Forecasts for electricity demand in South Africa (2014 – 2050) using the CSIR sectoral regression model

January 2016

Project report

Prepared for: Eskom
(as inputs into the IRP 2015)

Document Reference Number: CSIR/BE/SPS/ER/2015/0033/C
CSIR Groupwise DMS: 257002 (Pta General Library)

Project team leader: R Koen (012) 841-3045, **rkoen@csir.co.za**
Project team members: JP Holloway, P Mokilane, S Makhanya, T Magadla, R Koen

Table of Contents

List of Figures

List of Tables

1. Introduction

The CSIR developed a methodology for forecasting annual national electricity demand in collaboration with BHP Billiton in 2003. This methodology has subsequently been re-used in providing some of the forecasts used in the previous IRP and its revision.

A set of forecasts have again been developed using this methodology, in conjunction with updated historical data covering the period 1990 – 2013, for producing forecasts for the IRP2015. These forecasts, and a brief description of the models used to derive the forecasts, are provided in this document. However, this document provides only brief references to the modelling approach, and the full methodology is not explained here. For more information on the methodological aspects and the process of developing the methodology, please refer to previous reports or to [1].

2. Methodology

The methodology followed to obtain the forecasts presented in this document consisted of two parts. The first part consisted of putting together the required historical datasets to use as a basis for the set of forecasting models, and the second part consisted of compiling the models. Subsection 2.1 discusses the data-related task, while section 2.2 provides details on the set of forecasting models compiled.

2.1. Data selection and use

The data collection tasks involved the collection of electricity consumption data, the breakdown of this data per electricity usage sector, as well as the collection of data on the “drivers” of electricity consumption. The collection of the various types of data is discussed in the following sub-subsection, while the use of the “drivers” is explained in subsection 2.2.

2.1.1. Data on electricity consumption per sector

Data from various sources had already been compared extensively during the process of developing the BHP Billiton forecasts, and further data comparisons were done during the forecasting for the previous IRP. Since the models developed require the most up-to-date historical data available, this round of forecasting again involved doing data collection, derivation and comparisons on the “new” historical data that were collected.

Updated data on the electricity usage within the various electricity sectors were collected or derived. The sector breakdowns were checked by comparing the aggregated sector values to the national consumption figures published by Statistics SA in its P4141 series on electricity production volumes and sales, and adjusted where necessary. The sectors used in this report correspond to the categories used by the National Energy Regulator of South Africa (NERSA) that were also used by the Department of Energy, and reported to the International Energy Agency (see [2] for their 2007 statistics on electricity for South Africa, as well as [3] for a list of their data sources).

It should be noted that NERSA has not published any data on electricity demand per sector since 2006, and the data published by the Department of Energy for their Energy Balances datasets did not seem to provide reliable data for the period since 2006. Although the Energy Balances are published per year, comparison of the sectoral electricity estimates over time indicated values that remained exactly the same for some of the sectors over three years, thus indicating data reliability issues. While Eskom publishes data broken down per sector in their Annual reports, sectoral breakdowns are only done for Eskom’s direct customers. This leaves a large portion of the consumption belonging to the "Redistributor" sector which mainly represents municipalities (who in turn sell electricity to users within different sectors), and therefore needs to be broken down further into sectors.

The CSIR team has received data from Eskom in which Eskom has done their own (complete) sector breakdown estimates for internal planning purposes, and these estimates were understood to be based on Eskom customer categories, but adjusted to national consumption in each sector by breaking down the redistributor component into the other categories using estimates of Eskom's share in each category. However, the CSIR team used the Eskom estimates as comparative values only, and we compiled our own estimates of the sectoral breakdown values from a range of data sources. We also developed a new method to provide additional verification of the sector breakdowns, which is not discussed in this report (but details could be obtained from the CSIR project team, if required).

The graphs in Figures 1 – 5, below, illustrate the comparative values per sector from the various data sources, and also show the "CSIR Recommended" sectoral breakdowns in comparison to the values from these other sources.

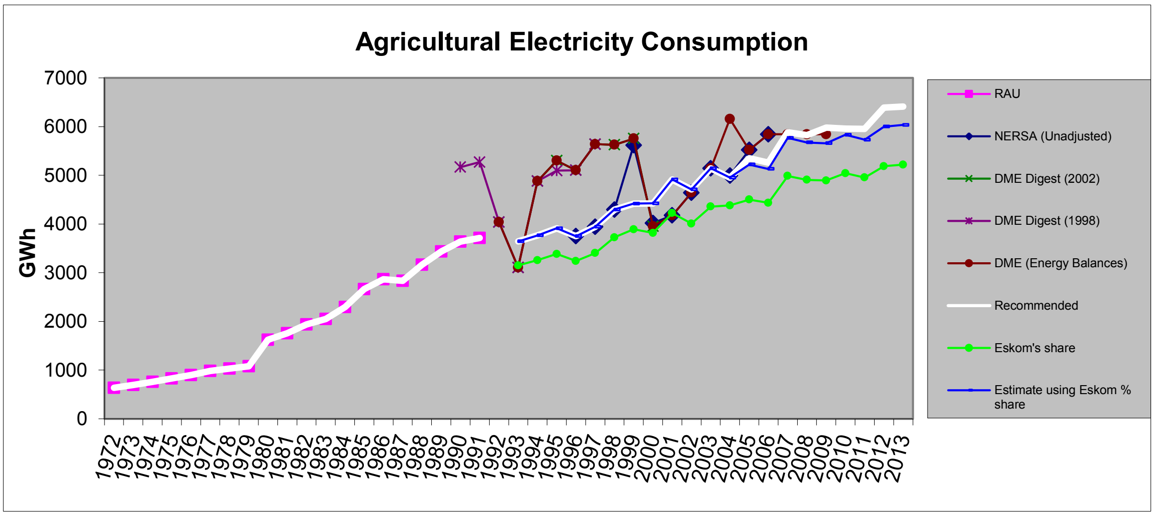

Figure 1 Comparing agricultural sector data between different sources

Although the agricultural sector is a small sector, Figure 1 indicates that the various sources differed quite widely on the pattern of consumption in this sector during the period 1990 – 2000, but that the sources are more in agreement since the mid 2000s.

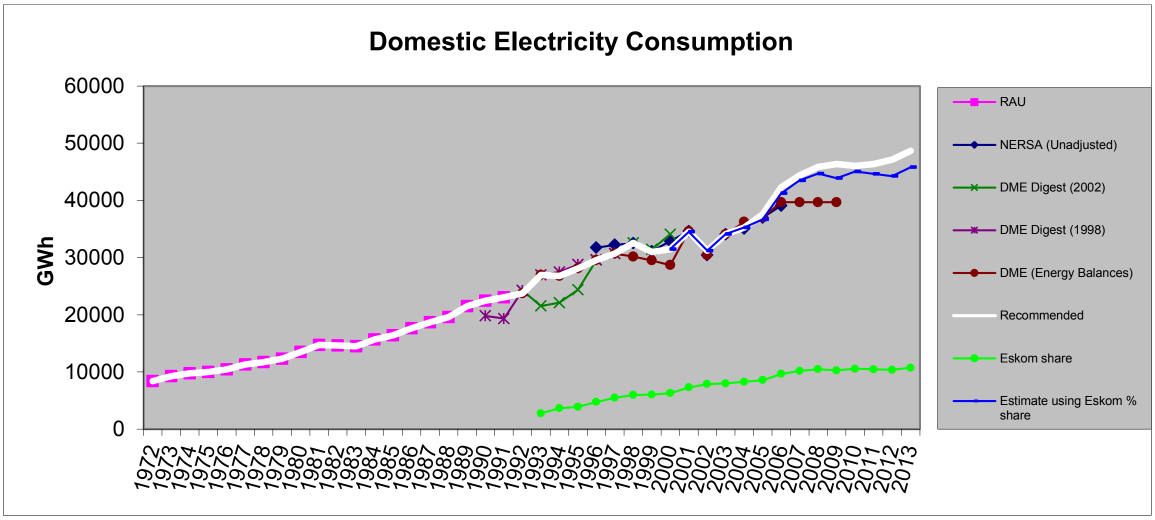

Figure 2 Comparing domestic sector data between different sources

For the domestic sector, the overall patterns between some sectors coincided, but generally the Eskom sector estimates were usually lower than other sources over the late 2000s. It is assumed that the estimates for this sector are problematic due to the fact that most of the domestic consumers are supplied with electricity via the municipalities, i.e. they form a large part of the "redistributors" sector within Eskom sales, and that relatively few domestic customers are direct Eskom customers.

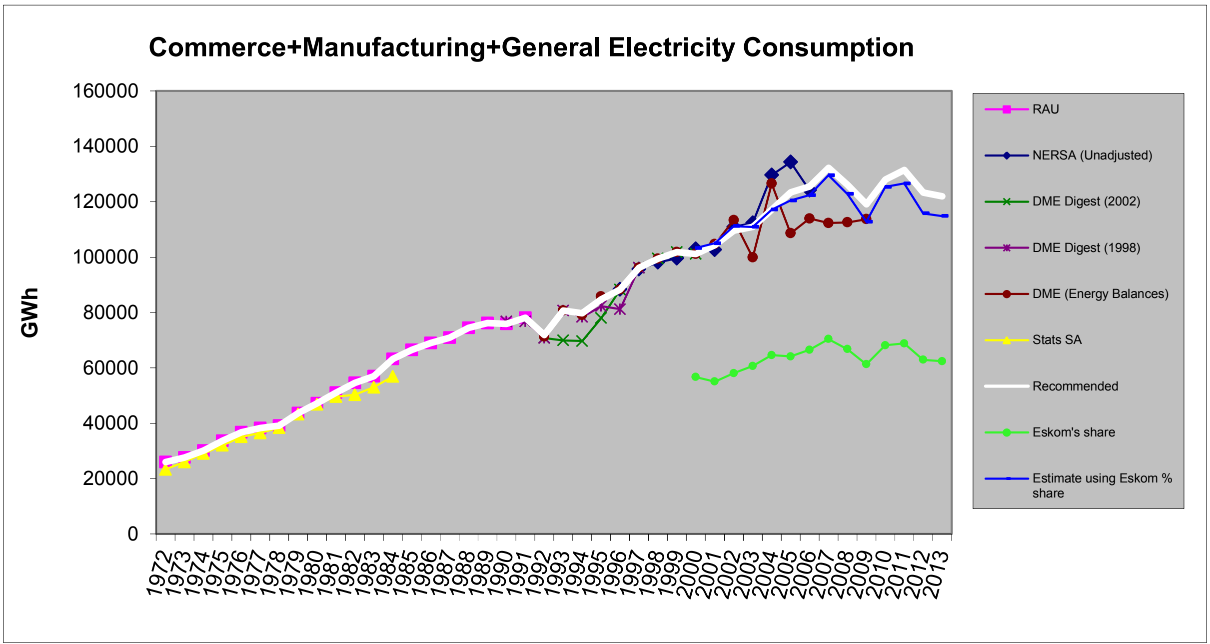

Figure 3 Comparing commercial and manufacturing sector data between different sources

Although most sources provide separate "Commerce" and "Manufacturing" sectors, definitions differ widely between them, and even within different years of the same source. Furthermore, most sources contain a "general" category, and the definition of this category is also not consistent. However, when data on "commerce", "manufacturing" and "general" sectors are combined for each of the various sources, the differences between the sources are not very substantial, as can be seen from Figure 3, and therefore the CSIR team prefers to combine these sectors into one.

Figure 4 shows that the various sources do not differ very much in terms of the pattern for the mining sector. Since Eskom supplies most of this sector directly, in the years where differences occurred, the Eskom values were considered to be the more reliable source and hence the Eskom figures were used.

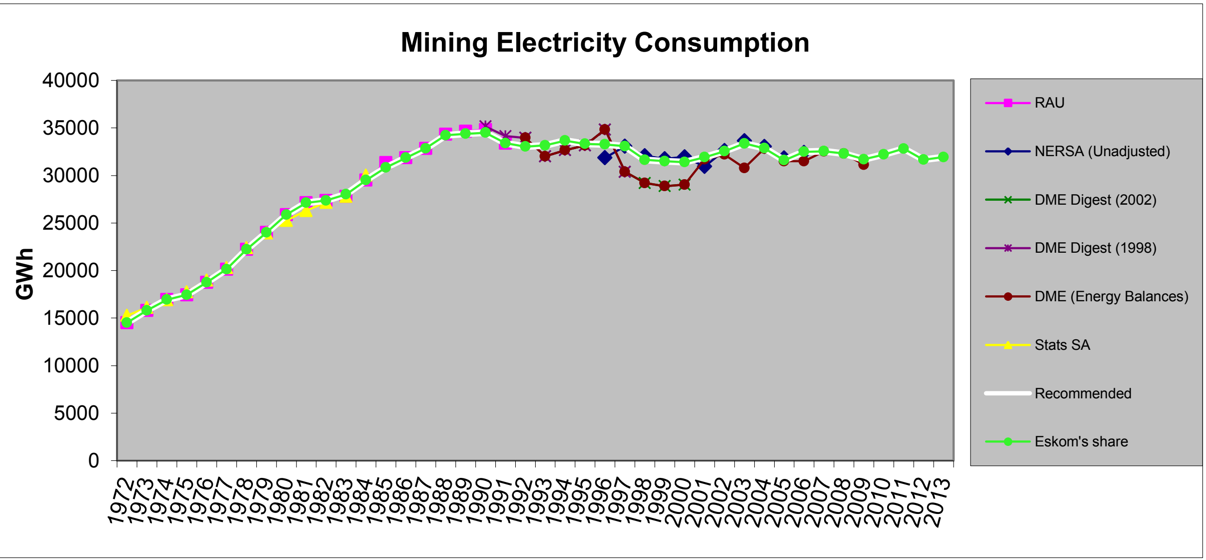

Figure 4 Comparing mining sector data between different sources

Figure 5 indicates quite big differences between sources for the transport sector, but again this is a fairly small sector.

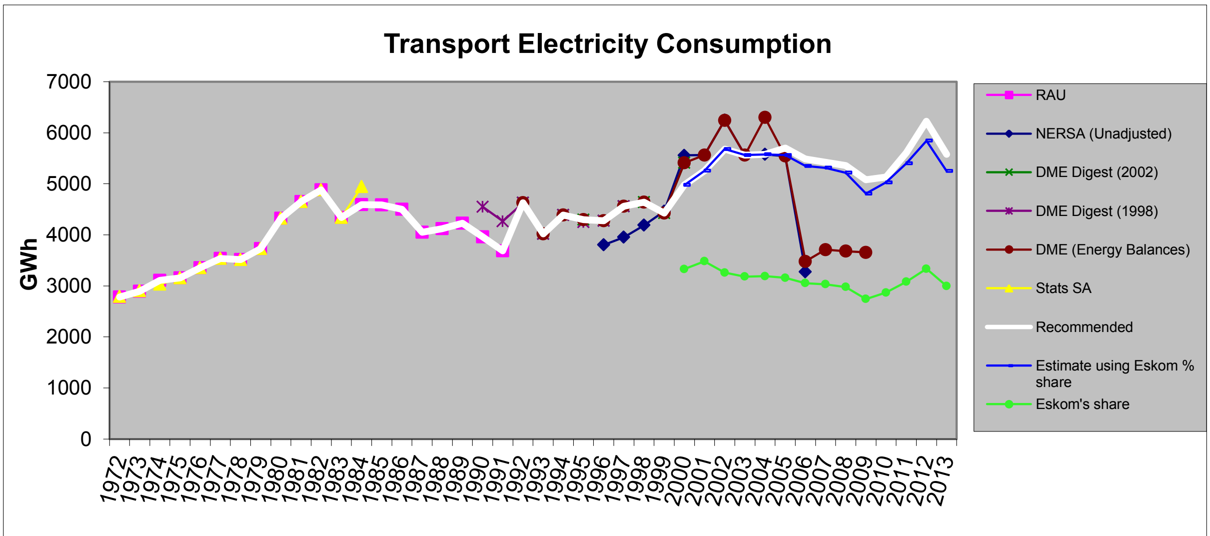

Figure 5 Comparing transport sector data between different sectors

2.1.2. Data on losses

The various sources consulted by the CSIR differed both in terms of their definition of losses as well as the way they applied the loss percentages. Some sources “added on” losses after estimating each sector, while other sources “deducted” the losses in order to adjust estimates downwards. The CSIR team applies the loss percentage to the aggregated sectors, i.e. the sector forecasts are obtained, aggregated and losses calculated on the aggregated total to obtain the final total.

The CSIR team decided to apply one total for losses (including both distribution and technical losses) to the combined total for all sectors in order to derive the total national consumption and so “adds on” the losses to obtain the annual total. Data was obtained from Eskom regarding percentage losses recorded, and losses were also estimated by comparing Eskom data with public domain data. Appropriate forecasts for loss percentages were discussed with Eskom after studying historical patterns. It was decided to fix the loss percentage at 11.5% for the entire forecasting period. This percentage corresponded with historical percentage fluctuations and, in discussion with Eskom staff, it was agreed that this value would be an estimate that would balance expansion of the transmission grid (i.e. increasing transmission losses) with changes in generation patterns (which may reduce other types of losses) over the medium to long term.

2.1.3. Data on drivers of electricity consumption

For data on potential "drivers" of electricity, historical data were obtained from the South African Reserve Bank, Chamber of Mines and Statistics SA. The values for these "drivers" were compiled in consultation with Eskom in order to use a consistent base for the forecasts, for instance, ensuring that GDP figures and the various indices were standardised according to the same base year.

Table 1 Sources for historical data on "drivers" of electricity consumption

"Driver" data	**Source**
Gross Domestic Product (GDP)	Reserve Bank of South Africa
Final Consumption Expenditure of Households (FCEH), also called Private Consumption Expenditure (PCE) in some sources	Reserve Bank of South Africa
Index for Manufacturing production volumes	Statistics SA (Statistical releases)
Index for Mining production volumes (gold, coal, iron ore, PGM and total index (including and excluding gold))	Statistics SA (Statistical releases)
Population	Statistics SA (Midyear estimates)
Number of households and average household size	Statistics SA (General Population Survey)
Gold ore milled and gold ore treated	Chamber of Mines

2.2. Regression model selection

The methodology followed was to analyse data on electricity consumption as well as on aspects that describe general demographic and economic conditions which could conceivably influence consumption. Multiple regression modelling was chosen as the technique to be used for forecasting the annual consumption within the individual electricity sectors by relating such influencing aspects (or "drivers") to the demand in each sector.

The development of models for the different electricity consumption sectors involved identifying a big set of measures that could be considered as possible / potential predictors for each sector, followed by regression modelling to determine the *best* forecasting models for the consumption in each sector that could be obtained from this set. The modelling involved an iterative process of fitting a model, assessing it, making changes, rerunning and comparing the model to the one(s) before the changes.

The "best" models were chosen from this iterative process to be statistically sound, to be as simple as possible (i.e. have as few "drivers" as possible), and to satisfy a logical understanding of the sector being forecasted. To know whether a model was statistically sound it had to show a good fit to the historical data, to have low levels of multi-collinearity and to show acceptable residual patterns. Model fit can be measured in various ways, but in this study the adjusted R^2 value was used. The closer the adjuster R^2 is to 1, the better the model fit. However, even models that fit the historical data well could suffer from high levels of multi-collinearity, so model fit alone is not sufficient. Multi-collinearity is the statistical term to indicate that the "drivers" included in the model are related to each other, and this can be a problem in a model intended for forecasting. Models therefore had to have low levels of multi-collinearity to be considered acceptable. The levels of multi-collinearity of a regression model can be measured by the condition index (in this study the so-called singular-value decomposition condition index, with the centering option, as discussed on pp 337 – 341 in [4], was used) and the value of the condition index should be below 30 to ensure low levels of multi-collinearity.

The CSIR team believes that the models derived for each sector fitted the collected historical data well and were also appropriate for forecasting future demand. Table 2 summarises the models (i.e., the group of CSIR models) used for each of the sectors' forecasts. Data about the statistical fit of the models (as indicated by the adjusted R^2), as well as the amount of multi-collinearity present in the model (as measured by the condition index), are given for each model.

Table 2 Summary of regression models used per sector

Electricity sector	**Model used (*Note: the "predictor variables" indicated in bold in each model*)**	**Adjusted R^2**	**Condition index**
Agriculture	-47339 + 3725.82×ln(**FCEH)**	Adjusted R^2 = 0.97	N/A if only 1 variable in model
Transport	975.24 + 45.61×**mining index excluding gold**	Adjusted R^2 = 0.74	N/A if only 1 variable in model
Domestic	-410694 + 31840×ln(**FCEH)** + 2339.48***recession**	Adjusted R^2 = 0.97	CI = 1.4
Commerce & manufacturing	11000 + 0.02259×**FCEH** + 687.14368 × **manufacturing index**×***correction factor*** **(NOTE:** • The "correction factor" adjusts for electricity intensity as explained in section 2.3 • The intercept value was adjusted to align the starting point of the forecasts (for 2014) with the observed actual values for 2014)	Adjusted R^2 = 0.9691	CI = 21.27
Mining	21784 + 75.868× **mining production index (excl. gold)** + 0.05268×**gold ore treated**	Adjusted R^2 = 0.55	CI = 6.3

Note that although CSIR was requested to use two different models in the commerce and manufacturing sector, one with and without the "correction factor", the model fitted without the correction factors was not considered to be as good as the one with the "correction factor", and therefore only one model was developed. The "correction factor" was modelled historically as explained in the next subsection, and used in the forecasts as explained in section 3.1.

2.3. Adjustments for changes in electricity intensity

The CSIR team has in the past (i.e. previously when a set of forecasts for electricity demand was developed) used the historical data as the main basis for developing forecasting models without adjusting either the historical data or the forecasts. The assumption has been that any changes with regard to electricity usage, such as responses to higher electricity prices, energy saving initiatives, and so on, would be recorded as part of the historical data, and therefore implicitly be factored into the models. However, for the previous revision of the IRP forecasts, a need was identified to add an explicit aspect regarding electricity intensity into the models for the manufacturing sector and not to rely only on the implicit incorporation of it based on historical patterns. This was considered necessary in order to provide a way to model future scenarios that contrast expansion of electricity intensive sectors of the economy with the development of less energy intensive sectors in order to achieve economic growth. Therefore, the suggested scenario descriptions require that the future patterns of electricity intensity would differ from its historical patterns. In this new IRP forecast it was decided to continue this precedent, since there was again one scenario that involved the expansion of less energy intensive sectors.

The way in which electricity intensity was added to the models was by incorporating a “correction factor” representing the ratio between electricity used and goods produced within, specifically, the manufacturing sector.

Data on electricity usage within the manufacturing and commercial sector was taken from the Eskom estimates, and the ratio between this electricity usage and the index of manufacturing volumes (as obtained from Statistics SA) was calculated and plotted as indicated in Figure 6. The figure shows the historical pattern for the period 1994 – 2013 (corresponding to the period for which this specific data was available) with the purple line, and a polynomial curve fitted to this line to represent the overall trend in this ratio as the blue line. When the ratio decreases, then it indicates that less electricity was required to produce the same volume of goods, and when it increases then more electricity was used in order to produce similar volumes of goods. The estimated “correction factor” values, obtained from the polynomial curve, were used to represent a proxy for the historical trend in the electricity intensity in the manufacturing sector.

The “correction factor” was multiplied with the manufacturing index and this combined variable was incorporated into the model (see Table 2 in section 2.2). In this way, the “correction factor” was used to adjust, or “correct”, the effect that the manufacturing index had on the electricity usage and therefore bring in some way of modelling the fact that less electricity seemed to have been used per unit produced.

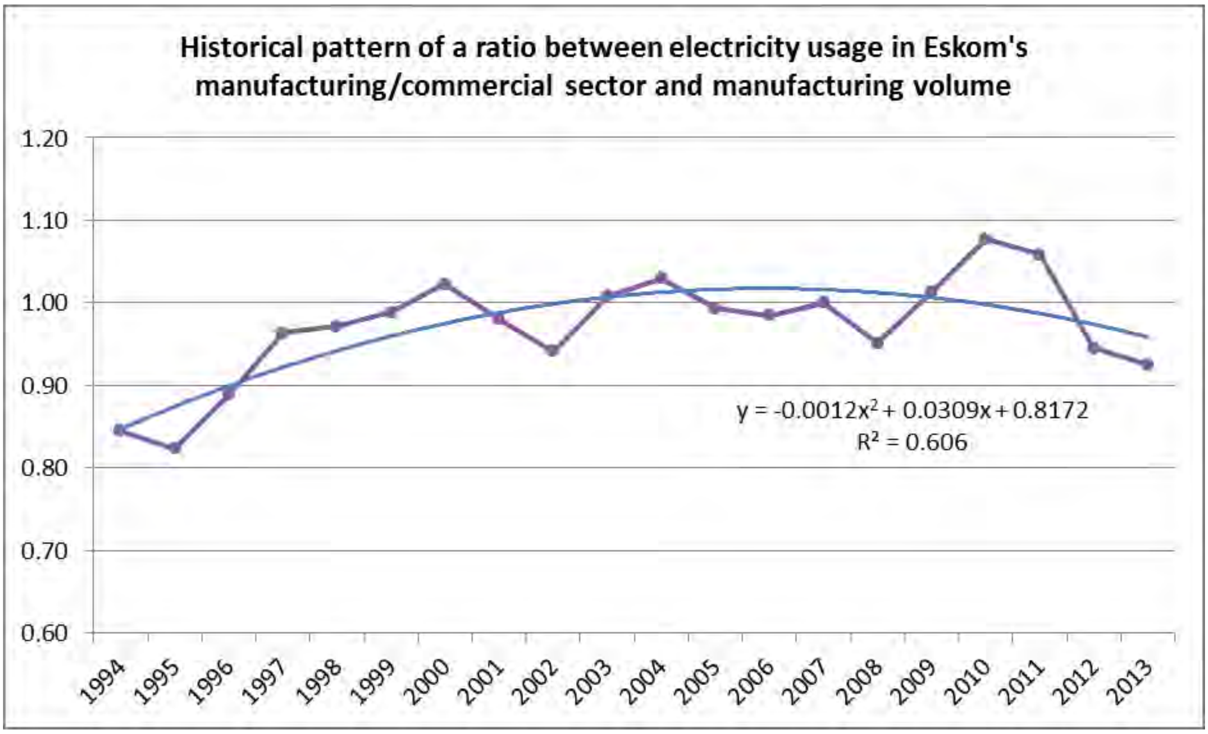

Figure 6 Model fitted for the electricity intensity “correction factor”

3. Forecasting results

This section provides the revised forecasts, namely demand forecasts for national consumption of electricity for the period 2014 – 2050.

3.1. Forecasted driver values used

In the IRP, four growth scenarios were specified for use in forecasting, namely the “High (Same sectors)”, “High (Less energy intensive)”, “Moderate” and “Low” scenarios. Expected values for the different driver variables were linked to each scenario. These scenarios represent the mechanism for introducing uncertainty regarding the future values of the drivers into the electricity forecasts. Differences between the scenarios were quantified in terms of economic variables, namely values for the expected GDP, the expected Final Consumption Expenditure of Households (FCEH), as well as the relevant manufacturing and mining indexes. For some drivers, namely population size and the percentage losses, only one set of forecasts were used throughout all the scenarios. The models were used by inserting the expected future values for each of the “driver” variables into the relevant sectoral models in order to obtain a forecast for each sector. The sectoral forecasts were aggregated and then adjusted for losses in order to obtain a forecast for national consumption. Note that, as explained in subsection 2.1.2 a fixed value of 11.5% was taken as the loss percentage across all scenarios, but that this percentage was “phased in” over the initial period from the 8.6% observed in 2013.

The following six tables summarise the “driver” values used for the forecasts. The first table (Table 3) provides the driver values that did not change between scenarios, while the next three (Table 4, Table 5 and Table 6) provide the growth percentages on the macro economic variables that differed between the scenarios. Table 4 provides GDP scenario values, Table 5 provides FCEH scenario values and Table 6 provides scenario forecasts for the Manufacturing Index. Table 7 and Table 8 provide the scenario forecasts for the measures related to the mining industry. Note that the annual data is provided as per calendar year, not per financial year, in all tables.

Table 3 Driver forecasts that were the same between different scenarios

Year	Population (in millions)	Line losses (% of sectoral total)
2014	53.48	9
2015	54.18	9.4
2016	54.83	9.9
2017	55.43	10.3
2018	56.04	10.7
2019	56.60	11.1
2020	57.11	11.5
2021	57.57	11.5
2022	58.03	11.5
2023	58.44	11.5
2024	58.85	11.5
2025	59.20	11.5
2026	59.55	11.5
2027	59.91	11.5
2028	60.21	11.5
2029	60.51	11.5
2030	60.81	11.5
2031	61.12	11.5

Year	Population (in millions)	Line losses (% of sectoral total)
2032	61.42	11.5
2033	61.73	11.5
2034	62.04	11.5
2035	62.35	11.5
2036	62.66	11.5
2037	62.97	11.5
2038	63.29	11.5
2039	63.61	11.5
2040	63.92	11.5
2041	64.24	11.5
2042	64.56	11.5
2043	64.89	11.5
2044	65.21	11.5
2045	65.54	11.5
2046	65.87	11.5
2047	66.19	11.5
2048	66.53	11.5
2049	66.86	11.5
2050	67.19	11.5

Table 4 GDP % growth forecasts per scenario

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2014	1.57	1.57	1.57	1.57
2015	1.40	2.20	2.50	2.50
2016	1.40	2.30	3.50	3.50
2017	1.80	2.70	4.00	4.00
2018	2.00	2.90	4.20	4.20
2019	2.00	3.00	4.50	4.50
2020	2.00	3.20	4.50	4.50
2021	2.20	3.50	4.50	4.50
2022	2.20	3.50	4.50	4.50
2023	2.20	3.60	4.50	4.50
2024	2.40	3.80	4.50	4.50
2025	2.40	3.80	4.50	4.50
2026	2.40	3.70	4.50	4.50
2027	2.40	3.70	4.30	4.30
2028	2.20	3.60	4.30	4.30
2029	2.20	3.60	4.30	4.30
2030	2.20	3.50	4.10	4.10
2031	2.20	3.50	4.10	4.10
2032	2.00	3.40	4.10	4.10
2033	2.00	3.30	4.00	4.00
2034	2.00	3.20	4.00	4.00
2035	2.00	3.20	3.80	3.80
2036	2.00	3.00	3.80	3.80
2037	1.80	3.00	3.80	3.80
2038	1.80	3.00	3.60	3.60
2039	1.80	3.00	3.60	3.60
2040	1.80	2.80	3.40	3.40
2041	1.80	2.80	3.40	3.40

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2042	1.80	2.80	3.40	3.40
2043	1.80	2.80	3.20	3.20
2044	1.80	2.80	3.20	3.20
2045	1.80	2.50	3.20	3.20
2046	1.80	2.50	3.00	3.00
2047	1.80	2.50	3.00	3.00
2048	1.80	2.50	3.00	3.00
2049	1.80	2.50	3.00	3.00
2050	1.80	2.50	3.00	3.00

Table 5 FCEH % growth forecasts per scenario

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2014	1.16	1.16	1.16	1.16
2015	1.25	1.84	2.50	1.90
2016	1.16	1.79	3.88	3.65
2017	1.54	2.21	4.13	4.14
2018	1.92	2.46	4.27	4.09
2019	1.97	2.54	4.55	4.33
2020	2.01	2.77	4.59	4.01
2021	2.05	3.28	4.58	3.90
2022	2.12	3.31	4.88	3.86
2023	2.05	3.40	4.78	3.74
2024	2.70	3.75	4.86	3.75
2025	2.71	3.82	4.87	3.87
2026	2.71	3.64	4.88	3.85
2027	2.71	3.74	4.65	3.82
2028	2.37	3.59	3.82	3.92
2029	2.35	3.70	4.67	3.91
2030	2.51	3.54	4.38	3.93
2031	2.51	3.57	4.41	3.92
2032	2.17	3.41	4.55	3.97
2033	2.15	3.33	4.39	3.96
2034	2.15	3.16	4.40	3.95
2035	2.15	3.29	4.09	3.83
2036	2.17	2.93	4.10	3.93
2037	1.83	3.06	4.12	4.06
2038	1.92	3.09	3.89	3.74
2039	2.26	3.58	3.05	4.26
2040	2.25	3.36	3.56	3.88
2041	2.30	3.45	3.55	3.87
2042	2.30	3.44	3.57	3.92
2043	2.30	3.43	3.41	3.56
2044	2.41	3.42	3.40	3.66
2045	2.40	2.89	3.40	3.72
2046	2.39	3.00	3.09	3.35
2047	2.43	2.99	3.11	3.34
2048	2.42	2.99	3.19	3.45
2049	2.41	2.98	3.19	3.45
2050	2.40	2.98	3.19	3.55

Table 6 Manufacturing index forecasts per scenario (base year = 2010)

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2014	106.4	106.4	106.4	106.4
2015	107.5	108.6	108.0	109.1
2016	108.6	111.3	110.2	111.8
2017	110.2	114.6	112.4	115.2
2018	111.9	118.3	115.2	119.2
2019	113.5	122.3	118.7	124.0
2020	115.2	126.7	122.2	129.9
2021	117.5	131.3	125.9	136.4
2022	119.9	136.3	129.7	143.5
2023	122.3	141.4	133.6	151.0
2024	124.1	146.8	137.3	158.8
2025	126.0	152.4	141.1	166.8
2026	127.9	158.2	145.1	175.1
2027	129.8	163.9	148.9	183.0
2028	131.7	169.8	152.7	191.2
2029	133.7	175.5	156.7	199.8
2030	135.3	181.5	160.8	208.2
2031	136.9	187.7	164.8	217.0
2032	138.6	194.1	168.4	226.1
2033	140.3	200.3	172.1	235.1
2034	141.9	206.7	175.9	244.5
2035	143.6	212.9	179.8	253.3
2036	145.4	219.3	183.7	261.9
2037	147.1	225.4	187.8	270.9
2038	148.6	231.7	191.5	280.1
2039	150.1	237.7	195.4	289.0
2040	151.6	243.5	199.3	298.3
2041	153.1	248.8	203.3	307.8
2042	154.6	254.3	207.3	317.7
2043	156.2	259.9	211.5	327.8
2044	157.4	265.6	215.7	337.7
2045	158.7	271.4	220.0	347.8
2046	159.9	276.9	224.4	358.2
2047	161.2	282.4	228.9	369.0
2048	162.5	288.1	233.0	379.3
2049	163.8	293.8	237.2	389.9
2050	165.1	299.7	241.5	400.1

Table 7 Forecasts for mining production index, excluding gold (base year = 2010)

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2014	102.7	102.7	102.7	102.7
2015	105.3	105.9	106.1	106.6
2016	108.1	109.4	109.7	110.7
2017	110.9	112.8	113.0	115.9
2018	113.7	116.2	116.4	122.4
2019	116.4	119.8	119.7	129.3
2020	119.0	123.5	123.1	136.0
2021	121.6	127.1	126.5	143.0

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2022	124.2	130.8	129.8	150.5
2023	127.0	134.5	133.1	158.3
2024	129.5	138.3	136.5	166.2
2025	132.1	142.0	139.9	174.3
2026	134.7	145.7	143.2	182.9
2027	137.3	149.5	146.6	191.5
2028	139.9	153.3	149.8	199.6
2029	142.5	157.1	153.1	208.1
2030	145.2	160.9	156.2	215.1
2031	147.9	164.6	159.3	222.4
2032	150.6	168.2	162.1	229.4
2033	153.4	171.8	165.1	236.2
2034	156.2	175.5	167.9	243.1
2035	159.1	179.1	170.7	250.3
2036	161.9	182.7	173.4	257.7
2037	164.7	186.2	175.9	264.0
2038	167.6	189.5	178.4	270.0
2039	170.5	192.8	181.0	276.0
2040	173.4	196.1	183.5	282.3
2041	176.0	199.4	186.1	288.6
2042	178.6	202.8	188.5	294.4
2043	181.1	206.2	191.0	300.3
2044	183.6	209.7	193.5	306.3
2045	186.1	213.3	196.0	311.6
2046	188.6	216.7	198.6	317.1
2047	190.7	220.2	200.8	322.6
2048	192.8	223.8	203.1	328.3
2049	195.0	227.4	205.4	334.0
2050	197.2	231.1	207.8	339.9

Table 8 Forecasts for gold ore treated (million metric tons)

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2014	41.6	41.6	41.6	41.6
2015	40.4	41.0	40.4	41.4
2016	39.2	40.4	39.2	41.2
2017	38.4	39.8	38.4	41.0
2018	37.6	39.4	37.6	40.8
2019	36.9	39.0	36.9	40.6
2020	36.1	38.6	36.1	40.4
2021	35.6	38.6	35.4	40.2
2022	35.0	38.6	34.7	40.0
2023	34.7	38.6	34.0	39.8
2024	34.3	38.6	33.3	39.8
2025	34.0	38.6	32.7	39.8
2026	33.8	38.6	32.0	39.8
2027	33.7	38.6	31.4	39.8
2028	33.5	38.6	30.7	39.8
2029	33.5	38.6	30.1	39.8
2030	33.5	38.6	29.5	39.8
2031	33.5	38.6	28.9	39.8

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2032	33.5	38.6	28.6	39.8
2033	33.5	38.6	28.3	39.8
2034	33.5	38.6	28.1	39.8
2035	33.5	38.6	27.8	39.8
2036	33.5	38.6	27.5	39.8
2037	33.5	38.6	27.2	39.8
2038	33.5	38.6	27.0	39.8
2039	33.5	38.6	27.0	39.8
2040	33.5	38.6	27.0	39.8
2041	33.5	38.6	27.0	39.8
2042	33.5	38.6	27.0	39.8
2043	33.5	38.6	27.0	39.8
2044	33.5	38.6	27.0	39.8
2045	33.5	38.6	27.0	39.8
2046	33.5	38.6	27.0	39.8
2047	33.5	38.6	27.0	39.8
2048	33.5	38.6	27.0	39.8
2049	33.5	38.6	27.0	39.8
2050	33.5	38.6	27.0	39.8

Since the “High (less energy intensive)” scenario has the same GDP growth as the “High (same sectors)” scenario but with the growth happening not in the mining and manufacturing economic sectors but rather in the tertiary economic sector, it was therefore considered important to distinguish between the electricity usage of the two scenarios by way of the “correction factor”. Therefore, for the “High (less energy intensive)” scenario a pattern was forecasted for future values of the “correction factor” as illustrated with the purple line in Figure 7, while for the other scenarios it was kept at a constant rate. The constant rate is illustrated with the red line in Figure 7. The two sets of forecasted values are compared with the historical pattern (the green line in Figure 7), which was also seen in Figure 6.

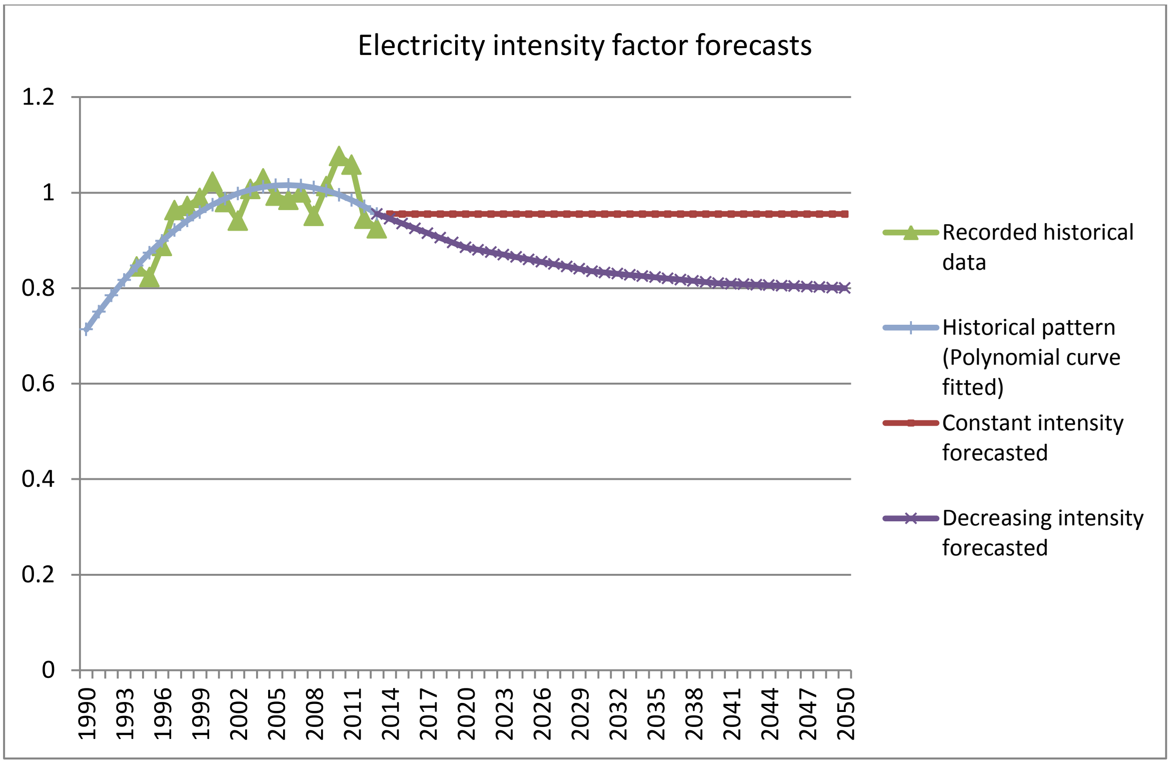

Figure 7 Values used for electricity intensity ratio in scenarios

3.2. Demand forecasts obtained

The forecasts obtained for each of the four scenarios are provided in Table 9 below. Note that the forecasts in Table 9 include the adjustments for energy intensity improvements in the manufacturing sector, as applicable to each scenario, by way of the "correction factor".

Table 9 National electricity demand: historical data and CSIR recommended forecasts (including adjustments for electricity intensity changes in the manufacturing sector)

Year	**Annual electricity demand forecasts (GWh) per scenario, provided per calendar year:**			
	Low	**Moderate**	**High (Less energy intensive)**	**High (Same sectors)**
2014	233758	233758	232960	233758
2015	236697	238080	236609	238623
2016	239850	243070	242087	245304
2017	243547	248694	247650	252907
2018	247628	254859	253855	261249
2019	251801	261430	260834	270539
2020	256046	268576	268029	280541
2021	259902	275428	274910	289988

Year	Annual electricity demand forecasts (GWh) per scenario, provided per calendar year:			
	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2022	263889	282669	282225	299978
2023	267885	290203	289637	310258
2024	272070	298301	297165	320945
2025	276335	306669	304899	331945
2026	280665	315114	312848	343373
2027	285060	323691	320573	354544
2028	289188	332340	327484	366115
2029	293360	341108	335590	378108
2030	297459	349934	343528	389904
2031	301615	359008	351929	402093
2032	305476	368140	360417	414713
2033	309372	377162	368926	427371
2034	313318	386208	377663	440451
2035	317317	395331	386186	453094
2036	321370	404242	394923	465922
2037	325100	413196	403895	479159
2038	328761	422375	412504	492268
2039	332855	432104	419956	506150
2040	337000	441394	428431	519879
2041	341200	450679	437330	533998
2042	345452	460169	446452	548543
2043	349756	469867	455517	562902
2044	354006	479779	464786	577384
2045	358306	489102	474278	592283
2046	362657	498374	483382	606936
2047	367061	507833	492690	621979
2048	371517	517484	502095	637116

Year	Annual electricity demand forecasts (GWh) per scenario, provided per calendar year:			
	Low	Moderate	High (Less energy intensive)	High (Same sectors)
2049	376027	527331	511716	652657
2050	380591	537379	521559	668272

The CSIR recommended forecasts obtained for all four of the scenarios are illustrated graphically in Figure 8, while the forecasts for the five sectors making up the total consumption are provided in five separate graphs in Figure 9.

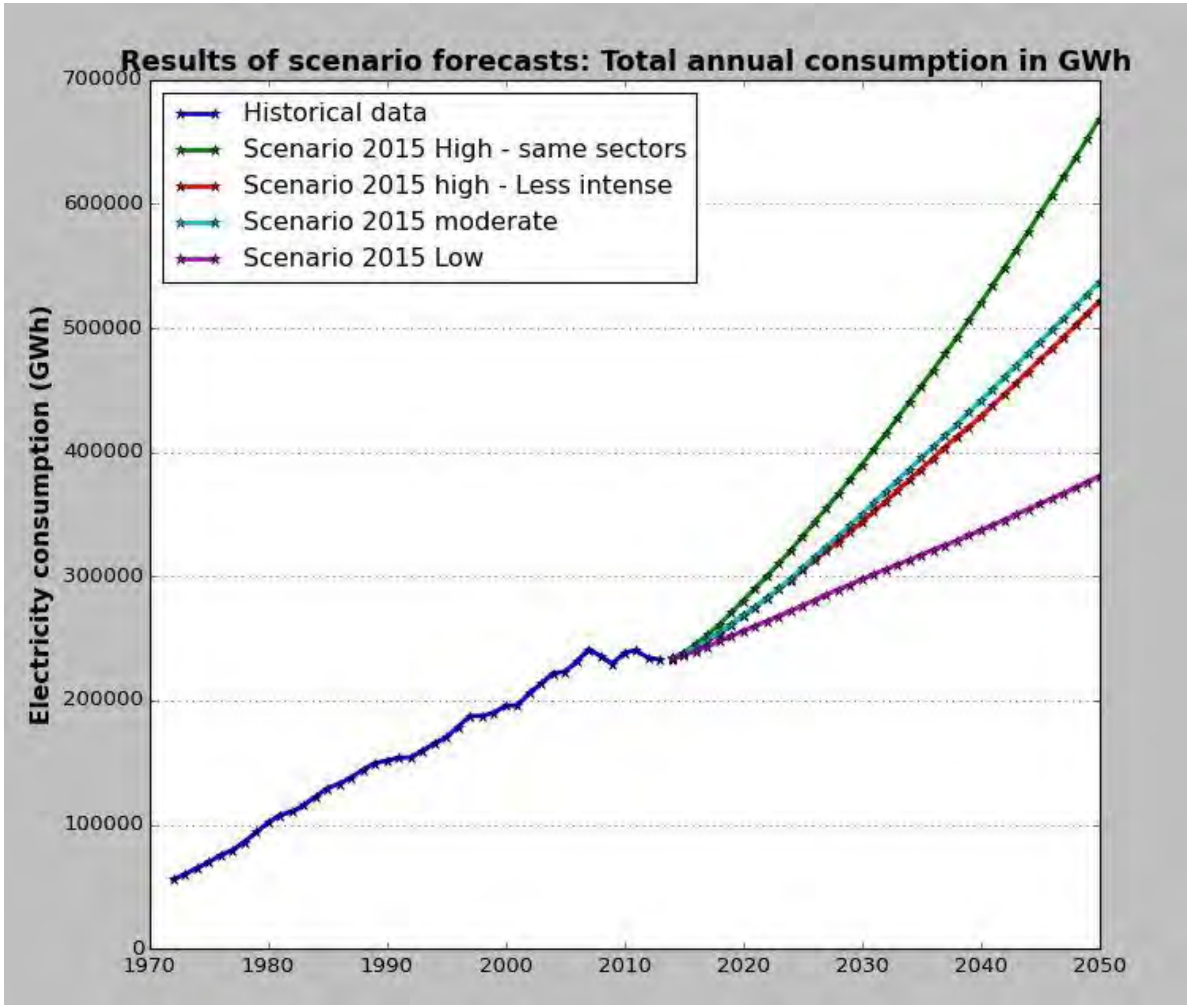

Figure 8 Recommended forecasts for national consumption of electricity using the "CSIR model"

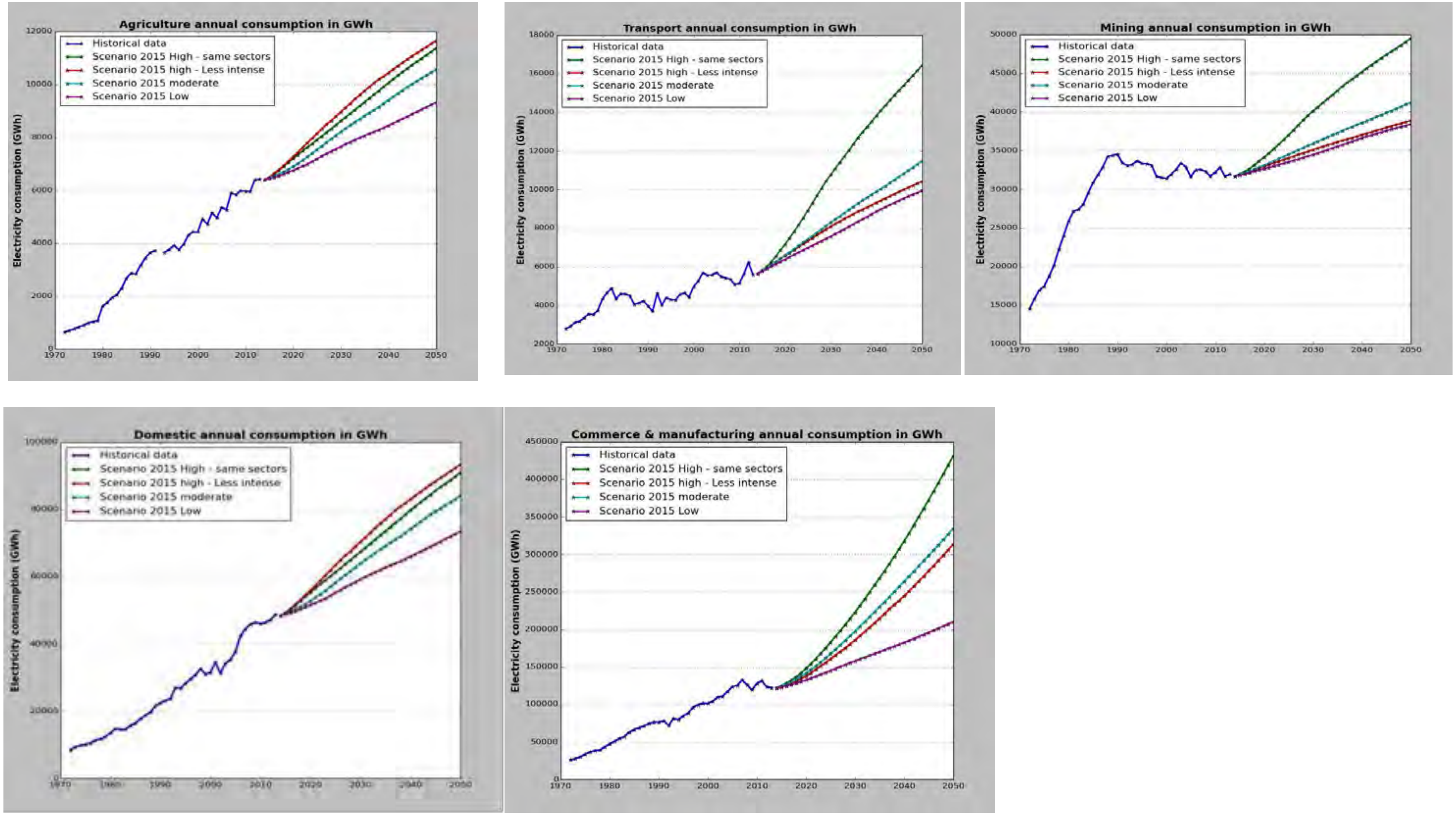

Figure 9 Forecasted values for the 5 electricity sectors

4. Final remarks

The “CSIR model” forecasts the national demand for electricity at a macro level, based on data relating to macro level economic and demographic indicators. The set of forecasts presented in this report were obtained using the methodology and scenarios as described to produce a set of forecasts as inputs into the IRP 2015 process.

5. References

[1] Koen, R., Holloway, J.P., 2014, *Application of multiple regression analysis to forecasting South Africa’s electricity demand*, Journal of Energy in Southern Africa (JESA), Vol 25, No 4, November 2014.

[2] Website of the International Energy Agency (iea), at the specific address http://www.iea.org/stats/electricitydata.asp?COUNTRY_CODE=ZA [accessed September 2012]

[3] Website of the International Energy Agency (iea), at the specific address http://wds.iea.org/wds/pdf/documentation_wedbes.pdf, pp 70 – 71 [accessed September 2012]

[4] Montgomery, D.C., Peck, E.A., Vining, G.G., 2006, Introduction to linear regression analysis (Ed 4), John Wiley & Sons Inc.