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REPUBLIC OF SOUTH AFRICA

FORECASTS FOR ELECTRICITY DEMAND IN SOUTH AFRICA (2017 – 2050) USING THE CSIR SECTORAL REGRESSION MODEL FOR THE INTEGRATED RESOURCE PLAN OF SOUTH AFRICA

May 2017 (updated scenarios)
Project report

Prepared by: CSIR

Forecasts for electricity demand in South Africa (2017 – 2050) using the CSIR sectoral regression model

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Prepared for: Eskom

(as inputs into the Integrated Resource Plan)

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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 a number of times, including providing forecasts used in the previous IRP and its revision.

A draft set of forecasts were developed using this methodology, by revising the models and applying the methodology to updated historical data, for producing forecasts for the IRP2015. After the publication of this initial set of forecasts by the Department of Energy, inputs were invited from the public and experts. Based on these inputs, as well as on data for 2014 and 2015 becoming available during the period after the development of the forecasts and the finalisation of user inputs, updates to the forecasting models and the scenarios underlying the initial forecasts were made. Data for the period 1990 – 2015 was therefore used to obtain updated scenario forecasts. A fifth scenario, namely "Junk status" was also added to the previous four scenarios. These updated forecasts are presented in this report.

The 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 IRP 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 by the CSIR team during the development of the methodology 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 sector 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. When the CSIR team compared historical sectoral electricity estimates published in the Energy Balances documents in order to set up a time series of sectoral breakdowns, it was found that values in some sectors remained exactly the same over more than one subsequent year, thus indicating data reliability issues. In addition, 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 this sector needs to be broken down further into sectors.

The CSIR team received data from Eskom in which Eskom had done their own sector breakdown estimates for internal planning purposes. 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 estimates (labelled "Recommended") for sectoral breakdowns in comparison to the values from the other sources.

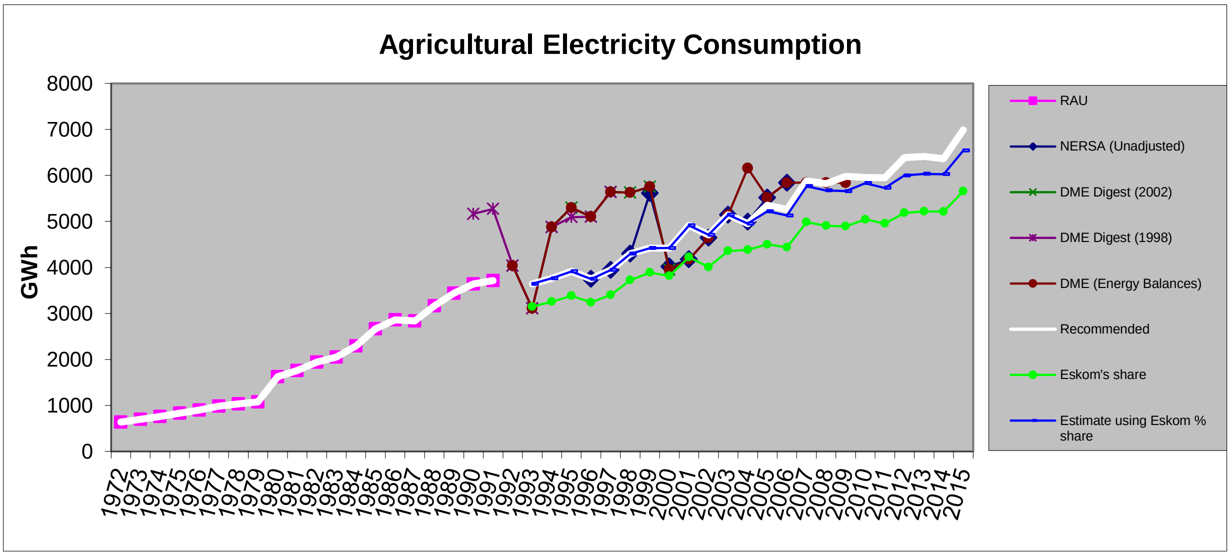

Figure 1 Comparing agricultural sector data between different sources

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 were more in agreement since the mid 2000s.

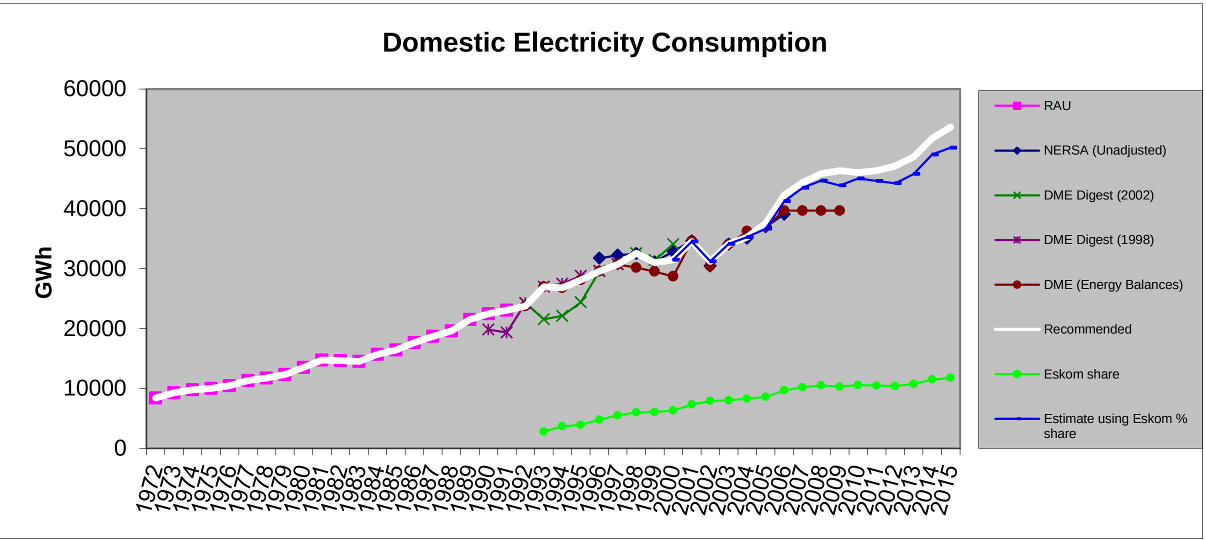

Figure 2 Comparing domestic sector data between different sources

For the domestic sector, the overall patterns between some sources 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.

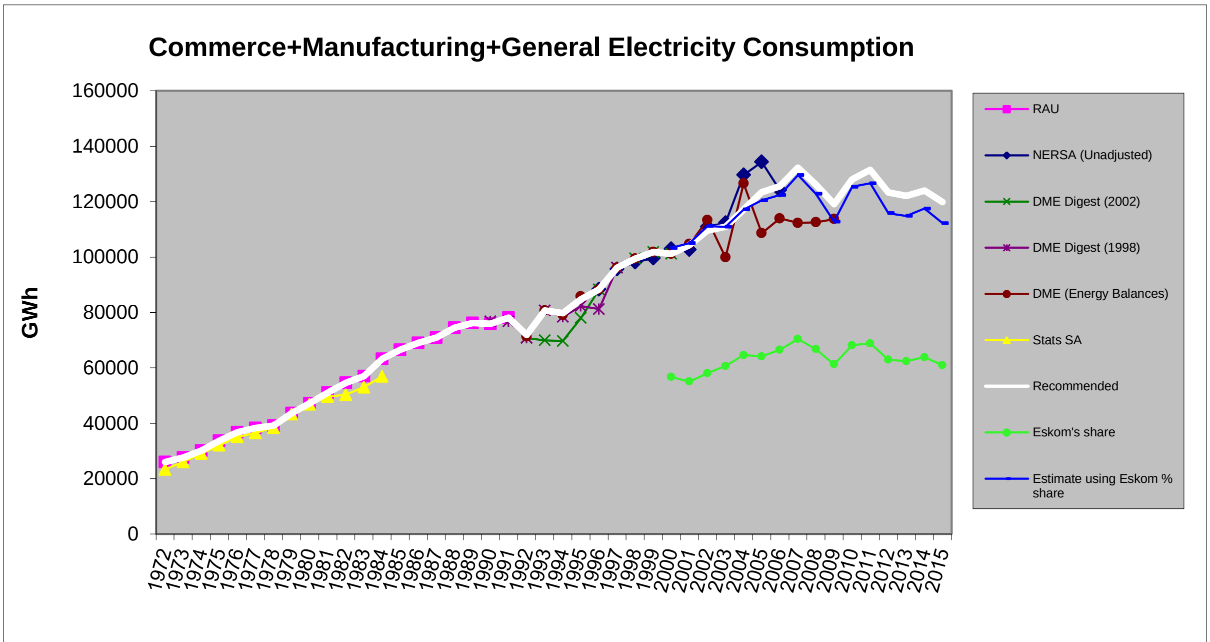

Figure 3 Comparing commercial and manufacturing sector data between different sources

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.

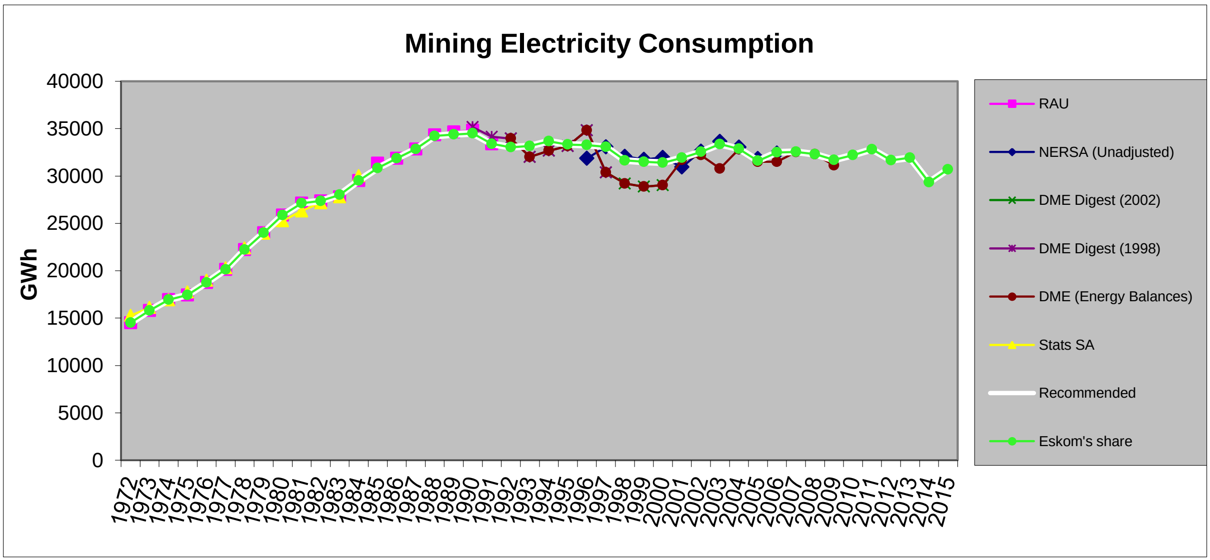

Figure 4 Comparing mining sector data between different sources

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

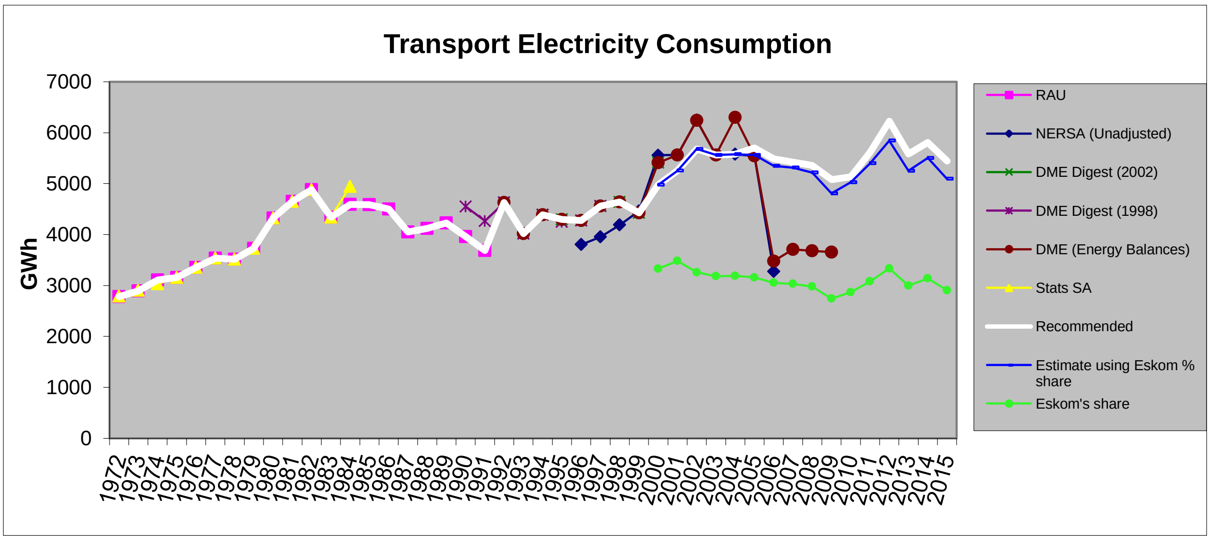

Figure 5 Comparing transport sector data between different sectors

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 has chosen to apply the loss percentage to the aggregated sectors, i.e. sector forecasts are obtained, aggregated and then losses are calculated on the aggregated total to obtain the final total.

The CSIR team also decided to apply one total for losses (i.e., including distribution and technical losses) to the combined total for all sectors in order to derive the total national consumption. 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% 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.

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 large 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 adjusted 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 revised 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	-42238 + 3356.46×ln(**FCEH**)	Adjusted R^2 = 0.96	N/A if only 1 variable in model
Transport	1612.11 + 37.29×**mining index excluding gold**	Adjusted R^2 = 0.65	N/A if only 1 variable in model
Domestic	-380485 + 29725×ln(**FCEH**) **NOTE:** • The intercept value was adjusted to align the starting point of the forecasts (for 2015) with the observed actual values for 2015)	Adjusted R^2 = 0.97	N/A if only 1 variable in model
Commerce & manufacturing	-69653 + 2577.51×**population** + 572.0×**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 2015) with the observed actual values for 2015	Adjusted R^2 = 0.96	CI =23.9
Mining	24454 + 49.094×p**latinum index**+ 0.053×**gold ore treated**	Adjusted R^2 = 0.69	CI = 26.3

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 indicates the declining pattern for the period 2009 - 2015 with the green line, and a logarithmic function fitted to the historical data pattern to represent the overall trend in this ratio as a black 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.

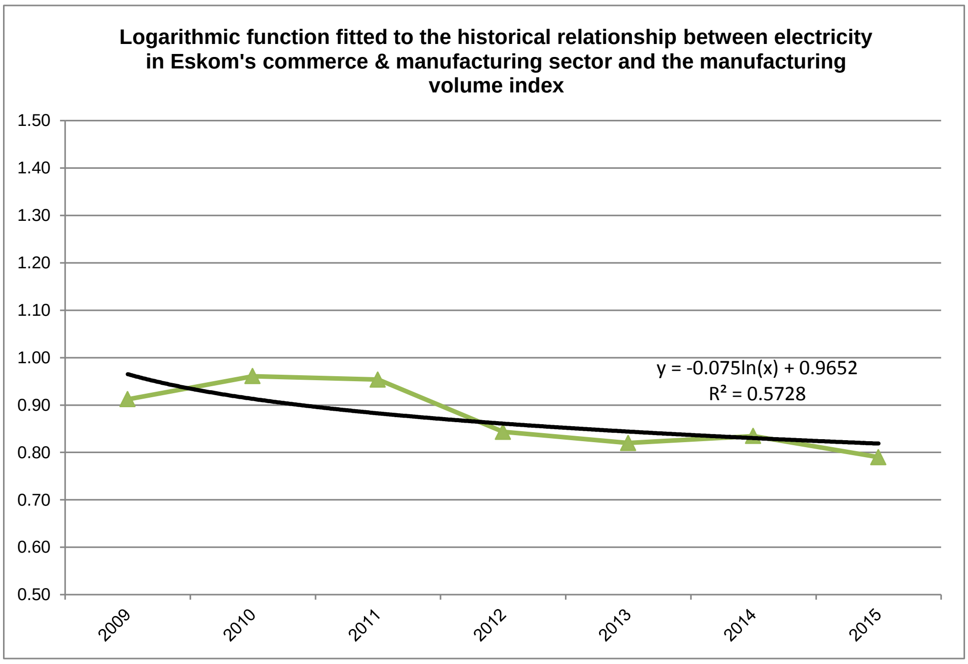

Figure 6 Model fitted for the electricity intensity "correction factor"

3. Forecasting results

This section provides the revised forecasts, namely demand forecasts for national consumption of electricity for the period 2016 – 2050.

3.1. Forecasted driver values used

In the IRP, five growth scenarios were specified for use in forecasting, namely the "High (Same sectors)", "High (Less energy intensive)", "Moderate", "Low" and "Junk status" 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% was taken as the loss percentage across all scenarios, but that this percentage was "phased in" from the lower values observed over the 2010 to 2015 period.

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. Tables 7, 8 and 9 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)
2017	56.53	7.5
2018	57.15	8
2019	57.72	8.5
2020	58.24	9
2021	58.70	9.5
2022	59.17	10
2023	59.59	10.5
2024	60.00	11
2025	60.36	11
2026	60.73	11
2027	61.09	11
2028	61.40	11
2029	61.70	11
2030	62.01	11
2031	62.32	11
2032	62.63	11
2033	62.95	11
2034	63.26	11

Year	Population (in millions)	Line losses (% of sectoral total)
2035	63.58	11
2036	63.90	11
2037	64.22	11
2038	64.54	11
2039	64.86	11
2040	65.18	11
2041	65.51	11
2042	65.84	11
2043	66.17	11
2044	66.50	11
2045	66.83	11
2046	67.16	11
2047	67.50	11
2048	67.84	11
2049	68.18	11
2050	68.52	11

Table 4 GDP % growth forecasts per scenario

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	1.40%	1.70%	3.00%	3.00%	0.30%
2018	1.70%	2.40%	3.70%	3.70%	0.50%
2019	2.00%	2.60%	4.50%	4.50%	0.50%
2020	2.00%	2.90%	4.50%	4.50%	0.50%
2021	2.20%	3.00%	4.50%	4.50%	0.80%
2022	2.20%	3.20%	4.50%	4.50%	1.10%
2023	2.20%	3.50%	4.50%	4.50%	1.20%
2024	2.40%	3.50%	4.50%	4.50%	1.30%
2025	2.40%	3.60%	4.50%	4.50%	1.50%
2026	2.40%	3.70%	4.50%	4.50%	1.80%
2027	2.40%	3.70%	4.30%	4.30%	2.50%
2028	2.20%	3.60%	4.30%	4.30%	4.30%
2029	2.20%	3.60%	4.30%	4.30%	4.30%
2030	2.20%	3.50%	4.10%	4.10%	4.10%
2031	2.20%	3.50%	4.10%	4.10%	4.10%
2032	2.00%	3.40%	4.10%	4.10%	4.10%
2033	2.00%	3.30%	4.00%	4.00%	4.00%
2034	2.00%	3.20%	4.00%	4.00%	4.00%
2035	2.00%	3.20%	3.80%	3.80%	3.80%
2036	2.00%	3.00%	3.80%	3.80%	3.80%
2037	1.80%	3.00%	3.80%	3.80%	3.80%
2038	1.80%	3.00%	3.60%	3.60%	3.60%
2039	1.80%	3.00%	3.60%	3.60%	3.60%
2040	1.80%	2.80%	3.40%	3.40%	3.40%
2041	1.80%	2.80%	3.40%	3.40%	3.40%
2042	1.80%	2.80%	3.40%	3.40%	3.40%
2043	1.80%	2.80%	3.20%	3.20%	3.20%
2044	1.80%	2.80%	3.20%	3.20%	3.20%
2045	1.80%	2.50%	3.20%	3.20%	3.20%
2046	1.80%	2.50%	3.00%	3.00%	3.00%
2047	1.80%	2.50%	3.00%	3.00%	3.00%

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2048	1.80%	2.50%	3.00%	3.00%	3.00%
2049	1.80%	2.50%	3.00%	3.00%	3.00%
2050	1.80%	2.50%	3.00%	3.00%	3.00%

Table 5 FCEH % growth forecasts per scenario

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	1.89%	1.78%	3.09%	2.93%	1.04%
2018	1.35%	1.90%	3.36%	3.05%	0.47%
2019	1.90%	2.05%	4.46%	4.19%	0.49%
2020	1.98%	2.53%	4.58%	3.95%	0.49%
2021	2.03%	2.44%	4.57%	3.83%	0.96%
2022	2.10%	2.89%	4.89%	3.81%	1.43%
2023	2.03%	3.34%	4.78%	3.68%	1.23%
2024	2.68%	3.20%	4.87%	3.71%	1.40%
2025	2.70%	3.42%	4.88%	3.82%	1.74%
2026	2.70%	3.60%	4.89%	3.81%	2.24%
2027	2.70%	3.72%	4.66%	3.79%	2.91%
2028	2.36%	3.56%	3.81%	3.87%	5.54%
2029	2.35%	3.66%	4.67%	3.86%	5.41%
2030	2.50%	3.51%	4.37%	3.93%	5.23%
2031	2.50%	3.53%	4.41%	3.91%	5.20%
2032	2.16%	3.38%	4.56%	3.96%	5.20%
2033	2.14%	3.30%	4.39%	3.96%	5.01%
2034	2.14%	3.13%	4.40%	3.95%	5.00%
2035	2.14%	3.26%	4.08%	3.83%	4.66%
2036	2.17%	2.90%	4.09%	3.94%	4.74%
2037	1.83%	3.04%	4.12%	4.06%	4.74%
2038	1.92%	3.07%	3.88%	3.75%	4.41%
2039	2.26%	3.57%	3.03%	4.28%	4.65%
2040	2.26%	3.34%	3.55%	3.90%	4.32%
2041	2.30%	3.44%	3.54%	3.89%	4.29%
2042	2.30%	3.43%	3.56%	3.94%	4.29%
2043	2.29%	3.42%	3.41%	3.57%	3.97%
2044	2.41%	3.41%	3.40%	3.67%	3.94%
2045	2.40%	2.88%	3.40%	3.72%	3.93%
2046	2.39%	2.99%	3.09%	3.35%	3.69%
2047	2.42%	2.98%	2.78%	3.34%	3.69%
2048	2.41%	2.98%	3.19%	3.46%	3.68%
2049	2.40%	2.97%	3.19%	3.45%	3.73%
2050	2.39%	2.97%	3.19%	3.56%	3.71%

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

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	108.40	109.47	109.47	110.54	107.64
2018	110.02	112.21	112.21	114.41	107.64
2019	111.67	115.57	115.57	118.99	107.64
2020	113.35	119.04	119.04	124.70	107.64
2021	115.62	123.21	122.61	130.94	107.64
2022	117.93	127.52	126.29	137.75	107.64

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2023	120.29	131.98	130.08	144.91	108.18
2024	122.09	137.00	133.72	152.44	108.72
2025	123.92	142.21	137.47	160.07	109.26
2026	125.78	147.61	141.32	168.07	109.81
2027	127.67	152.92	144.99	175.63	111.46
2028	129.58	158.43	148.76	183.54	113.69
2029	131.53	163.81	152.63	191.79	116.53
2030	133.11	169.38	156.60	199.85	119.09
2031	134.70	175.14	160.51	208.24	121.71
2032	136.32	181.10	164.04	216.99	124.39
2033	137.96	186.89	167.65	225.67	127.13
2034	139.61	192.87	171.34	234.70	129.92
2035	141.29	198.66	175.11	243.15	132.78
2036	142.98	204.62	178.96	251.41	135.44
2037	144.70	210.35	182.90	259.96	138.15
2038	146.14	216.24	186.56	268.80	140.91
2039	147.61	221.86	190.29	277.40	143.73
2040	149.08	227.19	194.09	286.28	146.60
2041	150.57	232.18	197.97	295.44	149.53
2042	152.08	237.29	201.93	304.89	152.52
2043	153.60	242.51	205.97	314.65	155.57
2044	154.83	247.85	210.09	324.09	158.69
2045	156.07	253.30	214.29	333.81	161.86
2046	157.32	258.37	218.58	343.83	164.77
2047	158.57	263.53	222.95	354.14	167.74
2048	159.84	268.80	226.96	364.06	170.76
2049	161.12	274.18	231.05	374.25	173.49
2050	162.41	279.66	235.21	383.98	176.27

Table 7 Forecasts for platinum production index (base year = 2010) per scenario

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	94.51	94.511	94.51	96.81	93.16
2018	97.35	97.535	97.35	103.58	94.09
2019	100.27	100.657	100.27	110.83	95.03
2020	102.77	104.180	102.77	117.48	95.98
2021	105.34	107.826	105.34	124.53	96.94
2022	107.98	111.276	107.66	131.38	97.91
2023	110.68	114.837	110.03	138.61	99.87
2024	113.11	118.512	112.45	145.54	101.87
2025	115.60	122.067	114.70	152.81	103.90
2026	117.91	125.729	116.99	160.45	105.98
2027	120.27	129.501	119.33	167.67	108.10
2028	122.67	133.386	121.72	175.22	110.26
2029	124.88	137.388	124.15	183.10	112.47
2030	127.13	141.235	126.64	188.60	114.72
2031	129.42	145.189	129.17	194.26	117.01
2032	131.75	148.964	131.49	200.08	119.12
2033	134.12	152.837	133.86	205.09	121.26
2034	136.53	156.658	136.27	210.21	123.44
2035	138.99	160.575	138.72	215.47	125.67

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2036	141.08	164.589	141.22	220.85	127.93
2037	143.19	168.210	143.34	226.38	129.85
2038	145.34	171.910	145.49	230.90	131.79
2039	147.52	175.693	147.67	235.52	133.77
2040	149.73	179.206	149.89	240.23	135.78
2041	151.98	182.791	152.13	245.04	137.81
2042	154.26	186.446	153.96	249.94	139.47
2043	156.57	190.175	155.81	254.94	141.14
2044	158.61	193.979	157.68	260.03	142.84
2045	160.67	197.858	159.57	265.24	144.55
2046	162.76	201.815	161.48	270.54	146.28
2047	164.88	205.852	163.42	275.95	148.04
2048	167.02	209.969	165.38	281.47	149.82
2049	169.19	214.168	167.37	287.10	151.61
2050	171.39	218.452	169.38	292.84	153.43

Table 8 Forecasts for mining production index, excluding gold (base year = 2010)

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	104.29	104.55	104.71	106.62	102.01
2018	106.99	107.63	107.85	112.84	102.58
2019	109.65	110.80	110.97	119.44	103.15
2020	112.11	114.22	114.06	125.83	103.73
2021	114.63	117.70	117.24	132.52	104.32
2022	117.21	121.11	120.19	139.51	105.36
2023	119.84	124.62	123.22	146.87	106.90
2024	122.29	128.23	126.32	154.25	108.46
2025	124.80	131.68	129.39	161.89	110.04
2026	127.23	135.23	132.42	169.91	111.65
2027	129.71	138.88	135.53	177.92	113.29
2028	132.24	142.49	138.47	185.58	115.74
2029	134.69	146.19	141.47	193.57	118.24
2030	137.18	149.85	144.36	200.04	120.64
2031	139.72	153.39	147.23	206.74	123.03
2032	142.31	156.87	149.90	213.22	125.25
2033	144.95	160.42	152.62	219.39	127.51
2034	147.63	163.98	155.25	225.73	129.70
2035	150.37	167.46	157.93	232.27	131.93
2036	152.93	171.01	160.45	239.00	134.03
2037	155.54	174.38	162.78	244.89	135.97
2038	158.19	177.61	165.15	250.32	137.95
2039	160.89	180.91	167.55	255.87	139.95
2040	163.64	184.08	169.96	261.55	141.95
2041	166.09	187.31	172.40	267.35	143.98
2042	168.50	190.60	174.64	272.70	145.84
2043	170.95	193.95	176.90	278.16	147.72
2044	173.27	197.37	179.20	283.72	149.63
2045	175.61	200.84	181.52	288.77	151.57
2046	177.99	204.23	183.88	293.92	153.52
2047	180.03	207.67	186.00	299.16	155.29
2048	182.10	211.18	188.16	304.49	157.08

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2049	184.19	214.75	190.33	309.92	158.89
2050	186.30	218.38	192.54	315.45	160.73

Table 9 Forecasts for gold ore treated (million metric tons)

Year	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2017	36.98	37.16	36.98	37.54	36.96
2018	36.24	36.79	36.24	37.35	36.22
2019	35.51	36.42	35.51	37.17	35.50
2020	34.80	36.06	34.80	36.98	34.79
2021	34.28	36.06	34.10	36.80	34.27
2022	33.76	36.06	33.42	36.61	33.75
2023	33.43	36.06	32.75	36.43	33.42
2024	33.09	36.06	32.10	36.43	33.08
2025	32.76	36.06	31.46	36.43	32.75
2026	32.60	36.06	30.83	36.43	32.59
2027	32.44	36.06	30.21	36.43	32.42
2028	32.27	36.06	29.61	36.43	32.26
2029	32.27	36.06	29.02	36.43	32.26
2030	32.27	36.06	28.43	36.43	32.26
2031	32.27	36.06	27.87	36.43	32.26
2032	32.27	36.06	27.59	36.43	32.26
2033	32.27	36.06	27.31	36.43	32.26
2034	32.27	36.06	27.04	36.43	32.26
2035	32.27	36.06	26.77	36.43	32.26
2036	32.27	36.06	26.50	36.43	32.26
2037	32.27	36.06	26.24	36.43	32.26
2038	32.27	36.06	25.97	36.43	32.26
2039	32.27	36.06	25.97	36.43	32.26
2040	32.27	36.06	25.97	36.43	32.26
2041	32.27	36.06	25.97	36.43	32.26
2042	32.27	36.06	25.97	36.43	32.26
2043	32.27	36.06	25.97	36.43	32.26
2044	32.27	36.06	25.97	36.43	32.26
2045	32.27	36.06	25.97	36.43	32.26
2046	32.27	36.06	25.97	36.43	32.26
2047	32.27	36.06	25.97	36.43	32.26
2048	32.27	36.06	25.97	36.43	32.26
2049	32.27	36.06	25.97	36.43	32.26
2050	32.27	36.06	25.97	36.43	32.26

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.

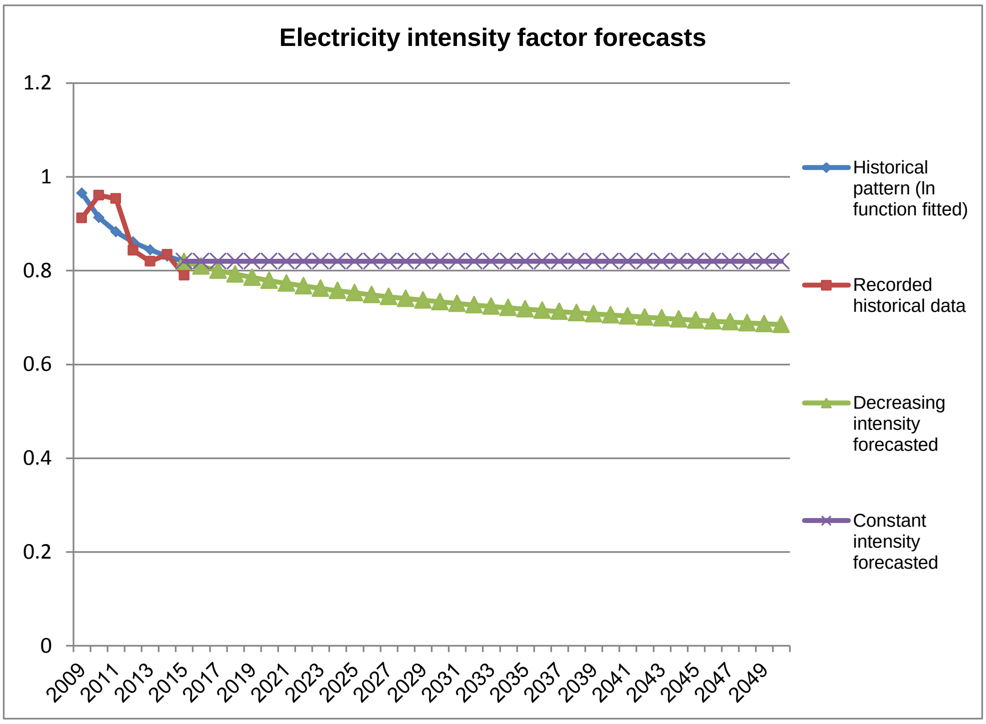

Figure 7 Values used for electricity intensity ratio ("correction factor") in scenarios

3.2. Demand forecasts obtained

The forecasts obtained for each of the five scenarios are provided in Table 10 below. Note that the forecasts in Table 10 include the adjustments for energy intensity improvements in the manufacturing sector, as applicable to each scenario, by way of the "correction factor".

Table 10 National electricity demand: 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)**	**Junk status**
2017	234539	235063	234195	236230	233695
2018	238871	240200	239228	242684	236699
2019	243303	245615	244874	249841	239592
2020	247635	251179	250500	257366	242356
2021	252181	256988	256085	265061	245167
2022	256825	263073	261871	273115	248192
2023	261358	269295	267568	281249	251367
2024	265853	275818	273284	289651	254637
2025	269028	281122	277673	296734	256735

Year	Annual electricity demand forecasts (GWh) per scenario, provided per calendar year:				
	Low	Moderate	High (Less energy intensive)	High (Same sectors)	Junk status
2026	272223	286610	282124	304052	259035
2027	275441	292109	286426	311119	262154
2028	278389	297490	290304	318226	266374
2029	281348	302861	294539	325551	270887
2030	284182	308266	298719	332604	275195
2031	287033	313783	302892	339849	279525
2032	289781	319339	306940	347301	283874
2033	292541	324799	310975	354665	288197
2034	295320	330296	315051	362226	292550
2035	298118	335743	319060	369462	296824
2036	300913	341167	323108	376662	301021
2037	303606	346496	327177	384026	305225
2038	306199	351920	331044	391363	309350
2039	308931	357396	334661	398780	313593
2040	311677	362622	338502	406222	317758
2041	314438	367722	342378	413821	321948
2042	317213	372887	346268	421581	326145
2043	320002	378119	350144	429382	330269
2044	322663	383419	354057	437070	334422
2045	325334	388603	358010	444912	338610
2046	328014	393629	361892	452790	342584
2047	330703	398716	365693	460835	346583
2048	333401	403868	369487	468726	350612
2049	336109	409084	373317	476776	354516
2050	338826	414366	377183	484638	358444

The CSIR recommended forecasts obtained for all five 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.

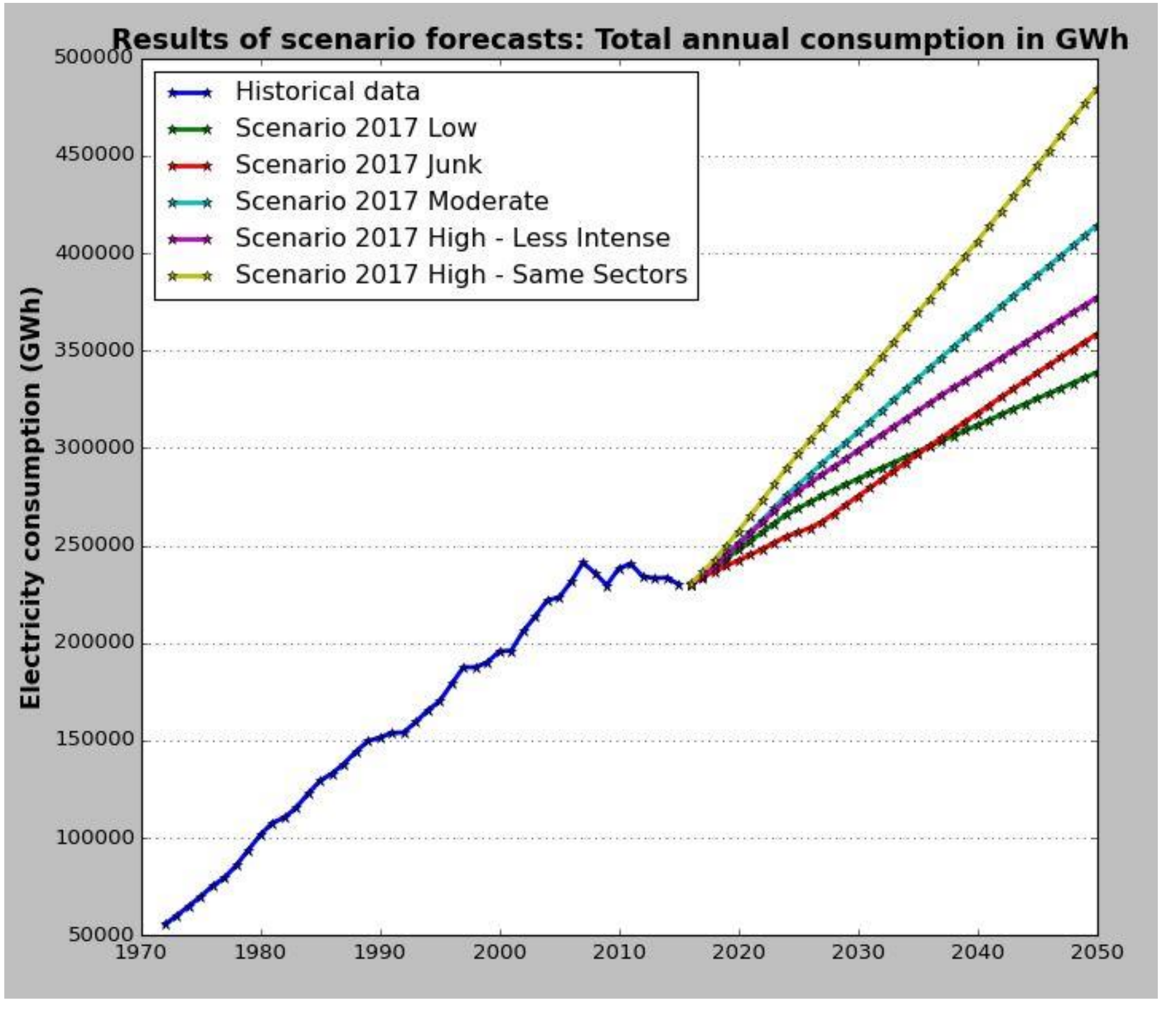

Figure 8 Recommended forecasts for national consumption of electricity using the "CSIR model"

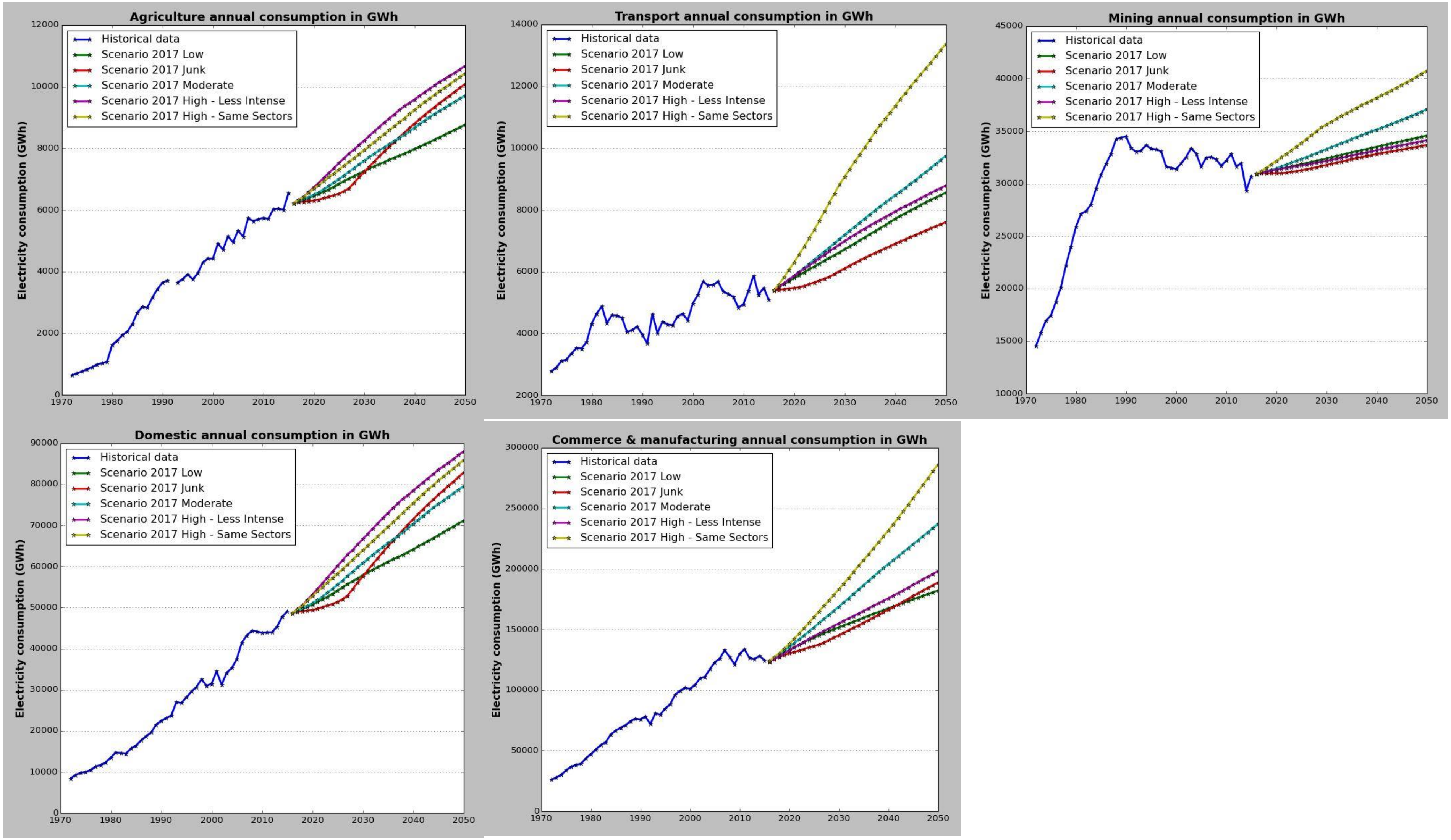

Figure 9 Forecasted values for the 5 electricity sectors

4. Final remarks

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

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