passenger vehicles as indicated in the figures below.

End-use fuel shares

Using data from the census 2001 and 2011 data sets on HH fuel usage for lighting, cooking and space heating, the change in fuel usage for end uses was estimated, as in Tables 63–65:

Table 63: The change in fuel usage for lighting, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Candles	Solar	Other	None
Low-income	21.0%	0.0%	-4.0%	-17.4%	0.4%	-0.3%	0.2%
Mid-income	6.1%	-0.2%	-1.9%	-4.4%	0.4%	-0.2%	0.2%
High-income	0.5%	-0.1%	-0.3%	-0.4%	0.4%	-0.2%	0.1%

Table 64: The absolute change in fuel usage for cooking, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Wood	Coal	Dung	Solar	Other	None
Electrified									
	29.9%	-0.6%	-15.7%	-12.0%	-0.6%	-0.5%	-0.2%	-0.3%	0.1%
Mid-income	2.3%	-0.9%	-7.0%	6.4%	-0.4%	-0.2%	-0.2%	-0.1%	0.1%
High-income	-1.6%	2.3%	-1.0%	0.5%	-0.1%	0.0%	-0.2%	0.1%	0.1%
Non-electrified									
Low-income		1.5%	9.3%	-8.7%	-1.1%	-1.2%	-0.1%	-0.4%	0.5%
Mid-income		-3.0%	2.8%	3.3%	-2.0%	-0.9%	-0.1%	-0.3%	0.3%

High-income		9.1%	-2.5%	-2.0%	-2.4%	-2.3%	-0.4%	-0.5%	0.4%

Table 65: The absolute change in fuel usage for heating, between 2001 and 2011 for households in Polokwane

	Electricity	Gas	Paraffin	Wood	Coal	Dung	Solar	Other	None
Electrified									
Low-income	13.2%	0.1%	-8.3%	-13.3%	-1.8%	-0.4%	-0.1%	-2.8%	13.3%
Mid-income	-11.2%	-0.1%	-3.6%	6.8%	-1.8%	-0.1%	0.0%	-2.3%	12.2%
High-income	-6.6%	1.4%	-0.5%	1.1%	-0.4%	0.0%	0.0%	-1.2%	6.2%
Non-electrified									
Low-income		0.4%	-16.1%	-5.5%	-2.6%	-0.6%	0.0%	-3.4%	27.5%
Mid-income		-2.5%	-25.0%	6.0%	-4.8%	-0.2%	-0.1%	-3.9%	30.1%
High-income		-2.1%	-24.0%	1.1%	-6.4%	-1.0%	0.3%	-3.7%	35.2%

Generally, electricity usage increased the most compared to other fuel sources. In this methodology, it may not be wise to use the numbers indicated in the tables above for HH fuel switching, but the general trend of fuel shifting is used – i.e. more uptake of electricity compared to other fuels.

Keeping these numbers in mind and the general trend to cleaner fuels, the following end-use fuel changes were used for this scenario.

The assumed changes for fuels in the household sector:

Lighting: All electrified HH's use CFLs by 2020, with only 1% using solar and 1% using incandescent. Non-electrified HHs shift toward more solar powered devices – a total of 10% by 2020 (up from 2.8% in the base year) and candles and paraffin shares at 85% and 5%.

Generally, the *cooking and space heating* end uses are assumed to move away from dirty fuels (such as coal, paraffin and wood, which are hazardous to health and pose a fire risk). Using the data from the tables above, the following assumptions on HH end-use fuel-shifting RE made.

Cooking: for electrified HHs:

85% of low income users use electricity, with gas making up 10% and wood 5% (down from 14%) by 2030.

90% of mid to high income users use electricity and 10% use gas by 2030.

For non-electrified HHs:

(The data shows a general increase in paraffin use.)

50% of low-income HHs still use paraffin (down from 61%), with wood at 25% (down from 33%) and gas at 25% (up from 5%) by 2025.

15% of mid-to-high income users use wood by 2025, paraffin usage drops to 25% (down from 49%) and gas makes up 60% by 2025.

Space heating: for electrified HHs:

80% of low-income HHs use electricity, with 10% using gas and 10% using wood for space heating by 2030.

85% of mid-to-high income HHs use electricity by 2030 (down from 87% today) and gas makes up 15% by 2030 (up from 1.85%)

For non-electrified HHs:

Wood use remains constant at 60%, paraffin usage drops to 25% (down from 37%), with gas making up 15% (up from 2.9%) by 2025 for low-income HHs.

For mid-to-high income – wood usage increases to 50%, paraffin drops to 15%, and gas increases from 6% to 35% of mid-to-high income HHs by 2025.

Water heating: for electrified HHs:

30% of low-income HHs have solar water heaters by 2030, 60% of HHs use electric geysers, and 10% use gas (this is a combination of gas geysers and gas stoves for low income).

20% of mid-to-high income HHs use solar-electric geysers by 2030, 5% use gas, and the remaining 75% use electric geysers.

For non-electrified HHs

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11.1.9 FUEL COSTS AND COSTING IN THE MODEL

The electricity price path for this scenario is used to infer the changes to electricity tariffs for Polokwane going forward (see Figure 10). The costs for diesel and petrol are assumed to track the changes in crude oil prices going into the future. The World economic outlook of 2013 published by the IEA is used for the price of crude going to 2030 in this scenario (see Table 66).

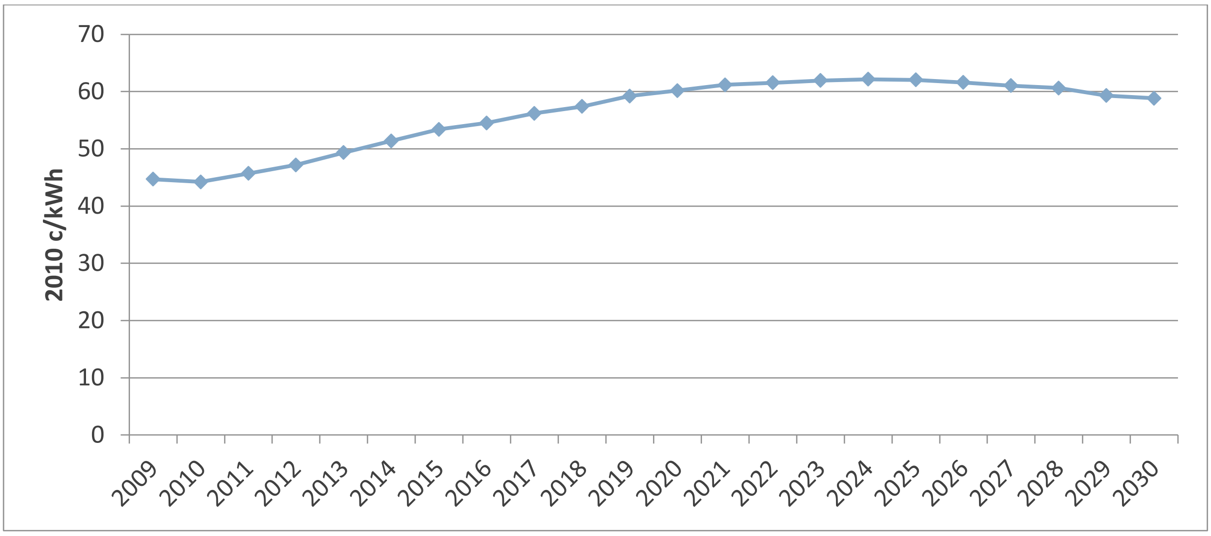

Figure 10: The electricity cost of supply trajectory for the Policy adjusted scenario from the IRP2010

Table 66: WEO 2013 crude oil import cost projections (2012 USD (real))

	2011	2015	2020	2025	2030	2035
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The price of inland diesel, petrol, paraffin and LPG (given in the table below for 2011 and 2015 from DoE website) are assumed to grow at the same rate as the crude oil price.

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	2011	2015
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Diesel (c/L)	925.62	1078.4
Paraffin (c/L)	700.68	734.9
LPG (R/kg)	23.45	

Costing in the model

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11.1.10 SCENARIO RESULTS

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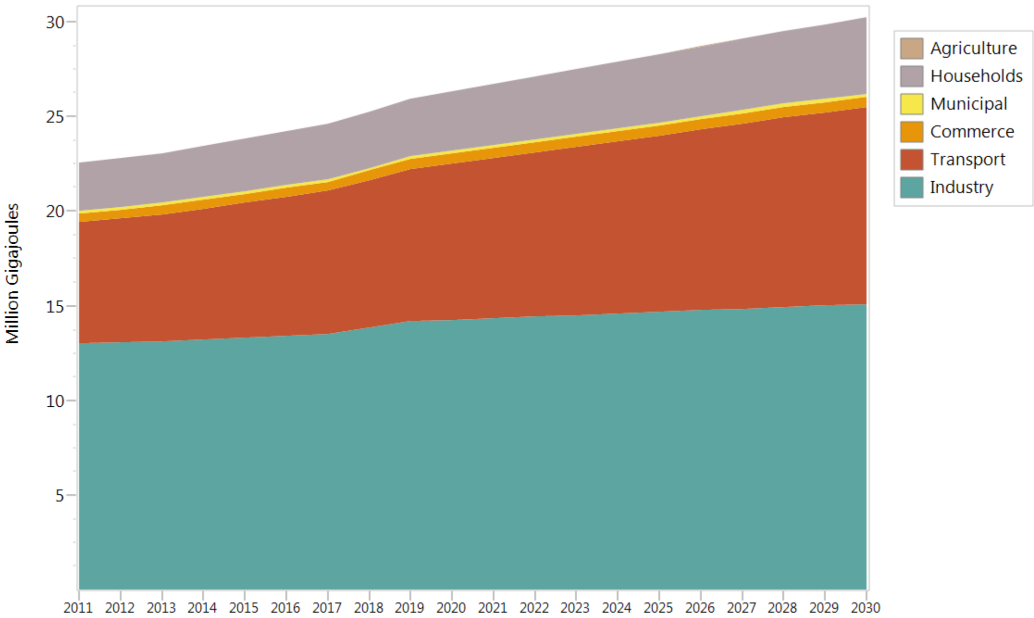


Figure 11: The projected energy consumption for Polokwane through to 2030 for the BAU scenario (Smelters included)

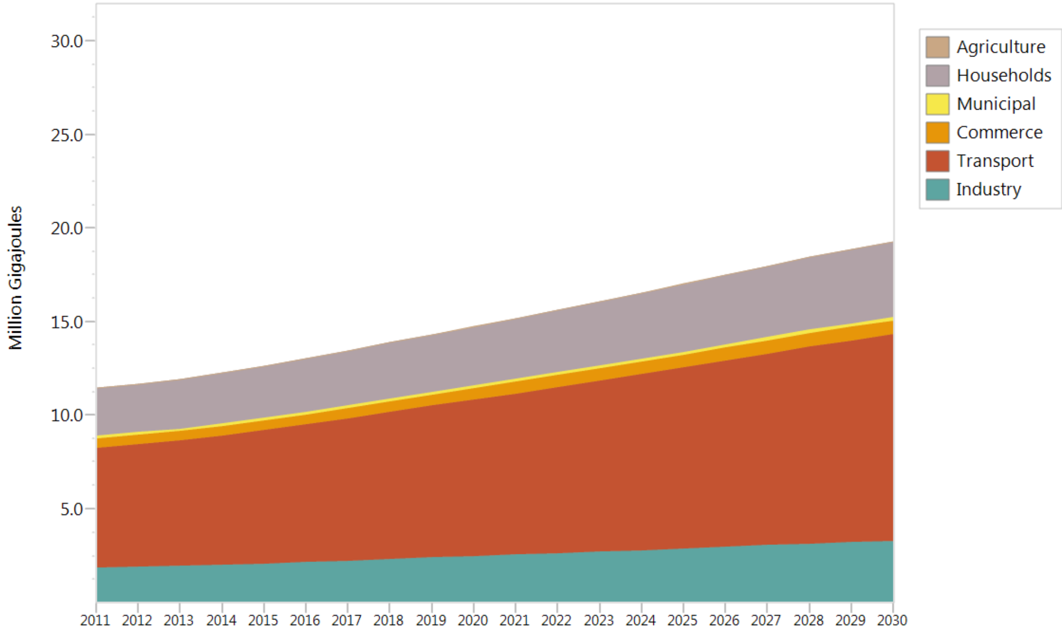


Figure 12: The BAU scenario where the two smelters have been excluded

Looking at the pie charts below, if one includes the smelters, the share of energy consumption for industry is almost 60% of all of Polokwane and this reduces to just less than half of all energy consumed in Polokwane by 2030. Without the smelters, however, transport is the largest energy consumer in the municipality.

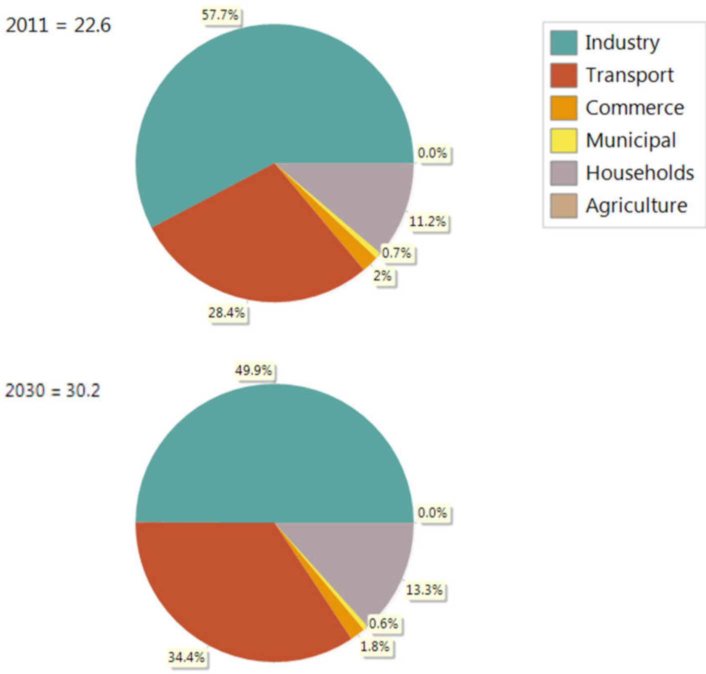


Figure 13: The share of energy consumption by each sector in Polokwane for the base year and end year showing the overall change in energy profile – smelters included.

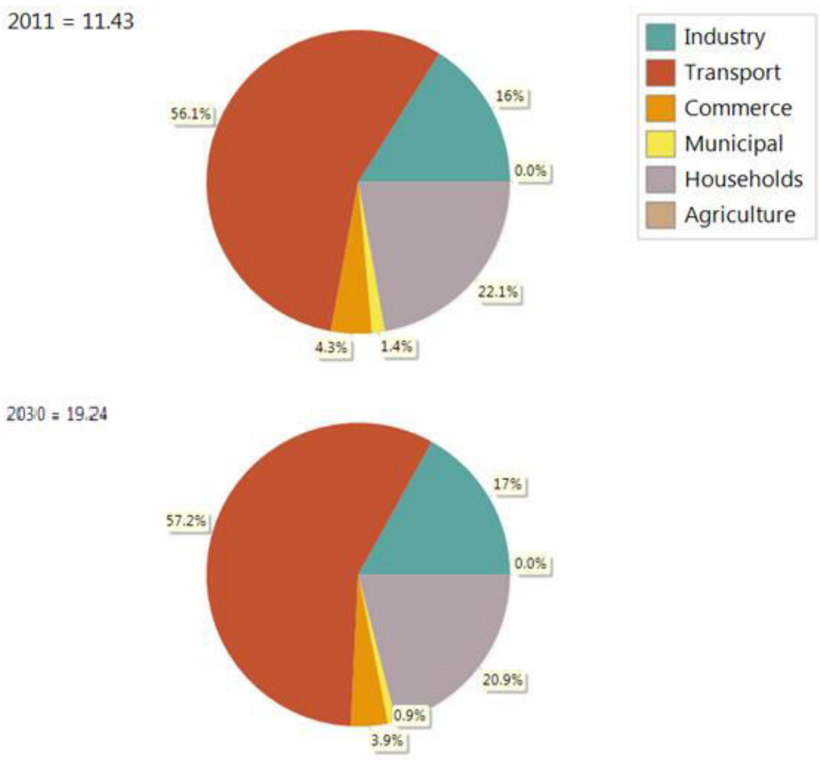


Figure 14: The energy share by sector for 2011 and 2030 in Polokwane where the smelters have been excluded

The increase in non-industry energy consumption shares in the model where smelters are included is a result of the industries generally not expanding much (save for an expansion in 2017 through to 2019) between 2011 and 2030, while the other sectors grow at roughly 2.7% pa on average. As indicated in the pie charts without smelters included, the shares of the subsectors are roughly the same as the base year.

The main source of fuel for Polokwane remains electricity going into the future with diesel and petrol making up a significant portion as well, as the following series of graphs shows. Petrol consumption, however, is mainly in passenger transport and mainly for local residents.

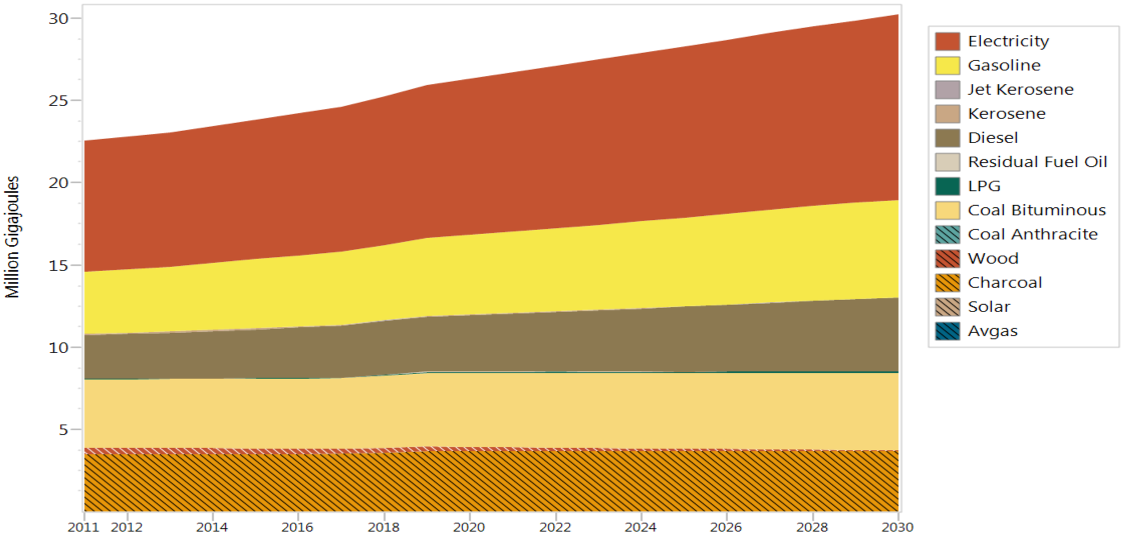


Figure 15: Energy consumption by fuel type for Polokwane in the BAU scenario, smelters included

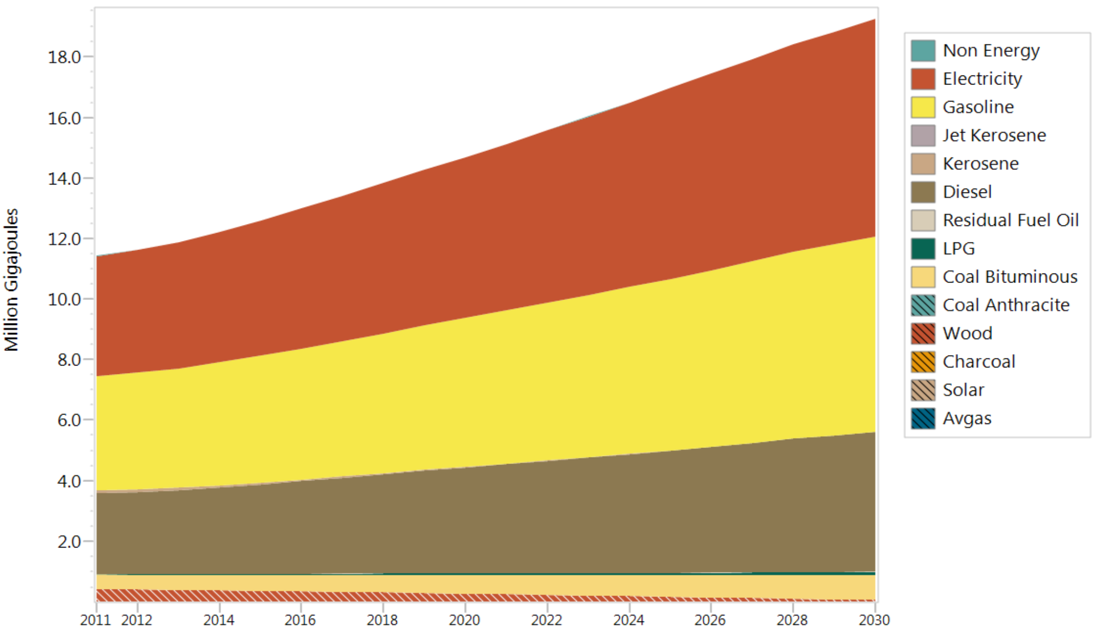


Figure 16: The fuel consumption in Polokwane for the BAU scenario where the smelters have been excluded

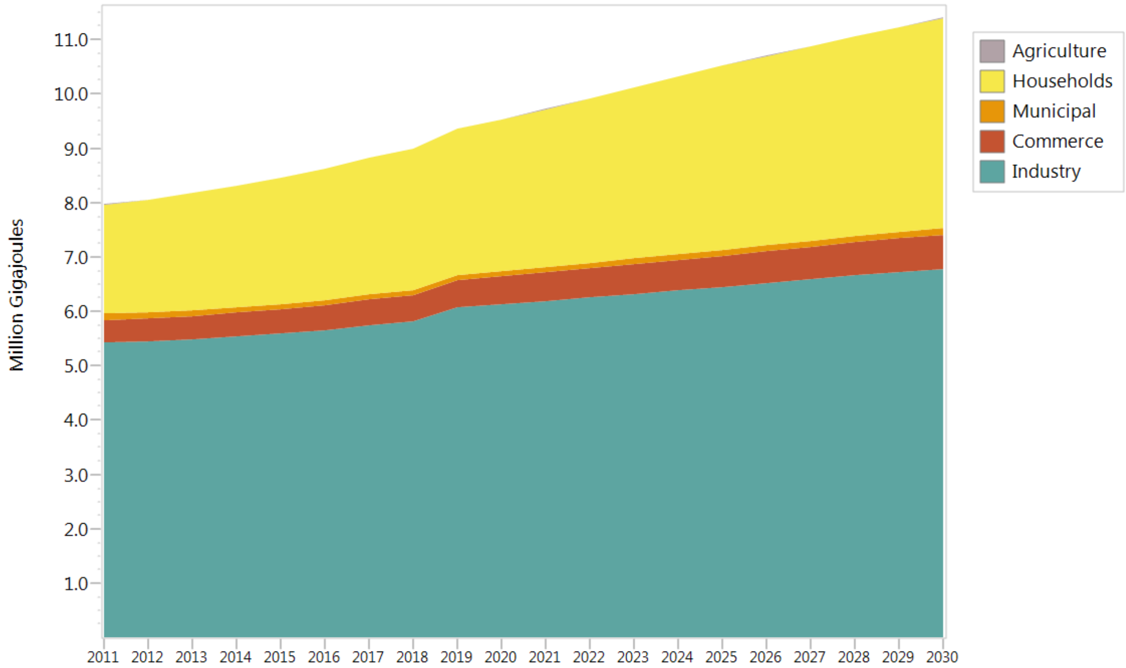


Figure 17: The total electricity consumption by sector for Polokwane in the BAU scenario – smelters included

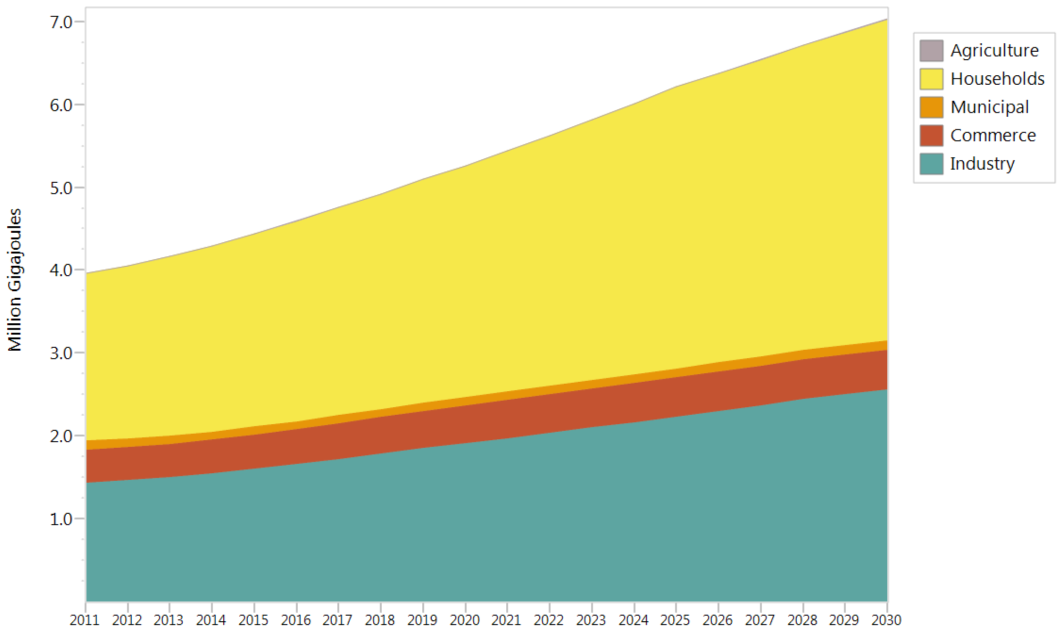


Figure 18: Electricity consumption in Polokwane BAU where the smelters have been excluded

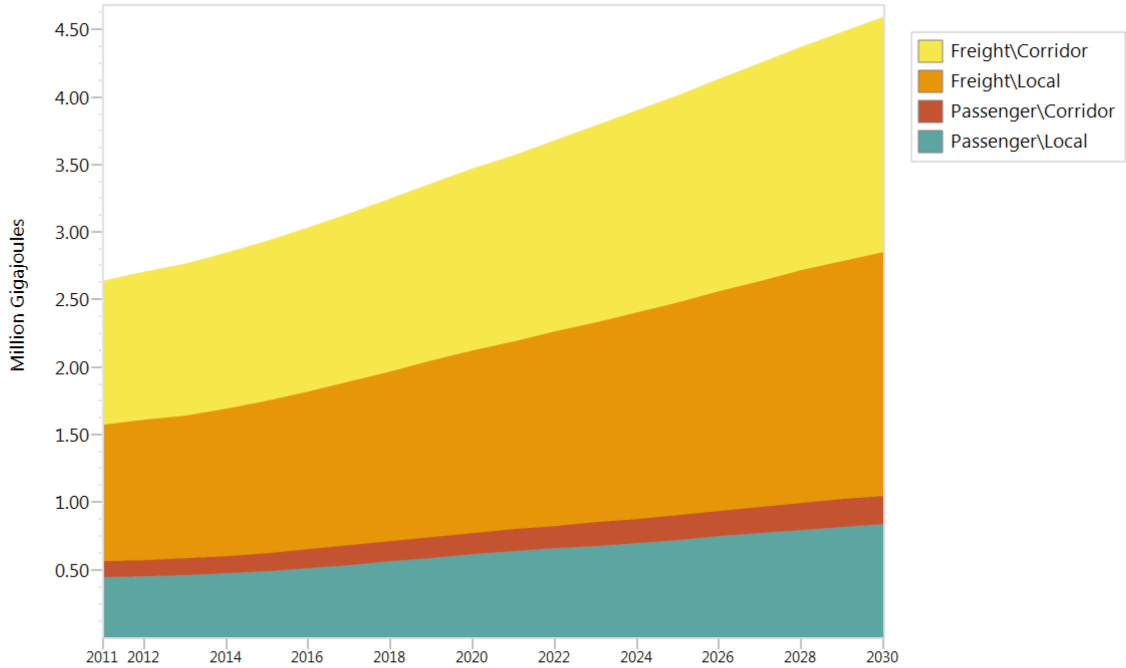


Figure 19: Diesel consumption in Polokwane by the subsectors for the BAU scenario

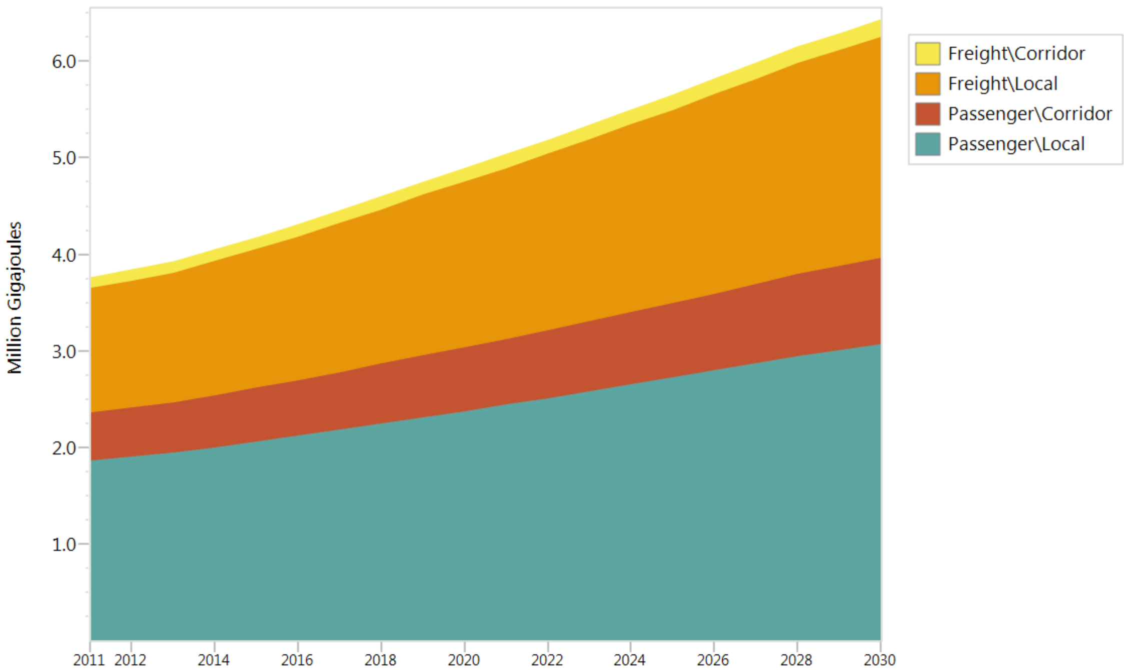
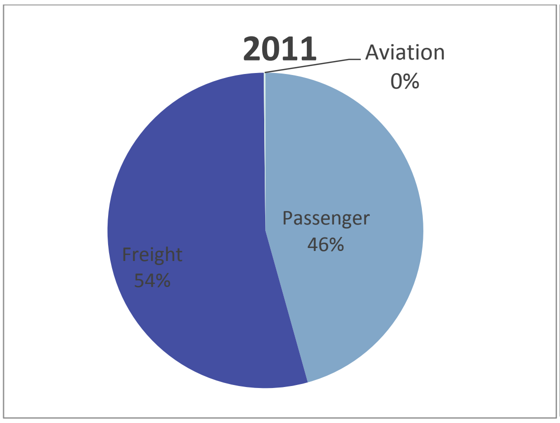


Figure 20: Petrol consumption in Polokwane for the BAU scenario

The change in share of the transport sector fuel consumption is very little by 2030 (Figure 21), and most of the passenger fuel consumption is in the private sector (Figure 22)



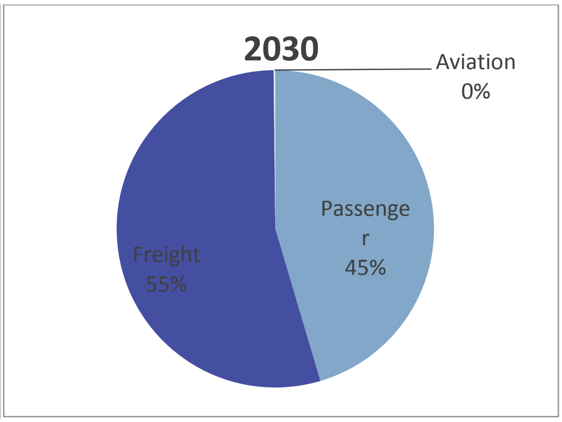
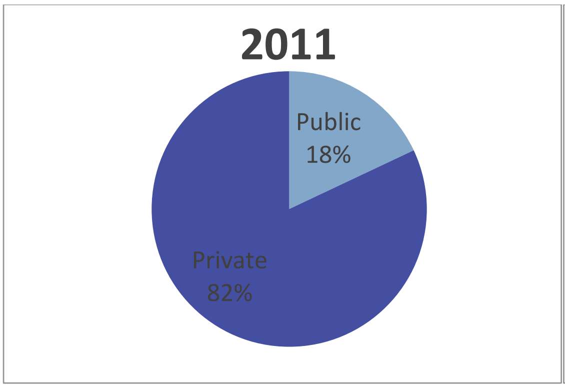


Figure 21: Transport sector energy consumption by subsector



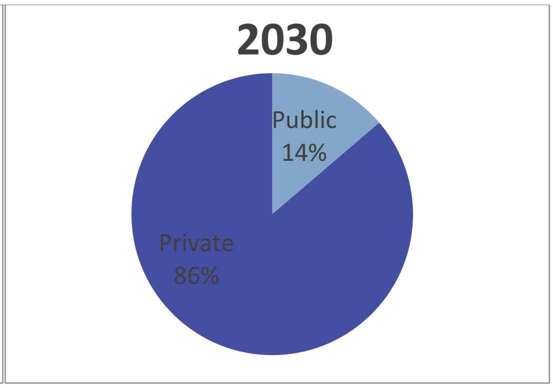


Figure 22: Passenger transport for the BAU scenario showing the total energy consumption split for private and public transport

The majority of petrol consumed in the city is for light passenger vehicles as indicated in the figures below.

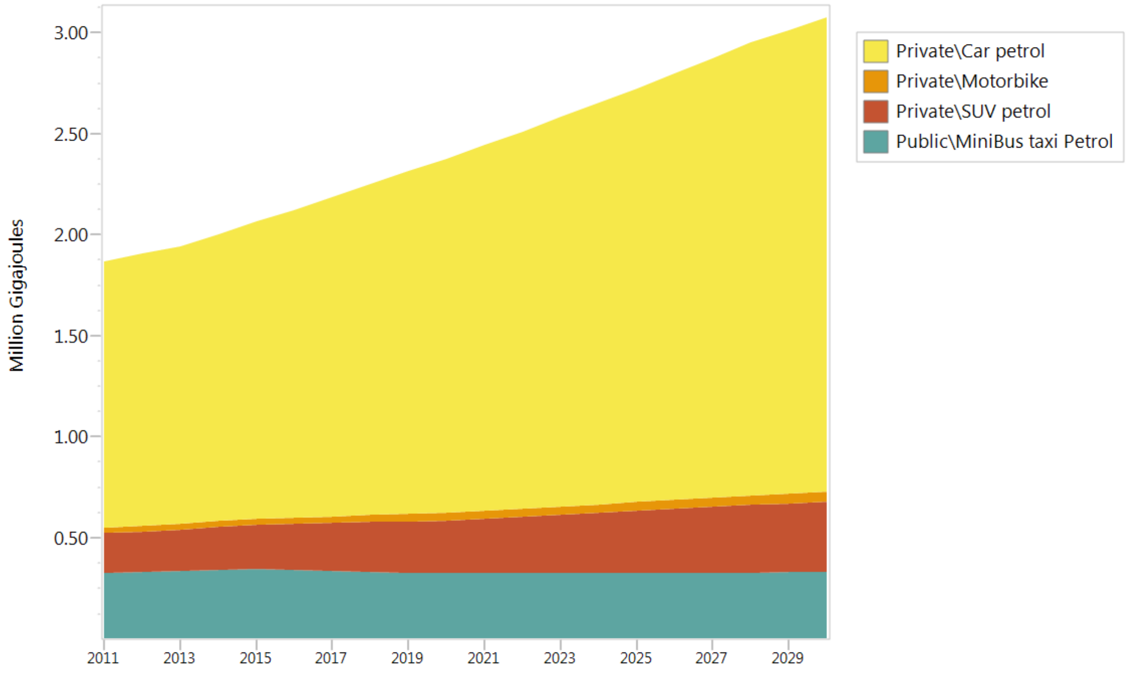


Figure 23: The petrol consumption for local passengers in Polokwane is mainly for light passenger vehicles

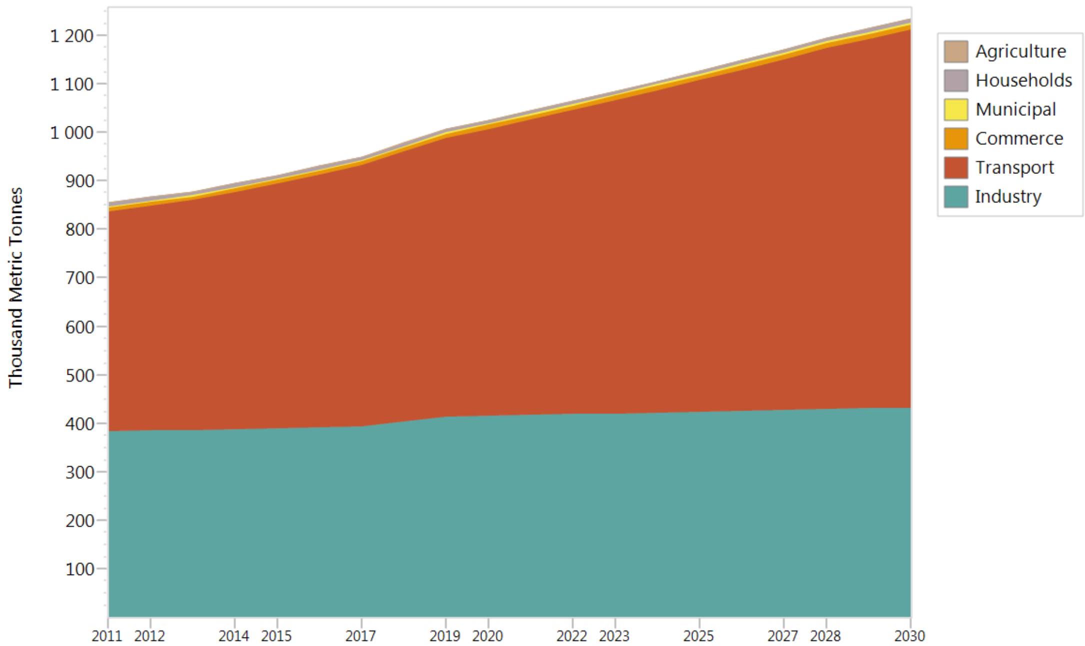


Figure 24: Combustion emissions (CO_2) by sector for Polokwane BAU scenario including smelters – not including electricity-related emissions

The carbon dioxide emissions for industry almost completely fall away in Figure 24 when the smelters are excluded. This is because most of the direct emissions come from the combustion of coal for the flash dryers in the Anglo Smelter.

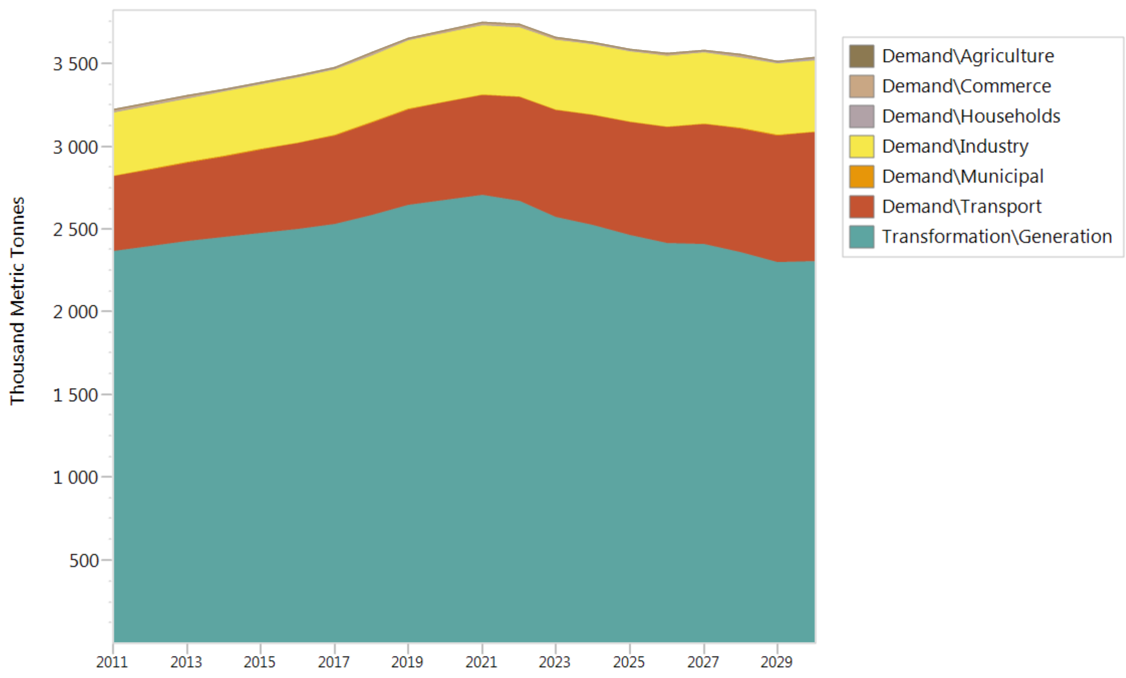


Figure 25: The CO_2 emissions for Polokwane (including smelters) including electricity-related emissions 'transformation\generation'

The decrease in overall emissions for Polokwane between 2020 and 2030 is from the large share of nuclear power generation in the Policy adjusted scenario in the IRP2010.

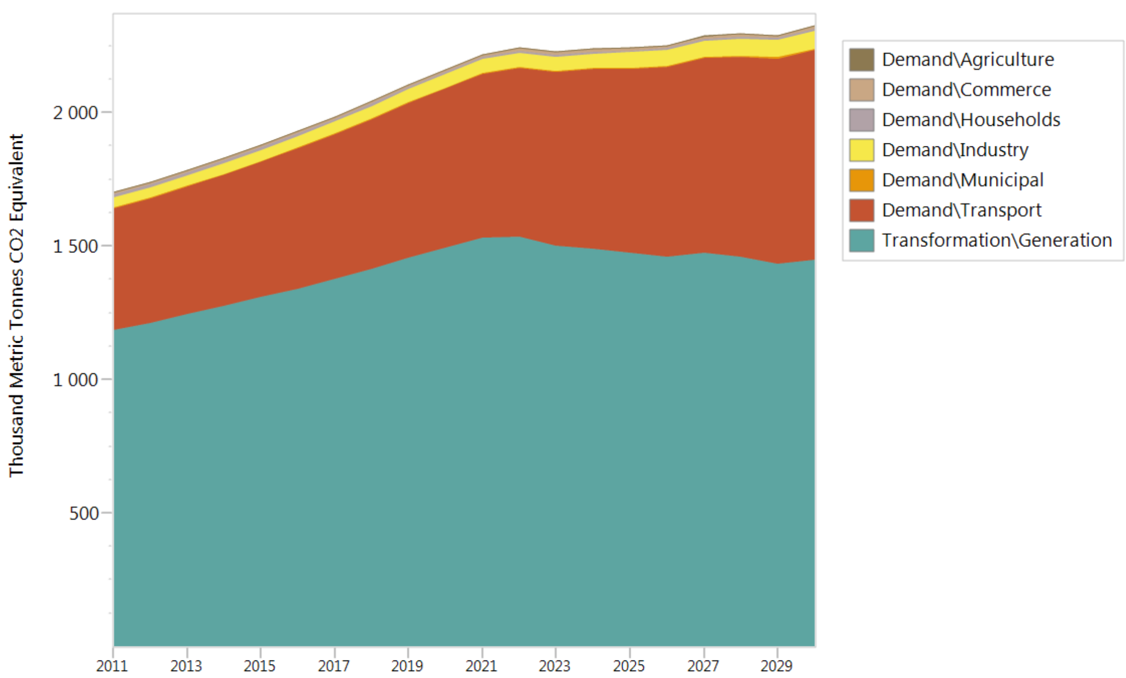


Figure 26: The CO_2 emissions from Polokwane including electricity, smelters excluded

Most of the emissions from electricity generation are from the large coal base in the South African national system. However there is a dip in the emissions profile of the electricity grid due to the nuclear build programme (see Figure 27 and Figure 28).

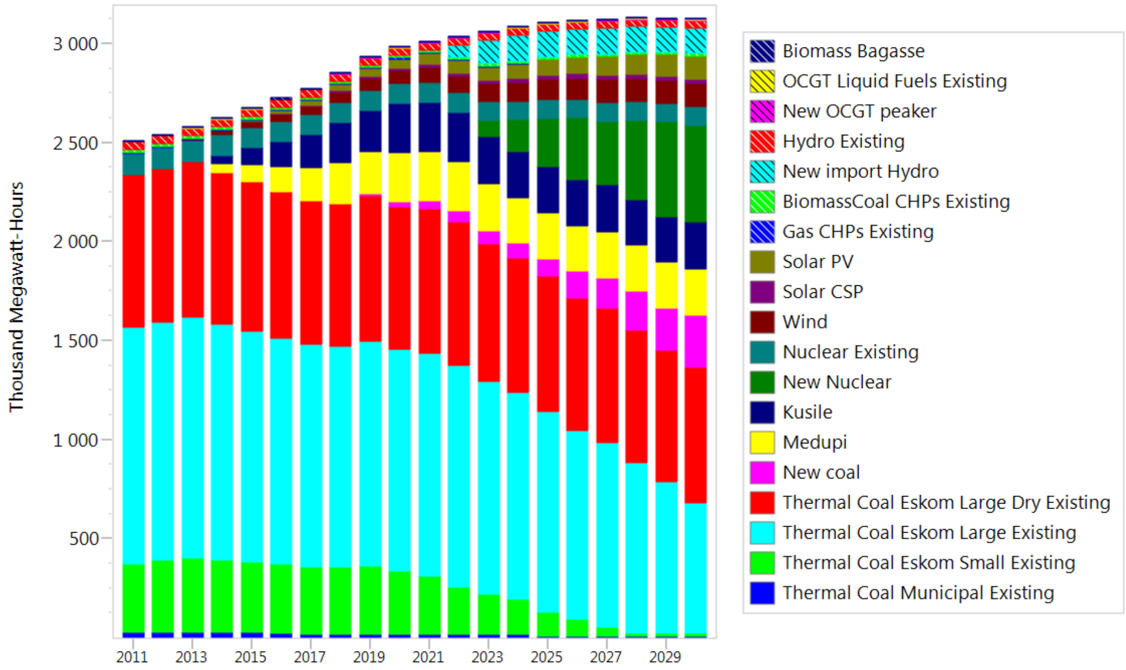


Figure 27: Electricity generation from the national grid for Polokwane, by technology type for the Policy adjusted scenario

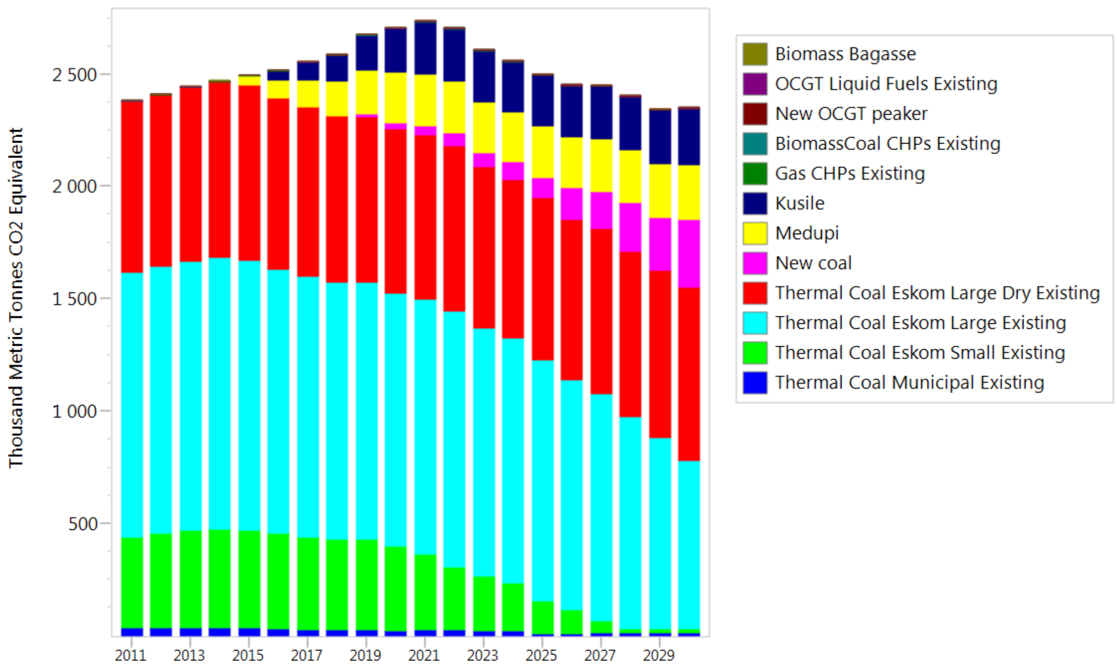


Figure 28: Emissions from electricity production by technology and fuel type

11.2 SENSITIVITY SCENARIOS

In this section, alternate key assumptions are testing to gauge their effects on the overall energy picture of Polokwane.

Population – high growth (sPOP)

In this scenario we explore the effect of increased population growth rate has on the energy picture.

- It is assumed that from 2016 to 2030 the growth rate averages 3% per year (instead of 1.58% in the BAU).

GDP and economy – increased growth rates (sGDP)

The economy directly drives several sectors within the model, and thus influences the energy consumed.

- In this scenario it is assumed that the growth rate of the GDP (nationally and therefore locally) achieves the peak of 3.7% from the weathering the storm scenario by 2017 and increases to 4% by 2020, and retains this growth level through to 2030.

The results of these two sensitivity scenarios are shown in the figure below, and indicate that overall the municipality is almost equally affected by each growth scenario.

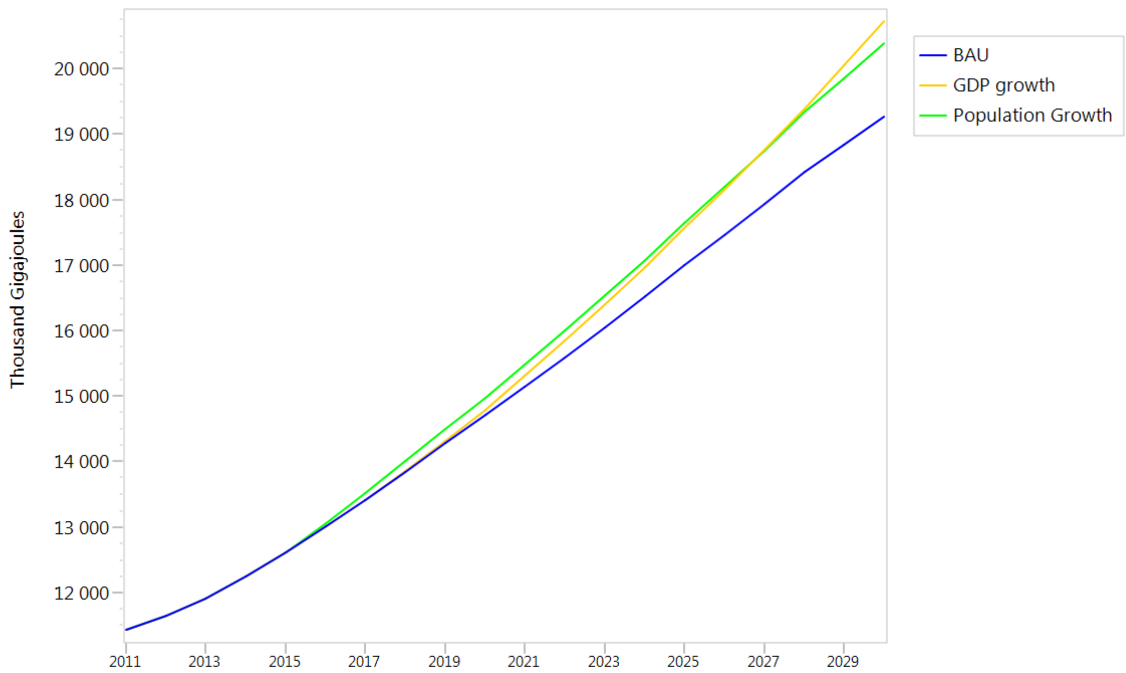


Figure 29: Total energy demand for Polokwane for the sensitivity scenarios testing population and GDP growths – not including smelters

The increase in energy consumption for the higher GDP scenario is a result of increased demand in passenger transport – there are more private vehicles and thus higher energy intensity, and an increase in local and corridor freight as well as an increase in local industry

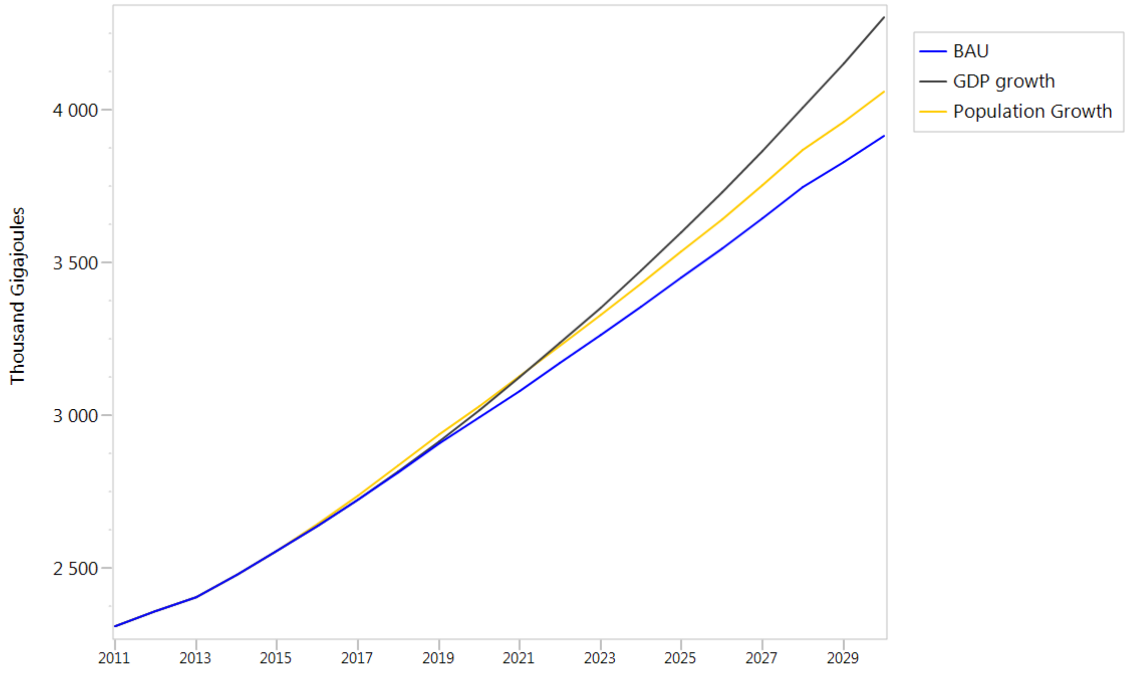


Figure 30: Local passenger energy demand for the sensitivity scenarios

The increase in GDP of Polokwane without an increase in population (relative to the BAU) leads to lower public transport energy consumption, as more people use private transportation.

The higher population growth rate generally leads to more demand in the HH sector by roughly 25%, and to some degree an increase in the passenger transport as well (this is not as much since in this scenario we increase the population without increasing the economic wealth of the city).

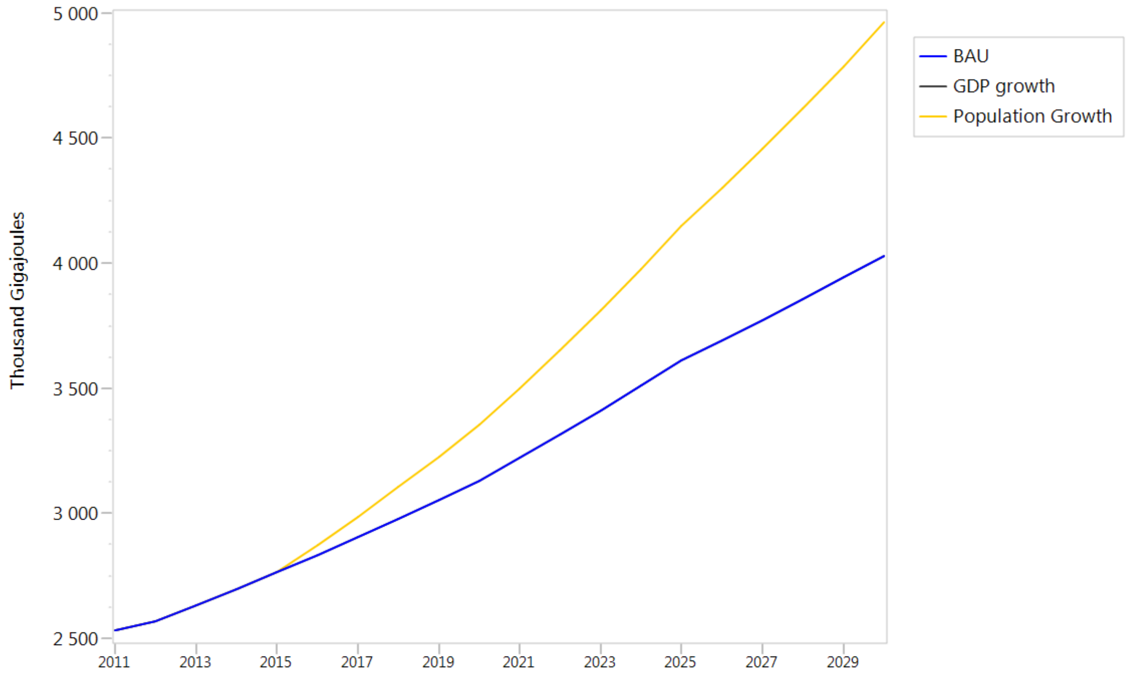


Figure 31: Residential sector energy consumption for the sensitivity scenarios

11.3 DEMAND SCENARIOS

11.3.1 TRANSPORT SCENARIOS

Private transport behavioural (PTB) change

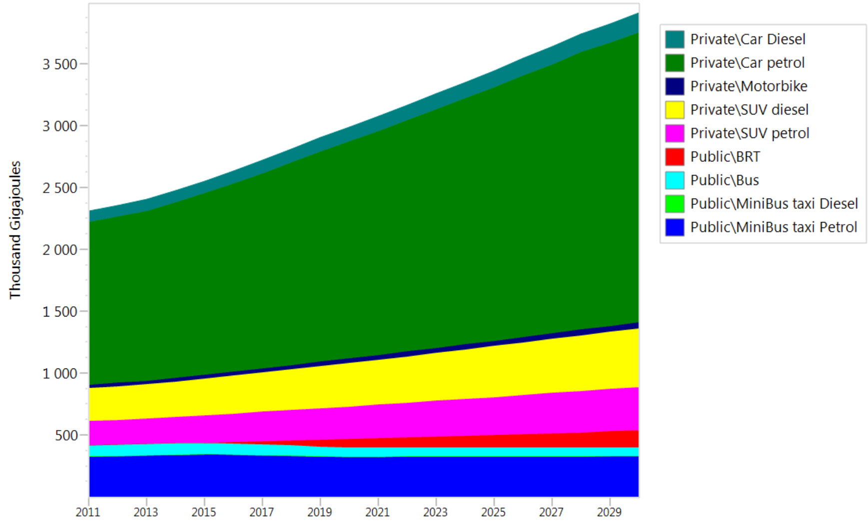
This scenario explores the concept of carpooling to improve energy efficiency within the city. Private car fuel consumptions accounts the most (about 30%) of the base year transportation fuel consumption.

In this scenario

The average occupancy of private vehicles increases from 1.4 in 2015 to 2 by 2030 through means of carpooling (see Table 68). This applies to both private light passenger and SUV vehicles. Note that this scenario is for the case where people using private vehicles start to carpool together and not the case where people using private vehicles would then lift a person who previously used a bus – this would be modal shift. See Figure 32 for energy demand for the passenger transport sector.

Table 68: PTB scenario summary

Sector	In the PTB Scenario	Comment
Passenger private transport	Light vehicle passenger occupancy average from 1.4 to 1.8 by 2030.	This leads to better fuel consumption for the same amount of passengers



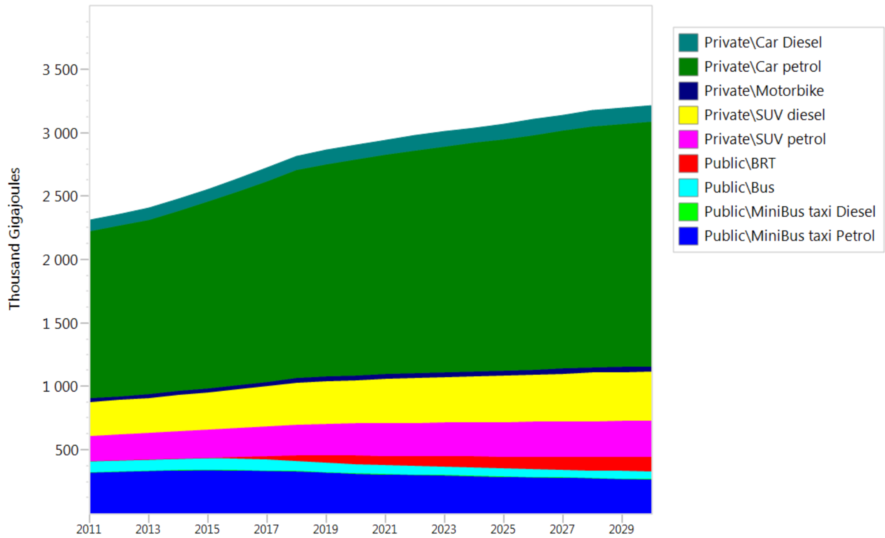


Figure 32: Energy demand for the passenger transport sector in the BAU (above) and the PTB (lower) scenario

Non-motorised transport shift (NMT)

This scenario is designed to explore the potential change in energy consumption if there is an increased usage (a modal shift) from motorised transportation to non-motorised (bicycles and walking) as compared to the BAU scenario.

In this scenario

More people begin to use bicycles and or walking as their main form of transport for general everyday use such as going to work or school. The share of non-motorised transportation begins to increase between 2015 and 2020 from 22.9% to 25% and then to 35% by 2030. Walking is the dominant form of non-motorised transport, but this is assumed to change in this scenario. The use of bicycles increases between 2015 and 2020 from just 2% of all non-motorised transport to 20% and this increases to 40% by 2030.

Table 69: NMT scenario summary

Sector	In this scenario	Comment
Passenger transport: Non-motorised	Non-motorised (both walking and cycling) share increases from 23% to	
Passenger transport: Non-motorised		

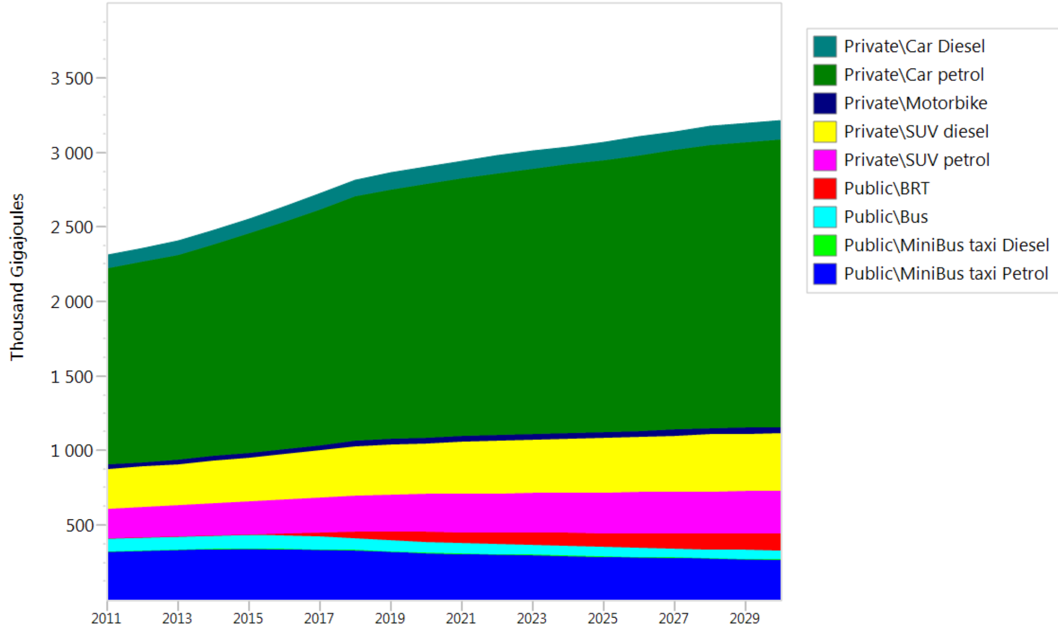


Figure 33: The energy consumption for the passenger transport sector for the NMT scenario

Increased public transport share (PbTS)

With the underlying assumptions on the GDP growth rates and population growth rates in the BAU scenario the resulting share of private transport of all passenger transport is about 49% in 2020. In this scenario this decreases to 40% by 2030 and public transportation makes up 60. It is assumed that the share split between bus, BRT, and minibus does not change from BAU.

Table 70: PbTS scenario summary

Sector	This scenario	Comment
Public transport share	From 52% in 2020 to 60% in 2030	A higher public transport share is assumed to also lead to higher occupancy numbers in buses, BRTs, and minibus taxis leading to lower energy intensities.

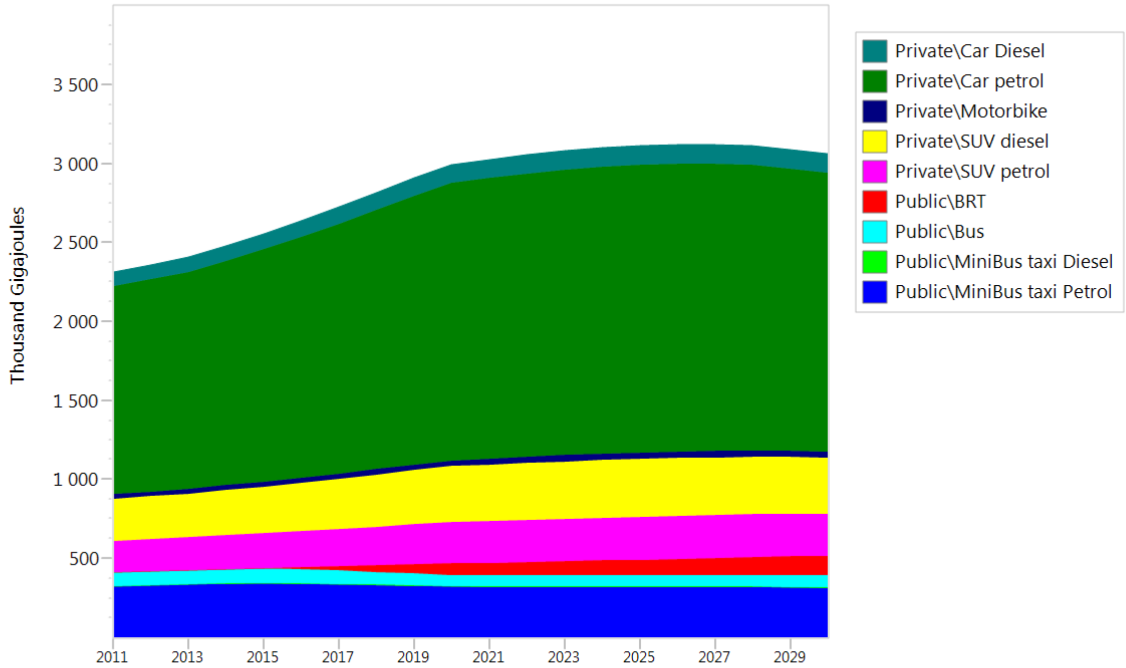


Figure 34: The energy consumption of the local passenger transport sector for the PbTS scenario

Efficient vehicles scenario (PTEF)

In this scenario, the effects of efficient vehicles for private passenger transport is explored through hybrid vehicles which utilise petrol engines and electric motors combined to improve fuel efficiency, and pure electric vehicles which run on stored electric charge in batteries.

In this scenario, hybrid car uptake is assumed to be larger than electric (by 2030) as hybrid vehicle cars already have an uptake in the country.

In this scenario:

- Electric vehicles make up 10% of private vehicles by 2030
- Hybrid vehicles make up 20% of private vehicles by 2030
- Most of the technology switching (from combustion to hybrid or electric) is assumed to come mainly from petrol cars

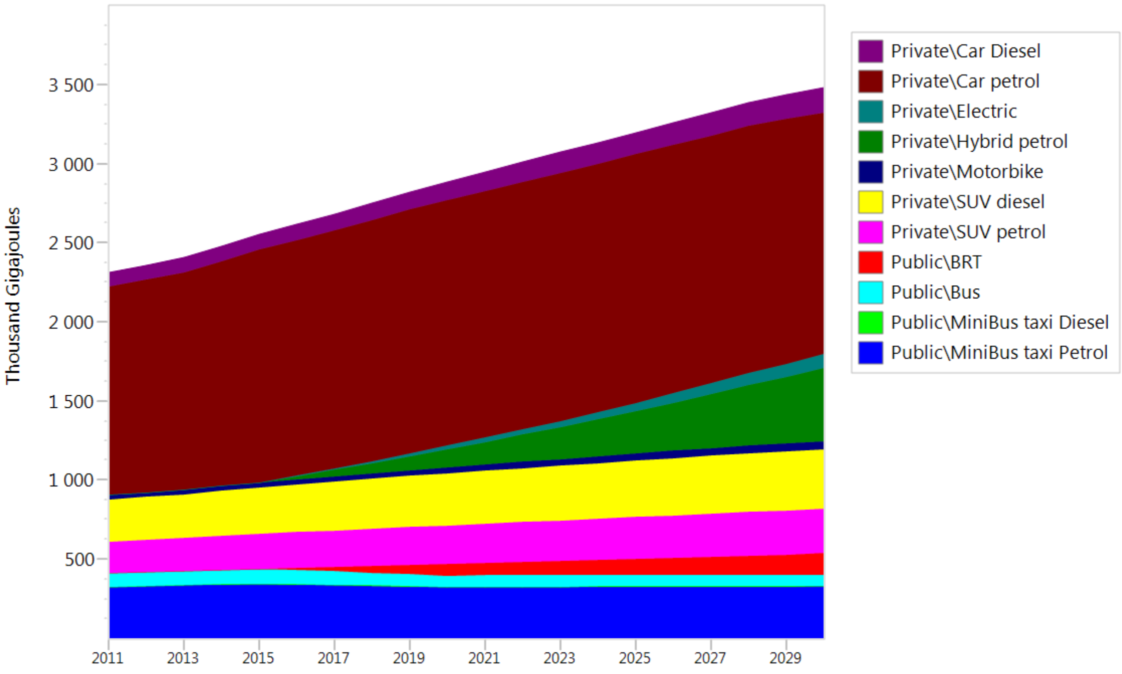


Figure 35: Fuel consumption for the efficient private vehicle scenarios

A summary of all the transport scenarios is given in the table below.

Table 71: Transport scenarios summary

Scenario	Sector	In the PTB Scenario	Comment
Private transport behaviour change PTB	Passenger transport: private	Light vehicle passenger occupancy average from 1.4 to 2 by 2030	This leads to better fuel consumption for the same amount of passengers
Non-motorised transport shift NMT	Passenger transport: Non-motorised	Non-motorised (both walking and cycling) share of all passenger demand increases from 23% to 30% by 2025, and to 35% by 2030 Bicycles' share of non-motorised: 20% by 2020, and 40% by 2030.	There is in general an increase in walking and cycling, and most of the increase is in cycling
Public transport share PbTS	Passenger transport: Public	Public transport share from 51% in 2020 to 60% in 2030 compared to 47% in the BAU	A higher public transport share is assumed to also lead to higher occupancy numbers in buses, BRT's, and Minibus taxi's leading to lower energy intensities.
Efficient vehicles Scenario PTEF	Passenger transport: private	10% passenger cars are electric by 2030 20% of cars are hybrid	

The scenarios compared to each other show similar fuel savings by 2030 (except for the efficient vehicles scenario), as shown in Figure 36. The energy savings is likewise for the emissions savings, as shown in Figure 37.

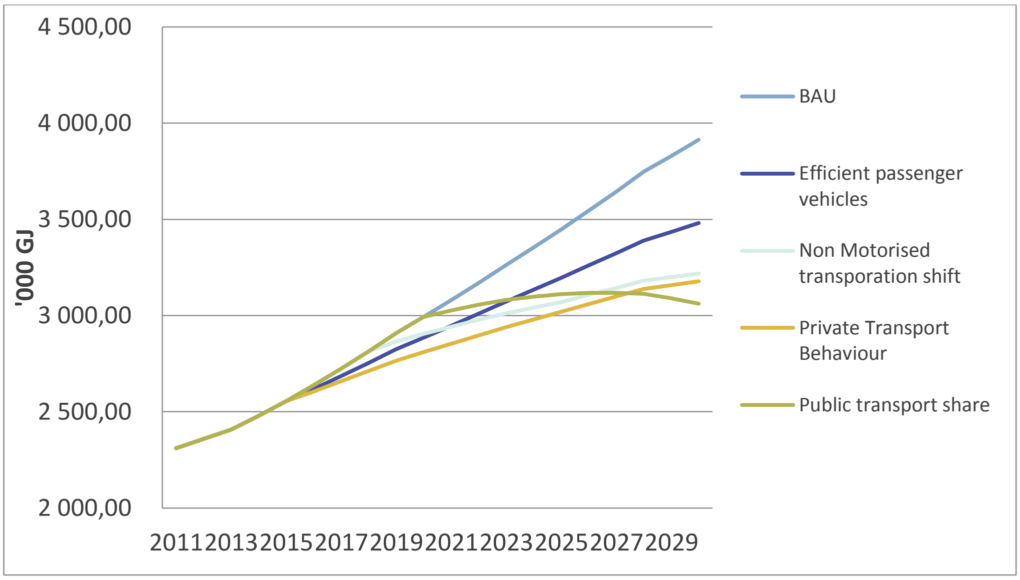


Figure 36: Total Polokwane local passenger energy demand comparing the transport scenarios to the BAU

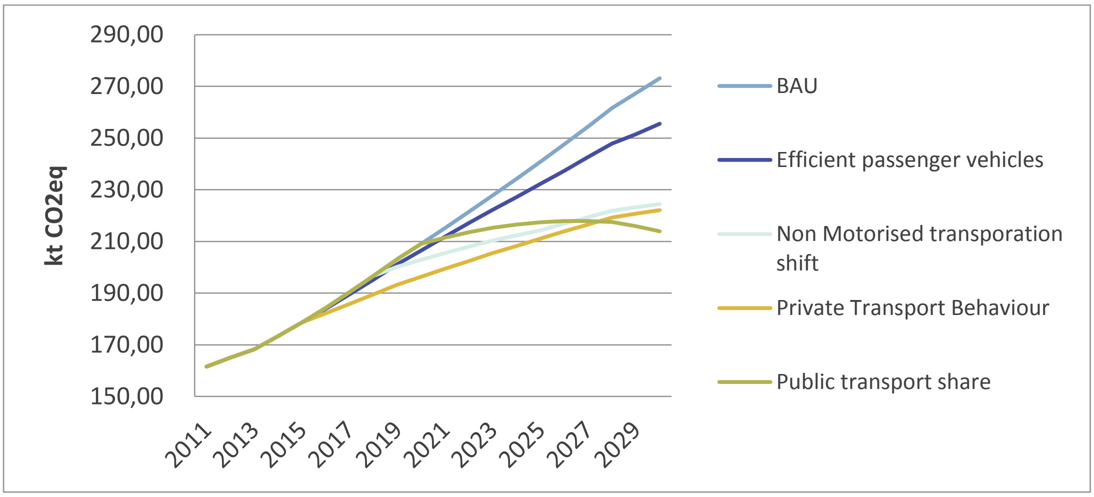


Figure 37: Polokwane local passenger CO_2 emissions comparing the transport scenarios (includes electricity emissions – for electric vehicles)

The use of electricity vehicles increases electricity consumption and thus the associated emissions from electricity. In Figure 37, where it is included, it accounts for about 19 kt in the year 2030 – thus reducing its emissions impacts. The saving in cost however differs from one transport scenario to the other, with NMT and Public transport saving the most money (if infrastructure costs are excluded), while efficient vehicles would be costlier – see figures below.

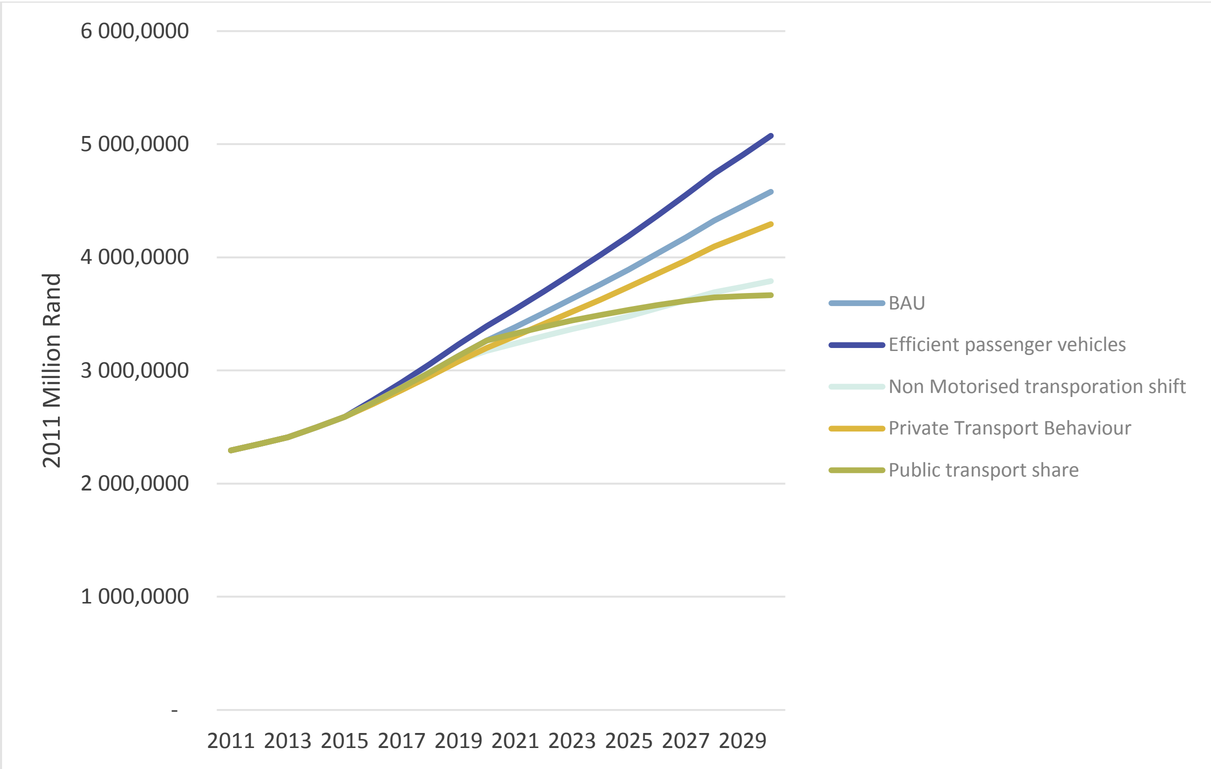


Figure 38: Total cost to the Polokwane local passenger transport sector for the transport scenarios

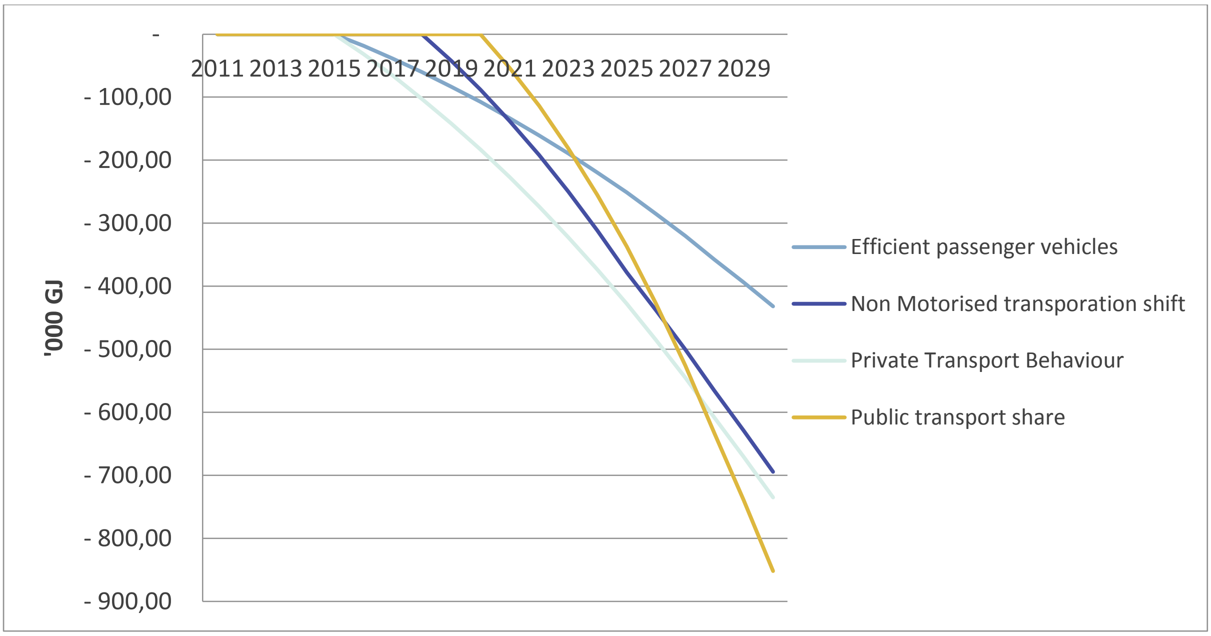


Figure 39: Annual cumulative energy savings impact to the whole city by transport scenarios.

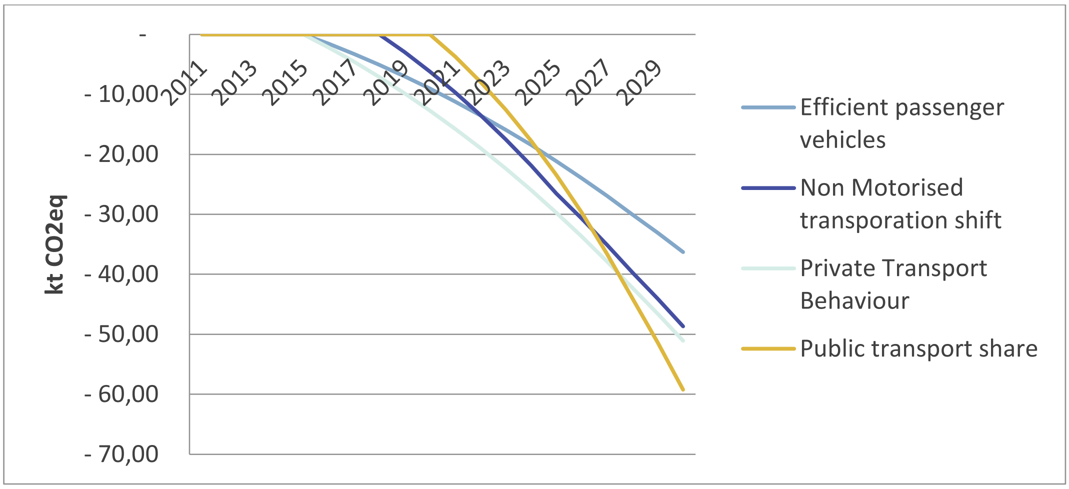


Figure 40: The annual city wide CO_2 emissions reductions for the transport scenarios

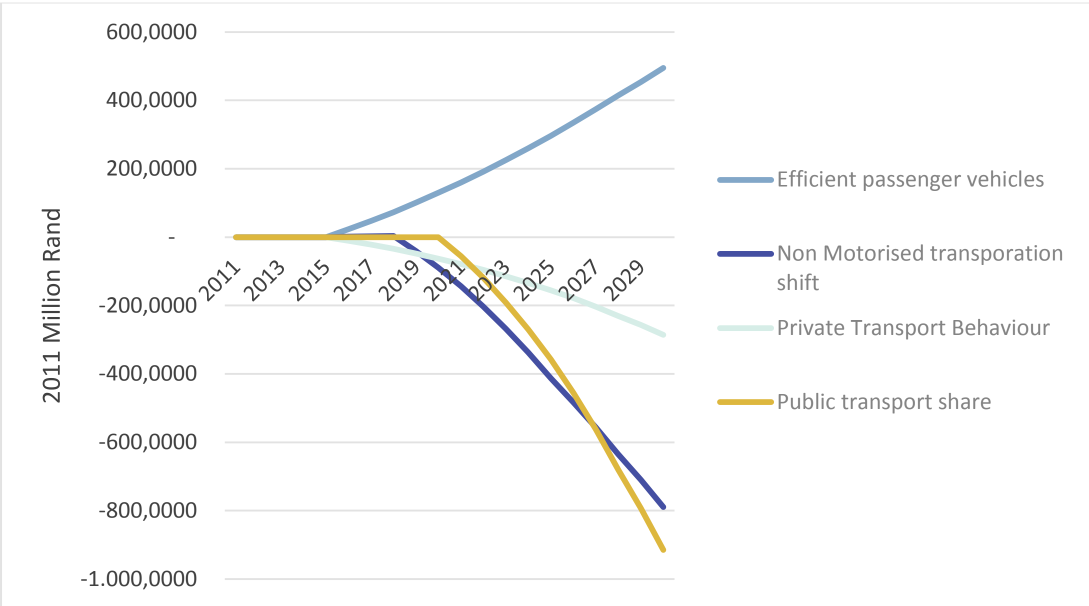


Figure 41: The annual cost to the Polokwane local passenger sector for the transport scenarios

Some discussion on the transport results

Cost reductions for the NMT scenario (walking and cycling a lot more) are much larger than for private vehicle occupancy shift, even though the energy savings for the latter has a larger energy savings. This is because the NMT scenario requires little capital (the cost of a bicycle) and no operating costs, while the private vehicles will still be consuming fuel in the PTB scenario (even though per pass-km they will be consuming less).

The public transport share scenario (PbTS) has the largest energy reductions of the scenarios by 2030, but cumulatively the private vehicle occupancy change (from 1.4 to 2) has the largest savings cumulatively through to 2030, compared to the other scenarios, but does not save the most money.

The efficient vehicles scenario, while saving the least amount of fuel compared to the rest of the scenarios, costs the local passenger economy more than it would save in fuel costs. This would be owing to the high upfront costs of the hybrid and electric vehicles, which are roughly a third more expensive than the standard combustion engine counterpart. These results are also affected by the implementation timeline – the BRT system and a move to more public transport will take time to implement, but higher occupancy levels and/or more non-motorised transport could be implemented sooner, and thus by 2030 the savings can be vastly different.

11.3.2 COMMERCIAL ENERGY EFFICIENCY SCENARIOS

The commercial sector energy consumption is largely dominated by lighting and space-heating and -cooling (also venting). This section will explore scenarios where the commercial sector becomes more energy efficient by changing out their existing technologies for new more efficient ones for these two main energy consumers.

Lighting (COML)

In this scenario all commercial buildings move to more efficient T5 fluorescent lights to meet all their lighting demands by 2030. The base scenario assumes that 40% of the current lighting is from T5s while the remainder are the less efficient fluorescent lights using magnetic ballasts.

Table 72: Commercial Energy Efficiency – Lighting scenario summary

Lighting type	Share	Comment
Fluorescent with magnetic ballast	From 60% to 0% by 2030	
Fluorescent with electronic ballast	From 40% to 100% by 2030	These are about 40% more efficient due to change in actual tube and the newer ballast type.

The BAU energy profile is given in Figure 42, with the scenario impact in Figure 43.

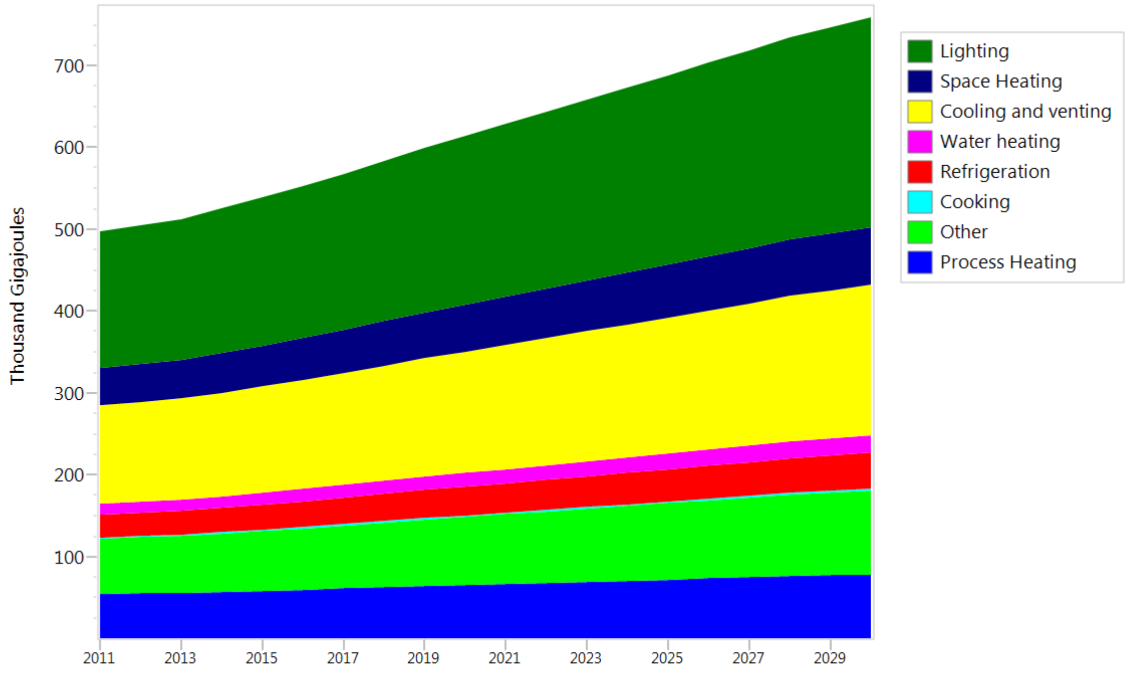


Figure 42: The demand by end use for the BAU scenario for the commercial sector of Polokwane

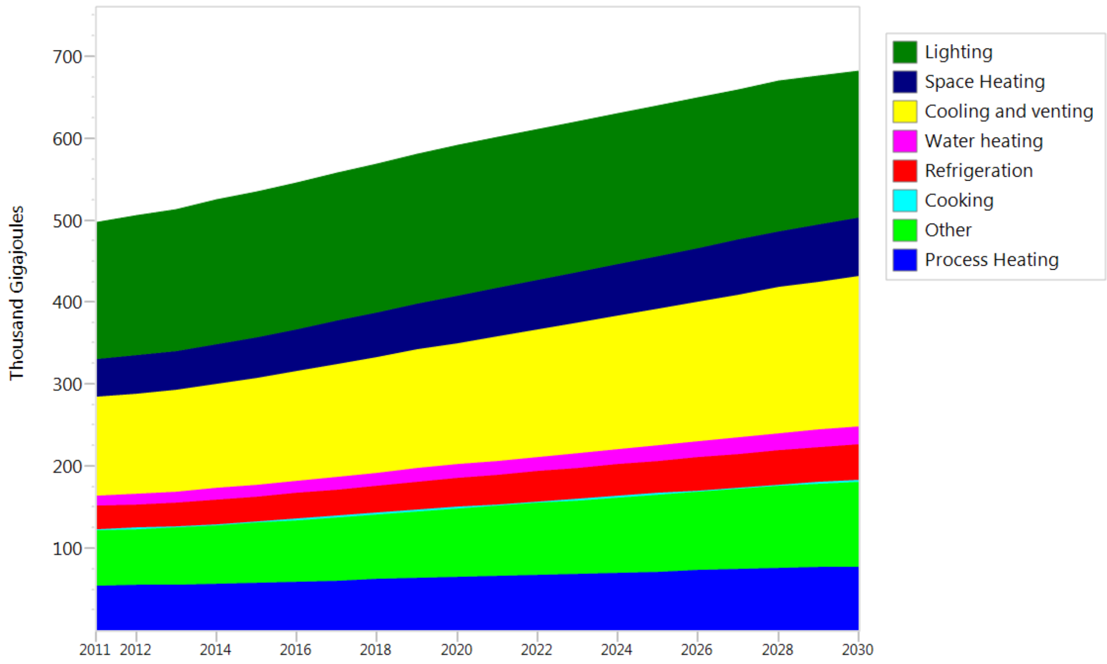


Figure 43: Commercial sector energy demand by end use in the efficient lighting scenario (COML)

Commercial sector HVAC efficiency (COMH)

Space heating and cooling systems are converted to variable refrigerant volume (VRV) systems which are about 32% more efficient. Figure 44 shows commercial sector energy demand for the HVAC scenario and Figure 45 shows it for the combined lighting and

HVAC efficiency scenarios – this is a result of the combination of these retrofits as well as the building code regulations coming into effect gradually.

Table 73: Commercial energy efficiency – space-heating and cooling systems summary

HVAC system	Share	Comment
Standard system with COP of 2.74	From 100% to 0% by 2030	
VRV with COP of 4	From 0% to 100% by 2030	These are about 32% more efficient

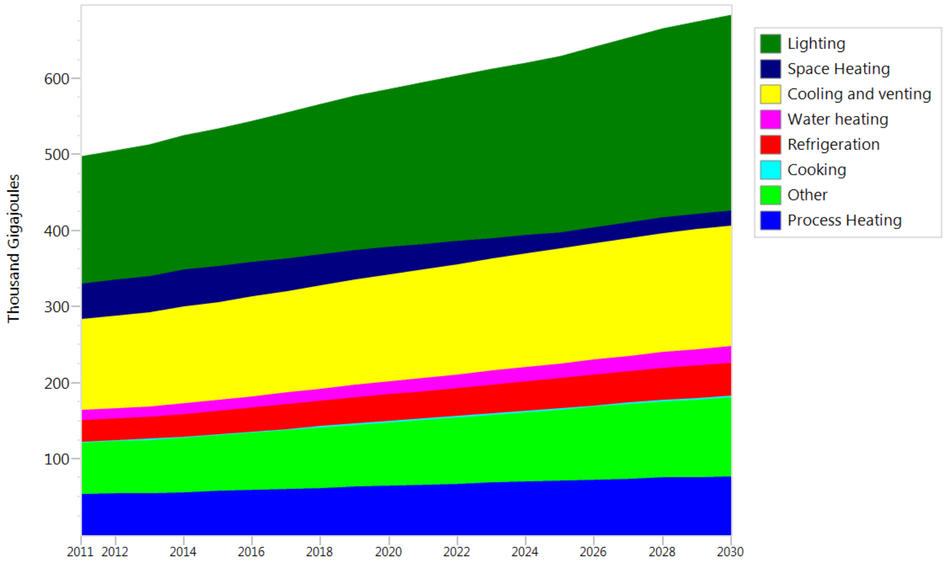


Figure 44: Commercial sector energy demand for the HVAC scenario (COMH)

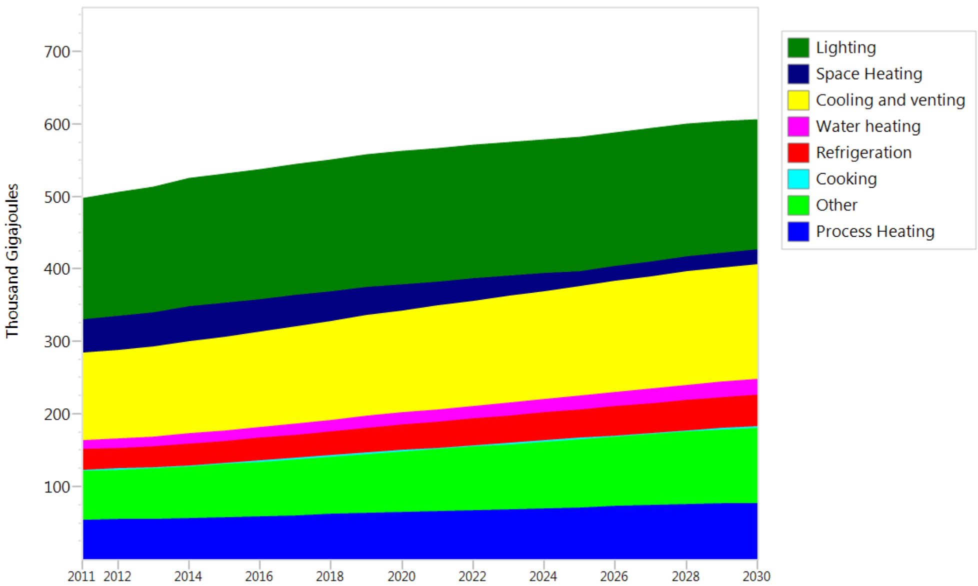


Figure 45: Commercial sector energy demand for the combined lighting and HVAC efficiency scenario

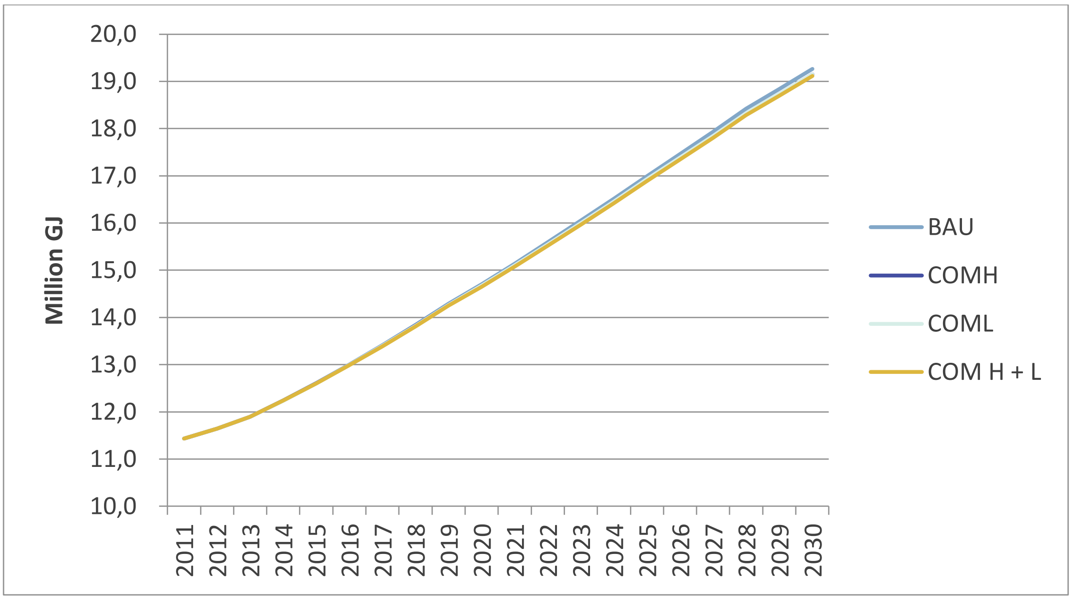


Figure 46: Polokwane energy consumption showing the commercial sector scenarios

The commercial sector energy consumption scenarios do not reduce the energy consumption of Polokwane significantly, but they do reduce the energy consumption of the commercial sector itself quite significantly, as shown in the figures below.

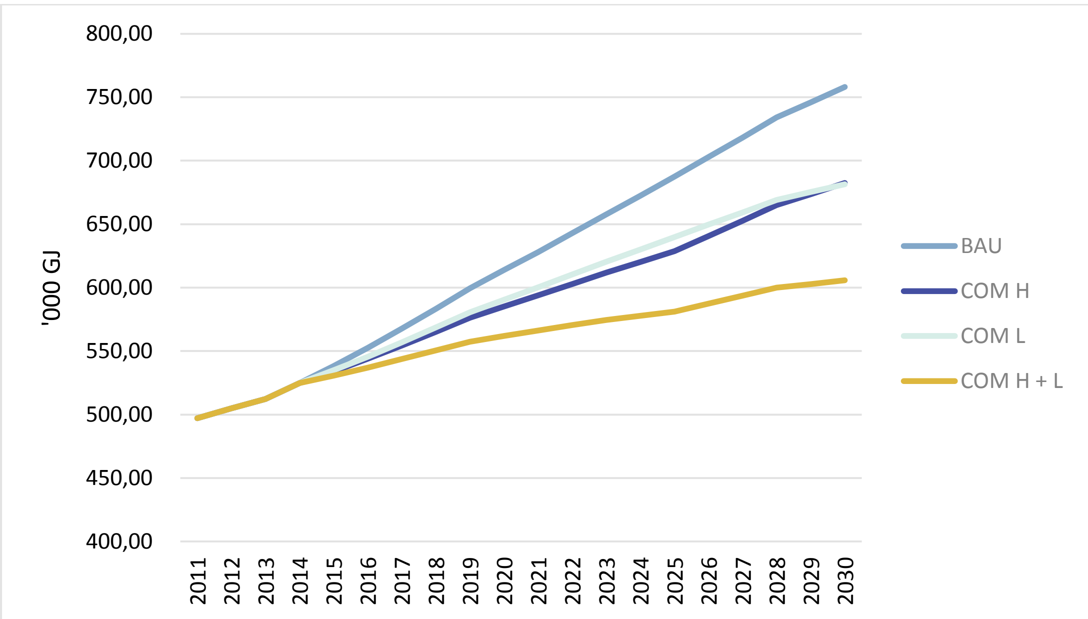


Figure 47: Polokwane commercial sector energy consumption for commercial sector scenarios

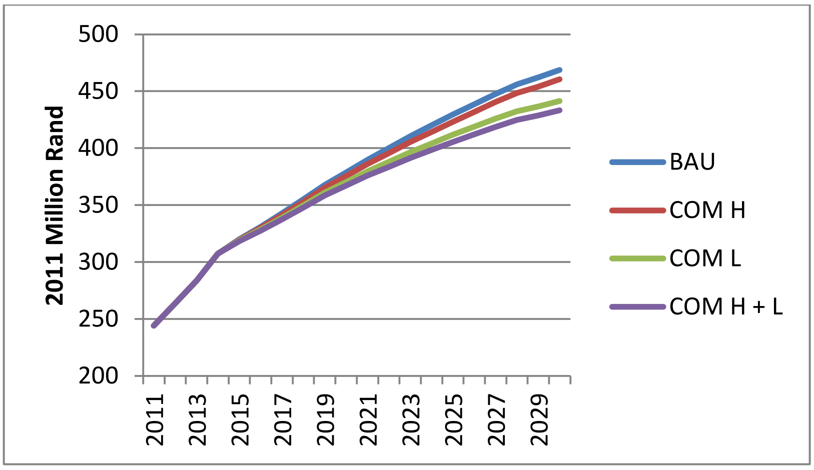


Figure 48: The costs to the Polokwane commercial sector in the commercial scenarios

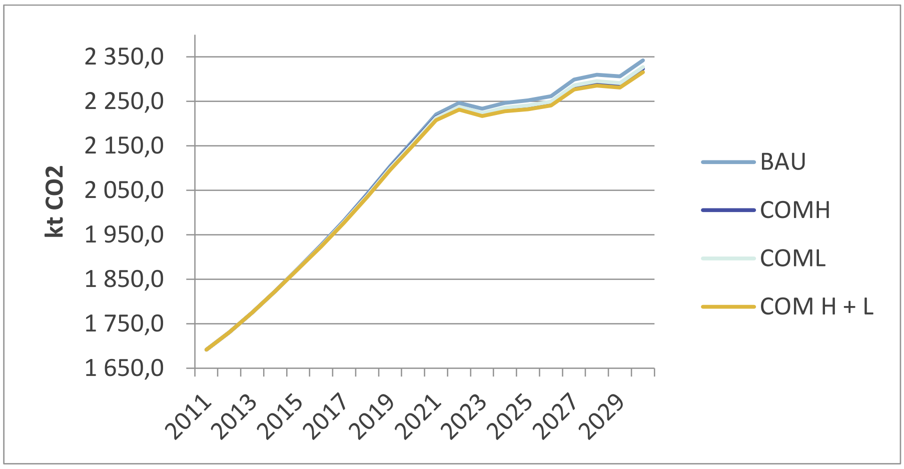


Figure 49: Polokwane CO_2 emissions for the commercial sector scenarios

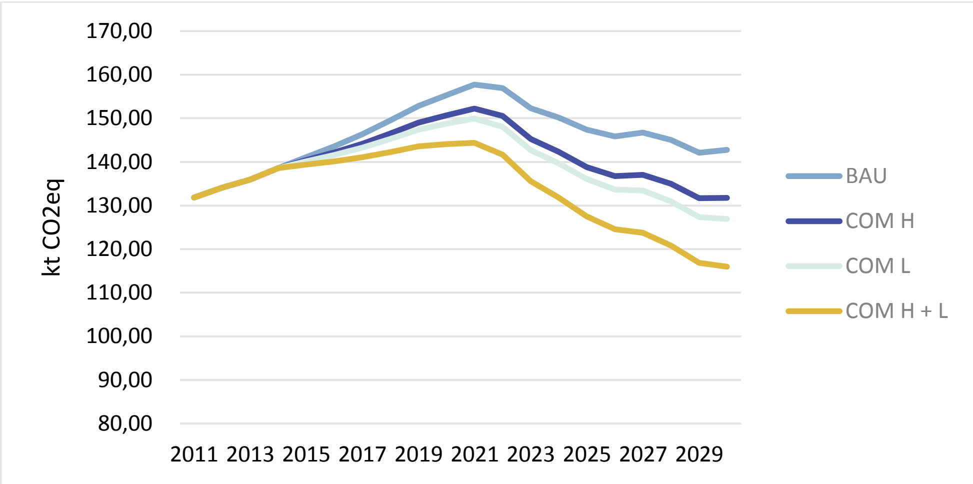


Figure 50: Polokwane commercial sector emissions reductions in the commercial sector scenarios (including electricity emissions)

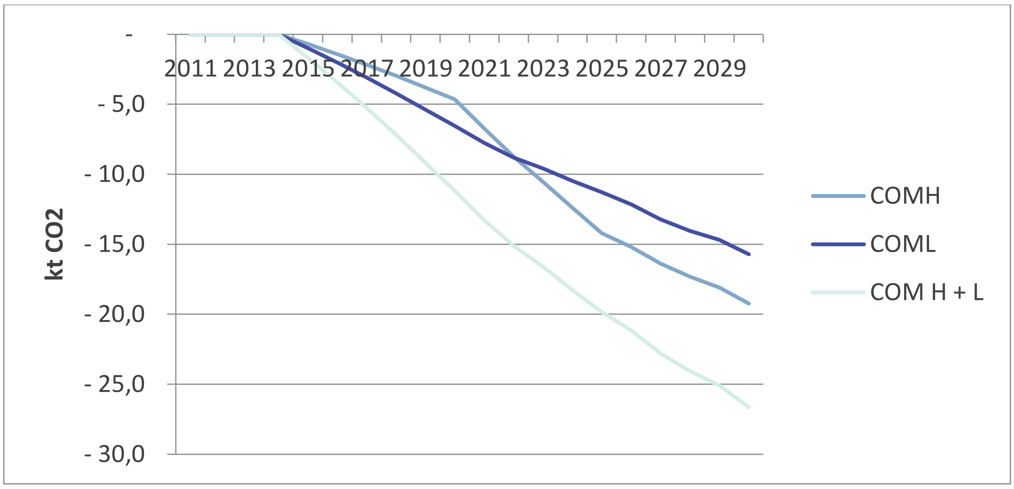


Figure 51: Polokwane cumulative emissions impact for the commerce sector

11.3.3 HOUSEHOLD ENERGY CONSUMPTION SCENARIOS

In this section, we will look at reducing the residential energy consumption within the city by utilising more efficient HH devices. This scenario builds upon the BAU scenario.

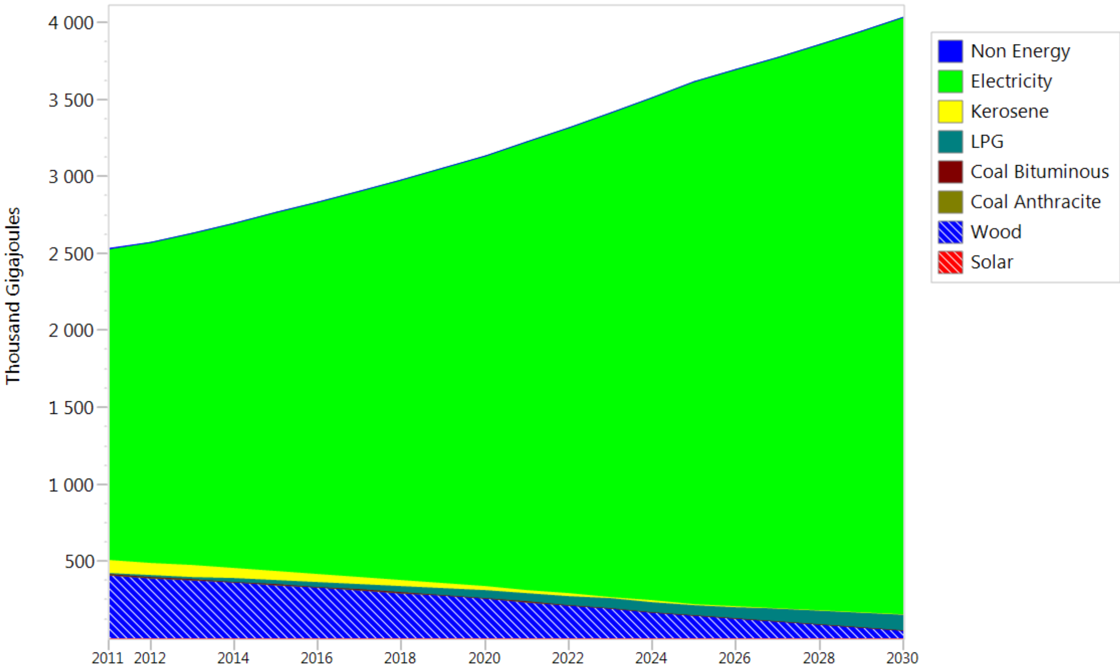
Water-heating (HHW)

Water-heating is the largest energy consumer in the residential sector and in this scenario HHs start to switch to 'efficient' water-heaters by installing insulation around the geyser and the piping, or by switching to solar water-heaters (SWHs). Also, some HHs in mid-to-high-income category are assumed to switch to using heat pumps.

Table 74: Residential water heating scenario summary

Category	Scenario assumptions
Low income	10% electrification with insulation by 2020 and 40% by 2030 (0% and 0% in BAU)

	40% SWH by 2030 (30% in BAU)
Mid to high income	10% SWH by 2020, 40% by 2030 (20% in BAU) 20% electrification with insulation by 2020, 10% by 2030 (0% in BAU) 5% heat pump by 2020, 50% by 2030 (0% in BAU)



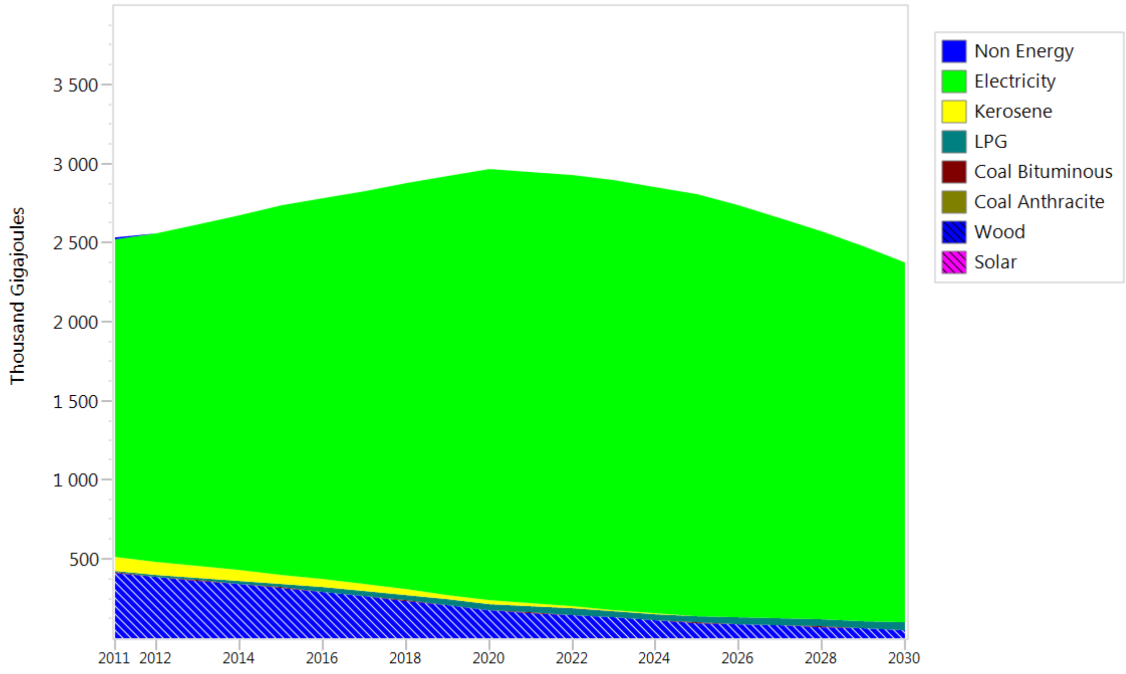


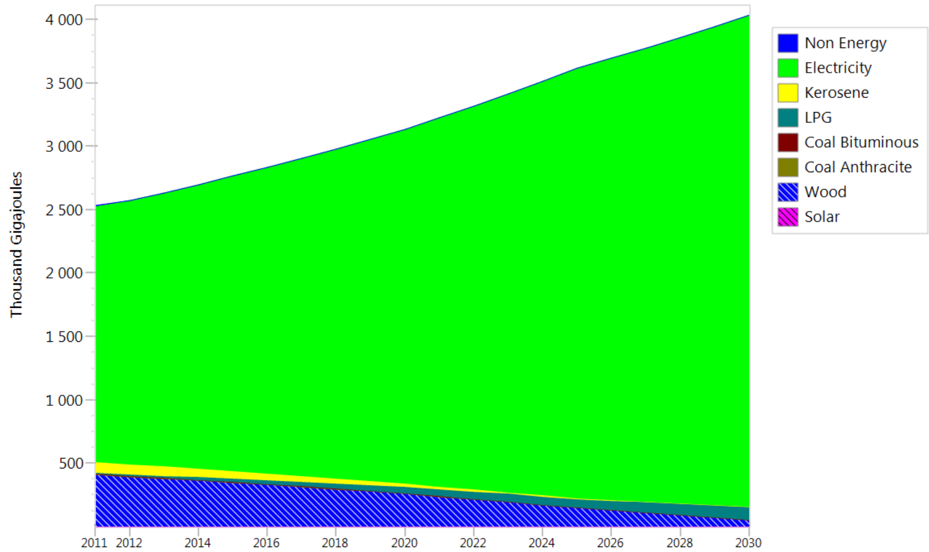
Figure 52: The Polokwane residential sector energy consumption for the BAU scenario (above) and the water-heating scenario HHW (below)

Lighting (HHL)

This scenario explores the energy savings from households moving to efficient lighting systems.

Table 75: Residential lighting scenario summary

Category	Scenario assumptions	Comment
Low-income	98% CFL by 2020 (as in BAU), 60% by 2030 (98% in BAU) 40% LED by 2030(0% in BAU)	High cost will be an issue until LED prices come down in the next 10 years or so. It is assumed LEDs become cost comparable to CFL between 2020 and 2030
Mid-to-high-income	95% CFL by 2020, 5% LED (0% in BAU) 10% CFL by 2030 (98% in BAU), 90% LED(0% in BAU)	



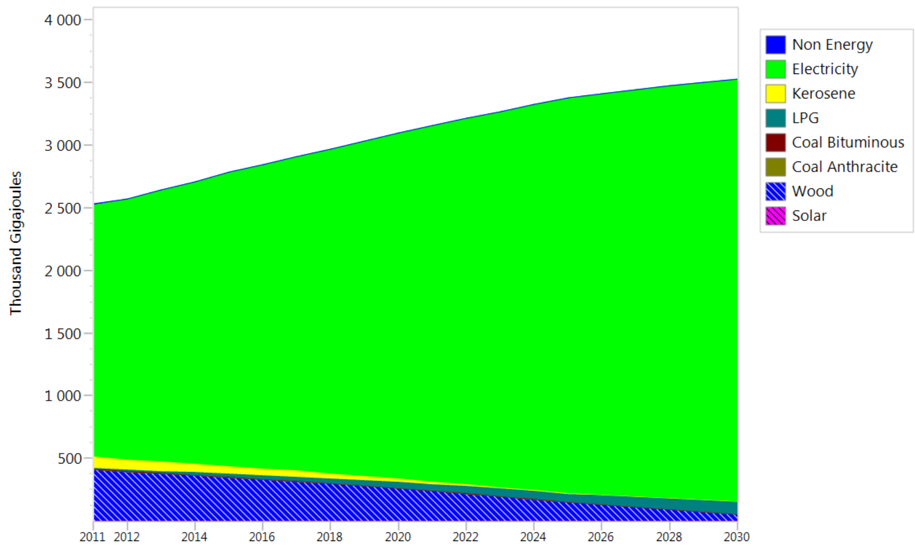


Figure 53: The Polokwane residential energy consumption for the lighting scenario HHL (non-energy is candles)

Residential scenario results

Below are the comparisons for the residential sector HH efficiency scenarios, showing the relative impacts each have on Polokwane's energy consumption

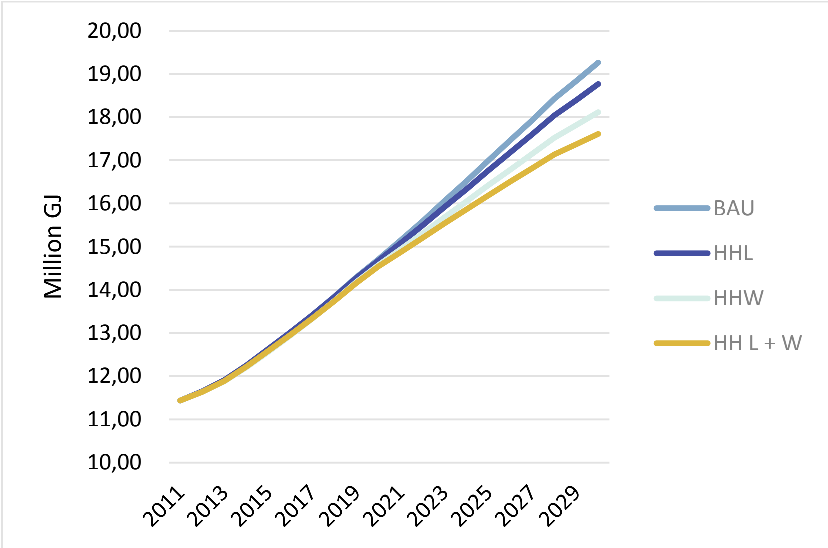


Figure 54: Polokwane total energy consumption for the residential scenarios

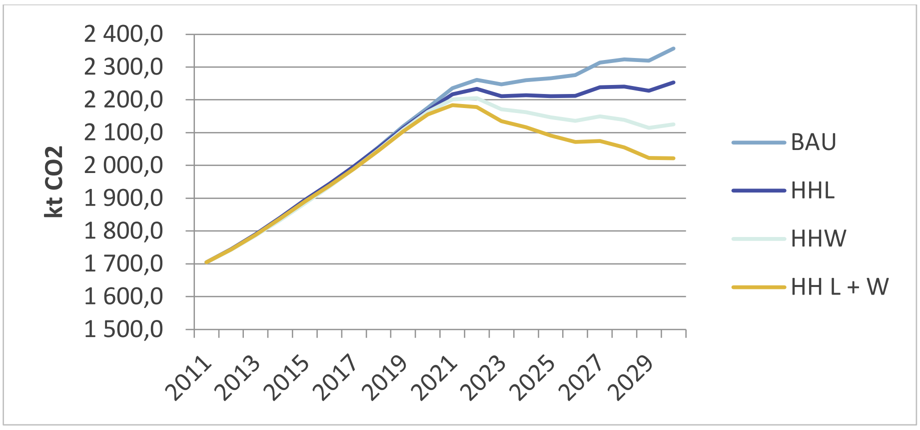


Figure 55: Polokwane total CO_2 emissions with the residential scenarios – includes electricity related emissions

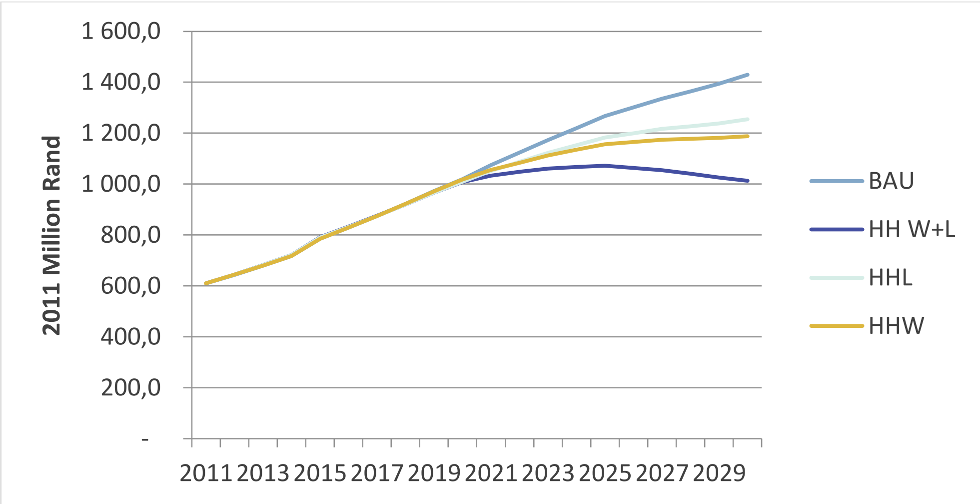


Figure 56: The Polokwane residential sector costs, comparing the residential energy efficiency scenarios

11.3.4 INDUSTRY ENERGY EFFICIENCY SCENARIO (INDEFF)

In this scenario, the impact of energy-efficient motors, heating, venting and cooling (HVAC) systems and lighting in industry are explored. There is limited detail about the industrial sector of Polokwane, and assumptions on the end-use demand are made using the Cape Town LEAP model inputs as guidelines. From these assumptions the following table indicates the breakdown of the scenario.

Table 76: Industry energy efficiency scenario detail

Item	HVAC	Lighting	Motors
Share of total energy*	10.3%	7.4%	49.1%
Efficiency intervention	VRV system	T5s fluorescents	Efficient motors
Efficiency gain	32%	42%	7%

* Note that these are the total shares for just these three energy end services out of a total of 9 end services. This breakdown comes from the Cape Town LEAP model.

Combining the efficiencies and their weighting in energy consumption in the table above results in about 9.8% efficiency gains overall. This total efficiency gain is implemented over 10 years between 2020 and 2030.

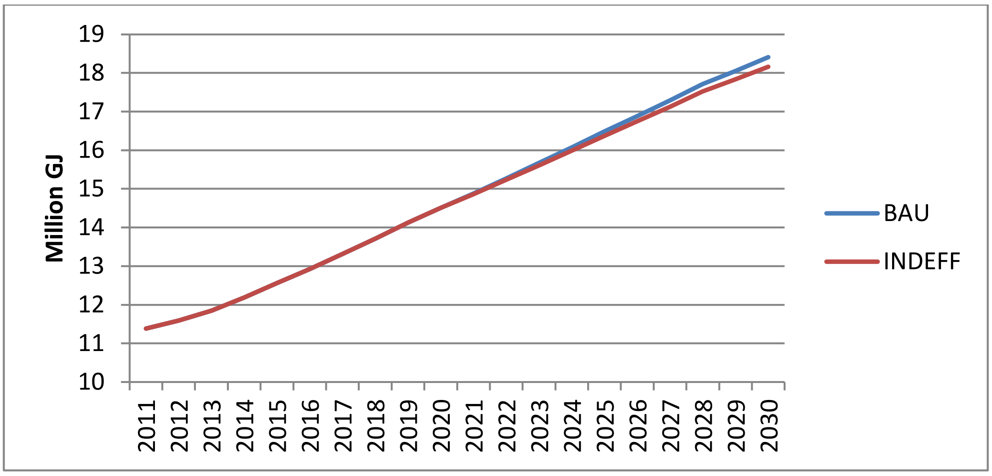


Figure 57: Total Polokwane energy consumption for the industry scenario – smelters excluded

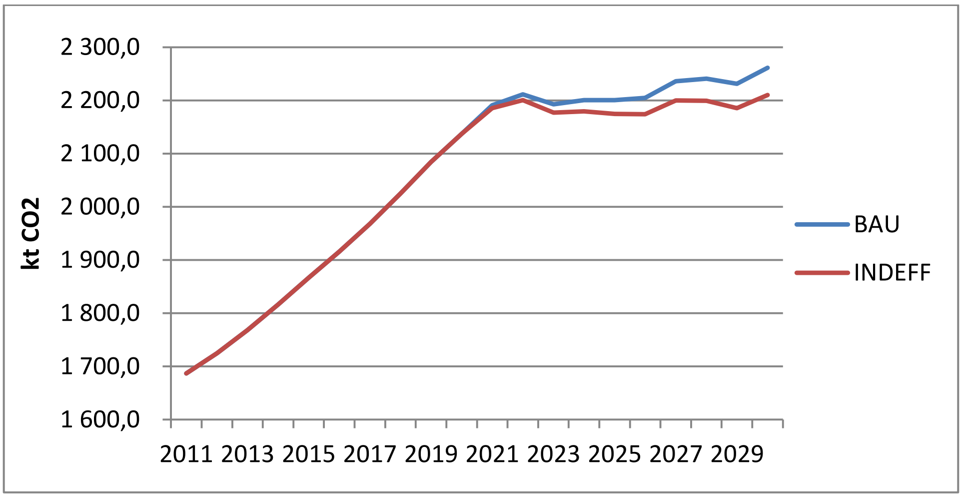


Figure 58: Total Polokwane CO_2 emissions (including electricity-related emissions) for industry efficiency scenario – smelters excluded

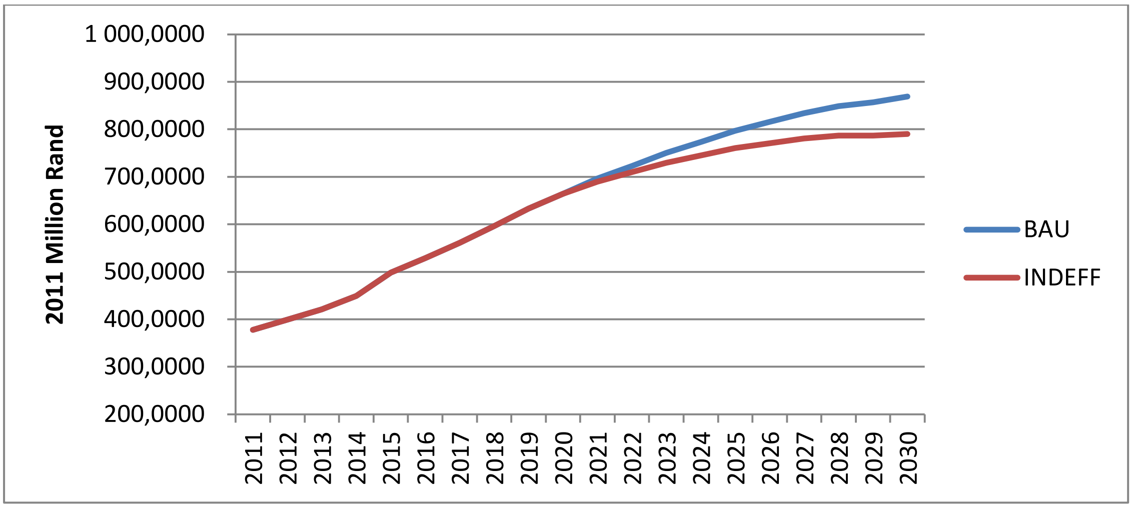


Figure 59: Costs in the industry sector for the industry efficiency scenario compared to BAU – does not include smelters or capital

11.4 ELECTRICITY GENERATION SCENARIOS

11.4.1 SOLAR PV (EMBED PV)

In this scenario, installation of rooftop solar PV systems in Polokwane is explored. It is assumed that commercial, industrial and the residential sectors start installing solar PV panels to meet some of their electricity demand. In this scenario, a broad uptake assumption is made in solar PV in the next few years – about 5% of electricity demand for each sector[8] (industry not including the smelters, commercial, residential) by 2020, and this rises to 20% by 2030. Using a capacity factor[9] of 20% – a little lower than the nearby Witkop REIPPP solar PV farm near Polokwane, Table 77 indicates the total inferred MW of installed capacity.

Table 77: The MW of embedded PV installed in Polokwane for the Embed PV

MW installed	2020	2025	2030
Residential	22.1	67.2	122.9
Industry	15.2	44.2	81.1
Commercial	3.6	9.4	15.1
Total	40.9	120.9	219.1

[8] Using a general 5% uptake and ramping this up to 20% over time for a sector is a broad assumption, while in a more detailed analysis this uptake would be done using a diffusion model like the Bass diffusion model which utilises a modified Gompertz distribution. These diffusion models calculate the total adoption of new products into a market based on the quantitative estimation of 'early adopters' and 'imitators' and other criteria for describing consumer behaviour and new products in the market space.

[9] Engineering News, SunEdison breaks ground on first SA project eyes yet more, Jan 2013. www.engineeringnews.co.za/article/sunedison-breaks-ground-on-first-sa-project-eyes-yet-more-2013-01-29.

11.4.2 LANDFILL GAS (LGAS)

The city of Polokwane sends between 20 000 and 30 000 tonnes of waste to the city landfill per month.[10] Other landfill gas projects in the country include Mariannhill and Bisasar Road landfills near Durban. The Mariannhill produces 1MW of electricity from the landfill site which receives 500 tonnes/day of waste. The Bisasar Road site, which is much larger, receives 3 500tonnes/day and produces 6.5MW of power. Using these numbers the potential MW of power from landfill gas is about 1.9MW per kt of waste received per day. Using 27 000 tonnes/month for the city of Polokwane[11], the potential capacity would be approximately 1.7MW. In this scenario it is assumed that 1.7MW of landfill gas is built and begins operating in the year 2020.

11.4.3 WASTE WATER TREATMENT BIOGAS (BGAS)

The Water Services Development Plan (WSDP) for Polokwane in 2010 indicated that there was about 12 037 million litres (ML) of waste water being treated at the city's waste water treatment works (WWTWs) in that year (Department of Water Affairs, 2010). The city of Johannesburg embarked on a biogas to electricity (and heat) project at several of their WWTWs. They treat approximately 1 billion litres per day and generate about 8.5MW of power.[12] Using these numbers as guidelines for potential power from biogas in Polokwane, then there is about 0.3MW potential from biogas. In this scenario it is assumed that this becomes operational in 2020 and continues operating at the same capacity through to 2030.

11.4.4 LEAP RESULTS

The results for electricity, emissions and cost impacts for these scenarios are presented in the following charts. It should be noted that the solar PV generation is on a much larger scale.

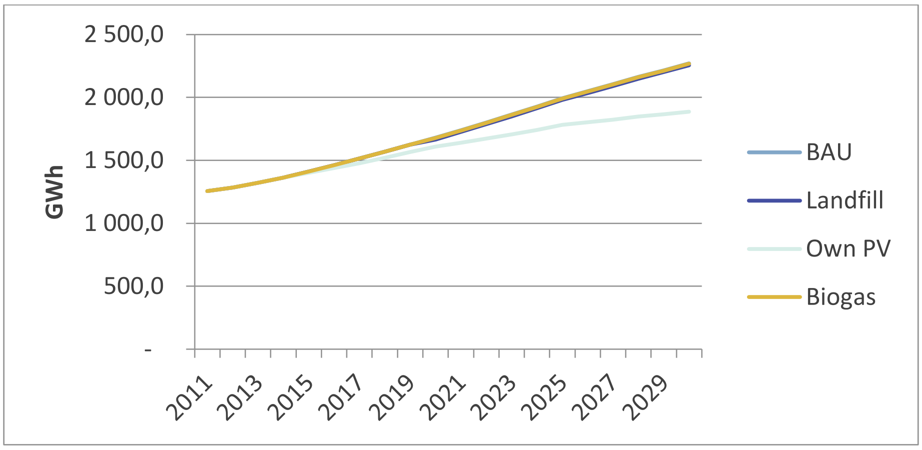


Figure 60: Polokwane electricity required from the national grid for the generation scenarios, smelters not included

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[10] From communication with Municipal partners of the SAMSET project.

[11] Limpopo province freight transport data bank.
http://www.ldrt.gov.za/application/freight_transport_databank/lim/industries/waste_disposal/index.html.

[12] From Infrastructure news 2013,
http://www.infrastructurene.ws/2013/08/21/jw-launches-south-african-first/.

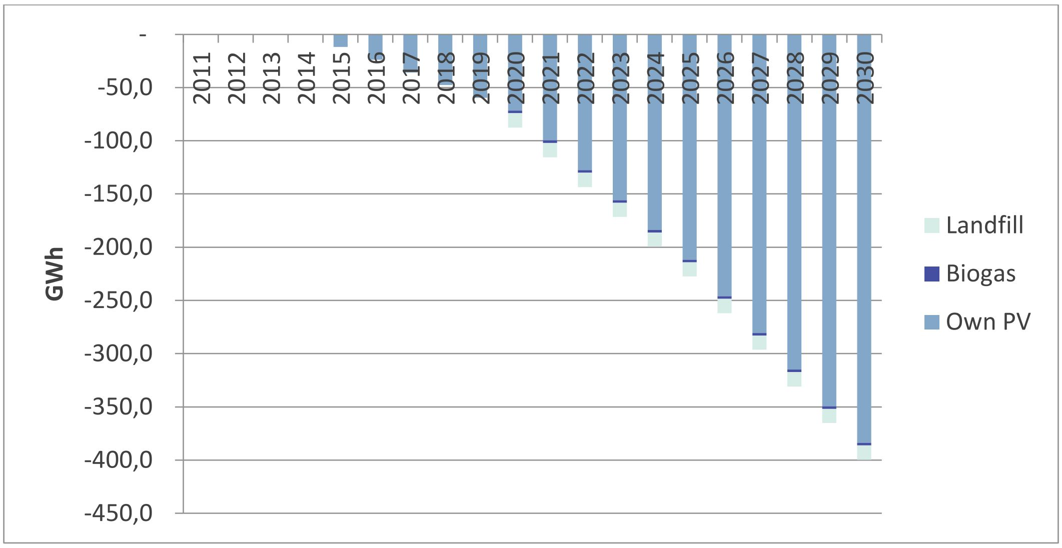

Figure 61: Reduced electricity consumption from the national grid for the generation scenarios

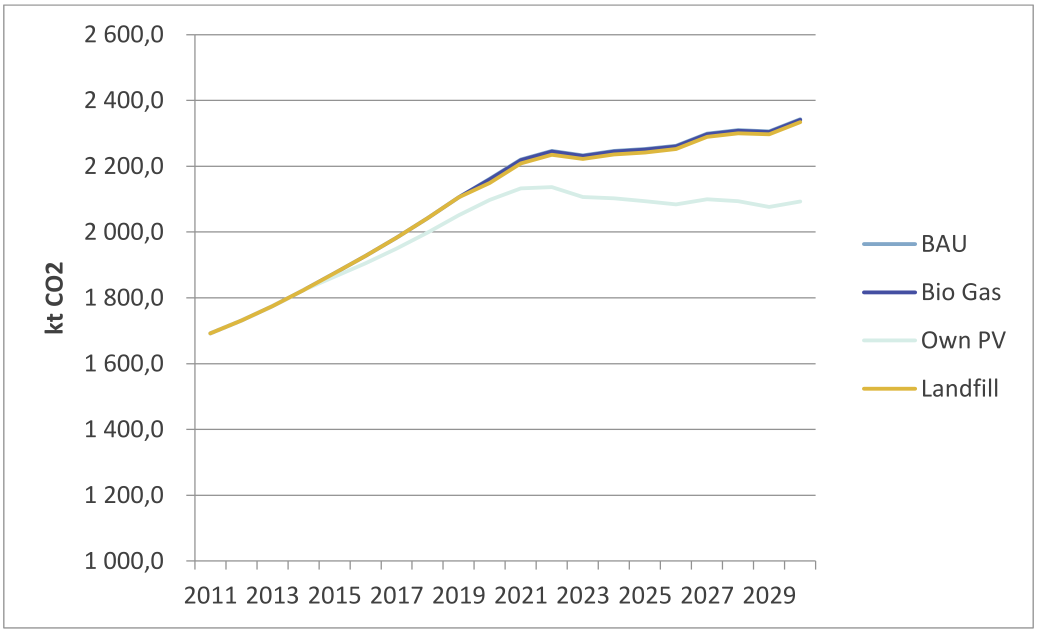

Figure 62: Polokwane emissions from electricity comparing the generation scenarios – smelters not included

11.5 COMBINED SCENARIOS

Here we present the scenario results for the built sector (residential, commercial, and industrial) and the transport sectors, as well as comparing these to the supply side scenarios (including solar PV, Landfill gas, and bio gas). Figure 63 shows that the impact of the transport scenarios is very comparable to the combined industry, residential and commercial scenarios.

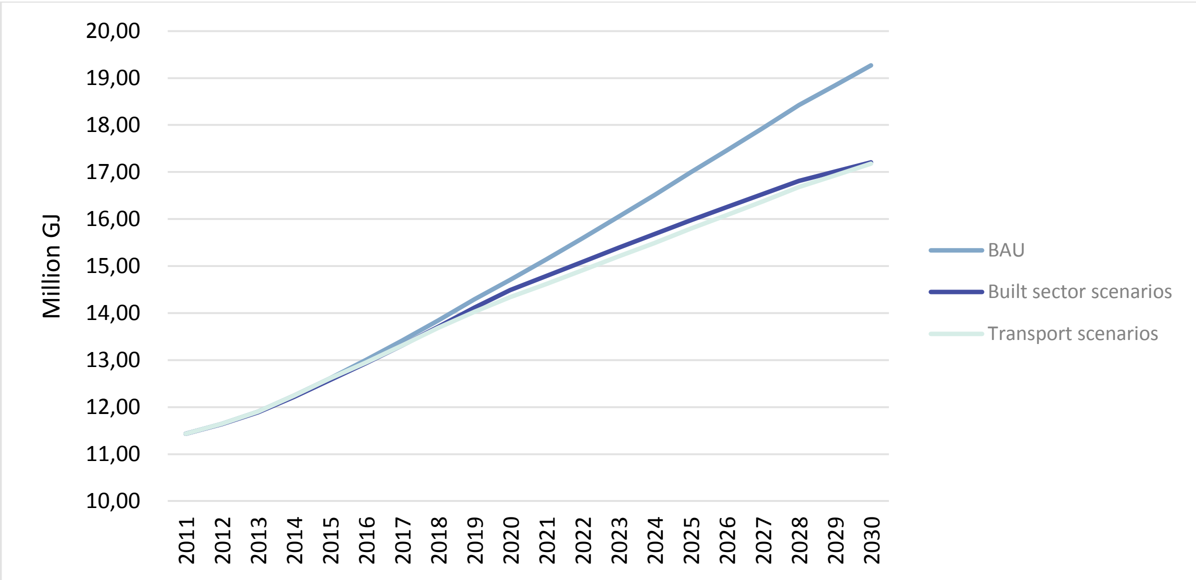

Figure 63: Comparing Polokwane energy consumption for the combined scenarios for transport and all built sectors (residential, commercial, and industrial)

The emissions for these scenarios and for the supply-side scenarios are presented in the figures below.

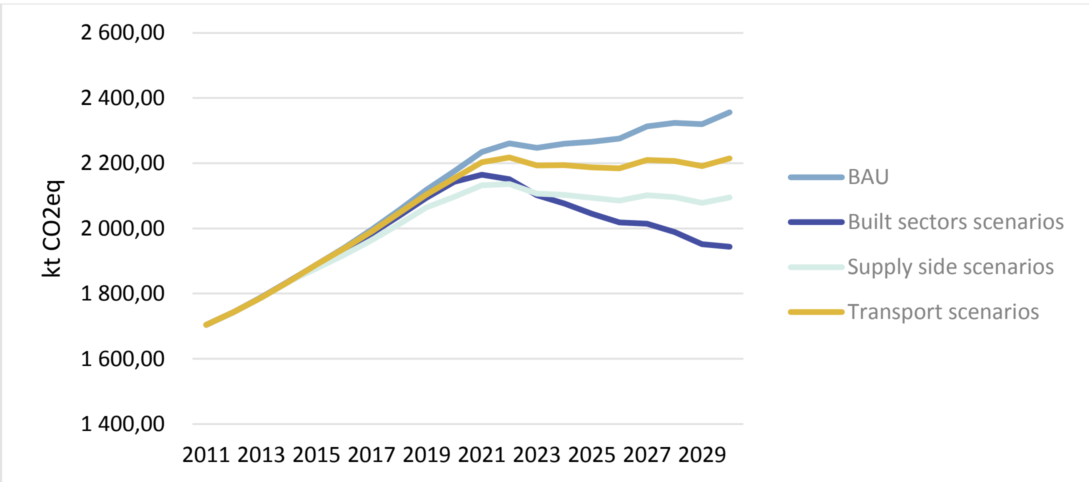

Figure 64: Total Polokwane emissions for demand-side and supply-side scenarios compared (includes electricity-related emissions, does not include smelters)

As indicated in the figures above, the built sectors scenarios have the largest impact on emissions, despite being very comparable on energy savings impact with the transport scenarios. This would be a result of the emissions related to electricity production (and thus the consumption-related emissions) from the national grid.

The figures below show what the energy consumption for Polokwane would look like for each fuel for all these scenarios combined, and their associated emissions impact.

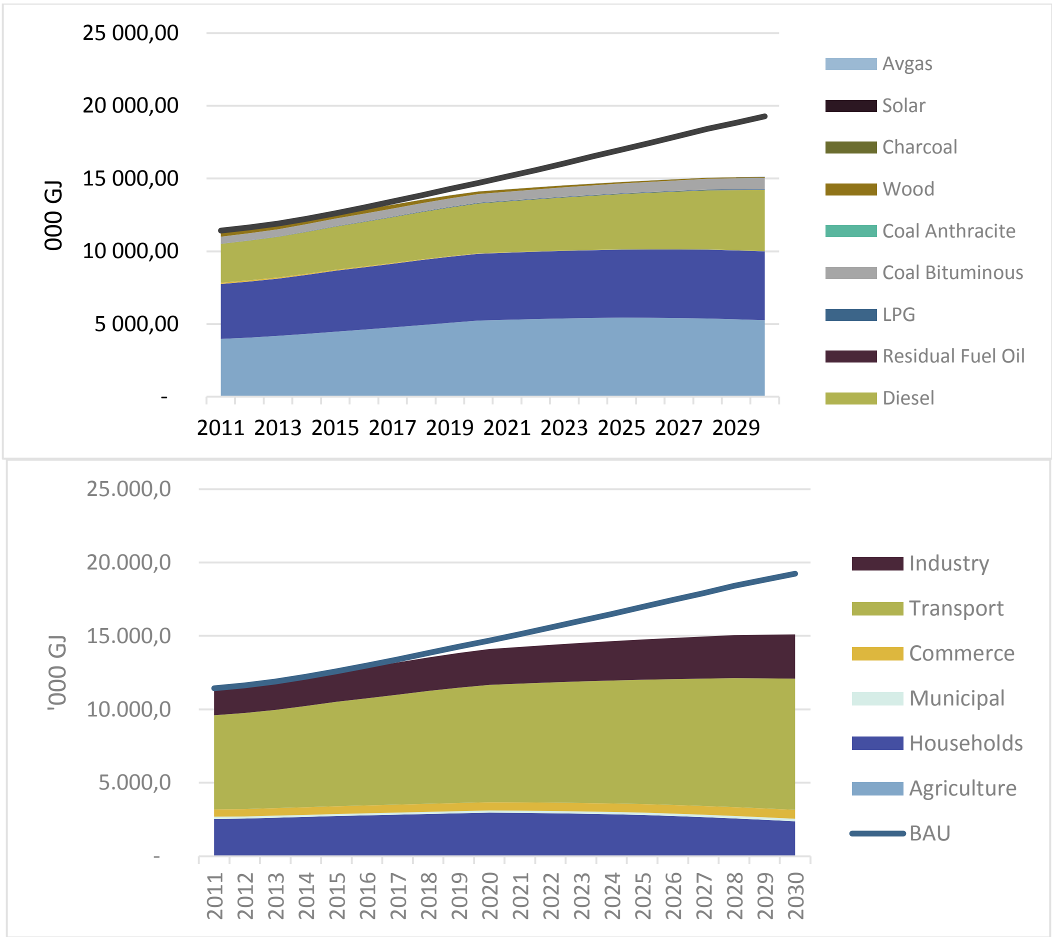

Figure 65: Energy consumption for Polokwane by fuel (above) and sector (below)

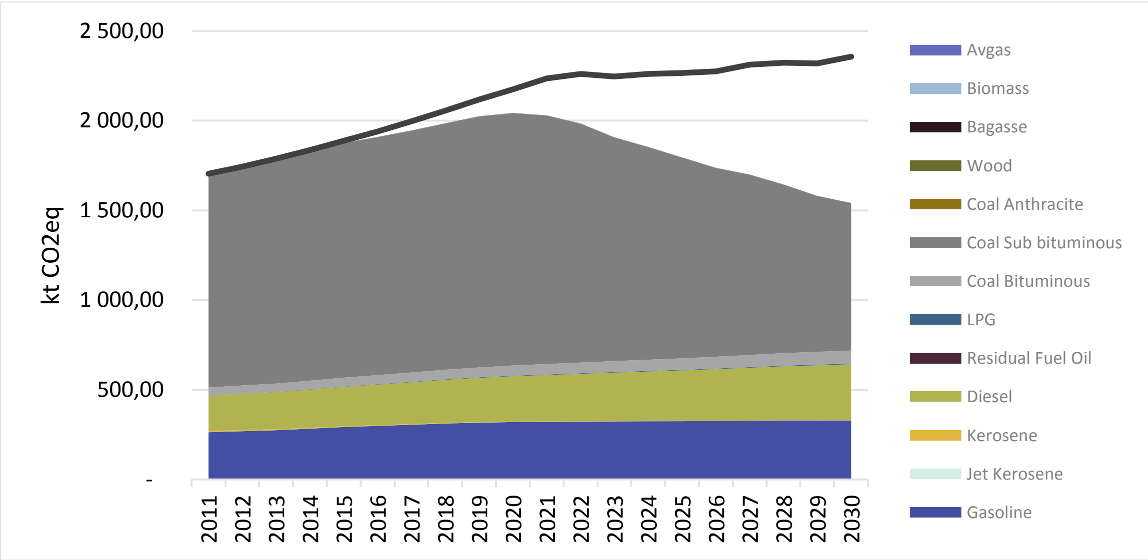

Figure 66: Energy consumption and emissions for Polokwane (without smelters) including emissions from electricity generation, for the combined built sector, transport and supply-side scenarios

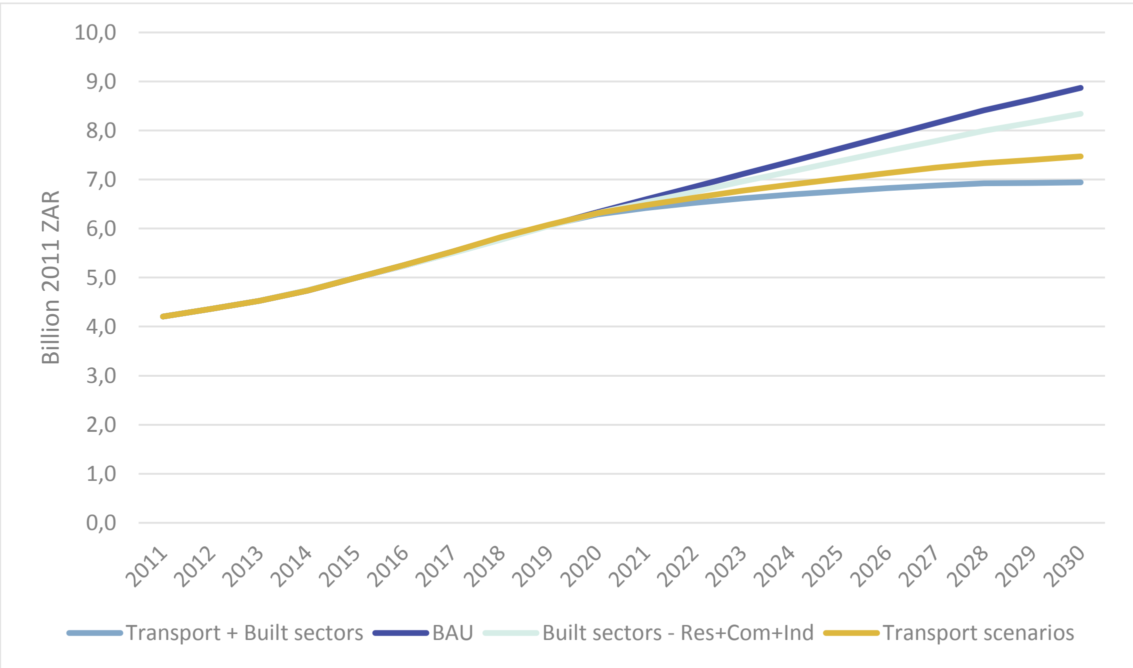

Figure 67: The cost to Polokwane for each combined scenario

12. DATA ISSUES

This section documents what data should be collected in future to improve the LEAP models and the results. Industry and transport make up the vast majority of fuel consumed within Polokwane; improvements to these two sectors would greatly improve the whole model.

12.1 TRANSPORT

The current analysis of available data provided for this model suggests that local freight quickly becomes one of the largest energy consumer in transport by 2030. This may not be the case in reality and further transport data relating to vehicle counts and loading would help clarify this possible error.

Freight

Data on rail activity within the city is missing – more specifically, the total fuel used for rail freight coming and going through the city as well as the tonnes of freight being shipped. Local road freight (within the city) is currently only based on vehicles registered. What is needed is a number on the total vehicles registered in Polokwane and are used there (or the number that are not used there), and their load and travel distance per week.

Passenger

Data on actual transportation behaviour is needed for the model – i.e. a survey on travel times by various modes of transport within the city and data to indicate the income level of the participants of the survey – this information will affect socio-economic scenarios and thus transport demand. This could be done through a household survey.

12.2 MUNICIPALITY

A breakdown of the type of vehicles used and the number of them in operation in the city is needed to more accurately map the municipal transportation demand. Clarification on the number of highway street-lamps still needing to be replaced, their original wattage and the planned replacement wattage is needed. For municipal buildings we have only total energy consumed for municipal buildings and do not know how this is allocated to space-heating, or devices etc.

12.3 HOUSEHOLDS

A survey is needed on the intensity values for HH energy services – i.e. how much wood is used for cooking, space-heating, water-heating, etc, for each income group and for both electrified and non-electrified HHs is needed.

12.4 COMMERCIAL SECTOR

Some of the AQM (2006) data was used, but this is for the year 2006. It would be useful to check with the local hospitals, clinics, and schools if they are still using coal or diesel for space heating and for incinerators. Total floor-space for commercial activity is also needed for future iterations and to improve on accuracy – there is no current data for total commercial floor-space. Also, planned future commercial space for the city would greatly improve the baseline scenario.

12.5 INDUSTRY

Here, of all sectors perhaps, there is the most data lacking. Fuel consumption at other manufacturers in Polokwane is missing. The 2006 Air Quality Management Plan report (AQM, 2006) does have some information about coal consumption at the Coca-Cola, Sasko and Enterprise factories, but more information (that is up to date) is needed. How electricity is used in the 'other industries' is unknown. Data or information on how industry uses electricity is required for improved resolution of the industrial sector. It was observed during SAMSET meetings in Polokwane that there are a number of brick manufacturers in the Polokwane area. There is no data for these industries.

12.6 OTHER ISSUES

There has been some confusion regarding the data for the total electricity sold to the municipality authority. The data given was for the municipality with and without 'wheeled' electricity amounts (electricity going to Eskom customers via the municipality grid) but comparing the two data sets still shows some ambiguity as to which data set was the account for the municipality without wheeled amounts (the total without wheeled was either 824GWh or 824 minus 64 GWh). It was only after finalising this report that this remaining underlying issue discovered. This clarification needs to take place during the next iteration of this work.

HFO from the SAPIA data shows 1 681 kL supplied to Polokwane, but the only indication of where HFO is consumed is from the AQM (2006) data showing consumption for dry cleaners (only ~70 000 L/year). Clarification of the use of this fuel is needed. In this model it is assumed to be consumed in 'other industry'

12.7 RECOMMENDATIONS ON FUTURE WORK

Of the data issues, the most important aspect to improve on is transport. Transport is the largest energy consumer in the municipality (if the smelters are excluded). A survey on how people get to work and what modes of transport they take will be necessary for future work and to better the understanding of the transport system in Polokwane.

Clarification of the municipal electricity consumption would, however, be the easiest to do and is of high importance as well.

The model horizon needs to be extended from the current year of 2030 to 2035 or 2040. While this will introduce greater uncertainty in the reliability of the results of scenarios, it may also help identify scenarios or interventions which may only have a significant impact after a long period.

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APPENDIX

Presented below is a list of all the scenarios and their descriptions for reference.

Table 78: Full scenarios list and details

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.
ALL	All demand sector scenarios combined	Implementation of all demand side scenarios
Sensitivity scenarios		
sPOP	Higher population growth rate	From 2016 to 2030, a higher growth rate of 3% pa is used (instead of 1.6% pa in the BAU)
sGDP	A higher GDP growth rate	From 2017, the GDP growth rate for both local and national remains at the peak rate in the 'weathering the storm' GDP scenario (from the IRP) of 3.7% and increases to 4% by 2020 through to 2030.
Transport scenarios		
PTB	Private transport scenario	Increase the occupancy of private cars for passengers from 1.4 currently to 2 people per car by 2030
NMT	Non-motorised transport	An increase in walking and cycling share of passenger-km (demand) with an increase from 23% to 25% by 2020, and 30% by 2030.
PbTS	Public transport share	A steady decrease in private transport and more uptakes in public transport. Public transport increases from 52% in 2020 to 60% (47% in BAU) in 2030
PTEF	Efficient passenger vehicles	An increase in hybrid and electric passenger vehicles with 10% of passenger cars electric by 2030 and 20% are hybrid
Demand sector scenarios		
COML	Commercial sector Lighting efficiency	All commercial buildings replace all lights bulbs with more efficient T5 CFL's with electronic ballasts
COMH	Commercial sector heating and cooling efficiency	All heating, cooling and venting systems are converted to variable refrigerant volume (VRV) systems which are 32% more efficient
INDEFF	Industry energy efficiency	Implementation of energy efficient motors, HVAC systems (to VRV's) and Lighting (to T5 CFLs with electronic ballasts)
HHW	Household water heating	A switch to more efficient water heaters in HHs. Low-income (BAU numbers in brackets): Elec w/ insulation 2020 – 10% (0), 2030 – 40% (0) SWH 2020 – 15% (15), 2030 – 40% (30)

		Mid-to-high income: Elec w/ insulation 2020 – 20% (0), 2030 – 10% (0) SWH 2020 – 10% (10%), 2030 – 40% (20) Heat Pump 2020 – 5% (0), 2030 – 50% (0)
HHL	Household Lighting	A switch to more efficient lighting in HHs. Low-income: Low income (BAU numbers in brackets): CFL 2020 – 98% (98), 2030 – 60% (98) LED 2020 – 0% (0), 2030 – 40% (0) Mid to high income (BAU numbers in brackets): CFL 2020 – 98% (98), 2030 – 10% (98) LED 2020 – 5% (0), 2030 – 90% (0)
Supply sector scenarios		
EmbedPV	Solar embedded PV	A rooftop solar PV scenario where 5% of Industrial, commercial and residential electricity demand is met by rooftop PV by 2020 and increasing to 20% by 2030.
LGAS	Landfill gas	A landfill gas plant is erected at the existing landfill with a capacity of 1.7MW (based off of existing landfill plants in SA) by 2020.
BGAS	Waste water treatment biogas generation	A biogas generation plant is built at the waste water treatment plant in Polokwane, and based on water flow rates this powers a gas plant of 0.3MW from 2020 onwards.

Table 79: Scenario detail of interventions for demand sectors

			2012	2014	2016	2018	2020	2022	2024	2026	2028	2030
Households electrified												
Low-income	Lighting	LED	0	0	0	0	5	5	5	5	5	5
Low-income	Lighting	CFL	69	76	84	91	95	95	95	95	95	95
Mid-to-high-income	Lighting	LED	0	0	2	3	5	22	39	56	73	90
Mid-to-high-income	Lighting	CFL	81	86	89	92	95	78	61	44	27	10
Low-income	Water-heating	Electric efficient	0	0	3	7	10	16	22	28	34	40
Low-income	Water-heating	SWH	2	5	8	12	15	20	25	30	35	40
Mid-to-high-income	Water-heating	Electric efficient	0	0	7	13	20	18	16	14	12	10
Mid-to-high-income	Water-heating	SWH	1	3	6	8	10	16	22	28	34	40
Mid-to-high-income	Water-heating	Heat pump	0	0	2	3	5	14	23	32	41	50

Households non-electrified												
Low-income	Lighting	Candles	87	87	86	86	85	85	85			
Low-income	Lighting	Solar	4	5	7	8	10	10	10			
Mid-to-high-income	Lighting	Candles	0	0	0	0	0	0	0			
Mid-to-high-income	Lighting	Solar	3	3	3	3	3	3	3			
Low-income	Water-heating	SWH	2	7	11	15	19	24	28			
Low-income	Water-heating	Gas stove	2	6	9	13	16	20	23			
Mid to-high-income	Water-heating	SWH	3	9	14	20	26	31	37			
Mid to-igh-income	Water-heating	Gas stove	3	7	12	16	20	24	28			
Commerce												
Lighting	Fluorescent		60	60	53	45	38	30	23	15	8	0
Lighting	Fluorescent efficient		40	40	48	55	63	70	78	85	93	100
Space-heating	Electric central system		100	100	88	75	63	50	38	25	13	0
Space-heating	Central efficient		0	0	13	25	38	50	63	75	88	100
Cooling and venting	Central efficient		0	0	13	25	38	50	63	75	88	100
Cooling and venting	Electric central system		100	100	88	75	63	50	38	25	13	0
Transport												
Motorised	Private	Car Diesel	5	5	5	5	5	5	5	5	5	5
Motorised	Private	Car petrol	76	76	74	71	67	64	60	57	53	49
Motorised	Private	Motorbike	2	2	2	2	2	2	2	2	2	2
Motorised	Private	SUV petrol	7	7	7	7	7	7	6	6	6	6
Motorised	Private	SUV diesel	10	10	10	9	9	9	9	8	8	8
Motorised	Private	Electric	0	0	1	2	3	5	6	7	9	10
Motorised	Private	Hybrid petrol	0	0	1	4	7	9	12	15	17	20
Non-motorised	Share		23	23	22	22	24	26	29	31	33	35
Motorised	Share		77	77	78	78	76	74	71	69	67	65
Private	Share		45	46	47	48	49	48	47	45	43	40
Public	Share		55	54	53	52	51	52	53	55	57	60

* This table excludes industry as the industry does not have detail on end use and the industry scenario used a change in final energy intensity overall adjusted for the assumed shares of HVAC, lighting and machinery efficiency improvements.

Table 80: Detailed energy impact of demand side scenarios for Polokwane

	2014	2015	2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026	2027	2028	2029	2030
Com HVAC	0	4	9	13	18	23	29	34	40	46	52	59	62	66	69	72	76
Com Lighting	0	3	7	11	15	19	23	28	32	37	42	48	53	59	65	71	77
Commercial sector	**0**	**8**	**16**	**24**	**33**	**42**	**52**	**62**	**72**	**83**	**95**	**107**	**115**	**125**	**134**	**143**	**152**
Household Lighting	0	3	7	12	16	21	32	63	98	135	176	221	266	314	365	419	476
Household Water heating	0	18	38	59	82	108	135	208	288	375	470	572	675	784	900	1023	1153
Households	**0**	**21**	**45**	**71**	**99**	**129**	**166**	**271**	**386**	**511**	**646**	**793**	**941**	**1098**	**1265**	**1442**	**1629**
Efficient pass. vehicles	0	0	19	39	60	83	108	133	160	189	219	251	285	320	357	394	432
Non-Motorised transport shift	0	0	0	0	0	42	88	138	192	250	312	378	438	500	566	629	694
Private transport behaviour	0	0	32	66	103	142	183	227	273	322	374	428	485	545	609	671	735
Public transport share	0	0	0	0	0	0	0	53	114	181	255	337	427	526	634	739	852
Transport*	**0**	**0**	**50**	**104**	**162**	**262**	**366**	**520**	**681**	**849**	**1021**	**1199**	**1375**	**1555**	**1740**	**1912**	**2085**

* The sum of the individual scenarios does not sum to the combined total as there are some scenarios which may affect the impact that other scenarios have – eg. The NMT scenario would affect the energy savings of private vehicle behaviour scenario

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