# POWER AFRICA TRANSACTIONS AND REFORMS PROGRAM (PATRP)

## Technical Assistance to the Ministry of Power in Ghana

# ELECTRICITY DEMAND FORECASTING AND SUPPRESSED DEMAND ESTIMATION STUDY

April 2016

This publication was produced for review by the United States Agency for International Development. It was prepared by Nexant, Inc. as subcontractor to Tetra Tech under Contract No. AID-623-C-14-00003.

# POWER AFRICA TRANSACTIONS AND REFORMS PROGRAM (PATRP)

## Technical Assistance to the Ministry of Power in Ghana

# Electricity Demand Forecasting and Suppressed Demand Estimation Study

**April 2016**

**DISCLAIMER:** The author's views expressed in this publication do not necessarily reflect the views of the United States Agency for International Development or the United States Government. This was prepared by Nexant, Inc. as subcontractor to Tetra Tech under Contract AID-623-C-14-00003.

# TABLE OF CONTENTS

**Section** **Page**


SECTION 1 EXECUTIVE SUMMARY ..... 1

1.1 STUDY GOAL ..... 1

1.2 STUDY APPROACH ..... 1

1.3 INPUT DATA AND ANALYSIS ASSUMPTIONS ..... 1

1.4 SUPPRESSED DEMAND ANALYSIS ..... 3

1.5 FORECASTING COMPONENTS, RESULTS AND KEY FINDINGS ..... 5

1.6 KEY FINDINGS AND IMPLICATIONS FOR THE DEVELOPMENT OF THE POWER SYSTEM13

SECTION 2 OVERVIEW ..... 15

2.1 BACKGROUND ..... 15

2.2 STUDY PURPOSE ..... 15

2.3 SUPPRESSED DEMAND COMPONENTS ..... 15

2.4 APPROACH ..... 16

2.5 REPORT STRUCTURE ..... 16

SECTION 3 POWER SECTOR HISTORICAL DEMAND, STUDIES, AND INPUT DATA ..... 18

3.1 INPUT DATA ..... 18

3.2 SUMMARY OF FORECASTING STUDIES ..... 29

3.3 FORECASTING INPUTS AND ASSUMPTIONS ..... 39

SECTION 4 SUPPRESSED DEMAND ANALYSIS ..... 54

4.1 SUPPRESSED DEMAND COMPONENTS ..... 54

4.2 ANALYSIS ..... 54

SECTION 5 DEMAND FORECASTING ..... 64

5.1 METHODOLOGY ..... 64

5.2 FORECAST MODEL DEVELOPMENT ..... 67

5.3 REGRESSION RESULTS ..... 73

5.4 VALIDATION FOR 2012-2014 PERIOD ..... 84

5.5 FORECAST AT THE DISTRIBUTION LEVEL AND VALIDATION ..... 88

5.6 TOTAL BASE CASE DEMAND FORECAST FOR THE 2015-2030 PERIOD ..... 92

5.7 BASE CASE SENSITIVITY ANALYSES ..... 101

5.8 SCENARIO RESULTS ..... 105

SECTION 6 CONCLUSIONS AND RECOMMENDATIONS ..... 116

6.1 CONCLUSIONS ..... 116
6.2 RECOMMENDATIONS ..... 118
**SECTION 7 REFERENCES ..... 119**
**SECTION 8 FORECASTING MODELS AND TESTS ..... 120**
8.1 UNIT ROOT TEST FOR ECG MODELS ..... 120
8.2 PROCESS AND RESULTS OF THE MODEL ESTIMATION ..... 120
8.3 DIAGNOSTIC TESTS ..... 126
**SECTION 9 REBOUND ANALYSIS EXAMPLES ..... 128**

## LIST OF TABLES AND FIGURES

Table 1-1: Growth Rate Scenario Assumptions for Total GDP ..... 2

Table 1-2: Electricity Price Growth Rate Scenario Assumptions ..... 2

Table 1-3: Total Population Growth Rate Scenario Assumptions ..... 2

Table 1-4: Scenario Assumptions for the Number of Residential Customers ..... 2

Table 1-5: Scenario Assumptions for the Number of Non-residential Customers ..... 3

Table 1-6: Scenario Assumptions for the Number ECG and NEDCo SLT Customers ..... 3

Table 1-7: Distribution Level Forecast for the Base Case (GWh) ..... 7

Table 1-8: Distribution Level Forecast, Base, Low and High Scenarios (GWh) ..... 8

Table 1-9: Distribution Level Forecast Comparison (GWh) ..... 9

Table 1-10: Base Case Total Demand Forecast (GWh) ..... 10

Table 1-11: Base Case Peak Load Forecast (MW) ..... 10

Table 1-12: Base Case Total Demand Forecast Comparison (GWh) ..... 11

Table 1-13: Base Case Peak Load Forecast Comparison (MW) ..... 11

Table 1-14: Total Low Growth Scenario Demand Forecast (GWh) ..... 12

Table 1-15: High Growth Scenario Total Demand Forecast (GWh) ..... 13

Table 3-1: Historical Sales Data by Customer Category (GWh) ..... 18

Table 3-2: Historical Sales for Residential Customers (GWh) ..... 20

Table 3-3: Historical Sales for Non-Residential Customers (GWh) ..... 21

Table 3-4: Historical Sales for Industrial Customers (GWh) ..... 21

Table 3-5: Historical Street Lighting Sales (GWh) ..... 22

Table 3-6: Historical ECG and NEDCo Sales and Losses (GWh) ..... 23

Table 3-7: Historical Sales for Industrial Customers (GWh) ..... 25

Table 3-8: Historical Sales for Industrial Customers (GWh) ..... 26

Table 3-9: Historical Peak Demand (MW) ..... 28

Table 3-10: ECG Base Case Forecast by Component for the 2014-2023 Period (GWh) ..... 30

Table 3-11: ECG Low Scenario Forecast by Component for the 2014-2023 Period (GWh) ..... 30

Table 3-12: ECG High Scenario Forecast by Component for the 2014-2023 Period (GWh) ..... 31

Table 3-13: VRA Base Case Forecast by Customer Class for the 2015-2030 Period (GWh) .... 32

Table 3-14: GRIDCo Base Case Forecast by Component for the 2015-2025 Period (GWh) ..... 33

Table 3-15: SNEP Base Case (BaU) Forecast by Component for the 2015-2035 Period (GWh) ..... 34

Table 3-16: SNEP AEG Forecast by Component for the 2015-2035 Period (GWh) ..... 35

Table 3-17: SNEP Total Generation and Loss Forecasts for the 2015-2035 Period (GWh) ..... 36

Table 3-18: Historical GDP and Component Data in constant 2006 prices (Million US$) ..... 40

Table 3-19: Adjusted GDP in constant 2006 prices (Million US$) ..... 42

Table 3-20: Historical Population and Number of Customers (million) ..... 43

Table 3-21: Historical Number of Customers ..... 43

Table 3-22: Historical Number of Customers Growth Rates ..... 44

Table 3-23: Adjusted Historical Number of Customers ..... 45

Table 3-24: Historical Real Average Electricity Tariffs for all Customers (GHS/MWh and USc/KWh) ..... 45

Table 3-25: Historical Nominal 2006 Average Electricity Tariffs for ECG SLT and NSLT Customers (GHS/MWh) ..... 46

Table 3-26: Historical Derived Indices ..... 47

Table 3-27: Historical Derived Indices Growth Rates ..... 48

Table 3-28: Historical Electricity Intensity Indices ..... 49

Table 3-29: Historical Electricity Intensity Indices Growth Rates ..... 49

Table 3-30: Scenario Growth Rate Assumptions for Total GDP ..... 50

Table 3-31: Scenario Growth Rate Assumptions for Industrial GDP ..... 50

Table 3-32: Scenario Growth Rate Assumptions for Services GDP ..... 50

Table 3-33: Electricity Price Growth Rate Scenario Assumptions ..... 50

Table 3-34: Total Population Growth Rate Scenario Assumptions ..... 51

Table 3-35: Scenario Assumptions for the Number of Residential Customers ..... 51

Table 3-36: Scenario Assumptions for the Number of Non-residential Customers ..... 51

Table 3-37: Scenario Assumptions for the Number ECG and NEDCo SLT Customers ..... 52

Table 3-38: Assumptions for the Future Coincident Factors ..... 52

Table 4-1: GRIDCo Load Relief Requests for the 2012-2014 Period (GWh) ..... 56

Table 4-2: Historical Sales Data Corrected for the Load Shedding with Increases (GWh) ..... 58

Table 4-3: GRIDCo Transmission Line Availability Indices for the 2011-2014 Period ..... 61

Table 4-4: ECG Network Reliability Indices for the 2010-2014 Period ..... 62

Table 5-1: Street Lighting Historical and S-Curve Fit (GWh) ..... 72

Table 5-2: Statistics for Residential Model ..... 74

Table 5-3: Residential Forecast for the Base Case, Low and High Scenarios (GWh) ..... 74

Table 5-4: Statistics for Non-Residential Model ..... 75

Table 5-5: Non-Residential Forecast for the Base Case, Low and High Scenarios (GWh) ..... 76

Table 5-6: Statistics for NLST Model ..... 77

Table 5-7: NSLT Forecast for the Base Case, Low and High Scenarios (GWh) ..... 78

Table 5-8: Statistics for SLT Model ..... 79

Table 5-9: SLT Forecast the Base Case, Low and High Scenarios (GWh) ..... 79

Table 5-10: Statistics for NLST+SLT Model ..... 80

Table 5-11: NSLT+SLT Forecast the Base Case, Low and High Scenarios (GWh) ..... 81

Table 5-12: Statistics for Direct Customers Model ..... 82

Table 5-13: Direct Customers Forecast the Base Case, Low and High Scenarios (GWh) ..... 82

Table 5-14: VRA Direct Customers Forecasts for the Base Case, Low and High Scenarios (GWh) ..... 83

Table 5-15: 2012-2014 Validation of Res, Non-Res and SL Forecasts (GWh) ..... 85

Table 5-16: 2012-2014 Validation of NSLT Forecasts (GWh) ..... 86

Table 5-17: 2012-2014 Validation of SLT Forecast (GWh) ..... 86

Table 5-18: 2012-2014 Validation of NSLT+SLT Forecast (GWh) ..... 87

Table 5-19: Distribution Level Forecast for the Base Case (GWh) ..... 89

Table 5-20: Distribution Level Forecast, Base, Low and High Scenarios (GWh) ..... 89

Table 5-21: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast for the Base Case (GWh) ..... 91

Table 5-22: Distribution Level Forecast Comparison (GWh) ..... 92

Table 5-23: VALCO Forecast, from GRIDCo/EC (GWh) ..... 93

Table 5-24: Mines Forecast (GWh) ..... 94

Table 5-25: Export Forecast (GWh) ..... 95

Table 5-26: Transmission Loss Estimates ..... 95

Table 5-27: Base Case Total Demand Forecast (GWh) ..... 96

Table 5-28: Base Case Peak Load Forecast (MW) ..... 97

Table 5-29: Base Case Total Demand Forecast Comparison (GWh) ..... 99

Table 5-30: Base Case Peak Load Forecast Comparison (MW) ..... 100

Table 5-31: Base Case Total Demand Forecast, with 20% Infrastructure Barrier Sensitivity (GWh) ..... 102

Table 5-32: Base Case Peak Load Forecast, with 20% Infrastructure Barrier Sensitivity (MW) ..... 102

Table 5-33: Distribution Demand Forecast, Sensitivity with No Loss Reduction (GWh) ..... 103

Table 5-34: Base Case Total Demand Forecast, Sensitivity with No Loss Reduction (GWh) ..... 104

Table 5-35: Base Case Peak Load Forecast, Sensitivity with No Loss Reduction (MW) ..... 104

Table 5-36: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast, Low Growth Scenario (GWh) ..... 105

Table 5-37: Comparison of Res, Non-Res, and SLT + SLT Forecast with Combined NSLT+SLT Forecast, Low Growth Scenario (GWh) ..... 106

Table 5-38: Total Low Growth Scenario Demand Forecast (GWh) ..... 107

Table 5-39: Low Growth Scenario Peak Load Forecast (MW) ..... 108

Table 5-40: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast, High Growth Scenario (GWh) ..... 110

Table 5-41: Comparison of Res, Non-Res, and SL + SLT Forecast with Combined NSLT+SLT Forecast, High Scenario (GWh) ..... 110

Table 5-42: High Growth Scenario Total Demand Forecast (GWh) ..... 112

Table 5-43: High Growth Scenario Peak Load Forecast (MW) ..... 113

Table 5-44: Demand Forecast Comparison for the High Growth Scenarios (GWh) ..... 114

Table 5-45: Peak Load Forecast Comparison for the High Growth Scenarios (MW) ..... 115

Table 8-1: Philips Perron Unit Root Test ..... 120

Table 8-2: Diagnostic Tests ..... 127

Figure 1-1: ECG Consumption by Customer Class including Load Shedding and Rebound Effect (GWh) ..... 4

Figure 1-2: NEDCo Consumption including Load Shedding and Rebound Effect (GWh)..... 4

Figure 1-3: Forecasting Components ..... 6

Figure 3-1: Historical Sales Chart by Customer Category ..... 20

Figure 3-2: Historical ECG Demand Breakdown Chart (GWh) ..... 24

Figure 3-3: Historical NEDCo Demand Breakdown Chart (GWh)..... 24

Figure 3-4: Historical Sales Chart Sales for Industrial Customers..... 26

Figure 3-5: T&D Losses during the 2000–2014 Period (GWh and %)..... 27

Figure 3-6: ECG Demand Forecasts Summary (GWh) ..... 37

Figure 3-7: Total Generation Requirement Comparison (GWh) ..... 38

Figure 3-8: Total Peak Load Forecasts Comparison (GWh)..... 38

Figure 4-1: Approach for Estimating Suppressed Demand Components ..... 55

Figure 4-2: Daily Demand Comparison for the First Monday in December ..... 57

Figure 4-3: ECG Historical Demand including Load Shedding and Rebound Effect (GWh)..... 58

Figure 4-4: NEDCo Historical Demand including Load Shedding and Rebound Effect (GWh) .. 59

Figure 4-5: ECG Actual and Revised Demand and Forecasting Trajectories (GWh) ..... 60

Figure 5-1: Forecasting Process and Steps..... 64

Figure 5-2: Forecasting Components ..... 66

Figure 5-3: Forecasting Flow Chart for a Single Consumer Category ..... 68

Figure 5-4: Street Lighting Historical and S-Curve Fit (GWh)..... 73

Figure 5-5: Residential Forecast for the Base Case, Low and High Scenarios (GWh)..... 75

Figure 5-6: Non-Residential Forecast the Base Case, Low and High Scenarios (GWh)..... 77

Figure 5-7: SLT Forecast the Base Case, Low and High Scenarios (GWh) ..... 80

Figure 5-8: Direct Customers Forecast the Base Case, Low and High Scenarios (GWh) ..... 83

Figure 5-9: 2012-2014 Validation of Res, Non-Res and SL Forecasts (GWh) ..... 85

Figure 5-10: 2012-2014 Validation of NSLT Forecasts (GWh) ..... 86

Figure 5-11: 2012-2014 Validation of SLT Forecast (GWh) ..... 87

Figure 5-12: 2012-2014 Validation of NSLT+SLT Forecast (GWh) ..... 88

Figure 5-13: Distribution Level Forecast for the Base Case, Low and High Scenarios (GWh) ... 90

Figure 5-14: Base Case Total Demand Forecast by Category (GWh) ..... 97

Figure 5-15: Base Case Peak Load Forecast (MW) ..... 98

Figure 5-16: Base Case Total Demand Forecast Comparison (GWh) ..... 99

Figure 5-17: Base Case Peak Load Forecast Comparison (MW) ..... 101

Figure 5-18: Total Low Growth Scenario Demand Forecast (GWh) ..... 108

Figure 5-19: Low Growth Scenario Peak Load Forecast by Category (MW) ..... 109

Figure 5-20: High Growth Scenario Total Demand Forecast by Category (GWh) ..... 113

Figure 5-21: High Growth Scenario Peak Load Forecast by Category (MW) ..... 114

Figure 9-1: Daily Demand Comparison for the Second Friday in July ..... 128

Figure 9-2: Daily Demand Comparison for the Second Saturday in July ..... 128

Figure 9-3: Daily Demand Comparison for the Second Monday in August ..... 129

Figure 9-4: Daily Demand Comparison for the Second Tuesday in August ..... 129

Figure 9-5: Daily Demand Comparison for the First Wednesday in October ..... 130

Figure 9-6: Daily Demand Comparison for the First Thursday in October ..... 130

Figure 9-7: Daily Demand Comparison for the First Monday in December ..... 131

Figure 9-8: Daily Demand Comparison for the First Wednesday in December ..... 131

# ACRONYMS

| Abbreviation | Definition |
|---|---|
| *BSP* | *Bulk Supply Point* |
| *DER* | *Distributed Energy Resources* |
| *DSM* | *Demand Side Management* |
| *ECG* | *Electricity Company of Ghana* |
| *EC* | *Energy Commission* |
| *GDP* | *Gross Domestic Product* |
| *Gh¢* | *Ghana Cedi* |
| *GoG* | *Government of Ghana* |
| *GRIDCo* | *Ghana Grid Company Limited* |
| *GWh* | *GigaWatt Hour* |
| *HFO* | *Heavy Fuel Oil* |
| *HV* | *High Voltage* |
| *IMF* | *International Monetary Fund* |
| *IPP* | *Independent Power Producer* |
| *kWh* | *Kilowatt Hour* |
| *LCPDP* | *Least Cost Power Development Plan* |
| *LOLE* | *Loss of Load Expectation* |
| *LOLP* | *Loss of Load Probability* |
| *LRMC* | *Long Run Marginal Cost* |
| *MoP* | *Ministry of Petroleum* |
| *MV* | *Medium Voltage* |
| *MVA* | *MegaVolt Amperes* |
| *MW* | *Mega Watt* |
| *MWh* | *Mega Watt Hour* |
| *NEDCo* | *Northern Electricity Distribution Company* |
| *NES* | *National Electrification Scheme* |
| *NSLT* | *Non–Special Load Tariff* |
| *OLS* | *Ordinary Least Squares* |
| *PATRP* | *Power Africa Transactions and Reforms Program* |
| *RE* | *Renewable Energy* |
| *SD* | *Suppressed Demand* |

| Abbreviation | Definition |
|---|---|
| *SLT* | *Special Load Tariff* |
| *T&D* | *Transmission and Distribution* |
| *USc* | *United States Cents* |
| *US$* | *United States Dollars* |
| *VALCO* | *Volta Aluminum Company* |
| *VRA* | *Volta River Authority* |

# Section 1 EXECUTIVE SUMMARY

## 1.1 STUDY GOAL

To estimate suppressed demand and develop a long-term demand forecast for power as a critical input when estimating the demand for natural gas. This study will help validate planned generation needs and projects and assess any potential supply deficits.

## 1.2 STUDY APPROACH

The approach to estimate suppressed demand and develop the demand forecast for the entire country included the following steps:

i. *Data Collection, Review, and Analysis:* Visits to government agencies and utilities involved in load forecasting, including ECG, EC, GRIDCo, and VRA. This step included data collection and review of utility operational and planning data and studies

ii. *Estimate Suppressed and Total Demand:* Use engineering and technical data to calculate the amount of suppressed demand and calculate total demand including demand recorded by utilities plus suppressed demand

iii. *Estimate Electricity Demand on the National Level Using Sectoral Approach:* Use econometric methods to conduct regression analysis for historical years that represent normal (e.g. unconstrained) supply/demand conditions to estimate total demand

iv. *Develop Unconstrained Demand:* Compare results from the sectoral approach with the results from direct estimation of suppressed and total demand to arrive at the best estimate of the unconstrained year 2014 demand

v. *Develop Scenarios and Analyze Demand for the 2015-2030 Period:* Develop three demand scenarios—medium (base), high and low— and forecast demand for the next 16 years

## 1.3 INPUT DATA AND ANALYSIS ASSUMPTIONS

For this study, we collected, reviewed, and used the most recent load forecasts and additional details about the inputs and results from Electricity Company of Ghana (ECG), GRIDCo, VRA, and the Energy Commission (EC).

The demand forecast was done for the following customer categories: Residential, Non-residential, Street Lighting and Industrial. Industrial sales were further divided into: Industrial Sales to ECG & NEDCo (SLT Customers, connected at the Distribution Level) and VRA Industrial Sales. VRA Industrial sales include the following customer categories: Mines, Other Direct Customers, and VALCO smelter, all connected at the Transmission Level. Electricity exports/imports to neighboring countries were estimated as a separate category.

The key variables used in the forecasting analysis are: Ghana population and number of households, electricity prices, customer population by category, and GDP and its components. Derived economic indices such as per-capita income and per-capita consumption were also considered in the analysis. Historical inputs to the forecasting models were adjusted, when

appropriate, to reflect unconstrained conditions, i.e. GDP and customer population were revised upward to account for the addition of suppressed demand in historical sales.

Tables 1-1 to 1-6 present Base Case, High and Low Growth scenario assumptions for all key input parameters over the next 16 year period. Different growth rate assumptions are presented for the near term 2015–2018 period (four years), for the mid-term 2019-2024 (six years) and for the long-term 2025-2030 period (six years). Lower percentage growth assumptions used for long-term demand forecasting take into account growth rates associated with a more mature and larger power sector. In addition, different growth rates were assumed for GDP components, consistent with the historical trend. Both mid-term and long-term growth rates for the number of customers take into account increased economic activity and the total number of households that are projected to be connected in the future. These growth rates reflect the impacts of the Income and Technologies barriers that affect electricity demand.

Table 1-1: Growth Rate Scenario Assumptions for Total GDP

| Period | Low GDP Growth Rate (%) | Base GDP Growth Rate (%) | High GDP Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 6.8% | 7.2% | 8.2% |
| 2019-2024 | 5.8% | 6.2% | 7.5% |
| 2025-2030 | 5.0% | 5.5% | 7.2% |

Table 1-2: Electricity Price Growth Rate Scenario Assumptions

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 4.0% | 6.0% | 8.0% |
| 2019-2024 | 2.0% | 4.0% | 6.0% |
| 2025-2030 | 1.0% | 2.0% | 4.0% |

Table 1-3: Total Population Growth Rate Scenario Assumptions

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 1.9% | 2.3% | 2.6% |
| 2019-2024 | 1.9% | 2.3% | 2.6% |
| 2025-2030 | 1.9% | 2.3% | 2.6% |

Table 1-4: Scenario Assumptions for the Number of Residential Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 6.0% | 8.0% | 10.0% |
| 2019-2024 | 5.0% | 6.0% | 7.0% |
| 2025-2030 | 4.0% | 4.5% | 5.0% |

Table 1-5: Scenario Assumptions for the Number of Non-residential Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 8.0% | 10.0% | 12.0% |
| 2019-2024 | 7.0% | 8.0% | 10.0% |
| 2025-2030 | 6.0% | 7.0% | 9.0% |

Table 1-6: Scenario Assumptions for the Number ECG and NEDCo SLT Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 8.0% | 10.0% | 12.0% |
| 2019-2024 | 7.0% | 8.0% | 10.0% |
| 2025-2030 | 6.0% | 7.0% | 9.0% |

## 1.4 SUPPRESSED DEMAND ANALYSIS

The objective of the suppressed demand analysis was to develop unconstrained demand for the 2012 -2014 period (e.g. the years demand was impacted by load shedding) to be used as a starting point for future demand forecasting. Our analysis addresses two key suppressed demand components impacting current demand:

i. *Supply Constraint*: Exists because electricity supplied in a power grid is inadequate to meet the demand

ii. *Infrastructure Barrier:* Exists because of inadequate delivery infrastructure. Examples include inadequate transmission and distribution networks

The remaining two components impacting future demand and will be addressed in developing the growth rate assumptions for scenarios for the next 16 year period. Those include:

i. *Income Barrier:* In low income countries resources are allocated according to the priority allotted to basic human needs

ii. *Technology Barrier:* Due to high initial cost or lack of capacity to absorb the technology

The long term impacts of the Income and Technology barriers are incorporated into the long-term growth rates assumptions for GDP, population, number of customers and electricity prices that directly affect electricity consumption.

Historical system operations data provided the insight into the supply constraint component of the suppressed demand. Load shedding information was extracted and verified using GRIDCo daily operations reports and ECG data. Rebound effect is an increase in customer demand before and after the load shedding to make up for the time when electricity is not available. The amount of rebound demand was estimated by comparing hourly demand curves for a number of representative days.

Figures 1-1 and 1-2 show the yearly impact the Supply Constraint component had on ECG and NEDCo demand including the combined effect of load shedding and the rebound effect. The figures show estimates of what the total demand would have been if both systems had not had any supply constraints during the 2012-2014 period.

Figure 1-1: ECG Consumption by Customer Class including Load Shedding and Rebound Effect (GWh)

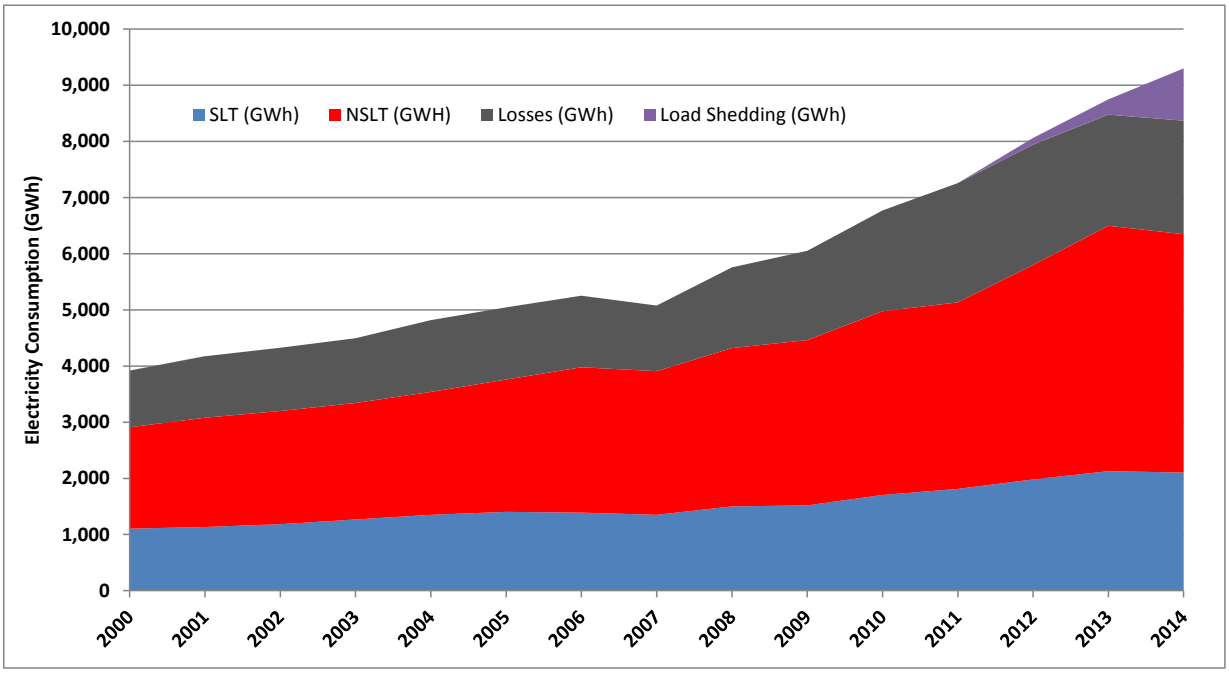
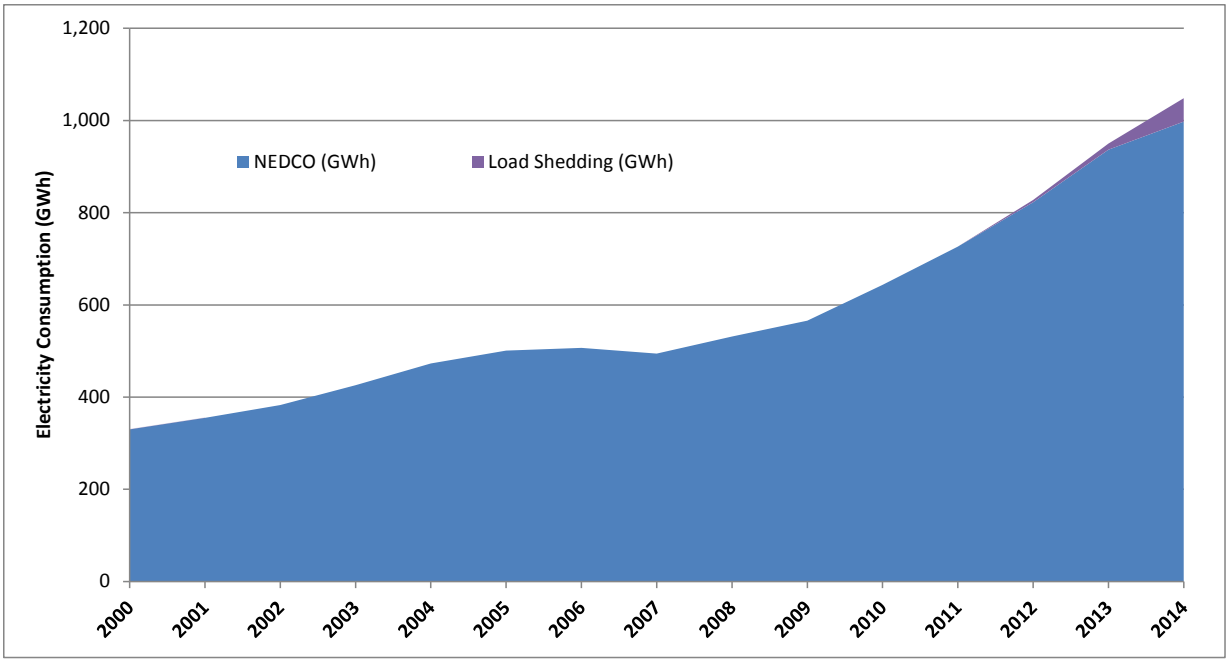



Figure 1-2: NEDCo Consumption including Load Shedding and Rebound Effect (GWh)




To establish an accurate starting point for future demand forecasting, the analysis also had to account for the actual losses in 2014, e.g. for the fact that losses did not improve in 2014 as planned. Since losses in 2014 remained at a similar 24% level of the total demand, we used the

actual loss value and increased the losses that would have been recorded on the unconstrained demand in 2014 by approximately 197 GWh.

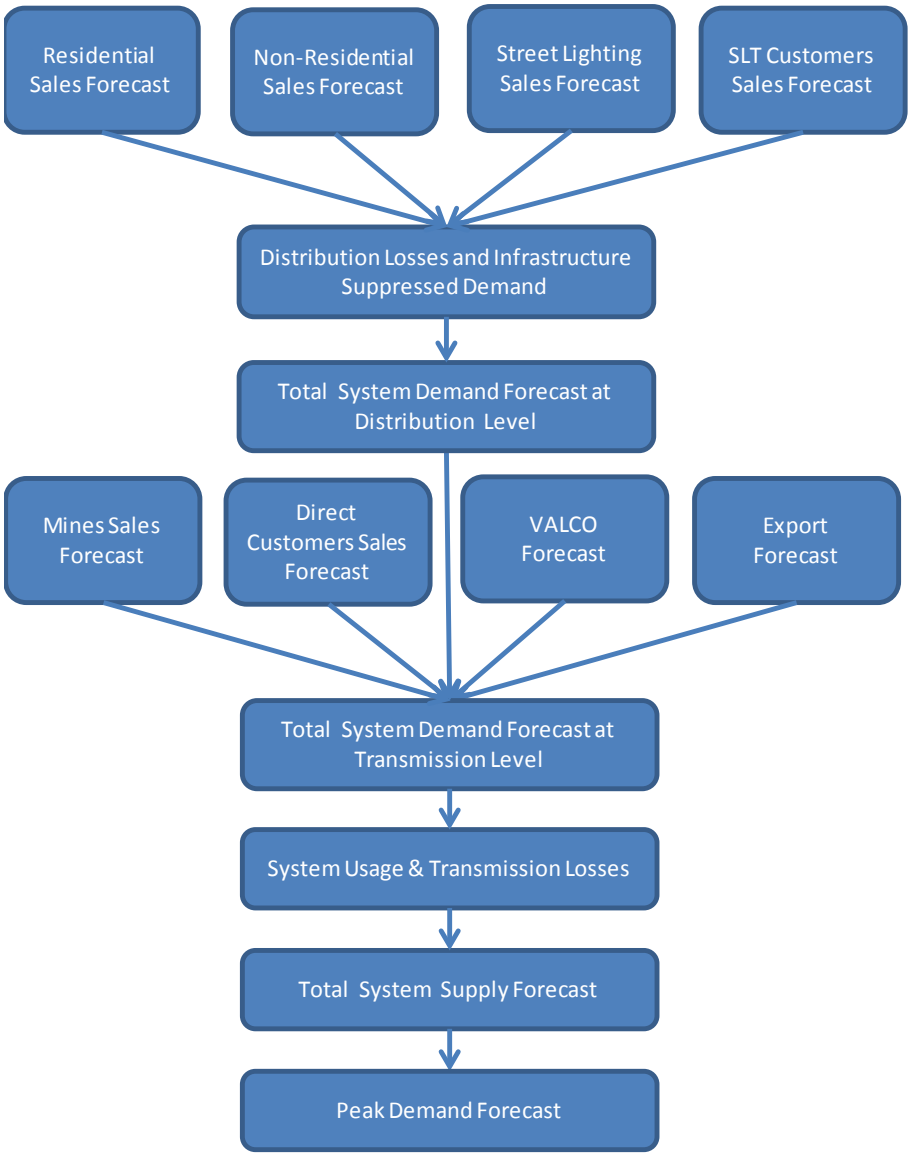
Current losses of around 2,000 GWh (between 23%-24% of total electricity purchases) are planned to be reduced to just over 13% by 2023. Assuming similar loss reduction in the NEDCo system, this goal implies that almost half, or about 1,000 GWh, of existing losses should be added to future sales over the next nine year period.

Based on reliability and outage information, we estimate that the combined Infrastructure Barrier component of the suppressed demand based on GRIDCo and ECG data accumulated over the last three years to be up to 10% or about 780 GWh of the combined demand at the distribution level (e.g. ECG and NEDCo demand). We estimate that by applying all measures specified by GRIDCo and ECG, the Infrastructure Barrier component of the suppressed demand could be eliminated and result in 10% increase in demand over the next five years. Since this estimate includes a high degree of uncertainty, sensitivity analysis has been conducted on this assumption.

## 1.5 FORECASTING COMPONENTS, RESULTS AND KEY FINDINGS

The individual component forecasts are the result of extensive data collection, independent variable identification, and regression modeling. Figure 1-3 presents the forecasting components and how these components are used in developing total system demand.

Figure 1-3: Forecasting Components




Residential, Non-residential, Street Lighting and Industrial customers (Industrial includes ECG & NEDCo SLT customers) are connected to the distribution system. Forecasts are developed for each of those customer categories via the regression modeling. Distribution losses and Infrastructure Suppressed Demand (e.g. estimates related to distribution system constraints) as well as any estimated conversion of commercial losses to actual demand are added to the total distribution system sales forecast to arrive at the total demand forecast at the distribution level.

Street Lighting has been fit to an S-Curve rather than a regression model because of the rapid historical growth observed during the 2000-2014 period. A forecast is also developed for the Direct Customers connected at the transmission system. Demand for Mines, VALCO and Exports is not independently forecasted in the model but is added to the total demand by selecting exogenous Government forecasts, which represent the best available forecasts for these specific categories of demand.

The built-in capabilities of Microsoft Excel were used for regression modeling, in addition to a more advanced statistical commercial package called XLSTAT. Log-Log linear multivariate models are developed and used for the forecasts, using Ordinary Least Squares (OLS) for parameter estimation. This method and models are similar to the methods and models used by ECG, VRA, and GRIDCo for demand forecasting.

Forecasting analysis of the historical 2012-2014 period was conducted to determine if the Supply Constraint component of the suppressed demand could be estimated and verified by forecasting. The historical input data for the forecasts were adjusted to reflect no-supply constraint conditions (e.g. GDP and number of customers were increased to represent estimated levels without constraints). This independent forecasting was conducted for the Residential, Non-Residential, and SLT categories. The regression models for each category used the same set of independent variables as fit for the 2015-2030 period, but were re-fit using only the 2000-2011 historical data, in order to forecast and validate the 2012-2014 period. Results were then compared with the actual historical demand including the Supply Constraint component.

Validation forecasting results for the historical 2012-2014 period compare well with the results of the Supply Component of the suppressed demand. Following the validation process, results from the direct analysis were used in developing the total demand forecasts for the 2015-2030 year period.

Forecasting for the 2015-2030 period was first conducted at the Distribution Level (e.g. forecast for the combined ECG and NEDCo demand), which includes Distribution Sales, Distribution Losses, and Suppressed Demand, and is developed from the independent component demands for Residential, Non-Residential, Street Lighting and SLT customer categories. For validation, comparison forecasts are made with regression models independently developed for two combined categories, providing an internal validation of forecasting results.

Table 1-7 shows the summary Distribution Level forecast developed from the individual component forecasts. The table presents total demand for Residential, Non-Residential, Street Lighting (e.g. Res, Non-Res, SL) categories combined, as well as forecasts for SLT, the adder accounting for Infrastructure Suppressed Demand, distribution losses and the adder accounting for commercial losses assumed to be converted to paying demand.

Table 1-7: Distribution Level Forecast for the Base Case (GWh)

| Year | Total (RES, NON_RES, SL) | SLT | Infrastructure Suppressed Demand Adder | Distribution Losses | Commercial Loss Adder (Per Year) | Total Incl. Losses and Adders |
|---|---|---|---|---|---|---|
| 2015 | 5,721 | 2,644 | 155 | 2,373 | 113 | 11,006 |
| 2016 | 6,184 | 2,854 | 311 | 2,399 | 227 | 11,974 |
| 2017 | 6,699 | 3,080 | 466 | 2,422 | 340 | 13,007 |
| 2018 | 7,261 | 3,323 | 621 | 2,439 | 454 | 14,098 |
| 2019 | 7,833 | 3,556 | 776 | 2,434 | 567 | 15,166 |
| 2020 | 8,438 | 3,791 | 776 | 2,414 | 681 | 16,100 |
| 2021 | 9,076 | 4,036 | 776 | 2,380 | 794 | 17,063 |

| | | | | | | |
|---|---|---|---|---|---|---|
| 2022 | 9,748 | 4,293 | 776 | 2,332 | 908 | 18,057 |
| 2023 | 10,453 | 4,566 | 776 | 2,268 | 1,021 | 19,083 |
| 2024 | 11,190 | 4,855 | 776 | 2,423 | 1,021 | 20,266 |
| 2025 | 11,921 | 5,141 | 776 | 2,577 | 1,021 | 21,435 |
| 2026 | 12,675 | 5,433 | 776 | 2,735 | 1,021 | 22,640 |
| 2027 | 13,461 | 5,737 | 776 | 2,899 | 1,021 | 23,895 |
| 2028 | 14,284 | 6,057 | 776 | 3,072 | 1,021 | 25,210 |
| 2029 | 15,151 | 6,393 | 776 | 3,253 | 1,021 | 26,594 |
| 2030 | 16,068 | 6,747 | 776 | 3,445 | 1,021 | 28,058 |

Table 1-8 shows the Distribution Level 2015-2030 period forecast for the Base Case, Low, and High Growth scenarios. Scenario results are derived from the High and Low Growth scenario forecasts developed independently for all customer categories.

Table 1-8: Distribution Level Forecast, Base, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 10,111 | 10,111 | 10,111 |
| 2015 | 10,953 | 11,006 | 11,085 |
| 2016 | 11,843 | 11,974 | 12,161 |
| 2017 | 12,782 | 13,007 | 13,327 |
| 2018 | 13,766 | 14,098 | 14,575 |
| 2019 | 14,725 | 15,166 | 15,837 |
| 2020 | 15,545 | 16,100 | 16,994 |
| 2021 | 16,385 | 17,063 | 18,207 |
| 2022 | 17,245 | 18,057 | 19,482 |
| 2023 | 18,124 | 19,083 | 20,823 |
| 2024 | 19,130 | 20,266 | 22,383 |
| 2025 | 20,108 | 21,435 | 24,025 |
| 2026 | 21,105 | 22,640 | 25,778 |
| 2027 | 22,131 | 23,895 | 27,660 |
| 2028 | 23,194 | 25,210 | 29,689 |
| 2029 | 24,302 | 26,594 | 31,883 |
| 2030 | 25,461 | 28,058 | 34,264 |
| Annual Average Growth Rate (2014-2030) | 5.9% | 6.6% | 7.9% |

Table 1-9 presents comparison with the VRA and GRIDCo forecasts. All three forecasts have similar results, with the Nexant forecast being slightly lower that the other two forecasts.

Table 1-9: Distribution Level Forecast Comparison (GWh)

| Year | Nexant (ECG and NEDCo) | VRA (ECG & NEDCo) | Difference from Nexant | GRIDCo (ECG & NEDCo) | Difference |
|---|---|---|---|---|---|
| 2014 | 10,111 | 10,111 | 0 | 10,360 | -249 |
| 2015 | 11,006 | 11,846 | -840 | 11,326 | -319 |
| 2016 | 11,974 | 12,533 | -559 | 12,187 | -213 |
| 2017 | 13,007 | 13,301 | -294 | 13,091 | -84 |
| 2018 | 14,098 | 14,455 | -357 | 14,118 | -20 |
| 2019 | 15,166 | 15,589 | -423 | 15,227 | -61 |
| 2020 | 16,100 | 16,727 | -627 | 16,427 | -327 |
| 2021 | 17,063 | 17,429 | -366 | 17,724 | -661 |
| 2022 | 18,057 | 18,541 | -484 | 19,126 | -1,069 |
| 2023 | 19,083 | 19,735 | -652 | | |
| 2024 | 20,266 | 21,031 | -765 | | |
| 2025 | 21,435 | 22,427 | -992 | | |
| 2026 | 22,640 | 23,882 | -1,242 | | |
| 2027 | 23,895 | 25,359 | -1,464 | | |
| 2028 | 25,210 | 26,893 | -1,683 | | |
| 2029 | 26,594 | 28,586 | -1,992 | | |
| 2030 | 28,058 | 30,384 | -2,326 | | |

The Base Case Total Demand Forecast for 2015-2030 is developed by starting with the forecast at the Distribution Level and adding forecasts for all customer categories connected at the transmission level - Mines, Direct Customer Sales, VALCO, and Exports. As stated earlier, the forecast for Direct Customers was developed independently, while forecasts for Mines, VALCO and Exports were based on the latest consensus forecasts performed by VRA, GRIDCo and the Energy Commission.

System usage and transmission losses are also calculated based on the total consumption to derive the Total Demand Forecast, e.g. required net generation supply. The assumed transmission losses are consistent with the assumptions included in the GRIDCo forecast and take into account all system expansion and improvements needed over the next 16 year period.

Table 1-10 shows the total Base Case demand for the 2015-2030 period. The Base Case total demand forecast for 2030 is close to 40,000 GWh and represents a 7.0% yearly growth rate over the 2014-2030 period. The table also presents growth rates for each demand component.

Table 1-10: Base Case Total Demand Forecast (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,006 | 1,618 | 359 | 12,983 | 625 | 1,088 | 589 | **15,285** |
| **2016** | 11,974 | 2,137 | 383 | 14,494 | 1,250 | 1,088 | 644 | **17,477** |
| **2017** | 13,007 | 2,179 | 412 | 15,598 | 1,250 | 1,482 | 692 | **19,022** |
| **2018** | 14,098 | 2,179 | 445 | 16,722 | 1,875 | 2,322 | 834 | **21,753** |
| **2019** | 15,166 | 2,241 | 481 | 17,888 | 3,125 | 3,007 | 944 | **24,964** |
| **2020** | 16,100 | 2,262 | 519 | 18,881 | 3,125 | 3,007 | 985 | **25,998** |
| **2021** | 17,063 | 2,404 | 561 | 20,028 | 3,125 | 3,304 | 1,031 | **27,487** |
| **2022** | 18,057 | 2,424 | 606 | 21,087 | 3,125 | 3,304 | 1,074 | **28,590** |
| **2023** | 19,083 | 2,565 | 654 | 22,303 | 3,125 | 3,304 | 1,123 | **29,855** |
| **2024** | 20,266 | 2,664 | 707 | 23,637 | 3,125 | 3,304 | 1,177 | **31,243** |
| **2025** | 21,435 | 2,826 | 762 | 25,023 | 3,125 | 3,304 | 1,207 | **32,660** |
| **2026** | 22,640 | 2,887 | 819 | 26,347 | 3,125 | 3,304 | 1,255 | **34,031** |
| **2027** | 23,895 | 2,948 | 880 | 27,723 | 3,125 | 3,304 | 1,302 | **35,454** |
| **2028** | 25,210 | 3,071 | 945 | 29,225 | 3,125 | 3,304 | 1,346 | **37,001** |
| **2029** | 26,594 | 3,101 | 1,013 | 30,709 | 3,125 | 3,304 | 1,388 | **38,526** |
| **2030** | 28,058 | 3,101 | 1,087 | 32,246 | 3,125 | 3,304 | 1,426 | **40,100** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 6.6% | 4.4% | 7.6% | 6.4% | 10.7% | 12.2% | 6.6% | 7.0% |

The corresponding Base Case peak load forecast was developed using the Base Case demand forecast and coincident factors consistent with the historical data. The resulting total peak load forecast, presented in Table 1-11, for year 2030 is 6,183 MW representing a 7% yearly growth rate over the 2014-2030 period.

Table 1-11: Base Case Peak Load Forecast (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,150 | 75 | 166 | 2,391 |
| 2016 | 2,398 | 150 | 159 | 2,707 |
| 2017 | 2,581 | 150 | 216 | 2,947 |
| 2018 | 2,781 | 225 | 338 | 3,345 |
| 2019 | 2,983 | 375 | 437 | 3,796 |
| 2020 | 3,147 | 375 | 437 | 3,959 |
| 2021 | 3,336 | 375 | 479 | 4,191 |
| 2022 | 3,511 | 375 | 479 | 4,365 |
| 2023 | 3,711 | 375 | 478 | 4,564 |
| 2024 | 3,931 | 375 | 477 | 4,784 |
| 2025 | 4,156 | 375 | 477 | 5,007 |

| | | | | |
|---|---|---|---|---|
| 2026 | 4,373 | 375 | 476 | 5,224 |
| 2027 | 4,598 | 375 | 476 | 5,449 |
| 2028 | 4,843 | 375 | 475 | 5,693 |
| 2029 | 5,085 | 375 | 474 | 5,934 |
| 2030 | 5,334 | 375 | 474 | 6,183 |
| Growth Rates | | | | |
| Average Annual 2014-2030 | 6.4% | 11.4% | 15.5% | 7.0% |

Table 1-12 shows the total Base Case demand forecast, at the net generation supply level, for the 2015-2030 period compared with the Base Case forecasts done by the EC (Business as Usual), VRA and GridCo. The Base Case total system forecasts for VRA, GRIDCo and Nexant are similar. The EC BaU forecast is higher in all years, primarily as the result of higher forecast for the household sector representing residential customers demand.

Table 1-12: Base Case Total Demand Forecast Comparison (GWh)

| Year | EC BaU | VRA | GRIDCo | Nexant |
|---|---|---|---|---|
| 2015 | 16,956 | 15,743 | 16,038 | 15,285 |
| 2016 | 18,737 | 17,688 | 17,901 | 17,477 |
| 2017 | 21,443 | 20,198 | 19,371 | 19,022 |
| 2018 | 22,976 | 21,756 | 21,829 | 21,753 |
| 2019 | 24,942 | 23,788 | 24,851 | 24,964 |
| 2020 | 28,284 | 27,007 | 25,955 | 25,998 |
| 2021 | 29,711 | 27,935 | 27,417 | 27,487 |
| 2022 | 31,209 | 29,130 | 28,543 | 28,590 |
| 2023 | 32,785 | 30,565 | 29,751 | 29,855 |
| 2024 | 34,441 | 32,030 | 31,030 | 31,243 |
| 2025 | 36,183 | 33,649 | 32,398 | 32,660 |
| 2026 | 38,030 | 35,217 | | 34,031 |
| 2027 | 39,971 | 36,808 | | 35,454 |
| 2028 | 42,009 | 38,523 | | 37,001 |
| 2029 | 44,153 | 40,305 | | 38,526 |
| 2030 | 46,407 | 42,164 | | 40,100 |

The Base Case peak load forecast comparison is presented in Table 1-13. Similar to the energy forecast comparison, the Base Case total peak load demand forecasts for VRA, GRIDCo and Nexant are close, while the EC BaU forecast is higher in all years.

Table 1-13: Base Case Peak Load Forecast Comparison (MW)

| Year | EC BaU | VRA | GRIDCo | Nexant |
|---|---|---|---|---|
| 2015 | 2,479 | 2,379 | 2,342 | 2,391 |
| 2016 | 2,736 | 2,624 | 2,626 | 2,707 |
| 2017 | 3,127 | 2,816 | 2,931 | 2,947 |
| 2018 | 3,346 | 3,205 | 3,194 | 3,345 |

| | | | | |
|---|---|---|---|---|
| 2019 | 3,628 | 3,648 | 3,613 | 3,796 |
| 2020 | 4,109 | 3,848 | 3,778 | 3,959 |
| 2021 | 4,310 | 4,027 | 3,997 | 4,191 |
| 2022 | 4,521 | 4,215 | 4,167 | 4,365 |
| 2023 | 4,743 | 4,428 | 4,350 | 4,564 |
| 2024 | 4,976 | 4,654 | 4,542 | 4,784 |
| 2025 | 5,221 | 4,895 | 4,748 | 5,007 |
| 2026 | 5,481 | 5,132 | | 5,224 |
| 2027 | 5,753 | 5,377 | | 5,449 |
| 2028 | 6,038 | 5,636 | | 5,693 |
| 2029 | 6,338 | 5,909 | | 5,934 |
| 2030 | 6,653 | 6,194 | | 6,183 |

Table 1-14 summarizes the total Low Growth Scenario demand for the 2014-2030 period. The Low Growth total demand forecast at the generation supply level for 2030 is almost 37,500 GWh. This represents a 6.5% yearly growth rate over this period, and is about 2,600 GWh, or 6.4%, below the Base Case 2030 forecast.

Table 1-14: Total Low Growth Scenario Demand Forecast (GWh)

| | Domestic Consumption | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 10,953 | 1,618 | 358 | 12,929 | 625 | 1,088 | 587 | **15,229** |
| **2016** | 11,843 | 2,137 | 382 | 14,363 | 1,250 | 1,088 | 639 | **17,340** |
| **2017** | 12,782 | 2,179 | 410 | 15,371 | 1,250 | 1,482 | 684 | **18,787** |
| **2018** | 13,766 | 2,179 | 442 | 16,387 | 1,875 | 2,322 | 821 | **21,404** |
| **2019** | 14,725 | 2,241 | 476 | 17,442 | 3,125 | 3,007 | 927 | **24,500** |
| **2020** | 15,545 | 2,262 | 512 | 18,319 | 3,125 | 3,007 | 962 | **25,413** |
| **2021** | 16,385 | 2,404 | 550 | 19,339 | 3,125 | 3,304 | 1,004 | **26,772** |
| **2022** | 17,245 | 2,424 | 592 | 20,261 | 3,125 | 3,304 | 1,042 | **27,731** |
| **2023** | 18,124 | 2,565 | 636 | 21,325 | 3,125 | 3,304 | 1,085 | **28,839** |
| **2024** | 19,130 | 2,664 | 684 | 22,478 | 3,125 | 3,304 | 1,132 | **30,038** |
| **2025** | 20,108 | 2,826 | 733 | 23,668 | 3,125 | 3,304 | 1,207 | **31,304** |
| **2026** | 21,105 | 2,887 | 785 | 24,777 | 3,125 | 3,304 | 1,255 | **32,461** |
| **2027** | 22,131 | 2,948 | 839 | 25,918 | 3,125 | 3,304 | 1,302 | **33,649** |
| **2028** | 23,194 | 3,071 | 897 | 27,162 | 3,125 | 3,304 | 1,346 | **34,937** |
| **2029** | 24,302 | 3,101 | 958 | 28,361 | 3,125 | 3,304 | 1,388 | **36,178** |
| **2030** | 25,461 | 3,101 | 1,022 | 29,584 | 3,125 | 3,304 | 1,426 | **37,439** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 5.9% | 4.4% | 7.2% | 5.8% | 10.7% | 12.2% | 6.6% | 6.5% |

Table 1-15 summarizes the High Growth scenario forecast. The High Growth scenario forecast, at the generation supply level, for year 2030 is estimated to increase to around 46,500 GWh and represents a higher 8.0% yearly growth rate over the 2014-2030 period (vs 7.0% for the Base Case).

Table 1-15: High Growth Scenario Total Demand Forecast (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,085 | 1,618 | 360 | 13,062 | 625 | 1,088 | 592 | **15,368** |
| **2016** | 12,161 | 2,137 | 386 | 14,684 | 1,250 | 1,088 | 652 | **17,674** |
| **2017** | 13,327 | 2,179 | 417 | 15,923 | 1,250 | 1,482 | 705 | **19,360** |
| **2018** | 14,575 | 2,179 | 453 | 17,206 | 1,875 | 2,322 | 853 | **22,257** |
| **2019** | 15,837 | 2,241 | 492 | 18,571 | 3,125 | 3,007 | 971 | **25,674** |
| **2020** | 16,994 | 2,262 | 536 | 19,792 | 3,125 | 3,007 | 1,020 | **26,944** |
| **2021** | 18,207 | 2,404 | 584 | 21,196 | 3,125 | 3,304 | 1,076 | **28,701** |
| **2022** | 19,482 | 2,424 | 637 | 22,544 | 3,125 | 3,304 | 1,131 | **30,103** |
| **2023** | 20,823 | 2,565 | 695 | 24,083 | 3,125 | 3,304 | 1,192 | **31,705** |
| **2024** | 22,383 | 2,664 | 759 | 25,806 | 3,125 | 3,304 | 1,262 | **33,497** |
| **2025** | 24,025 | 2,826 | 827 | 27,678 | 3,125 | 3,304 | 1,207 | **35,314** |
| **2026** | 25,778 | 2,887 | 900 | 29,566 | 3,125 | 3,304 | 1,255 | **37,250** |
| **2027** | 27,660 | 2,948 | 980 | 31,588 | 3,125 | 3,304 | 1,302 | **39,318** |
| **2028** | 29,689 | 3,071 | 1,065 | 33,825 | 3,125 | 3,304 | 1,346 | **41,600** |
| **2029** | 31,883 | 3,101 | 1,158 | 36,142 | 3,125 | 3,304 | 1,388 | **43,959** |
| **2030** | 34,264 | 3,101 | 1,258 | 38,623 | 3,125 | 3,304 | 1,426 | **46,478** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 7.9% | 4.4% | 8.6% | 7.6% | 10.7% | 12.2% | 6.6% | 8.0% |

## 1.6 KEY FINDINGS AND IMPLICATIONS FOR THE DEVELOPMENT OF THE POWER SYSTEM

Key findings from the Suppressed Demand analysis are:

- The most recent load shedding (started in 2012) is so severe as to significantly impact the country's overall economic development and growth. VALCO was the single customer most severely affected during the generation constrained years and consumption significantly reduced in each of the shortage years
- The Supply Constraint component of the suppressed demand (e.g. load shedding for ECG and NEDCo customers) was estimated to be 940 GWh. The Infrastructure Barrier component was estimated to be 776 GWh. With the additional impact on mining and direct customers, Suppressed Demand in 2014 was estimated to be 16% of the total domestic consumption
- The impact on VALCO consumption is about 2,500 GWh (4 additional pot-lines) and the potential increase in exports is about 1,800 GWh. With those two demand categories included, total Suppressed Demand is estimated to be 6,000 GWh or close to 50% of the 2014 supply

Key findings from the Demand Forecasting analysis are:

- The 2030 Base Case total system demand forecast is just over 40,000 GWh and is comparable with VRA and GRIDCo forecasts, representing a 7.0% yearly growth rate over the 2014-2030 period. The EC Business as Usual forecast is higher in all years,

primarily due to the higher forecast for the household sector. The household category consumption in the EC forecast increases by more than 100% from 2014 to 2015, and thus the forecast begins from a much higher demand level.

- The total 2030 Base Case peak demand forecast is 6,183 MW representing a 7% yearly growth rate over the 2014-2030 period
- Forecasting analysis showed the limited impacts of the Infrastructure Component of the suppressed demand. Sensitivity analysis showed that as demand increases, this component represents a relativity small percentage of the total demand
- Forecasting analysis showed significant impacts of the loss reduction program. Sensitivity analysis showed that as demand increases, distribution system loss reduction efforts are the critical component in reducing overall demand. Without the reduction in distribution losses, the system will need to supply significant additional energy to cover both technical and commercial losses
- The total demand forecast under the Low Growth Scenario is estimated to be just under 37,500 GWh by year 2030, and represents only a 6.5% yearly growth rate over the 2014-2030 period
- The total demand forecast under the High Growth Scenario demand forecast is estimated to be about 46,500 GWh and represents a 8.0% yearly growth rate over the 2014-2030 period

Key implications for the power system development are:

- Under the Base Case conditions, Ghana's electricity demand is forecasted to reach over 40,000 GWh by 2030. This represents a significant increase in demand that will need to be accompanied by an adequate increase in natural gas supply available for generation resources (since a large portion of new generation will use natural gas as a fuel)
- System peak load is forecasted to increase to 6,183 MW representing a 7% yearly growth rate over the 2014-2030 period. A corresponding increase in new generation additions and related fuel supply system improvements will need to be planned, financed and built. They will need to be capable of providing robust and reliable electricity supply to all Ghana customers
- Forecasting should be conducted or updated on a yearly basis to keep pace with the rapid development of the power sector

# Section 2 Overview

## 2.1 Background

Nexant has delivered a Market Review of the demand for natural gas for Ghana. The Review drew on a number of previous studies of the demand for electricity.

- A key assumption of the gas demand studies is that the main use for domestic gas is as fuel for the power sector. As a consequence, the long-term demand forecast for power is a critical input when estimating the demand for natural gas.
- Many of the gas demand studies have included an estimate of the "suppressed demand" for power (demand for power which is not satisfied) based on an ECG analysis prepared in the mid-1990s.
- Given Ghana's rapid economic growth and development since 1995, many parties in the power sector believe the level of suppressed demand is significant, potentially impacting the accuracy of power demand forecasts used as an input to estimate the demand for natural gas.
- As part of its follow on work to the Gas Action Plan, Nexant was asked to update its Market Review of the demand for natural gas for Ghana.

## 2.2 Study Purpose

The Suppressed Demand and Forecasting Study is a key input to the Market Review update under the current Gas Action Plan. The purpose of the Study is to estimate the power demand in Ghana over the next 16 year period, matching the Market Review planning horizon, by:

- Providing assessment of the suppressed demand by analyzing suppressed demand components
- Analyzing historical electricity consumption and country economic indicators and develop projections of the total energy and peak demand assessment for Ghana including suppressed demand
- Assessing total demand, that includes the suppressed demand component, including assessment of GRIDCo and ECG loss reduction programs, to help validate planned VRA, and IPPs generation projects, and any potential supply deficits
- Providing input for analyzing the development and improvements in power generation, transmission and distribution infrastructure in the next 16 years to supply total demand

## 2.3 Suppressed Demand Components

Suppressed demand is defined as a desire and willingness to consume electricity, but due to various barriers, this desire is not met. Barriers are usually described and evaluated using the following distinct categories:

- *Supply Constraint:* Exists because electricity supplied in a power grid is inadequate to meet the demand.
- *Infrastructure Barrier:* Exists because of an inadequate delivery infrastructure. Examples include inadequate transmission and distribution networks.

- *Income Barrier:* In low income countries resources are allocated according to the priority allotted to basic human needs.
- *Technology Barrier:* Due to high initial cost or lack of capacity to absorb the technology.

## 2.4 APPROACH

Our approach to estimate Suppressed Demand and develop the demand forecast for the entire country included the following steps:

- *Conducted data Collection, Review, and Analysis:* Nexant staff meet with all stakeholders and visited all major Government agencies and utilities involved in load forecasting including: ECG, EC, GRIDCo, and VRA. We collected and reviewed available utility operational and planning data and studies.
- *Estimated Suppressed and Total Demand:* Used engineering and technical data to calculate the amount of suppressed demand from existing customers facing load shedding using duration and frequency of scheduled outages as well as unmet demand from unscheduled outages. Calculated total demand including demand recorded by utilities plus suppressed demand.
- *Estimated Electricity Demand for the Historical Constrained Period:* Used regression analysis for historical years that represent normal (e.g. unconstrained) supply/demand conditions. Conducted the demand analysis of the most recent 2012-2014 period using the 2000-2011 historical data and forecasting inputs adjusted to account for 2012-2014 supply constraints.
- *Developed Unconstrained Demand:* Compared results from the historical period with the results from direct estimation of suppressed and total demand to arrive at the best estimate of the unconstrained year 2014 demand. This demand was used as a starting point for demand forecasting for the next 16 year period.
- *Estimated Future Electricity Demand on the National Level Using Sectoral Approach:* Used regression analysis for future years starting from the demand that represent normal (e.g. unconstrained) supply/demand conditions. Forecast was developed for the 2015-2030 period with the regression analysis and parameters developed starting from the unconstrained historical and applying future demand and input data forecasts.
- *Develop Scenarios and Analyze Demand for the 2015-2030 Period:* Developed three scenarios—medium (Base Case), high and low—that include different Gross Domestic Product (GDP) growth rates, population/utility customer development, and electricity price levels. Forecasts were compared with the forecasts developed by Ghana entities.

## 2.5 REPORT STRUCTURE

The reminder of the report covers all key study steps and results:

Section 3 Provides overview of demand forecasting studies, input data, and assumptions

Section 4 Describes suppressed demand analysis and results

Section 5 Describes the methodology used for demand forecasting, the benchmarking results for the historical 2012–2014 period and the demand forecast for the 2015-2030 period that includes the Suppressed Demand components.

Section 6 Presents key study observations, conclusions and recommendations

Section 7 Includes key references

Section 8 Provides details on the selection and specification of the regression models

Section 9 Provides details and presents examples on the rebound effect analysis and estimation

# Section 3 Power Sector Historical Demand, Studies, and Input Data

## 3.1 Input Data

### 3.1.1 Input Data Sources

The accuracy of the analysis and results of any forecasting study is highly dependent on the quality of input data. Consequently, to assure the best starting point for our analysis, we collected and reconciled several existing databases and studies. We also prepared a Study Data Questionnaire specifically tailored for this study. The document identified a detailed list of system information and data required for study execution. In response to the data request, ECG, GRIDCo, VRA, and the Energy Commission provided the most recent load forecasts and additional details and clarifications about the inputs and results. The Nexant study team also worked closely with Ghana counterparts in verifying and clarifying data inconsistencies and filling in data gaps. Section 7 lists all key documents received during the course of the study.

Electricity demand forecasting in Ghana is conducted by utility companies and government agencies including the Energy Commission, ECG, GRIDCo, and VRA. The scope of each forecast and the forecasting time horizon is driven by individual company needs and goals. The Energy Commission, GRIDCo, and VRA develop demand forecasts that cover the entire country demand including VALCO, mines, other direct customers and exports, while the ECG demand forecast is done for its service territory and customers.

This section presents a review of the input data used for analysis followed by an overview of the key demand forecasts done in Ghana. Input data and assumptions are updated to reflect year 2014 actual demand and GDP values. Section 5 presents Nexant's demand forecasting results and a comparison with the demand forecasting results from the studies presented in this section.

### 3.1.2 Historical Electricity Demand and Components

Historical consumption data by customer category is presented in Table 3-1. Residential and Non-Residential sales include sales to ECG, NEDCo and VRA customers. Street lighting sales includes sales to ECG and NEDCo. Customer classifications by category and historical inputs are based on the information obtained from the Energy Commission. Inputs also reflect the most recent demand forecasts received from VRA and GRIDCo.

Table 3-1: Historical Sales Data by Customer Category (GWh)

| Year | Residential | Non-Residential | Industrial | Street Lighting | Total Sales |
|---|---|---|---|---|---|
| 2000 | 1,464.0 | 551.2 | 4,305.1 | 15.2 | 6,336 |
| 2001 | 1,593.5 | 579.7 | 4,336.8 | 18.1 | 6,528 |
| 2002 | 1,648.2 | 602.0 | 3,903.4 | 23.2 | 6,177 |
| 2003 | 1,696.0 | 620.0 | 2,205.8 | 30.6 | 4,552 |

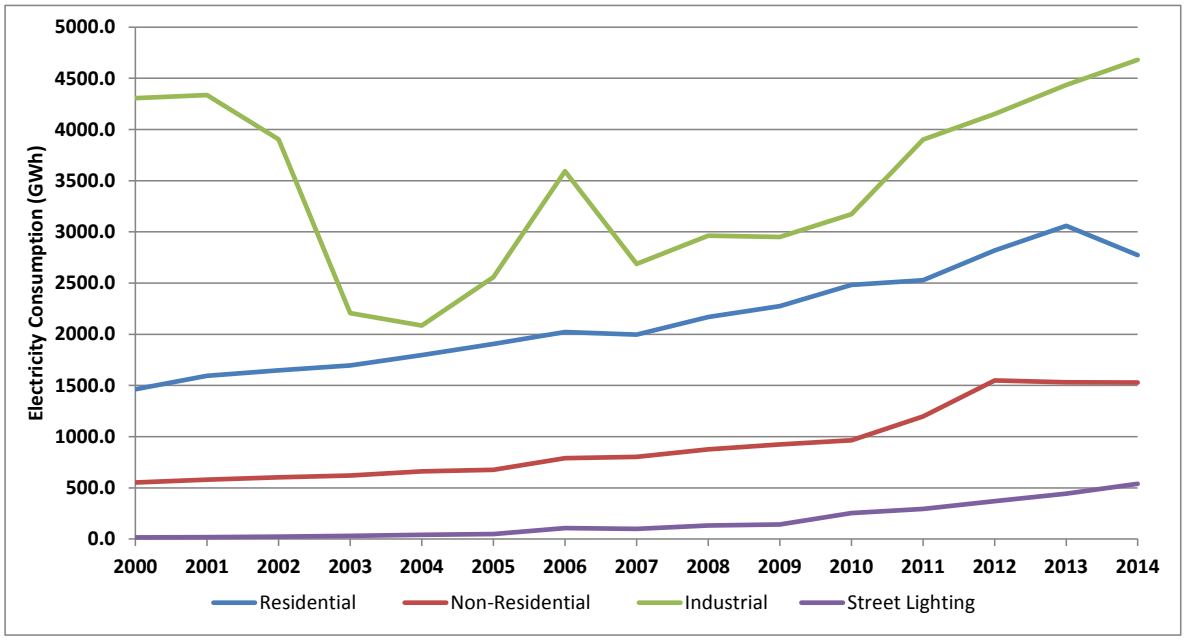
| | | | | | |
|---|---|---|---|---|---|
| 2004 | 1,797.9 | 660.3 | 2,085.5 | 40.8 | 4,584 |
| 2005 | 1,905.4 | 676.0 | 2,559.1 | 50.2 | 5,191 |
| 2006 | 2,022.0 | 789.9 | 3,592.4 | 108.0 | 6,512 |
| 2007 | 1,996.6 | 802.2 | 2,687.4 | 100.8 | 5,587 |
| 2008 | 2,168.4 | 876.1 | 2,963.0 | 131.7 | 6,139 |
| 2009 | 2,275.1 | 924.4 | 2,951.0 | 143.5 | 6,294 |
| 2010 | 2,483.2 | 965.8 | 3,174.1 | 254.3 | 6,877 |
| 2011 | 2,527.0 | 1,198.5 | 3,901.1 | 295.5 | 7,922 |
| 2012 | 2,819.0 | 1,548.8 | 4,153.2 | 369.5 | 8,890 |
| 2013 | 3,060.1 | 1,532.0 | 4,435.0 | 444.7 | 9,472 |
| 2014 | 2,772.3 | 1,529.1 | 4,681.0 | 539.7 | 9,522 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015

Historical information is presented for the 2000-2014 period, consistent with the historical period used to develop future forecast. Data is also used to highlight the impact that supply constraints during this period had on various demand components.

The most recent load shedding in Ghana started in 2012 and is still ongoing in 2015. During the earlier 2000-2011 period, load shedding occurred in years 2002, 2003, 2004 and 2007. Before 2000, load shedding also impacted year 1998 demand. Pre 2000 data is not used for forecasting and is not presented in the report. Table 3-1 sales data clearly show the impact that the years with supply constraints had on demand for residential sales (e.g. decrease in year 2014) and non-Residential sales (constant over the last 3 years). Despite the supply constraints, Industrial and Street Lighting consumption substantially increased. Figure 3-1 shows the relative size for each sales component and prominently displays the supply constraints impacts

Figure 3-1: Historical Sales Chart by Customer Category




Source: Reconciled data received from the Energy Commission of Ghana, December 2015

A more detailed breakdown for Residential sales into ECG, NEDCo and VRA components is presented in Table 3-2. The breakdown shows that supply constraints for the most part impacted ECG customers, as seen in years 2007 and 2014 sales. VRA residential sales are small and include several townships.

Table 3-2: Historical Sales for Residential Customers (GWh)

| Year | ECG | NEDCo | VRA |
|---|---|---|---|
| 2000 | 1,288.8 | 150.3 | 24.9 |
| 2001 | 1,402.9 | 165.5 | 25.1 |
| 2002 | 1,448.8 | 172.0 | 27.4 |
| 2003 | 1,483.4 | 181.1 | 31.6 |
| 2004 | 1,557.2 | 200.1 | 40.6 |
| 2005 | 1,664.3 | 211.7 | 29.4 |
| 2006 | 1,781.2 | 215.4 | 25.4 |
| 2007 | 1,756.3 | 214.7 | 25.7 |
| 2008 | 1,923.0 | 218.1 | 27.4 |
| 2009 | 2,026.5 | 222.0 | 26.7 |
| 2010 | 2,217.4 | 235.0 | 30.8 |
| 2011 | 2,203.9 | 292.2 | 30.8 |
| 2012 | 2,472.3 | 310.7 | 36.0 |
| 2013 | 2,621.3 | 391.0 | 47.8 |
| 2014 | 2,332.3 | 398.0 | 42.0 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015

A similar breakdown for Non-Residential sales is presented in Table 3-3. The supply constraint is visible (e.g. small increases) in ECG year 2007 sales and also in sales to both ECG and NEDCo customers during the last two years.

Table 3-3: Historical Sales for Non-Residential Customers (GWh)

| Year | ECG | NEDCo | VRA |
|---|---|---|---|
| 2000 | 503.0 | 48.2 | 0.0 |
| 2001 | 525.0 | 54.7 | 0.0 |
| 2002 | 544.0 | 58.0 | 0.0 |
| 2003 | 561.0 | 59.0 | 0.0 |
| 2004 | 590.0 | 70.3 | 0.0 |
| 2005 | 625.0 | 50.4 | 0.6 |
| 2006 | 699.0 | 90.0 | 0.9 |
| 2007 | 700.3 | 101.0 | 0.8 |
| 2008 | 760.0 | 115.3 | 0.8 |
| 2009 | 786.7 | 136.9 | 0.8 |
| 2010 | 819.9 | 145.0 | 0.9 |
| 2011 | 1,032.6 | 165.2 | 0.8 |
| 2012 | 1,347.3 | 200.4 | 1.0 |
| 2013 | 1,338.0 | 193.0 | 1.0 |
| 2014 | 1,331.0 | 198.0 | 0.1 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015.

The breakdown of sales to Industrial customers is presented in Table 3-4. Industrial Sales include sales to Special Load Tariff (SLT) customers of ECG and NEDCo as well as bulk customers of VRA including VALCO.

Table 3-4: Historical Sales for Industrial Customers (GWh)

| Year | ECG | NEDCo | VRA |
|---|---|---|---|
| 2000 | 1,103.0 | 33.5 | 3,168.6 |
| 2001 | 1,134.0 | 30.4 | 3,172.4 |
| 2002 | 1,184.0 | 35.4 | 2,684.0 |
| 2003 | 1,268.0 | 42.5 | 895.3 |
| 2004 | 1,351.0 | 52.5 | 682.0 |
| 2005 | 1,421.0 | 50.0 | 1,088.1 |
| 2006 | 1,390.0 | 51.0 | 2,151.4 |
| 2007 | 1,352.0 | 50.0 | 1,285.4 |
| 2008 | 1,501.0 | 58.2 | 1,403.8 |

| | | | |
|---|---|---|---|
| 2009 | 1,525.0 | 53.9 | 1,372.1 |
| 2010 | 1,718.0 | 92.7 | 1,363.4 |
| 2011 | 1,814.0 | 62.2 | 2,024.9 |
| 2012 | 1,979.8 | 56.4 | 2,117.0 |
| 2013 | 2,171.0 | 74.0 | 2,190.0 |
| 2014 | 2,125.0 | 96.0 | 2,460.0 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015

The breakdown for Street Lighting is presented in Table 3-5. Historical sales values show a rapid increase in street lighting demand, mostly expanded to cover the ECG service area.

Table 3-5: Historical Street Lighting Sales (GWh)

| Year | ECG | NEDCo |
|---|---|---|
| 2000 | 15.2 | |
| 2001 | 18.1 | |
| 2002 | 23.2 | |
| 2003 | 30.6 | |
| 2004 | 40.8 | |
| 2005 | 50.2 | |
| 2006 | 108.0 | |
| 2007 | 100.8 | |
| 2008 | 131.7 | |
| 2009 | 143.5 | |
| 2010 | 216.3 | 38 |
| 2011 | 234.5 | 61 |
| 2012 | 279.5 | 90 |
| 2013 | 365.7 | 79 |
| 2014 | 473.7 | 66 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015

When comparing total demand at the utility level, ECG demand is by far the largest component in Ghana. Table 3-6 and Figure 3-2 present ECG historical demand summarized into the two tariff categories and components ECG uses for forecasting future demand: SLT customers and NSLT customers. SLT customers include industrial customers with the peak demand of 100kVA and above while the NSLT customers include residential and non-residential customers with a peak demand off less than 100kVA, as well as street lighting consumption. The values clearly indicate negative impacts on ECG sales in years 2007 and 2014. NEDCo total sales combine residential, non-residential, industrial customers and street lighting consumption.

The table also shows distribution losses for both ECG and NEDCo service areas. Distribution losses include both technical and commercial loss components. Loss percentages are calculated based on the total purchases (e.g. purchases include distribution losses). Losses in both systems continue to be at a high level and represent a significant part of the overall demand.

Table 3-6: Historical ECG and NEDCo Sales and Losses (GWh)

| Year | ECG - SLT | ECG - NSLT | ECG - Losses | NEDCo Sales | NEDCo - Losses | Total Losses (%) |
|---|---|---|---|---|---|---|
| 2000 | 1,103 | 1,807 | 1,079 | 232 | 98 | 27.2% |
| 2001 | 1,134 | 1,946 | 1,095 | 251 | 104 | 26.5% |
| 2002 | 1,184 | 2,016 | 1,126 | 265 | 118 | 26.4% |
| 2003 | 1,268 | 2,075 | 1,153 | 283 | 143 | 26.3% |
| 2004 | 1,351 | 2,188 | 1,279 | 323 | 150 | 27.0% |
| 2005 | 1,421 | 2,340 | 1,285 | 312 | 189 | 26.6% |
| 2006 | 1,390 | 2,588 | 1,275 | 356 | 151 | 24.7% |
| 2007 | 1,352 | 2,557 | 1,237 | 366 | 128 | 24.2% |
| 2008 | 1,501 | 2,815 | 1,483 | 392 | 137 | 25.6% |
| 2009 | 1,525 | 2,957 | 1,570 | 413 | 153 | 26.0% |
| 2010 | 1,718 | 3,254 | 1,799 | 511 | 124 | 26.0% |
| 2011 | 1,814 | 3,471 | 1,974 | 581 | 138 | 26.5% |
| 2012 | 1,980 | 4,099 | 1,865 | 658 | 165 | 23.2% |
| 2013 | 2,171 | 4,325 | 1,983 | 737 | 200 | 23.2% |
| 2014 | 2,125 | 4,137 | 2,108 | 758 | 240 | 25.1% |

Sources: 2014 ECG Energy Forecasting Report, November 2014, the Energy Commission of Ghana, National Energy Statistics, 2005-2014, April, 2015

Figures 3-2 and 3-3 visually present the ECG and NEDCo sales and losses from Table 3-6.

Figure 3-2: Historical ECG Demand Breakdown Chart (GWh)

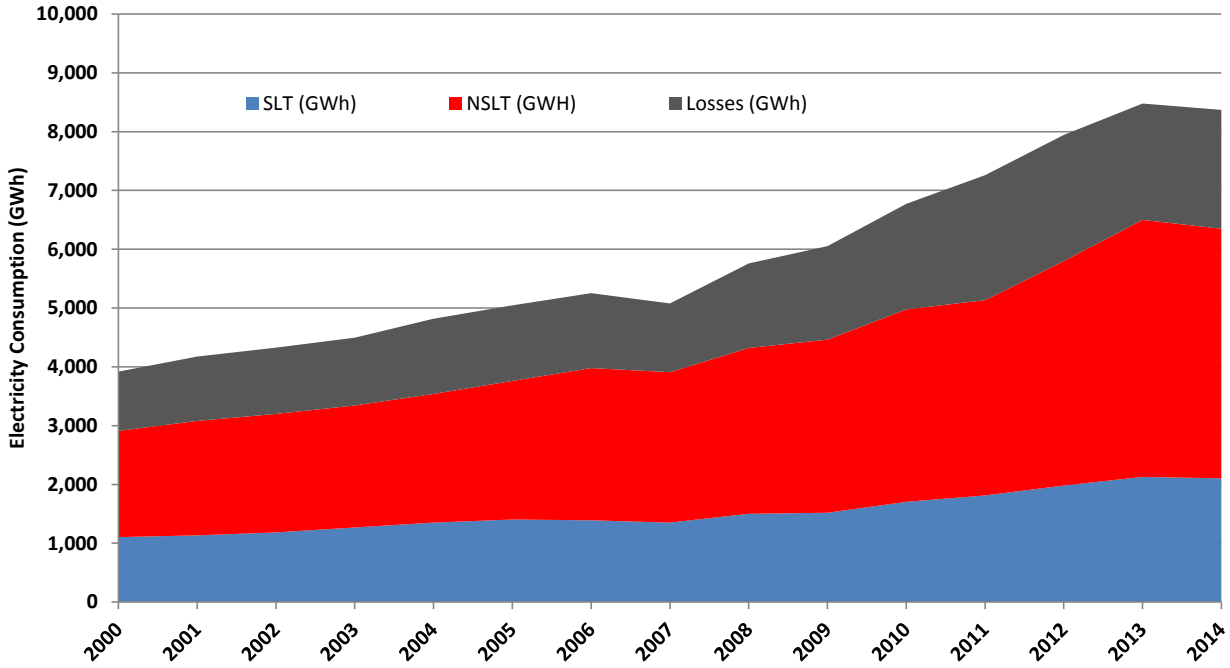
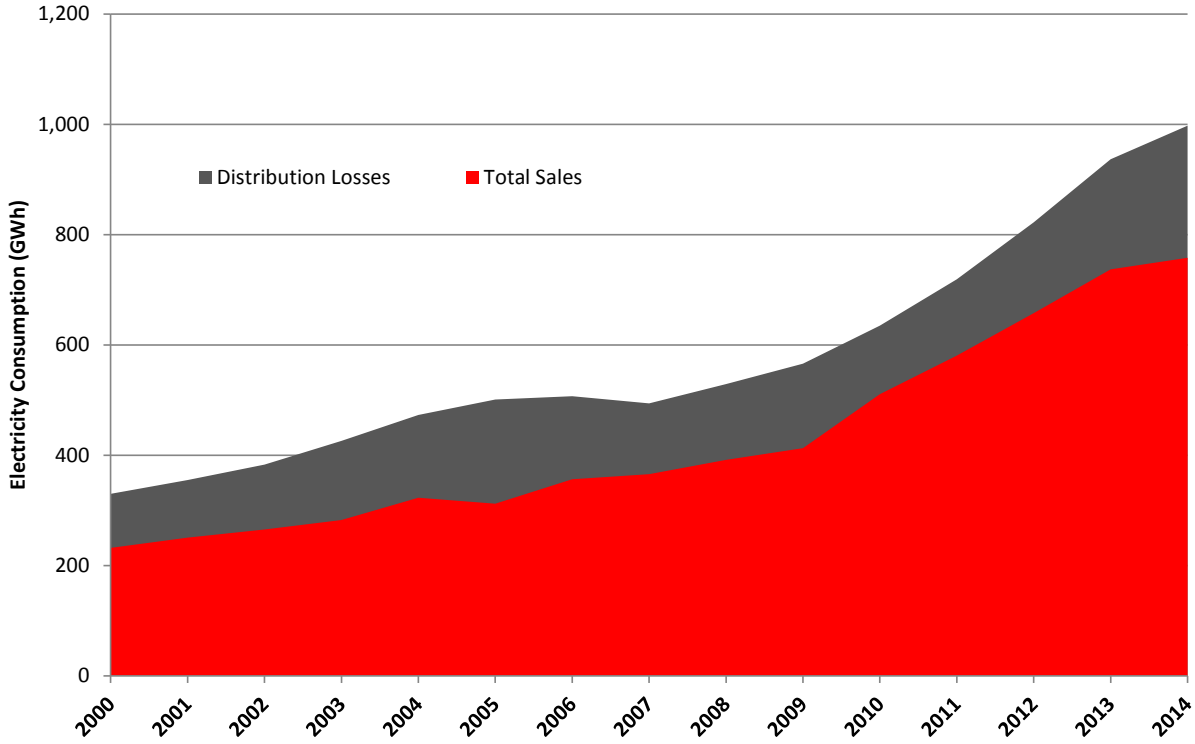



Figure 3-3: Historical NEDCo Demand Breakdown Chart (GWh)




A more detailed breakdown for VRA Industrial sales is presented in Table 3-7. Industrial VRA Sales includes sales to Mines, Other Direct Customers and VALCO. Historical VRA sales data, also presented in Figure 3-4, clearly shows the impact that supply constraints had on VALCO demand. VALCO was the most severely affected customer during the generation constrained

years, whose consumption had to be significantly reduced in each of the shortage years. During the last four years VALCO has only operated a single pot-line with a total consumption of around 600 GWh. Demand for the mining sector also shows a slowdown during the last 4-5 years. The Other Direct Customers category represents a small component of total sales to industrial customers, but shows a significant historical increase over time and particularly in 2014.

Table 3-7: Historical Sales for Industrial Customers (GWh)

| Year | Mines | Other Direct Customers | VALCO |
|---|---|---|---|
| 2000 | 630 | 58 | 2,505 |
| 2001 | 569 | 64 | 2,565 |
| 2002 | 562 | 83 | 2,063 |
| 2003 | 573 | 104 | 250 |
| 2004 | 599 | 113 | 10 |
| 2005 | 753 | 106 | 259 |
| 2006 | 874 | 105 | 1,199 |
| 2007 | 1,003 | 106 | 205 |
| 2008 | 1,143 | 118 | 259 |
| 2009 | 1,251 | 138 | 10 |
| 2010 | 1,243 | 144 | 7 |
| 2011 | 1,302 | 160 | 597 |
| 2012 | 1,386 | 163 | 606 |
| 2013 | 1,458 | 193 | 588 |
| 2014 | 1,553 | 339 | 611 |

Sources: VRA 2015-2030 Load Forecast, Final Report October 2014, GRIDCo 2015 Electricity Supply Plan. March 2015.

Figure 3-4: Historical Sales Chart Sales for Industrial Customers

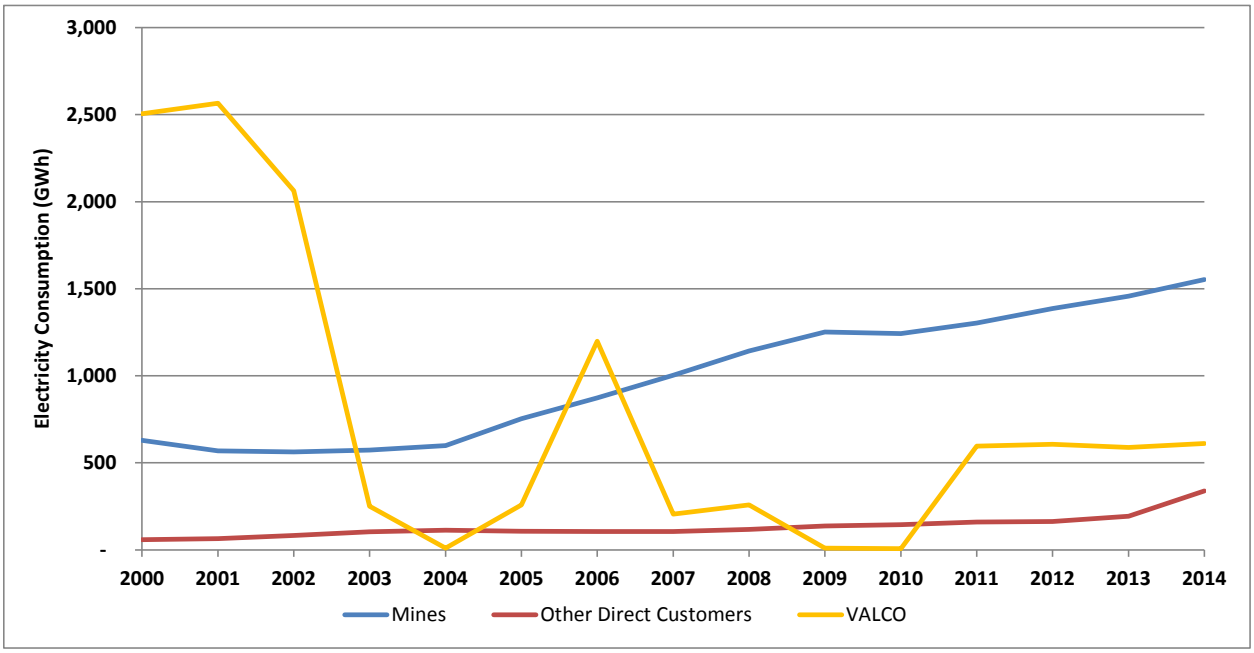



Table 3-8 presents Imports, Exports and Transmission Losses. Also included in the same table is the information on transmission losses as a percentage of the total transmission system demand. Both Imports and Exports have significantly decreased in recent years. The decrease in exports is also directly related to supply constraints and is below contractual quantities. Transmission losses are at an elevated level, indicating high loading of the transmission lines in general combined with the impact of increased reactive loading on transmission lines.

Table 3-8: Historical Sales for Industrial Customers (GWh)

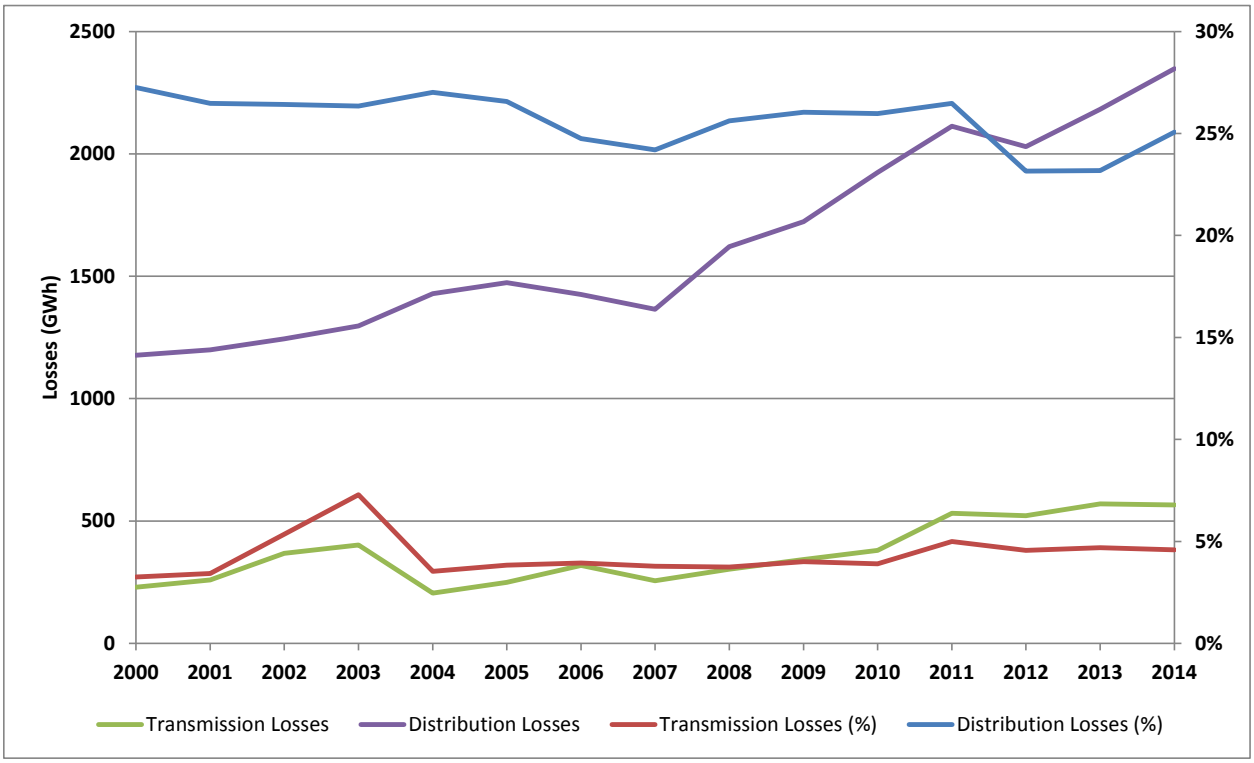
| Year | Imports | Exports | Transmission Losses | Transmission Losses (%) |
|---|---|---|---|---|
| 2000 | 864 | 392 | 229 | 3.3% |
| 2001 | 462 | 302 | 259 | 3.4% |
| 2002 | 1,146 | 612 | 368 | 5.3% |
| 2003 | 940 | 604 | 402 | 7.3% |
| 2004 | 878 | 665 | 205 | 3.5% |
| 2005 | 815 | 639 | 249 | 3.8% |
| 2006 | 629 | 754 | 318 | 3.9% |
| 2007 | 435 | 246 | 256 | 3.8% |
| 2008 | 275 | 538 | 303 | 3.7% |
| 2009 | 198 | 752 | 343 | 4.0% |
| 2010 | 106 | 1,036 | 380 | 3.9% |
| 2011 | 81 | 691 | 531 | 5.0% |
| 2012 | 128 | 667 | 522 | 4.6% |
| 2013 | 27 | 530 | 570 | 4.7% |

| | | | | |
|---|---|---|---|---|
| 2014 | 51 | 522 | 565 | 4.6% |

Sources: The Energy Commission of Ghana National Energy Statistics, 2000-2013 October, 2014; The Energy Commission of Ghana National Energy Statistics, 2005-2014, April, 2015

Figure 3-5 presents a graphical summary of historical transmission and distribution (T&D) losses. Distribution losses include both technical and commercial components. Distribution losses, as a percentage of total purchases at the distribution system, are very high, near 25%[1], despite the efforts by ECG and NEDCo to reduce both technical and commercial losses. The Energy Commission estimates that commercial losses currently represent about half of the total distribution losses.

Figure 3-5: T&D Losses during the 2000–2014 Period (GWh and %)




## 3.1.3 System Peak Load

The summary of the peak demands recorded during the 2000–2014 period is presented in Table 3-9. GRIDCo recorded maximum coincident peak load for the national interconnected system of 2061 MW in 2014. This represented an increase of 332 MW or a growth of 19.2% over the 2012 peak load of 1,729 MW. This increase was in spite of system load shedding during the last three years.

[1] Loss percentages would be even higher if calculated based on the total sales at the distribution system.

Table 3-9: Historical Peak Demand (MW)

| Year | Ghana Load at Peak | System Peak | VALCO | Exports |
|---|---|---|---|---|
| 2000 | 820 | 1,161 | 286 | 55 |
| 2001 | 854 | 1,181 | 293 | 34 |
| 2002 | 879 | 1,227 | 236 | 112 |
| 2003 | 925 | 1,135 | 29 | 181 |
| 2004 | 985 | 1,049 | 1 | 63 |
| 2005 | 1,064 | 1,325 | 30 | 231 |
| 2006 | 1,104 | 1,393 | 137 | 152 |
| 2007 | 1,158 | 1,274 | 23 | 93 |
| 2008 | 1,208 | 1,367 | 30 | 129 |
| 2009 | 1,263 | 1,423 | 1 | 159 |
| 2010 | 1,391 | 1,506 | 1 | 114 |
| 2011 | 1,502 | 1,665 | 68 | 95 |
| 2012 | 1,658 | 1,729 | 69 | 2 |
| 2013 | 1,791 | 1,943 | 67 | 85 |
| 2014 | 1,970 | 2,061 | 67 | 24 |

Sources: The Energy Commission of Ghana National Energy Statistics, 2000-2013, October, 2014; The Energy Commission of Ghana National Energy Statistics, 2005-2014, April, 2015; VRA 2015-2030 Load Forecast, Final Report October 2014.

Ghana Load at Peak includes coincident demand for all domestic customers including ECG, NEDCo, Other Direct Customers and Mines. System Peak represents total system peak demand, including Ghana Load at Peak as well as coincident peak demand for VALCO and Exports. Based on the coincident historical peak load data for Ghana Load at Peak and the total System Peak obtained from the Energy Commission and the VALCO coincident peak load, we calculated coincident peak load for exports.

This peak load and total generation requirement translates into load factors for domestic customers of 72.1% for 2014, 77.9% for 2013 and 78.8% for 2012. This high load factor seems to be the combined result of low seasonal variations in demand and load-shedding during the peak demand periods. As a comparison, the Kenya power system also has low seasonal variations in demand and is forecasted to have around a 68% load factor during the next ten year period[2].

[2] Kenya 10 Year Power Sector Expansion Plan 2014 -2024 http://erc.go.ke/images/docs/Ten_Year_Power_Sector_Expansion_Plan-2014-2024.pdf

## 3.2 SUMMARY OF FORECASTING STUDIES

This section presents summaries and key comparisons of the recent demand forecasts received from the Energy Commission, ECG, VRA and GRIDCo.

### 3.2.1 ECG 2014 Forecast Report

The ECG 2014 Energy Forecast Report presents energy consumption and a demand forecast for ECG customers only for the 10-year period from 2014 to 2023. The report is an update of the 2013 Energy Forecast Report. The objective of this latest review was to improve upon the previous year's methodology to produce forecast results with higher accuracy.

For demand forecasting, ECG customers are categorized into two categories:

1. Special Load Tariff (SLT) customers
2. Non-Special Load Tariff (NSLT) customers

The SLT customers include industrial customers who consume a demand equal to/greater than 100kVA, while the NSLT customers include both residential and commercial customers who consume less than 100kVA. ECG's forecasting approach was to develop independent forecasting models for each customer category (e.g. SLT and NSLT) to forecast consumption from 2014 to 2023. Losses (as a percentage of purchases) are projected for the same period to be in line with the ongoing System Losses Reduction Plan approved by the ECG Management. ECG stated that forecasting for only two customer categories was the best option based on available input data (e.g. input data does not support further disaggregation of customers to more distinct categories such as residential, non-residential, street lighting). The variables used in the forecasting analysis include: ECG's Electricity Prices, Customer Population and GDP.

Total GDP was used as a substitute for income for the NSLT category. Services and industrial components of GDP (Non-Agriculture GDP) were used as substitutes for income (output) for the SLT category, since the SLT category is predominantly industrial consumers and large commercial users of electricity. Electricity consumption is the dependent variable for which the forecasting model was developed, categorized into NSLT and SLT sales. NSLT forecasting utilized the Ordinary Least Squares (OLS) – Multiple Linear Regression Model (Log–Log), which examines the historical behavior of various key variables to build a model for predicting future demand. The SLT forecasting model utilized an Auto-Regressive Model, which includes the lagged values of the dependent variable as an independent variable.

Table 3-10 presents ECG results for the Base Case. Tables 3-11 and 3-12 present results for the High and Low scenarios.

Table 3-10: ECG Base Case Forecast by Component for the 2014-2023 Period (GWh)

| Year | NSLT Sales | SLT Sales | Losses | Purchases |
|---|---|---|---|---|
| 2014 | 4,799 | 2,329 | 1,849 | 8,977 |
| 2015 | 5,213 | 2,526 | 1,887 | 9,626 |
| 2016 | 5,661 | 2,737 | 1,924 | 10,321 |
| 2017 | 6,143 | 2,961 | 1,958 | 11,062 |
| 2018 | 6,660 | 3,201 | 1,989 | 11,850 |
| 2019 | 7,177 | 3,463 | 2,002 | 12,643 |
| 2020 | 7,718 | 3,735 | 2,040 | 13,493 |
| 2021 | 8,291 | 4,020 | 2,076 | 14,387 |
| 2022 | 8,898 | 4,320 | 2,110 | 15,328 |
| 2023 | 9,539 | 4,635 | 2,141 | 16,315 |

Source: 2014 ECG Energy Forecasting Report, November 2014

NSLT sales in 2030 are forecast to continue to be about twice the amount of the SLT sales. Losses are estimated to decrease to 13.15% of the total ECG purchases, in line with the target value, primarily targeting the commercial loss component.

Table 3-11: ECG Low Scenario Forecast by Component for the 2014-2023 Period (GWh)

| Year | NSLT Sales | SLT Sales | Losses | Purchases |
|---|---|---|---|---|
| 2014 | 4,730 | 2,308 | 1,839 | 8,876 |
| 2015 | 5,097 | 2,488 | 1,865 | 9,449 |
| 2016 | 5,491 | 2,675 | 1,888 | 10,054 |
| 2017 | 5,914 | 2,870 | 1,907 | 10,691 |
| 2018 | 6,364 | 3,073 | 1,923 | 11,360 |
| 2019 | 6,800 | 3,295 | 1,918 | 12,013 |
| 2020 | 7,253 | 3,521 | 1,935 | 12,708 |
| 2021 | 7,730 | 3,754 | 1,950 | 13,433 |
| 2022 | 8,232 | 3,995 | 1,962 | 14,189 |
| 2023 | 8,759 | 4,246 | 1,971 | 14,975 |

Source: 2014 ECG Energy Forecasting Report, November 2014

Table 3-12: ECG High Scenario Forecast by Component for the 2014-2023 Period (GWh)

| Year | NSLT Sales | SLT Sales | Losses | Purchases |
|---|---|---|---|---|
| 2014 | 4,896 | 2,341 | 1,873 | 9,110 |
| 2015 | 5,393 | 2,544 | 1,939 | 9,875 |
| 2016 | 5,935 | 2,765 | 2,005 | 10,705 |
| 2017 | 6,525 | 3,005 | 2,070 | 11,601 |
| 2018 | 7,165 | 3,264 | 2,136 | 12,565 |
| 2019 | 7,826 | 3,550 | 2,187 | 13,563 |
| 2020 | 8,527 | 3,849 | 2,267 | 14,642 |
| 2021 | 9,278 | 4,167 | 2,347 | 15,791 |
| 2022 | 10,082 | 4,503 | 2,427 | 17,012 |
| 2023 | 10,941 | 4,859 | 2,506 | 18,306 |

Source: 2014 ECG Energy Forecasting Report, November 2014

### 3.2.2 VRA 2015-2030 Load Forecasting Study Report

The latest VRA load forecast was developed by the System Planning department and presents an update of the previous forecast for the 2012–2025 period. The report presents the methodology and results of the VRA Load Forecast Study, and forecasts electricity demand and peak loads for the 2015-2030 period. The forecast was developed for six categories of VRA customers:

- ECG
- NEDCo
- Direct sales to the Mines supplied by VRA
- Other direct customers within Ghana, which includes VRA Townships
- VALCO smelter
- Exports to neighboring countries

Electricity consumption was forecast using regression analysis. Country GDP was used to determine growth patterns for ECG and NEDCo. Mines, Other direct customers, Exports, and VALCO forecasts were based on information provided by that category of customers and VRA's experience with those customers. Three forecasting scenarios were developed including:

- *Base Case:* Best estimate forecast recommended for planning
- *High Growth:* Higher growth of the national economy than that projected for the Base Case forecast
- *Low Growth:* Slower pace of growth of the national economy than that projected for the Base Case forecast

Table 3-13 presents VRA Base Case results for each of the customer categories.

Table 3-13: VRA Base Case Forecast by Customer Class for the 2015-2030 Period (GWh)

| Year | ECG | NEDCo | Mines | Direct | Total Domestic | VALCO | Export | Losses | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2015 | 10,690 | 1,156 | 1,618 | 434 | 13,898 | 620 | 1,069 | 649 | 16,236 |
| 2016 | 11,248 | 1,285 | 2,137 | 491 | 15,161 | 620 | 1,073 | 684 | 17,538 |
| 2017 | 11,909 | 1,392 | 2,179 | 545 | 16,024 | 1,240 | 1,939 | 779 | 19,982 |
| 2018 | 12,959 | 1,496 | 2,179 | 597 | 17,231 | 1,240 | 2,257 | 819 | 21,547 |
| 2019 | 14,001 | 1,588 | 2,241 | 648 | 18,479 | 1,860 | 2,261 | 893 | 23,493 |
| 2020 | 15,015 | 1,712 | 2,262 | 756 | 19,745 | 1,860 | 2,261 | 917 | 24,783 |
| 2021 | 15,629 | 1,800 | 2,404 | 810 | 20,642 | 1,860 | 2,261 | 951 | 25,715 |
| 2022 | 16,622 | 1,919 | 2,424 | 859 | 21,823 | 1,860 | 2,261 | 969 | 26,913 |
| 2023 | 17,687 | 2,048 | 2,565 | 910 | 23,210 | 1,860 | 2,261 | 1,021 | 28,352 |
| 2024 | 18,851 | 2,180 | 2,664 | 961 | 24,656 | 1,860 | 2,261 | 1,044 | 29,821 |
| 2025 | 20,111 | 2,316 | 2,826 | 969 | 26,221 | 1,860 | 2,261 | 1,101 | 31,443 |
| 2026 | 21,397 | 2,485 | 2,887 | 969 | 27,738 | 1,860 | 2,261 | 1,156 | 33,015 |
| 2027 | 22,718 | 2,641 | 2,948 | 971 | 29,278 | 1,860 | 2,261 | 1,211 | 34,610 |
| 2028 | 24,087 | 2,806 | 3,071 | 971 | 30,935 | 1,860 | 2,261 | 1,271 | 36,328 |
| 2029 | 25,604 | 2,982 | 3,101 | 971 | 32,659 | 1,860 | 2,261 | 1,334 | 38,114 |
| 2030 | 27,217 | 3,167 | 3,101 | 971 | 34,457 | 1,860 | 2,261 | 1,399 | 39,977 |

Source: VRA 2015-2030 Load Forecast, Final Report, October 2014

Total Domestic energy consumption in 2015, excluding VALCO and Exports, is forecast to be 13,898 GWh. The high growth projected for 2015 is accounted for by load shedding experienced in 2014. Total Domestic sales, excluding VALCO and exports, is projected to grow at an average annual rate of 6.2% in the forecast period increasing from 13,898 GWh in 2015 to 34,457 GWh in 2030. The total Sales forecast, which represents total power supply to Domestic Consumers, VALCO, Exports and System Usage, is expected to increase at an average rate of 6.2% from 16,236 GWh in 2015 to 39,977 GWh in 2030. The System Peak demand, which includes VALCO and VRA Exports, is also expected to grow by an average of 6.3% from 2,335 MW in 2015 to 5,827 MW in 2030.

### 3.2.3 GRIDCo 2015 Electricity Supply Plan

The latest GRIDCo 2015 Supply Plan starts with the estimated demand and supply scenario for 2015 as a basis for the outlook for Ghana's bulk power supply system for the 2014-2025 period (for both generation and transmission subsystems). The Plan also captures a short-term (2016-2018) demand outlook and presents an overview of generation and transmission system performance in 2014. The methodology for developing the demand forecast is not presented in the report. Similarly to the VRA forecast, the demand forecast is done for the following customer categories:

- ECG
- NEDCo

- Mines
- Other direct sales within Ghana
- VALCO smelter
- Exports to neighboring countries (CEB, SONABEL)

The latest GRIDCo forecast uses the actual 2014 electricity demand, and estimates that the coincident peak demand for the year 2015 will be 2,341 MW. This represents an 18.8 % growth over the 2014 peak demand of 1,970.7 MW. The estimated peak demand for 2015 is built upon the expected actual load for 2014, e.g. load that includes 2014 suppressed demand estimated by GRIDCo.

The total forecasted demand for 2015 is 16,039 GWh. This includes estimated transmission losses of 3.7% of total energy generation. With an actual energy consumption of 13,071 GWh in 2014, the projected 2015 figure represents a growth of about 22.7% and an increase of 2,968 GWh. 2015 projected growth in consumption includes the energy that could not be served in 2014. Based on the demand/supply analysis, only 13,928 GWh is expected to be supplied while the remaining 2,111 GWh might have to be shed because of the expected supply deficit.

Table 3-14 presents the GRIDCo Base Case results.

Table 3-14: GRIDCo Base Case Forecast by Component for the 2015-2025 Period (GWh)

| Year | ECG | NEDCo | Mines | Direct | Total Domestic | VALCO | Export | Losses | Total |
|---|---|---|---|---|---|---|---|---|---|
| 2014 | 9,298 | 1,062 | 1,824 | 368 | 12,552 | 620 | 828 | 545 | 14,545 |
| 2015 | 9,920 | 1,142 | 2,101 | 549 | 13,712 | 620 | 1,088 | 618 | 16,038 |
| 2016 | 10,477 | 1,213 | 2,641 | 582 | 14,913 | 1,240 | 1,088 | 660 | 17,901 |
| 2017 | 11,060 | 1,287 | 2,948 | 649 | 15,944 | 1,240 | 1,482 | 705 | 19,371 |
| 2018 | 11,692 | 1,368 | 3,076 | 659 | 16,795 | 1,875 | 2,322 | 837 | 21,829 |
| 2019 | 12,465 | 1,468 | 3,172 | 674 | 17,779 | 3,125 | 3,007 | 940 | 24,851 |
| 2020 | 13,292 | 1,576 | 3,289 | 683 | 18,840 | 3,125 | 3,007 | 983 | 25,955 |
| 2021 | 14,178 | 1,693 | 3,397 | 692 | 19,960 | 3,125 | 3,304 | 1,028 | 27,417 |
| 2022 | 15,126 | 1,818 | 3,397 | 701 | 21,042 | 3,125 | 3,304 | 1,072 | 28,543 |
| 2023 | 16,140 | 1,952 | 3,395 | 716 | 22,203 | 3,125 | 3,304 | 1,119 | 29,751 |
| 2024 | 17,225 | 2,096 | 3,395 | 716 | 23,432 | 3,125 | 3,304 | 1,169 | 31,030 |
| 2025 | 18,385 | 2,251 | 3,395 | 716 | 24,747 | 3,125 | 3,304 | 1,222 | 32,398 |

Source: GRIDCo 2015 Electricity Supply Plan, March 2015.

## 3.2.4 Energy Commission

### *3.2.4.1 2015 Energy Outlook for Ghana*

The purpose of the Energy Commission (EC) Energy Outlook is to give government, industry and business indications of the levels/quantities of electricity, liquid and gaseous fuels that would be required to be provided by energy producers for the next 12 months. The report also discusses factors that could influence future demand and supply. The latest Energy

Commission 2015 Energy Outlook presents supply and demand forecasts for electricity, crude oil, petroleum products, natural gas and charcoal for the year 2015.

The total electricity requirement for 2015 is estimated to range from 14,150-14,730 GWh with VALCO operating one potline; and to maintain economic growth at an average of 4.2-4.5%. Based on the planned expansion of generation capacity, the available electricity supply in 2015 is estimated to be 14,300-14,500 GWh.

The Outlook also estimated the impact that persistent load-shedding has on the economy and GDP growth. This analysis was used as a reference when we estimated GDP impacts.

#### *3.2.4.2 SNEP Electricity Demand Forecast*

The EC provided forecasts developed for the upcoming SNEP report covering the 2015–2035 period. Electricity demand in Ghana is forecasted for two scenarios: Business as Usual/Base Case (BaU) and the Accelerated Economic Growth (AEG) scenario. Forecasts are developed for the following customer categories: Households, Services, Industry, VALCO, Agriculture, Transport and Exports.

The EC uses the LEAP computer-based model to forecast total energy demand and supply. The forecast was primarily based on the projection into the future of economic (demand) sector/subsector outputs and the energy intensities of the end-uses and/or appliances, thus using a 'bottom up approach' for demand forecasting and energy planning. VRA and ECG provided support in the analysis for the transmission and distribution systems. The energy demand (not the energy consumption) was evaluated for all sectors of the economy. The assumptions and drivers that guided the energy demand projections are based on the Government policies and programs.

Tables 3-15 and 3-16 present EC results for the Base Case and AEG scenarios. Sales forecasts show that with the projected number of plants expected to come on line from 2016, it could be assumed that VALCO will be able to operate at least two pot-lines beginning 2016 and 3-4 pot-lines by 2020, and above 4 pot-lines from 2020 onwards.

Table 3-15: SNEP Base Case (BaU) Forecast by Component for the 2015-2035 Period (GWh)

| Year | Households | Services | Industry | VALCO | Agriculture | Transport | Total | Exports |
|---|---|---|---|---|---|---|---|---|
| 2015 | 7,009 | 3,052 | 3,706 | 646 | 3 | 6 | 14,423 | 550 |
| 2016 | 7,480 | 3,396 | 3,948 | 1,291 | 3 | 7 | 16,126 | 552 |
| 2017 | 7,970 | 3,765 | 4,198 | 1,290 | 4 | 8 | 17,236 | 2,105 |
| 2018 | 8,480 | 4,162 | 4,457 | 1,289 | 4 | 9 | 18,402 | 2,416 |
| 2019 | 9,011 | 4,589 | 4,726 | 1,288 | 5 | 10 | 19,629 | 3,128 |
| 2020 | 9,565 | 5,047 | 5,029 | 3,218 | 5 | 11 | 22,875 | 3,127 |
| 2021 | 10,036 | 5,548 | 5,349 | 3,215 | 6 | 13 | 24,168 | 3,126 |
| 2022 | 10,525 | 6,085 | 5,681 | 3,213 | 7 | 14 | 25,526 | 3,125 |
| 2023 | 11,032 | 6,662 | 6,026 | 3,210 | 9 | 15 | 26,954 | 3,124 |
| 2024 | 11,558 | 7,281 | 6,383 | 3,208 | 10 | 17 | 28,457 | 3,123 |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| 2025 | 12,103 | 7,946 | 6,753 | 3,205 | 11 | 18 | 30,037 | 3,121 |
| 2026 | 12,635 | 8,659 | 7,184 | 3,202 | 13 | 20 | 31,714 | 3,120 |
| 2027 | 13,184 | 9,425 | 7,629 | 3,200 | 15 | 22 | 33,475 | 3,119 |
| 2028 | 13,750 | 10,247 | 8,091 | 3,197 | 18 | 24 | 35,327 | 3,118 |
| 2029 | 14,335 | 11,129 | 8,570 | 3,195 | 20 | 26 | 37,274 | 3,117 |
| 2030 | 14,938 | 12,076 | 9,066 | 3,192 | 22 | 28 | 39,322 | 3,116 |
| 2031 | 15,545 | 13,113 | 9,636 | 3,190 | 25 | 30 | 41,539 | 3,116 |
| 2032 | 16,169 | 14,224 | 10,227 | 3,187 | 28 | 33 | 43,867 | 3,116 |
| 2033 | 16,811 | 15,415 | 10,839 | 3,184 | 31 | 35 | 46,316 | 3,116 |
| 2034 | 17,471 | 16,692 | 11,474 | 3,182 | 34 | 38 | 48,891 | 3,116 |
| 2035 | 18,149 | 18,061 | 12,145 | 3,179 | 37 | 41 | 51,612 | 3,116 |

Source: Forecast received from the Energy Commission of Ghana, December 2015

Table 3-16: SNEP AEG Forecast by Component for the 2015-2035 Period (GWh)

| Year | Households | Services | Industry | VALCO | Agriculture | Transport | Total | Exports |
|---|---|---|---|---|---|---|---|---|
| 2015 | 7,691 | 3,448 | 4,023 | 644 | 4 | 14 | 15,824 | 550 |
| 2016 | 8,319 | 3,895 | 4,329 | 1,285 | 5 | 17 | 17,850 | 552 |
| 2017 | 8,976 | 4,384 | 4,647 | 1,283 | 5 | 20 | 19,316 | 2,105 |
| 2018 | 9,663 | 4,919 | 4,979 | 1,281 | 6 | 23 | 20,872 | 2,416 |
| 2019 | 10,381 | 5,503 | 5,325 | 1,279 | 7 | 27 | 22,522 | 3,128 |
| 2020 | 11,130 | 6,142 | 5,717 | 3,193 | 7 | 31 | 26,219 | 3,127 |
| 2021 | 11,804 | 6,855 | 6,131 | 3,187 | 9 | 35 | 28,022 | 3,126 |
| 2022 | 12,502 | 7,633 | 6,563 | 3,182 | 11 | 40 | 29,931 | 3,125 |
| 2023 | 13,224 | 8,480 | 7,015 | 3,177 | 13 | 45 | 31,953 | 3,124 |
| 2024 | 13,970 | 9,403 | 7,486 | 3,172 | 14 | 50 | 34,096 | 3,123 |
| 2025 | 14,742 | 10,407 | 7,986 | 3,167 | 16 | 56 | 36,373 | 3,121 |
| 2026 | 15,481 | 11,501 | 8,554 | 3,162 | 20 | 62 | 38,779 | 3,120 |
| 2027 | 16,242 | 12,691 | 9,146 | 3,157 | 23 | 68 | 41,327 | 3,119 |
| 2028 | 17,023 | 13,987 | 9,764 | 3,152 | 27 | 76 | 44,028 | 3,118 |
| 2029 | 17,825 | 15,398 | 10,410 | 3,146 | 31 | 83 | 46,894 | 3,117 |
| 2030 | 18,648 | 16,934 | 11,986 | 3,141 | 35 | 91 | 50,836 | 3,116 |
| 2031 | 19,491 | 18,623 | 12,801 | 3,136 | 40 | 100 | 54,192 | 3,116 |
| 2032 | 20,363 | 20,460 | 13,652 | 3,131 | 45 | 109 | 57,761 | 3,116 |
| 2033 | 21,262 | 22,458 | 14,542 | 3,126 | 50 | 119 | 61,558 | 3,116 |
| 2034 | 22,192 | 24,631 | 15,473 | 3,121 | 56 | 130 | 65,602 | 3,116 |
| 2035 | 23,150 | 26,994 | 16,453 | 3,116 | 61 | 141 | 69,916 | 3,116 |

Source: Forecast received from the Energy Commission of Ghana, December 2015

The EC added estimated losses to sales forecasts to arrive at the total generation requirements. Table 3-17 provides Total Generation values received from the EC. Based on those total numbers we calculated loss amounts for both the Base Case and AEG scenario.

Table 3-17: SNEP Total Generation and Loss Forecasts for the 2015-2035 Period (GWh)

| Year | BaU | | | AEG | | |
|---|---|---|---|---|---|---|
| | Generation | Losses | Losses (%) | Generation | Losses | Losses (%) |
| 2015 | 16,956 | 2,532 | 17.6% | 18,559 | 2,735 | 17.3% |
| 2016 | 18,737 | 2,611 | 16.2% | 20,698 | 2,848 | 16.0% |
| 2017 | 21,443 | 4,207 | 24.4% | 23,794 | 4,478 | 23.2% |
| 2018 | 22,976 | 4,574 | 24.9% | 25,749 | 4,878 | 23.4% |
| 2019 | 24,942 | 5,313 | 27.1% | 28,171 | 5,649 | 25.1% |
| 2020 | 28,284 | 5,409 | 23.6% | 31,994 | 5,774 | 22.0% |
| 2021 | 29,711 | 5,543 | 22.9% | 33,987 | 5,964 | 21.3% |
| 2022 | 31,209 | 5,683 | 22.3% | 36,096 | 6,165 | 20.6% |
| 2023 | 32,785 | 5,830 | 21.6% | 38,330 | 6,377 | 20.0% |
| 2024 | 34,441 | 5,984 | 21.0% | 40,696 | 6,600 | 19.4% |
| 2025 | 36,183 | 6,146 | 20.5% | 43,210 | 6,836 | 18.8% |
| 2026 | 38,030 | 6,317 | 19.9% | 45,864 | 7,085 | 18.3% |
| 2027 | 39,971 | 6,495 | 19.4% | 48,674 | 7,347 | 17.8% |
| 2028 | 42,009 | 6,683 | 18.9% | 51,653 | 7,624 | 17.3% |
| 2029 | 44,153 | 6,879 | 18.5% | 54,811 | 7,917 | 16.9% |
| 2030 | 46,407 | 7,085 | 18.0% | 59,090 | 8,255 | 16.2% |
| 2031 | 48,863 | 7,324 | 17.6% | 62,806 | 8,614 | 15.9% |
| 2032 | 51,443 | 7,575 | 17.3% | 66,757 | 8,996 | 15.6% |
| 2033 | 54,155 | 7,839 | 16.9% | 70,962 | 9,404 | 15.3% |
| 2034 | 57,009 | 8,118 | 16.6% | 75,439 | 9,838 | 15.0% |
| 2035 | 60,023 | 8,411 | 16.3% | 80,217 | 10,301 | 14.7% |

Source: Forecast received from the Energy Commission of Ghana, December 2015

The results show gradual decreases in losses over time[3]. Loss amounts are in general lower than historical values since the EC methodology considers commercial electricity losses as part of non-paid electricity demand and therefore this component is directly included in the demand forecast.

[3] Calculation also shows lower loss amounts in 2015 and 2016.

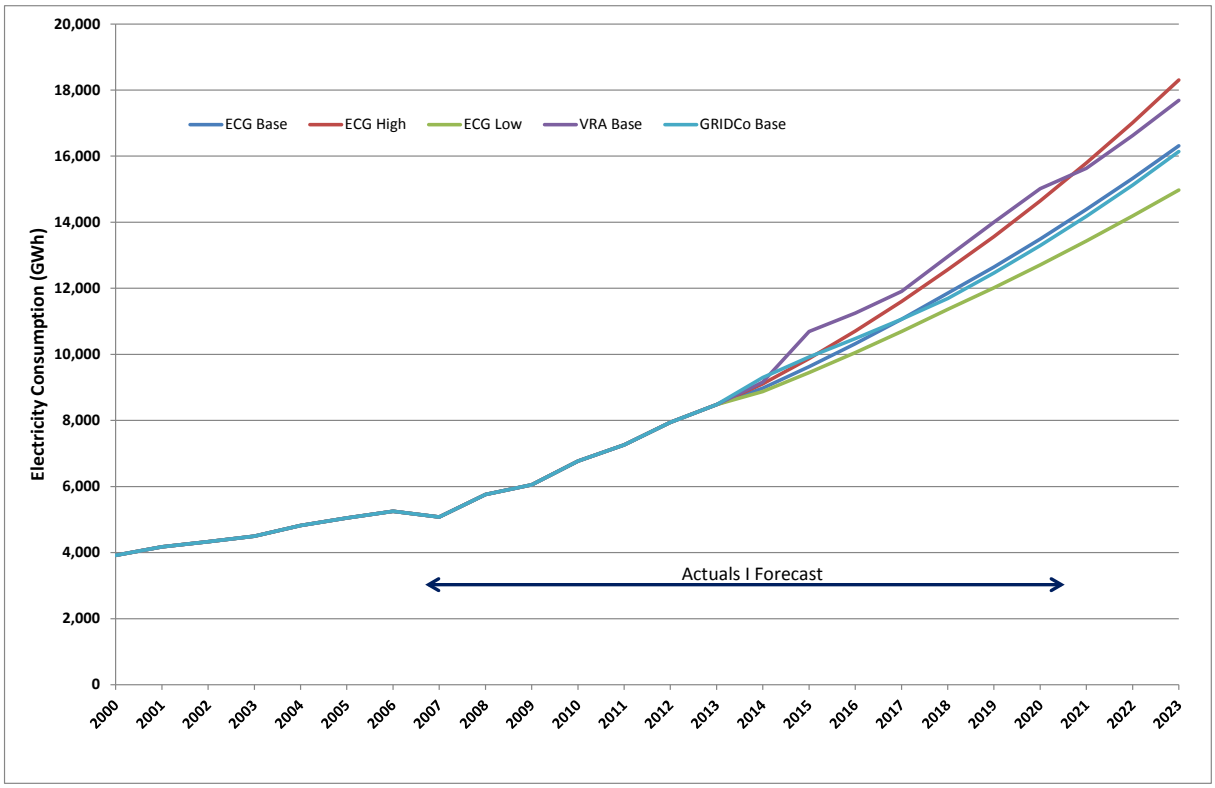
## 3.2.5 Forecast Comparisons

Following the foregoing review of Ghana forecasts, this section presents two key forecast comparisons.

### *3.2.5.1 ECG Demand Forecast Comparison*

Because ECG's consumption is about 62% of the total system energy, it is important to compare results from all available forecasts. Figure 3-6 presents the most recent demand forecasts done by ECG, VRA, and GRIDCo for the 2014-2023 period (e.g. the period forecasted by ECG). ECG forecasts include Base Case and Low and High Growth scenarios. Since both VRA and GRIDCo forecasts estimate ECG purchases (e.g. total ECG sales including distribution losses), forecast comparison could only be done on the purchase level. The figure shows that GRIDCo forecasting results closely follow the ECG Base Case demand, while VRA forecasting results closely follow the ECG High Demand scenario. The EC forecast is not included in the comparison, since EC forecast uses a different methodology and customer categories than ECG, GRIDCo and VRA.

Figure 3-6: ECG Demand Forecasts Summary (GWh)




### *3.2.5.2 Total Demand Forecast Comparison*

Figure 3-7 presents the Energy Commission, VRA and GRIDCo total generation requirement comparison until year 2030. The VRA and GRIDCo (up to 2025) forecasts follow similar trajectories and total amounts. The Energy Commission forecast starts higher in 2015 and continues to be higher during the entire forecasted period. Peak load forecasts are all derived

from the energy forecast and thus follow similar trajectories. More comparisons and underlying explanations are provided in Section 5 with the presentation of the Nexant forecast results.

Figure 3-7: Total Generation Requirement Comparison (GWh)

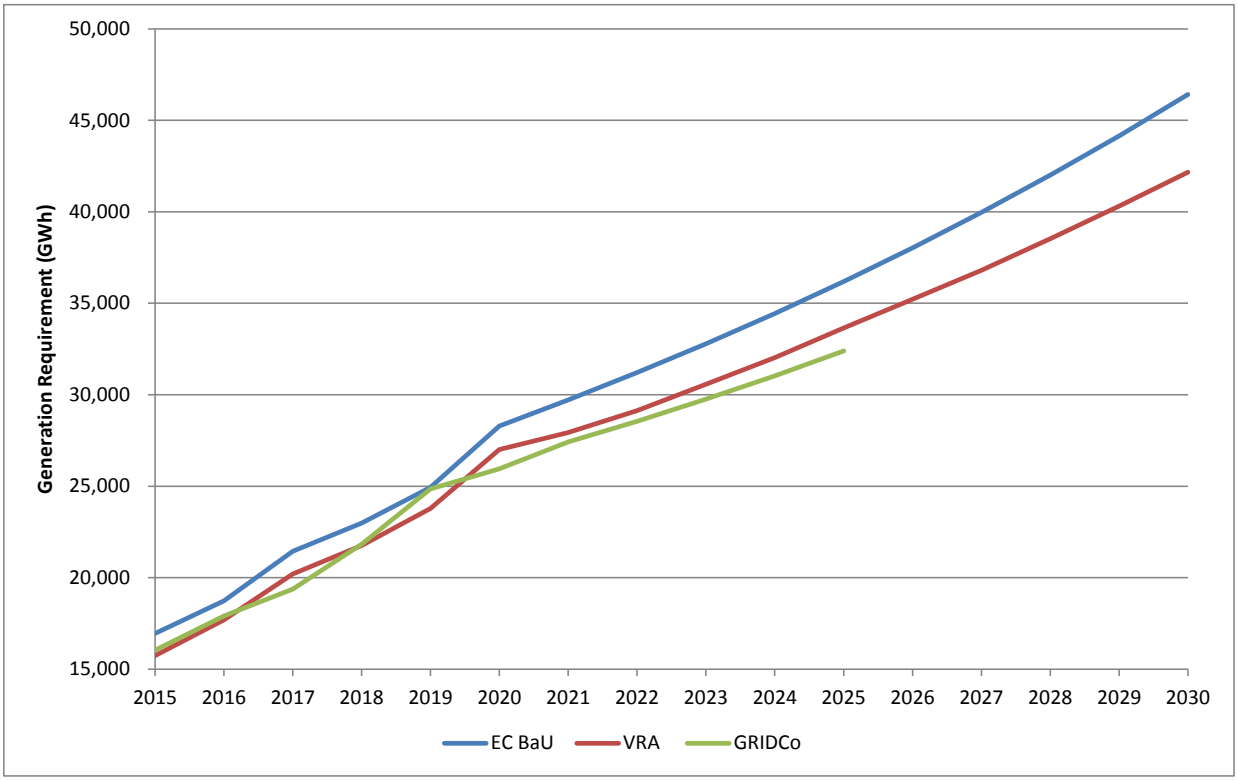
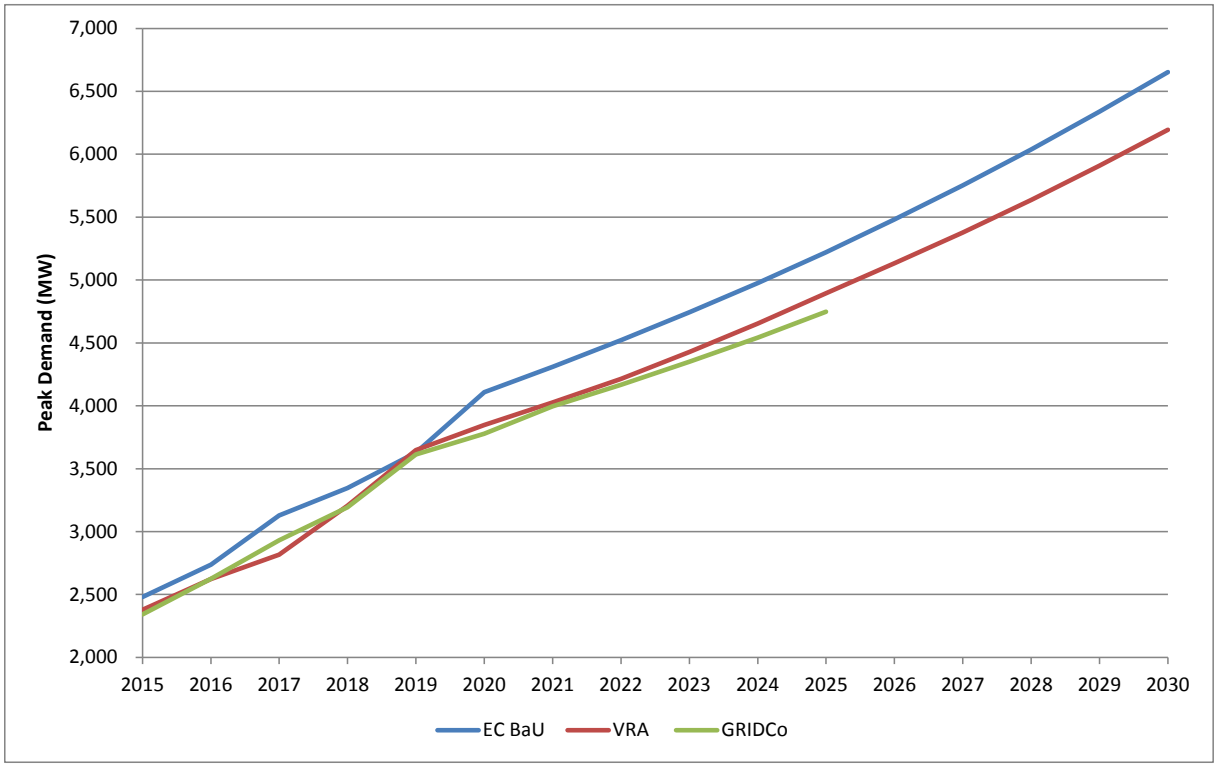



Figure 3-8: Total Peak Load Forecasts Comparison (GWh)



# 3.3 FORECASTING INPUTS AND ASSUMPTIONS

## 3.3.1 Analysis Years

Our forecasting analysis includes the 16-year period from 2015 to 2030, starting with the most accurate demand for year 2014. Starting year 2014 demand includes actual demand adjusted to account for the suppressed demand component. Assumptions for all significant input variables used for demand forecasting were developed for the entire 16 year forecasting period.

Demand for electricity is dependent on many factors such as income levels, electricity prices, population, suppressed demand, weather conditions, number of customers, etc. The goal of demand forecasting is to capture the causes of trends by modeling relationships between electricity demand and economic, technological or demographic variables. As part of the forecasting analysis we looked at the comprehensive list of potential independent variables and also derived indices that could impact demand in Ghana including:

- Total country GDP
- Sectoral GDP - Agricultural, Industrial, Services
- Total Ghana population
- Number of households
- Average household size
- Number of customers by category - Residential, Non-Residential, SLT customers
- Electricity prices by tariff class
- Total electricity consumed/ GDP
- Electricity intensity index for residential and industrial customers
- Per capita income
- Per capita consumption
- Per capita consumption for residential customers

From this set of variables, we reviewed historical trends, statistically tested dependencies and developed forecasting models that use the most appropriate sets of independent variables impacting demand for different demand sectors and customer categories.

## 3.3.2 Gross Domestic Product (GDP)

### *3.3.2.1 Historical Values*

Country GDP and sectoral GDP components are among the key inputs used in demand forecasting. GDP is known to have strong correlation with electricity demand. The most recent revised GDP (at constant prices) for 2014 estimates a growth of 4.2% over the 2013 revised estimate. The agriculture sector recorded the highest growth of 5.2%, followed by Industry with 4.1% and the Services sector with a growth of 3.9%. Though the estimates show an improvement in the growth of agriculture, its share was reduced from 21.6% of GDP in 2013 to 21.4% in 2014. The industrial sector, with 28.4% of total GDP and with the slowest growth, saw

a decline in growth from 6.6% in 2013 to 3.9% in 2014. Of all the industrial activities, the construction subsector recorded the highest growth in 2014 of 7.4%.

The services sector remains the largest sector, with about half of total GDP. The sector growth rate however decreased from 10.3% in 2013 to 4.1% in 2014. This information points to the impact that load shedding and supply issues had on overall economic growth in Ghana. Table 3-18 presents total and GDP component values for the last 14 years. The information was obtained from the Ghana Statistical Services Economic Statistics. The statistics present GDP at Basic Prices (e.g. excluding taxes) and the total GDP in purchasers prices. The complete set of inputs for all GDP components for the 2000–2014 period[4] was developed based on available economic data.

Table 3-18: Historical GDP and Component Data in constant 2006 prices (Million US$)

| Year | GDP Agriculture | GDP Industry | GDP Services | GDP (at basic prices) | Net Indirect Taxes | GDP (in purchasers prices) |
|---|---|---|---|---|---|---|
| 2000 | 4,111 | 2,674 | 6,274 | 13,059 | 657 | 13,716 |
| 2001 | 4,261 | 2,793 | 6,552 | 13,606 | 684 | 14,290 |
| 2002 | 4,439 | 2,924 | 6,861 | 14,225 | 715 | 14,940 |
| 2003 | 4,717 | 3,065 | 7,190 | 14,971 | 753 | 15,723 |
| 2004 | 5,051 | 3,215 | 7,542 | 15,807 | 795 | 16,602 |
| 2005 | 5,208 | 3,445 | 8,081 | 16,734 | 841 | 17,576 |
| 2006 | 5,415 | 3,704 | 8,690 | 17,810 | 895 | 18,705 |
| 2007 | 5,322 | 3,930 | 9,358 | 18,610 | 1,303 | 19,913 |
| 2008 | 5,716 | 4,522 | 10,106 | 20,344 | 1,248 | 21,592 |
| 2009 | 6,129 | 4,725 | 9,928 | 20,782 | 1,554 | 22,336 |
| 2010 | 6,453 | 5,053 | 10,918 | 22,424 | 1,677 | 24,101 |
| 2011 | 6,507 | 7,157 | 11,909 | 25,574 | 1,913 | 27,487 |
| 2012 | 6,657 | 7,947 | 13,346 | 27,950 | 2,090 | 30,040 |
| 2013 | 7,003 | 8,475 | 14,519 | 29,998 | 2,244 | 32,242 |
| 2014 | 7,369 | 8,804 | 15,078 | 31,251 | 2,338 | 33,589 |

Source: Ghana Statistical Service, National Accounts Statistics, Revised Gross Domestic Product 2014, January 2015, www.statsghana.gov.gh

While there were significant year-to-year variations, overall GDP has increased 6.6% over the last 14 years. During this period, the industrial GDP component increased the most, 8.9% in the last 14 years but only 7.1% in the last three years. During the same 14 year period, the services GDP component increased at the same rate as the total GDP, while the agriculture component lagged the overall increase, with a growth rate of 4.3%.

[4] Data source: http://www.statsghana.gov.gh/economic.html GDP Components for the 2000-2005 period are estimated based on 2006 ratios. The Basic price is the amount receivable by the producer exclusive of taxes payable on products and inclusive of subsidies receivable on products.

The World Bank[5] indicates that electricity is the second most important constraint to business activities in the country and that Ghana lost about 1.8% of GDP during the 2007 power crisis. The most recent load shedding is even more severe and is significantly impacting country overall economic development and growth. The dip in the GDP growth during the last few years has been directly attributed to slow growth in the manufacturing subsector and the services sector largely due to the inadequate supply and nation-wide load shedding. Ghana's real GDP growth in 2013 of only 7.3%, a drop from 8.8% in 2012, is directly attributed to electricity shortages. GDP growth in 2014 has further been reduced to 4.2%, at least 3% lower than the long-term growth rate. Despite the slowdown, the overall growth in the non-agriculture sectors remained at relatively high levels.

#### *3.3.2.2 Historical GDP Impact Assumptions*

In order to estimate suppressed demand over the last three years, it was necessary to estimate the consequent impact that suppressed demand had on GDP over the 2012-2014 period and accordingly adjust GDP values. In estimating the monetary impact, we took into account historical analysis from the 2013 World Bank report and other estimates such as the Ghana Institute of Statistical, Social and Economic Research (ISSER) study[6]. In estimating the impact that 2014 load shedding had on GDP growth, we considered several reference values. The first value was the actual GDP growth in 2014 that showed a reduction of around 3% (GDP growth in 2014 was 4.2%[7], a drop from 7.1% growth in 2013. The second value was the ISSER study that estimated that GDP growth was reduced by at least 2% in 2014 due to load shedding. In addition, GDP growth in 2013 was 7.1%, a drop from the 8.8% growth achieved in 2012. As the Energy Commission pointed out, this dip in the GDP growth has been attributed to negative growth in the Manufacturing and Services sectors largely due to the inadequate grid power supplied culminating into nation-wide load shedding for part of the year.

Using these reference values, we estimated the 2014 GDP reduction to be about 3%. Based on the amount of load shedding in years 2012 and 2013 compared with year 2014, and the estimated GDP reduction factor for 2014, we further estimated GDP reductions of 1% for 2012 and 1.5% for 2013, for a combined cumulative[8] reduction of 5.6% in GDP over the entire three year period.

Table 3-19 presents estimates of GDP growth rates and component values without electricity shortages.

---

[5] World Bank, Energizing Economic Growth in Ghana: Making the Power and the Petroleum Sectors Rise to the Challenge, February, 2013

[6] Institute of Statistical, Social and Economic Research (ISSER) of the University of Ghana: "Electricity insecurity and its impact on doing business in Ghana"

[7] Ghana Statistical Service, Revised Gross Domestic Product 2014, January 2015, www.statsghana.gov.gh

[8] Cumulative GDP impact is calculated as 1.01*1.015*1.03 = 1.056 or 5.6% over the 3 year period.

Table 3-19: Adjusted GDP in constant 2006 prices (Million US$)

| Year | GDP Agriculture | GDP Industry | GDP Services | GDP (at basic prices) | Net Indirect Taxes | GDP (in purchasers) |
|---|---|---|---|---|---|---|
| 2011 | 6,507 | 7,157 | 11,909 | 25,574 | 1,913 | 27,487 |
| 2012 | 6,724 | 8,026 | 13,479 | 28,230 | 2,111 | 30,340 |
| 2013 | 7,179 | 8,688 | 14,884 | 30,752 | 2,300 | 33,053 |
| 2014 | 7,781 | 9,296 | 15,921 | 32,998 | 2,469 | 35,467 |

#### *3.3.2.3 Future GDP Growth Rate Assumptions*

Future GDP growth rate assumptions are based on several sources including assumptions used in demand forecasts produced by Ghana utilities, World Bank, International Monetary Fund (IMF), and the African Economic Outlook.

The African Economic Outlook states that Ghana's economy has maintained a commendable growth trajectory. In 2013 growth decelerated and is considerably lower than the growth achieved in 2011 and 2012. Growth has, however, been broad-based, driven largely by service-oriented sectors and industry, which on average have been growing at an accelerated rate. Over the medium term to 2015, the Outlook expects that the economy will register a robust growth of around 8%, bolstered by improved oil and gas production, increased private-sector investment, improved public infrastructure development and sustained political stability. The World Bank forecasts real GDP growth of 4.5% in 2015, 5.5% in 2016 and 6% in 2017. IMF forecasts real GDP growth for Ghana of 3.5% in 2015, 6.4% in 2016 and 4.3% by 2020. Based on all those inputs, we developed Base Case and High and Low GDP Growth rate assumptions that are presented in the scenario inputs Section 3.3.6.

### 3.3.3 Population and Number of Customers

#### *3.3.3.1 Historical Values*

In 1989 the Ministry of Energy instituted the National Electrification Scheme (NES) as the Government's principal policy to extend electricity to all parts of the country over a 30-year period from 1990-2020. Almost 1,400 communities were connected to the national grid in 2013, bringing the total number of communities connected nationally to 6,857, covering a population of about 19 million. National electrification access was estimated at around 75% as of December 2013. All regional and district capitals are now connected to the national grid. The 80,000 remaining communities which are not connected to the grid are largely small settlements with an average population of about 100. Over 1,000 communities have been earmarked for electrification in 2014.

Historical population and number of households are presented in Table 3-20. The data is based on census data from 2000 and 2010, interpolations, and recent estimates. During the last 14 years Ghana's population increased by an average rate of 2.8%.

Table 3-20: Historical Population and Number of Customers (million)[9]

| Year | Population (million) | Number of Households (million) |
|---|---|---|
| 2000 | 18.41 | 3.70 |
| 2001 | 18.96 | 3.88 |
| 2002 | 19.52 | 4.05 |
| 2003 | 20.10 | 4.23 |
| 2004 | 20.69 | 4.41 |
| 2005 | 21.31 | 4.58 |
| 2006 | 21.94 | 4.76 |
| 2007 | 22.59 | 4.94 |
| 2008 | 23.26 | 5.11 |
| 2009 | 23.95 | 5.29 |
| 2010 | 24.66 | 5.47 |
| 2011 | 25.24 | 5.61 |
| 2012 | 25.82 | 5.76 |
| 2013 | 26.43 | 5.91 |
| 2014 | 27.04 | 6.06 |

Sources: 2010 Population & Housing Census National Analytical Report, Ghana Statistical Service May, 2013, Population Projection, 2010 to 2014, National, www.statsghana.gov.gh

Historical data for the number of ECG and NEDCo SLT Customers, Non-residential and Residential customers is presented in Table 3-21.

Table 3-21: Historical Number of Customers[10]

| Year | NEDCo | | | ECG | | |
|---|---|---|---|---|---|---|
| | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers |
| 2000 | 27 | 18,099 | 97,147 | 768 | 155,146 | 661,411 |
| 2001 | 28 | 20,122 | 108,817 | 800 | 169,685 | 723,395 |
| 2002 | 28 | 21,606 | 118,049 | 827 | 184,081 | 784,766 |
| 2003 | 27 | 23,049 | 129,395 | 853 | 207,602 | 885,039 |

[9] Population and number of households are obtained from Ghana Statistical Services.

[10] Population is obtained from Ghana Statistical Services and the number of customers from ECG analysis inputs. Ghana population is estimated to increase at 2.6% per year over the next 10-year period. Consistent with other in-country forecasts, this input was not found to have good correlation with electricity demand and was not used in the subsequent demand forecasting.

| | | | | | | |
|---|---|---|---|---|---|---|
| 2004 | 23 | 32,550 | 141,573 | 879 | 220,790 | 1,004,443 |
| 2005 | 34 | 32,181 | 170,543 | 930 | 240,261 | 1,082,787 |
| 2006 | 29 | 37,433 | 192,665 | 987 | 258,270 | 1,154,402 |
| 2007 | 31 | 41,601 | 206,655 | 1,024 | 286,900 | 1,257,024 |
| 2008 | 31 | 47,266 | 231,175 | 1,126 | 318,578 | 1,403,232 |
| 2009 | 35 | 53,446 | 268,177 | 1,198 | 360,188 | 1,602,572 |
| 2010 | 41 | 60,461 | 281,705 | 1,328 | 393,969 | 1,725,267 |
| 2011 | 40 | 68,562 | 323,778 | 1,441 | 436,885 | 1,897,960 |
| 2012 | 41 | 77,989 | 405,665 | 1,606 | 436,503 | 2,141,473 |
| 2013 | 49 | 90,516 | 464,821 | 1,833 | 455,209 | 2,154,965 |
| 2014 | 54 | 104,110 | 508,824 | 1,980 | 675,670 | 2,281,089 |

Source: Reconciled data received from the Energy Commission of Ghana, December 2015

Consistent with Ghana Government electrification efforts, the total number of ECG and NEDCo customers in all categories significantly increased over the last 15 years. Growth rates for the entire period and for the last 3 years are presented in Table 3-22. Historical growth rates for customer categories are used as references in developing future growth rate assumptions presented in Section 3.3.6. Growth rates for the last 3 years show comparable or higher short-term growth rates in all categories for all but for the number of ECG residential customers.

Table 3-22: Historical Number of Customers Growth Rates

| Period | NEDCo | | | ECG | | |
|---|---|---|---|---|---|---|
| | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers |
| 2000-2014 | 5.1% | 13.3% | 12.6% | 7.0% | 11.1% | 9.2% |
| 2011-2014 | 10.5% | 14.9% | 16.3% | 11.2% | 15.6% | 6.3% |

### *3.3.3.2 Adjusted Assumptions*

The slow growth rate for ECG residential customers is attributed to supply constraints, so we estimated the number of residential customers without load shedding in years 2013 and 2014. This estimate takes into account the impact of supply constraints and is used as starting point for future forecasting. The adjustment made to the number of ECG residential customers (e.g. increases) is presented in Table 3-23. With these increases, the 14-year growth rate would be around 10%. Since the short-term growth rates for all other customer categories are higher than the long-term growth rate, we did not see the need to adjust other customer population forecasting inputs.

Table 3-23: Adjusted Historical Number of Customers

| Year | NEDCo | | | ECG | | |
|---|---|---|---|---|---|---|
| | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers | Number of SLT Customers | Number of Non-residential Customers | Number of Residential Customers |
| 2013 | 49 | 90,516 | 464,821 | 1,833 | 455,209 | 2,339,471 |
| 2014 | 54 | 104,110 | 508,824 | 1,980 | 675,670 | 2,555,776 |

#### *3.3.3.3 Future Growth Rate Assumptions*

Future growth rate assumptions are based on historical rates and the values used in the Ghana government agency's demand forecasts. Base Case and High and Low Growth rate assumptions for each customer category are presented in the scenario input summary Section 3.3.6 below.

### 3.3.4 Electricity Pricing

#### *3.3.4.1 Historical Values*

Ghana is becoming a country with relatively high electricity prices. With the new tariff increases in early 2014, average commercial and industrial tariffs in Ghana were higher than in South Africa, Nigeria, Ethiopia, Libya, Kenya and Namibia[11]. Table 3-24 presents historical average electricity tariffs[12] for all end users in GHS/kWh and in US$/kWh. Ghana also has the highest difference between average industrial tariffs and residential tariffs[13]. The high industrial tariff is likely to curtail local production and encourage imports of finished consumer products. For comparison, in 2014 the United States had an average electricity tariff for industrial customers of around 7 USc/kWh and a residential tariff of around 12.5 USc/kWh[14].

Table 3-24: Historical Real Average Electricity Tariffs for all Customers (GHS/MWh and USc/KWh)

| Year | Average End User Tariff (GHS/MWh) | Exchange Rate (GHS/US$) | Average End User Tariff (USC/kWh) |
|---|---|---|---|
| 2000 | 17 | 0.7 | 2.4 |
| 2001 | 34 | 0.73 | 4.7 |
| 2002 | 65 | 0.84 | 7.7 |
| 2003 | 71 | 0.88 | 8.0 |
| 2004 | 74 | 0.9 | 8.2 |

[11] From the Energy Commission 2014 Energy Outlook.

[12] From the Energy Commission National Energy Statistics. The most recent December 2015 tariff revision was not included in the analysis, as future tariff increases are included in the 2015-2030 forecasting assumptions.

[13] World Energy Outlook Special Report: Africa Energy Outlook, page 66

[14] IAE: 2015 Key World Energy Statistics

| | | | |
|---|---|---|---|
| 2005 | 73 | 0.91 | 8.0 |
| 2006 | 78 | 0.92 | 8.4 |
| 2007 | 97 | 0.97 | 10.0 |
| 2008 | 148 | 1.2 | 12.3 |
| 2009 | 148 | 1.43 | 10.4 |
| 2010 | 211 | 1.45 | 14.5 |
| 2011 | 245 | 1.55 | 15.8 |
| 2012 | 232 | 1.88 | 12.4 |
| 2013 | 307 | 1.97 | 15.6 |
| 2014 | 464 | 3.20 | 14.5 |

Sources: The Energy Commission of Ghana National Energy Statistics, 2000-2013 October, 2014: The Energy Commission of Ghana National Energy Statistics, 2005-2014, April, 2015.

Household incomes have risen significantly since the 1990s. Recent trends show per capita GDP[15] of 1,305 US$ in 2010 (1,867 Gh¢) with an increase to 1,613 US$ in 2012 (2,916 Gh¢). It has since declined to 1,427 US$ in 2014 (4,195 Gh¢). Increased income will tend to increase acquisition of household appliances and a lead to a shift to cleaner fuels such as electricity. Lower residential tariffs also explain part of the increase in electricity consumption and the corresponding increase of the residential sector in spite of the general increase in electricity tariffs and recent declines in per capita income. Higher income also means that large commercial customers and affluent residential customers are likely to compensate for power deficits during load shedding periods with private generators. Table 3-25 presents historical average electricity tariffs for SLT and NSLT customers in GHS/MWh. Since values in this table are converted to nominal 2006 values, the 2006 tariff for ECG customers at 78 GHS/MWh is about the same as the average real tariff for the current year.

Table 3-25: Historical Nominal 2006 Average Electricity Tariffs for ECG SLT and NSLT Customers (GHS/MWh)

| Year | SLT Customers | NSLT Customers |
|---|---|---|
| 2000 | 58.94 | 64.92 |
| 2001 | 74.37 | 90.09 |
| 2002 | 97.90 | 111.76 |
| 2003 | 112.07 | 108.27 |
| 2004 | 103.03 | 95.18 |
| 2005 | 89.87 | 84.71 |
| 2006 | 78.72 | 77.35 |
| 2007 | 87.74 | 86.85 |

[15] GDP per capita in current US$

| | | |
|---|---|---|
| 2008 | 120.27 | 118.16 |
| 2009 | 101.71 | 94.17 |
| 2010 | 119.19 | 148.48 |
| 2011 | 126.91 | 153.39 |
| 2012 | 118.81 | 142.09 |
| 2013 | 134.10 | 154.20 |
| 2014 | 161.15 | 218.09 |

Source: 2014 ECG Energy Forecasting Report, November 2014

#### *3.3.4.2 Future Growth Rate Assumptions*

Future growth rate assumptions are based on historical rates, values used in the ECG demand forecasts, and our judgment based on the current relatively high tariff levels. The Base Case as well as the High and Low Growth rate assumptions are presented in the scenario input Section 3.3.6 below. The future growth rate assumptions also reflect the Income and Technology barriers that affect electricity demand.

### 3.3.5 Derived Indices

#### *3.3.5.1 Historical Values*

Table 3-26 presents indices derived from the historical data considered as potential inputs used for forecasting, including:

- Total Electricity Consumed/ GDP (kWh/ US$ 2006) - calculated as the ratio of Total Electricity Consumed over GDP (at basic prices)
- Average Household Size - calculated as the ratio of Total Population over Number of Households
- Per Capita Consumption (KWh/capita) - calculated as the ratio of Total Electricity Consumed over Total Population
- Per Capita Residential Consumption (KWh/capita) - calculated as the ratio of Residential Consumption over Total Population
- Per Capita Income (2006 US$/capita) - calculated as the ratio of GDP (at basic prices) over Total Population

Derived indices are typically ratios developed from historical data that may provide additional insight into electricity consumption. Those inputs could then be used as independent variables for forecasting as substitutes for one or more original inputs, for example, Per Capita Income reflecting both GDP and population.

Table 3-26: Historical Derived Indices

| Year | Total Electricity Consumed/ GDP (kWh/US$ 2006) | Average Household Size | Per Capita Consumption (kWh/capita) | Per Capita Residential Consumption (kWh/capita) | Per Capita Income (2006 US$) |
|---|---|---|---|---|---|
| 2000 | 485 | 4.97 | 344 | 80 | 709 |
| 2001 | 480 | 4.89 | 344 | 84 | 718 |

| | | | | | |
|---|---|---|---|---|---|
| 2002 | 434 | 4.81 | 316 | 84 | 729 |
| 2003 | 304 | 4.75 | 227 | 84 | 745 |
| 2004 | 290 | 4.69 | 222 | 87 | 764 |
| 2005 | 310 | 4.65 | 244 | 89 | 785 |
| 2006 | 366 | 4.61 | 297 | 92 | 812 |
| 2007 | 300 | 4.58 | 247 | 88 | 824 |
| 2008 | 302 | 4.55 | 264 | 93 | 875 |
| 2009 | 303 | 4.53 | 263 | 95 | 868 |
| 2010 | 307 | 4.51 | 279 | 101 | 909 |
| 2011 | 310 | 4.50 | 314 | 100 | 1013 |
| 2012 | 318 | 4.49 | 344 | 109 | 1082 |
| 2013 | 316 | 4.47 | 358 | 116 | 1135 |
| 2014 | 305 | 4.46 | 352 | 103 | 1156 |

Growth rates for all indices over the entire 14 year period and for the last 3 years are presented in Table 3-27.

We analyzed historical values and growth rates to assess the derived indices that should be used as potential inputs for forecasting. Average Household Size and Per Capita Income are both good potential inputs for forecasting. However, total Electricity Consumed per GDP and Per Capita Consumption indices are distorted by VALCO operations and thus are less useful. Per Capita Residential Consumption shows a sharp increase during the supply constrained years and seemed to be distorted by the rapid electrification rate. Based on this assessment, we decided not to include three remaining indices as forecasting inputs.

Table 3-27: Historical Derived Indices Growth Rates

| Period | Total Electricity Consumed/ GDP (kWh/US$ 2006) | Average Household Size | Per Capita Consumption (kWh/capita) | Per Capita Residential Consumption (kWh/capita) | Per Capita Income (2006 US$) |
|---|---|---|---|---|---|
| 2000-2014 | -3.3% | -1.0% | 0.2% | 1.8% | 3.5% |
| 2011-2014 | -0.5% | -0.3% | 3.9% | 0.8% | 4.5% |

Table 3-28 presents electricity intensity indices including:

- Intensity of Non-Residential Electricity Consumption (kWh/US$ 2006 of GDP Services) - calculated as the ratio of Non-Residential electricity consumption over GDP in the Services sector
- Intensity of Industrial Electricity Consumption (kWh/US$ 2006 of GDP Industrial) - calculated as the ratio of Industrial electricity consumption over GDP in the Industrial sector

Table 3-28: Historical Electricity Intensity Indices

| Year | Intensity of Non-Residential El. Consumption (kWh/US$ 2006 of GDP Services) | Intensity of Industrial El. Consumption (kWh/US$ 2006 of GDP Industrial) |
|---|---|---|
| 2000 | 88 | 1610 |
| 2001 | 88 | 1553 |
| 2002 | 88 | 1335 |
| 2003 | 86 | 720 |
| 2004 | 88 | 649 |
| 2005 | 84 | 743 |
| 2006 | 91 | 970 |
| 2007 | 86 | 684 |
| 2008 | 87 | 655 |
| 2009 | 93 | 625 |
| 2010 | 88 | 628 |
| 2011 | 101 | 545 |
| 2012 | 116 | 523 |
| 2013 | 106 | 523 |
| 2014 | 101 | 532 |

Growth rates for all indices the entire 14 year period and for the last 3 years are presented in Table 3-29.

Table 3-29: Historical Electricity Intensity Indices Growth Rates

| Period | Intensity of Non-Residential El. Consumption (kWh/US$ 2006 of GDP Services) | Intensity of Industrial El. Consumption (kWh/US$ 2006 of GDP Industrial) |
|---|---|---|
| 2000-2014 | 1.0% | -7.6% |
| 2011-2014 | 0.3% | -0.8% |

We reviewed inputs for the two intensity indices to see if those should be used for forecasting. Intensity of Industrial Electricity Consumption also shows distortion by VALCO operations. Intensity of Non-Residential Electricity Consumption shows a sharp increase in 2011 and a minimal growth rate for the rest of the historical period. Based on this assessment, we did not include intensity inputs in our forecasting.

### 3.3.6 Scenario Inputs

Tables 3-30 to 3-32 present Base Case, High and Low Growth scenario assumptions for all input parameters over the 16-year forecasting period. Different growth rate assumptions are

presented for the near term 2015–2018 period (four years), for the mid-term 2019-2024 (six years) and for the long-term 2025-2030 period (six years). Lower percentage growth assumptions used for long-term demand forecasting take into account growth rates associated with a more mature and larger power sector. These growth rates reflect the impacts of the Income and Technologies barriers that affect electricity demand.

GDP scenario inputs assume higher growth rates for the Industrial and Services sectors than for the total GDP. Assumptions are consistent with the historical trend and the larger role those two sectors have on economic growth. Based on inputs for the Industrial and Services sectors, the growth rate for the Agriculture sector is calculated. Growth rates presented in the scenario tables were selected to produce a realistic (e.g. lower) growth rate for the Agriculture sector, which is also in line with the historical trend.

Table 3-30: Scenario Growth Rate Assumptions for Total GDP

| Period | Low GDP Growth Rate (%) | Base GDP Growth Rate (%) | High GDP Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 6.8% | 7.2% | 8.2% |
| 2019-2024 | 5.8% | 6.2% | 7.5% |
| 2025-2030 | 5.0% | 5.5% | 7.2% |

Table 3-31: Scenario Growth Rate Assumptions for Industrial GDP

| Period | Low GDP Growth Rate (%) | Base GDP Growth Rate (%) | High GDP Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 7.5% | 7.8% | 8.5% |
| 2019-2024 | 6.5% | 7.0% | 8.0% |
| 2025-2030 | 5.8% | 6.2% | 7.5% |

Table 3-32: Scenario Growth Rate Assumptions for Services GDP

| Period | Low GDP Growth Rate (%) | Base GDP Growth Rate (%) | High GDP Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 7.5% | 7.8% | 9.0% |
| 2019-2024 | 6.5% | 7.0% | 8.5% |
| 2025-2030 | 5.8% | 6.2% | 8.0% |

Electricity Price growth rate assumptions, presented in Table 3-33, are lower than the historical trend. The assumptions take into account that the prices are already at relatively high levels. In addition, the Low GDP Growth scenario is linked with the High Price increase assumption because high prices will tend to lower GDP growth and vice versa.

Table 3-33: Electricity Price Growth Rate Scenario Assumptions

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 4.0% | 6.0% | 8.0% |
| 2019-2024 | 2.0% | 4.0% | 6.0% |
| 2025-2030 | 1.0% | 2.0% | 4.0% |

Population growth rate assumptions presented in Table 3-34 are consistent with historical trends and the most recent estimates. The Low GDP Growth scenario uses the High Population increase assumptions. This assumption reflects the trend that higher incomes are associated with the decreased population growth rates.

Table 3-34: Total Population Growth Rate Scenario Assumptions

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 1.9% | 2.3% | 2.6% |
| 2019-2024 | 1.9% | 2.3% | 2.6% |
| 2025-2030 | 1.9% | 2.3% | 2.6% |

Growth rates for the number of customers for Residential, Non-residential and SLT customer classes, presented in Tables 3-25 to 3-27, are selected to be consistent with the historical trend.

Table 3-35: Scenario Assumptions for the Number of Residential Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 6.0% | 8.0% | 10.0% |
| 2019-2024 | 5.0% | 6.0% | 7.0% |
| 2025-2030 | 4.0% | 4.5% | 5.0% |

Both mid-term and long-term growth rates for the number of residential customers take into account total number of households (e.g. electrification rate) that could be connected in the future. Our growth rate assumptions for residential customers represent reduced growth rates compared with the growth rates for residential customers assumed in the ECG 2014 forecast. Revised assumptions are based on the difference between the total number of customers in 2014 (around 2.8 million) and the total number of households in Ghana (around 6 million) in Tables 3-20 and 3-21. Based on the current electrification rate in Ghana, a majority of residential customers will be connected over the next 10years and thus longer term growth rates will significantly decrease, reflecting the connections of new residential customers that result from the combined effects of population increases and the reduction in average household size.

Table 3-36: Scenario Assumptions for the Number of Non-residential Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 8.0% | 10.0% | 12.0% |
| 2019-2024 | 7.0% | 8.0% | 10.0% |
| 2025-2030 | 6.0% | 7.0% | 9.0% |

Table 3-37: Scenario Assumptions for the Number ECG and NEDCo SLT Customers

| Period | Low Growth Rate (%) | Base Growth Rate (%) | High Growth Rate (%) |
|---|---|---|---|
| 2015-2018 | 8.0% | 10.0% | 12.0% |
| 2019-2024 | 7.0% | 8.0% | 10.0% |
| 2025-2030 | 6.0% | 7.0% | 9.0% |

Our growth rate assumptions for non-residential and SLT customers are consistent with the growth rates assumed in the ECG 2014 forecast, including the reduced rate for the final 5 year period.

### 3.3.7 Coincident Peak Load Assumptions

Table 3-38 lists assumptions for the future Coincident Load Factors (CLFs). Ghana Load at Peak includes maximum demand for Ghana including ECG, NEDCo, and Direct Customers of VRA and Mines (e.g. excluding VALCO and Exports).

Table 3-38: Assumptions for the Future Coincident Factors

| Period | Ghana Load at Peak (%) | VALCO (%) | Exports (%) |
|---|---|---|---|
| 2015-2030 | 72.1% | 95.1% | 75.0% |

We used historical information and the most recent 2014 value to estimate the future load factor for domestic customers. Future coincident peak load factors for VALCO and Exports, used to develop system peak load forecast, are based on EC and GRIDCo assumptions. Both the Energy Commission and GRIDCo forecasts estimate that the system load factor will remain constant over the next 12-15 years. We agree with this estimate, based on our assumption that the increase in load factor resulting from increases in VALCO and mining consumption (both having high load factors) will be compensated with a decrease in load factor that is the result of increased consumption in the residential and non-residential sectors.

### 3.3.8 Exogenous Government Forecasts

For Mining, VALCO and Exports we used exogenous consensus forecasts developed by Ghana entities. The key assumptions are presented below. Tables showing detailed year-by-year forecasts in GWh are presented in Section 5 as inputs for developing total system forecasts for all customer categories.

#### *3.3.8.1 Mining Sector Assumptions*

Ghana is a major gold producer and exporter, and the gold sector continues to attract new investments. The country is also rich in other natural resources including diamonds, manganese ore, limestone, silica sand, and bauxite. The mining industry has grown steadily over the years, reflecting increased gold prices during the last 10 year period. Future gold and other commodity pricing will clearly impact demand in the mines sector.

Forecast for the Mines sector was based on VRA and GRIDCo estimates. VRA total demand for the mining sector in year 2030 is similar to the GRIDCo total demand estimated in year 2025.

The only difference is that VRA used more conservative assumptions regarding mine opening or expansion and forecasted similar sector demand 5 year later. The estimates are based on information VRA and GRIDCo gathered by interviewing major mining companies and the Minerals Commission. The Minerals Commission also provided information on new mines that have obtained permits to operate and are likely to commence operation during the forecasting period.

The demand forecast is based on: the expected output of existing mines including anticipated expansion plans, and mines currently being planned; the possibility of new mines opening further into the future; the availability of suitable ore deposits, the world market price of gold and the investment programs by the individual mines and the relationship between mine production and electricity consumption.

#### *3.3.8.2 VALCO Assumptions*

Both the EC and GRIDCo forecasts show a similar forecast for the number of VALCO pot-lines in operation in future years. That number is based on the projected number of electricity generation plants expected to come on line from 2016 onwards. VALCO is assumed to reach full operating capacity during the 2019/2020 period.

In developing our forecast we assumed that VALCO can operate two pot-lines starting in 2016, 3 pot-lines in 2018, and 5 pot-lines in 2019 and onwards.

#### *3.3.8.3 Export Assumptions*

Exports are dependent on the supply conditions in Ghana and the availability of capacity to provide the contractually specified export amounts. Both the EC and GRIDCo forecasts show that the consensus export forecasts assume supply will return to normal levels by 2016/2017 and show increases in exports from the existing 600 GWh/year level to over 3,000 GWh/year by 2019.

# Section 4 SUPPRESSED DEMAND ANALYSIS

## 4.1 SUPPRESSED DEMAND COMPONENTS

The objective of the suppressed demand analysis was to develop unconstrained demand for the 2012 -2014 period (e.g. the years demand was impacted by load shedding) to be used as a starting point for future demand forecasting. We define unconstrained demand as the demand consisting of the actual historical demand in 2014 and the suppressed demand that would have been consumed in 2014 if adequate generation supply was available and most of the network constraints were lifted from the system. Consequently our analysis addresses two key suppressed demand components impacting current demand:

i. *Supply Constraint*: Exists because electricity supplied in a power grid is inadequate to meet the demand

ii. *Infrastructure Barrier:* Exists because of inadequate delivery infrastructure. Examples include inadequate transmission and distribution networks

The remaining two components include:

iii. *Income Barrier:* In low income countries resources are allocated according to the priority allotted to basic human needs

iv. *Technology Barrier:* Due to high initial cost or lack of capacity to absorb the technology

The long term impacts of the Income and Technology barriers are incorporated into the long-term growth rates assumptions for GDP, population, number of customers and electricity prices that directly affect electricity consumption. Those components impact future demand and are addressed in developing the load forecast for the next 16-year period.

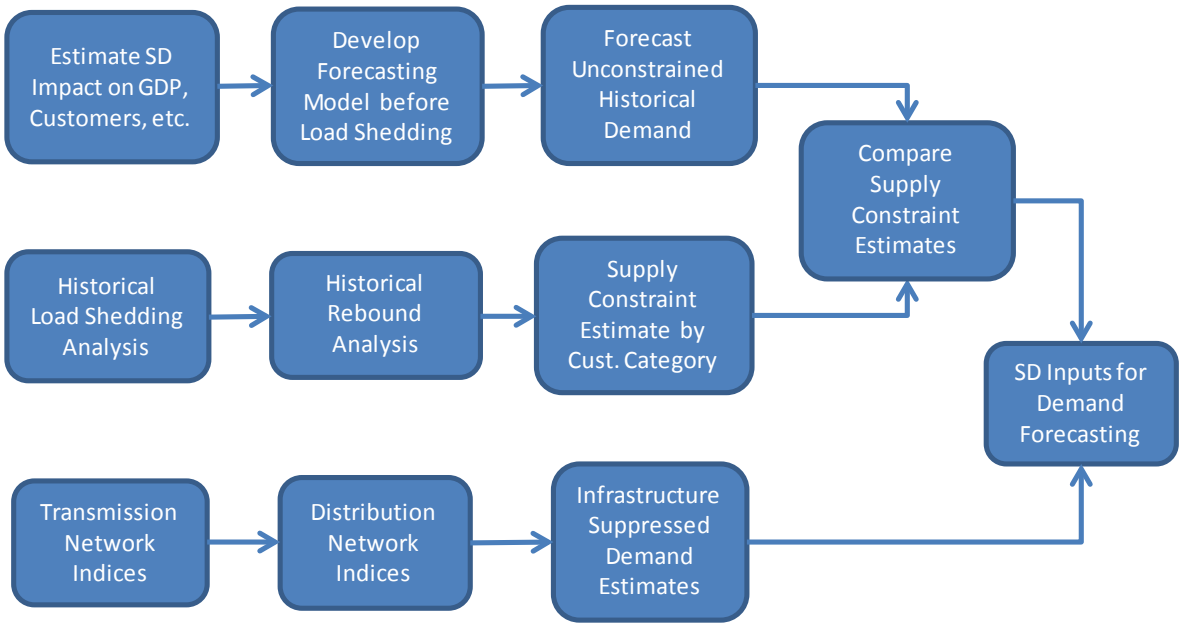
## 4.2 ANALYSIS

### 4.2.1 Approach

Figure 4-1 presents a chart describing the steps used in estimating the Supply Constraint and Infrastructure Barrier components of Suppressed Demand.

The process for estimating both components directly from historical data is described in more detail below. As an additional check and validation of the estimates the direct supply constraint estimates are compared with the results of forecasts done for the historical 2012-2014 period demand, conducted using historical inputs from 2000- 2011, with the 2012-2014 period inputs revised (GDP and number of customers) to account for the Suppressed Demand impacts.

Figure 4-1: Approach for Estimating Suppressed Demand Components




After the direct Supply Constraint component estimate is compared and validated against the forecast estimate, it is used as a starting point for forecasting future demand. Because the Infrastructure component estimate could only be validated by direct system measurements (which were not available), we used sensitivity analysis to assess the impact that the Infrastructure component estimate has on the total system demand.

### 4.2.2 Estimating Supply Constraint Component

Historical system operations data provides the most reliable insight into the supply constraint component of the suppressed demand. For our analysis, we used system operations data received from GRIDCo and ECG to estimate the two key impacts that supply constraints have on electricity demand: the requested amount of load shedding and the rebound effect. Load shedding requests show the full amount of load reduction asked to be provided by each entity. Daly requests are developed by GRIDCo and are called load relief requests. Rebound effect analysis shows how much of the load reduction amount was made-up by customers in the period prior and after the load shedding periods.

In general terms, the rebound effect (or take-back effect) is used to describe the extent of the energy savings related to energy efficiency increase. In our analysis we refer to the rebound as the amount of electricity consumption that is made-up before or after the scheduled load shedding period. Typical rebound consumption would be consumption by refrigerators that will tend to increase after the load shedding. Rebound consumption would include electricity used for cooking or ironing, activities that will tend to be advanced or postponed due the load shedding. Rebound effect analysis was also used to estimate demand made up from self-generation.

#### 4.2.2.1 Load Shedding Analysis

The critical first step was to analyze load shedding request data received from GRIDCo for the last three years (2012 to 2014 period). GRIDCo provided daily operations reports listing load relief (e.g. load shedding) requested from ECG, NEDCo, VALCO and few large customers. GRIDCo's load shedding request data was compiled only for the customers connected to the system. The data does not include consumption for electricity users who rely on self-generation and are either disconnected from the grid or were never connected to the grid. In order to use this information we had to extract ECG and NEDCo values from all daily files (after conversion of individual daily requests in PDF format to Excel and development of a Visual Basic program in Excel to automatically extract the data), then tabulate and add all data for each entity to arrive to the total annual values. In response to our data request, we also received daily load shedding quotas applied by ECG for 2014. Daily quotas were the amount of load shedding requested by GRIDCo from ECG customers. We compiled all daily ECG information to arrive at the total year 2014 requested load relief (e.g. shedding) value. Table 4-1 presents ECG and NEDCo load shedding values for the last three years. Table 4-1 also shows that the two independent values for 2014 obtained from GRIDCo (1,172 GWh) and ECG (1,230 GWh) are very close. Comparison of the same 2014 ECG and GRIDCo values was used to verify the GRIDCo data analysis for other customers and periods.

Table 4-1: GRIDCo Load Relief Requests for the 2012-2014 Period (GWh)

| | 2012 | 2013 | 2014 |
|---|---|---|---|
| ECG | 150.0 | 343.0 | 1,172 (1,230) |
| NEDCo | 5.0 | 13.3 | 50.8 |

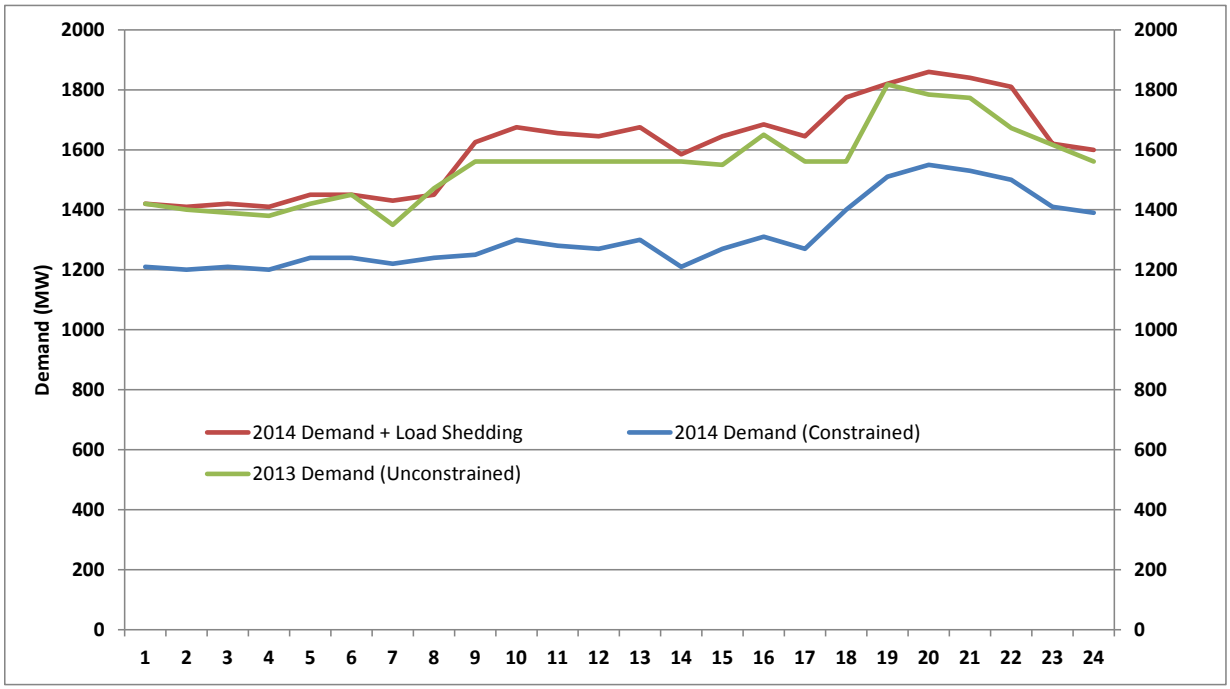
Table 4-1 clearly shows an increase in load shedding over the last three-year period, with the significant increase in 2014 primarily impacting ECG customers. Load relief was also requested from a few mining companies, but the total amounts were not greater than 1 GWh.

#### 4.2.2.2 Rebound Analysis

Rebound effect is an increase in customer demand in anticipation of the scheduled load shedding. This demand is an increase from the 'regular' demand schedule before and after the load shedding to make up for the time when electricity is not available. An example of the rebound effect is the increase in refrigeration demand after the load shedding.

The amount of rebound demand was estimated by comparing hourly demand curves for a number of representative days in different seasons in 2013 and 2014. Representative days were selected to include days with no load shedding in 2013 and with load shedding in 2014. Daily demand curves were read from GRIDCo Daily Reports. Daily Reports contain information regarding the actual demand and the requests for load relief. To be selected for the comparison analysis, representative days in 2013 had to have no load relief while the same day and week in 2014 had to include significant load relief requests. In order to make this comparison accurate and comparable, demand in 2013 had to be increased by the estimated growth in demand between years 2013 and 2014. To illustrate the approach, Figure 4-2 show sample comparisons for one day in December. All days included in the analysis are presented in Section 9.

Figure 4-2: Daily Demand Comparison for the First Monday in December




Analysis of the rebound effect is represented by three daily demand curves. The 2013 Unconstrained Demand line shows the hourly unconstrained demand in 2013 increased by the anticipated load growth of 11.5% between 2013 and 2014. This line represents the most likely unconstrained demand for the same day in 2014. Due to the load shedding in 2014, actual demand shown in the 2014 constrained demand line demonstrates that the constrained demand was significantly lower. By adding the load shedding hourly requests to the constrained demand we developed total anticipated demand for the day. The line shows that the total 2014 demand including load shedding is higher than the anticipated demand. The amount by which the demand is higher is used to estimate the rebound effect, e.g. rebound effect is the difference between the two load profiles. Sample daily analyses show the rebound effect to vary between 3% and 37% of the load relief requests. The wide range of outcomes is the result of year to year comparisons that included different load conditions in similar days over the two year period[16]. The average rebound value for all sample days is calculated as 23.4%. Consequently, the load shedding amounts, as developed in Section 4.2.1.1, were reduced by 23.4% to account for the rebound effect.

#### *4.2.2.3 Supply Constraint Results*

Based on the load shedding and the rebound analysis results, actual demand was increased to account for load shedding. Demand for each customer category is increased proportionally to historical demand from 2012-2014. Table 4-2 presents the revised total amounts and the

[16] More accurate comparisons are done using two similar days in the same week or month. This comparison could not be done as load shedding in 2014 occurred on a daily basis.

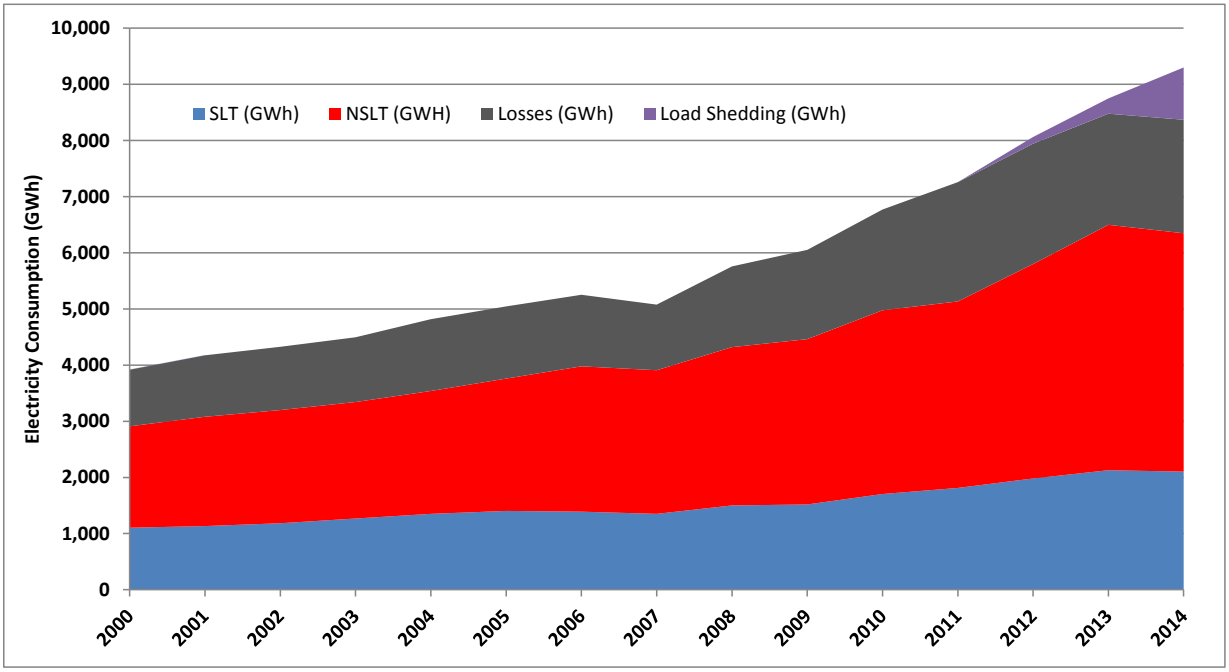
amounts added in each category. The total added demand is less than the amount of load shedding to account for both the rebound effect and into order to account for the loss impact (e.g. increase in sales would also increase system losses).

Table 4-2: Historical Sales Data Corrected for the Load Shedding with Increases (GWh)

| Year | Residential | Non-Residential | SLT (ECG & NEDCo) |
|---|---|---|---|
| 2012 | 2,859 (+40) | 1,571 (+22) | 2,065 (+29) |
| 2013 | 3,154 (+94) | 1,580 (+48) | 2,312 (+67) |
| 2014 | 3,075 (+302) | 1,700 (+171) | 2,449 (+228) |

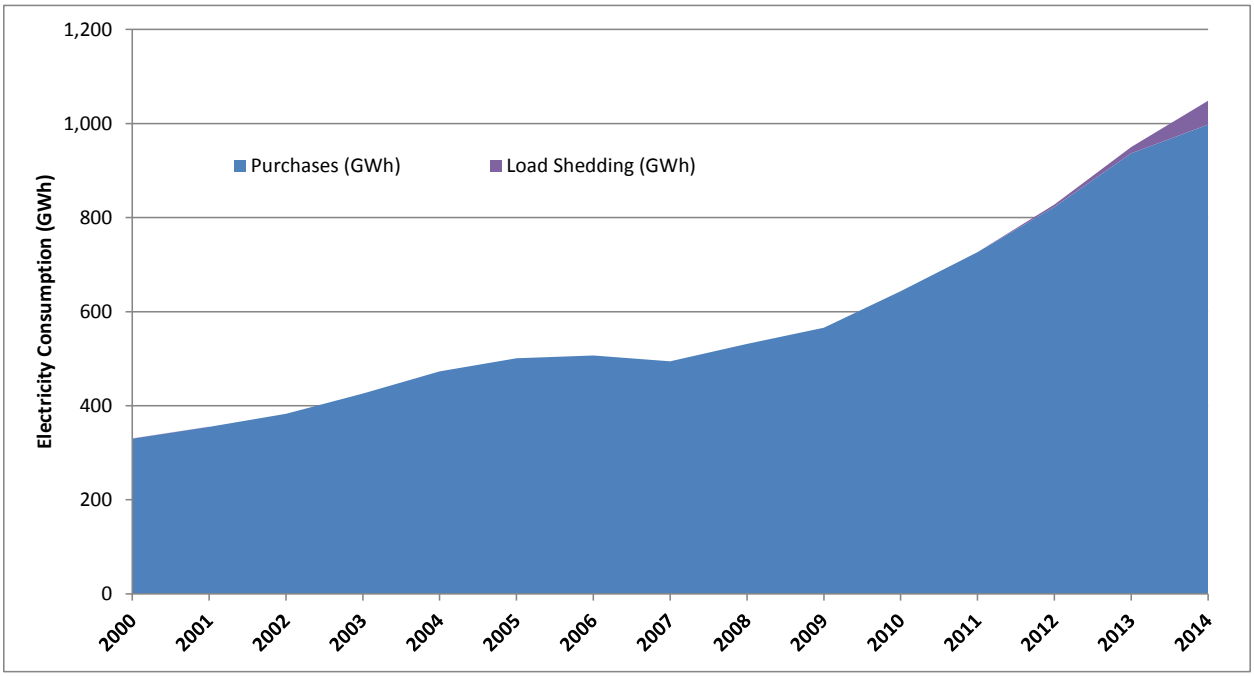
These increased sales are used as the starting point for forecasting future demand. In addition, we show the impact load shedding would have on the actual demand recorded for ECG and NEDCo. Figures 4-3 and 4-4 show the estimated ECG and NEDCo demand including the combined effect of load shedding and the rebound effect. These figures are developed for illustrative purpose[17] to clearly show the impact that supply constraints had on demand and the steady increase in total demand that would have been experienced if the system did not have any supply constraints during the 2012-2014 period.

Figure 4-3: ECG Historical Demand including Load Shedding and Rebound Effect (GWh)




[17] Since our forecast was developed for Residential, Non-Residential, SLT categories, adjusted values from Table 4-2 were used for forecasting analysis.

Figure 4-4: NEDCo Historical Demand including Load Shedding and Rebound Effect (GWh)




## 4.2.3 Distribution Loss Impact and Future Assumptions

To establish an accurate starting point for future demand forecasting, the analysis also accounts for the actual losses in 2014, e.g. for the fact that losses did not improve in 2014 as planned. Since losses in 2014 remained at a similar 24% level of the total demand, we used the actual loss value and increased the losses that would have been recorded on the unconstrained demand in 2014 by approximately 197 GWh.

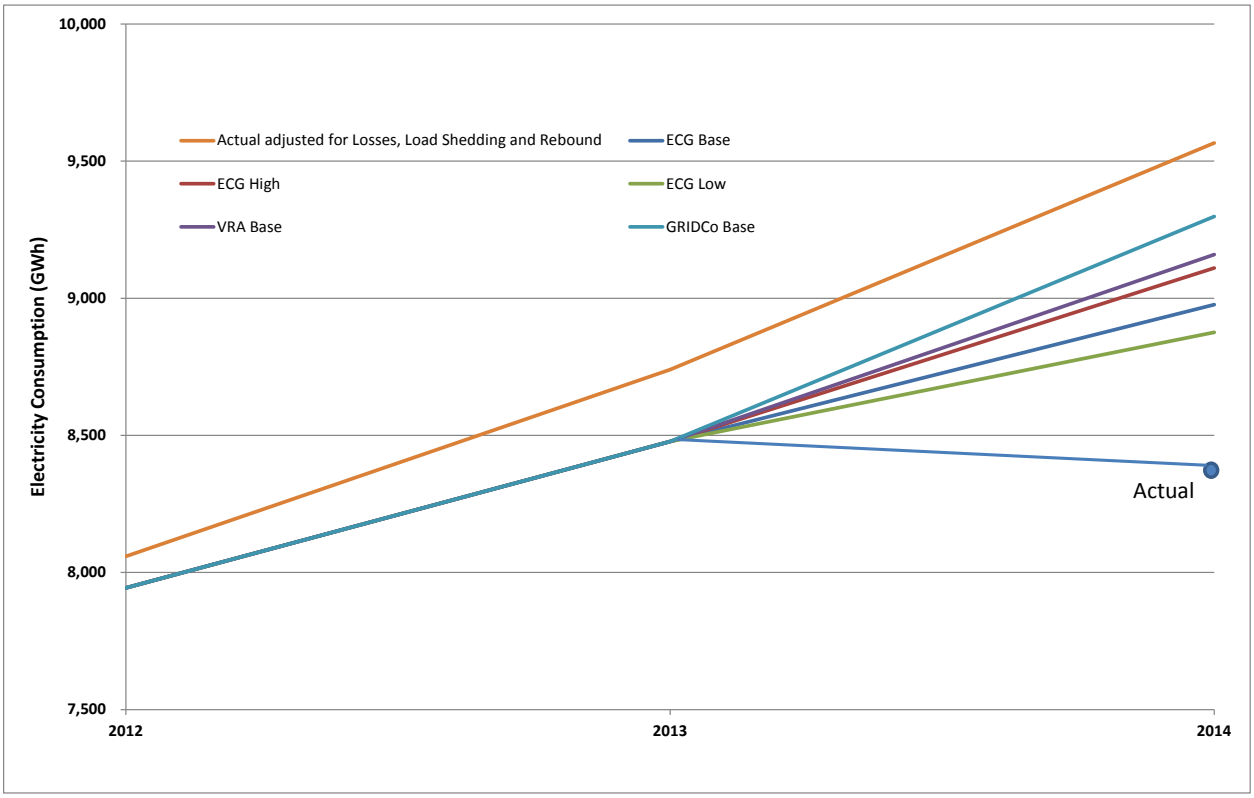
Going forward, we assumed loss reduction to be in line with ECG's ongoing loss reduction strategy, only delayed for one year. This is consistent with the ECG forecast for the period 2014–2023 that includes a component of the savings from the Commercial Loss Reduction program being undertaken by ECG Management. Current losses of around 2,000 GWh (between 23%-24% of total electricity purchases) are planned to be reduced to just over 13% by 2023. Assuming similar loss reduction in the NEDCo system, this goal implies that almost half, or about 1,000 GWh, of existing losses should be added to future sales over the next nine year period. We assumed a prorated impact, so that each year will see an increase in demand by 103 GWh e.g. the amount of commercial losses assumed to be converted to actual sales.

### *4.2.3.1 Combined ECG Results*

Figure 4-5 presents in more detail the 2012-2014 period of actual and adjusted ECG demand, as well as the starting values and trajectories for the most recent ECG demand forecasts for 2014. The top (yellow) line shows the combined impact and adjusted demand including load shedding, rebound effect and loss impact as estimated by Nexant. The figure clearly shows that the actual ECG demand for 2014 was lower than any of the forecasted values and also demonstrates that the starting point for forecasting 2015 demand must be adjusted to include supply constraint impacts. In addition, Figure 4-5 also shows that all the ECG, VRA and

GRIDCo forecasts for 2014 start with the actual demand for 2013 and are not adjusted to account for supply constraints in 2013. The GRIDCo forecasting analysis seems to be compensating for the load shedding in 2013 by increasing the anticipated growth rate in 2014, as seen by the steeper slope of the GRIDCo forecast between 2013 and 2014.

Figure 4-5: ECG Actual and Revised Demand and Forecasting Trajectories (GWh)




As presented in the flowchart diagram of our methodology and approach in Figure 4-1, the results of this direct suppressed demand analysis are next compared with the results of regression model forecasts that are specified for the 2012-2014 period using historical 2000-2011 data and using revised 2012-2014 data to account for the Suppressed Demand impacts (e.g.. adjustments in GDP and number of customers.) After the direct suppressed demand estimates are compared and validated against the forecasted estimates, the revised 2012-2014 data are used as a starting basis for forecasting future demand, as described in Section 5.

## 4.2.4 Estimating Infrastructure Barrier Component

The best information with which to estimate the Infrastructure Barrier Component of the suppressed demand was to start with the transformer loading and system reliability indices of transmission and distribution networks received from GRIDCo and ECG.

### *4.2.4.1 Adequacy of Transmission Network*

As GRIDCo noted, their major challenge in providing security and reliability on the transmission network are inadequate transmission line capacity which could lead to transmission line overloads. Of course, overloads are mostly observed during the peak period and are due to the

growth in demand which had not been accompanied by expansion or reinforcement of the transmission network. In addition, other transmission network issues include:

- Insufficient reactive power compensation which could lead to inadequate customer supply voltage. This condition is due to low customer-end power factors, leading to high generator reactive power outputs and transfer of reactive power over long distances. This increases transmission line losses and voltage drops which impacts the quality of supply.
- Inability of the transmission network to withstand some single contingencies. This is a measure of a transmission network's ability to withstand an outage of a single network element and a result of deferred investment in the transmission network (e.g. network does not satisfy standard N-1 criterion). Presently, a significant percentage of the transmission network is radial, and a contingency on any of these radial lines results in outages and load shedding.

Table 4-3: GRIDCo Transmission Line Availability Indices for the 2011-2014 Period

| Year | 2011 | 2012 | 2013 | 2014 |
|---|---|---|---|---|
| Average Availability | 99.17% | 98.78% | 99.30% | 99.41% |

Source: GRIDCo 2015 Electricity Supply Plan. March 2015.

For the latest reported 2014 period, transmission lines recorded an average availability of 99.41%. As presented in Table 4-3, this represents a slight increase over the 2013 figure and is consistently above the Public Utility Regulatory Commission performance target of 98.5%. The increase in performance is, among other issues, attributed to numerous network upgrades and expansion projects which were completed during the last few years. The values also include the system supply constraints, that being the time during which some lines were disconnected to provide load shedding (e.g. load shedding is partially included in reliability numbers). The historical numbers show little or no impact on load shedding from transmission system performance.

#### *4.2.4.2 Adequacy of Transformer Capacity and Distribution Network*

On the distribution network side, ECG reports that most BSP's in their network now satisfy the N-1 criteria for transformers. There are still a few stations with single transformers. This means that any time maintenance work is being carried on those BSP's it results in total outages to customers. Plans are already in place to double the number of transformers in all the single transformer stations.

Standard operating procedures require that under normal operating conditions transformers are loaded below 100% of their rated capacities. Under emergency or contingency conditions, the loading could increase to 120% of the rated capacity for a short period of time. The overload situation in substations across the ECG network is gradually being eliminated through the injection of new BSP's and the upgrade of existing stations.

ECG reliability indices are presented in Table 4-4.

Table 4-4: ECG Network Reliability Indices for the 2010-2014 Period

| Distribution Reliability Indices | Units | 2010[18] | 2011[19] | 2012 | 2013 | 2014 |
|---|---|---|---|---|---|---|
| **Metropolitan** | | | | | | |
| SAIDI | hrs/cust. yr | 293.9 | 31.6 | 247.9 | 4.0 | 138.3 |
| SAIFI | no./cust. yr | 43.1 | 23.2 | 69.0 | 3.5 | 78.1 |
| CAIDI | hrs/no. | 281.6 | 1.6 | 15.7 | 4.4 | 1.8 |
| **Urban** | | | | | | |
| SAIDI | hrs/cust. yr | 0.0 | 0.0 | 189.5 | 14.1 | 268.5 |
| SAIFI | no./cust. yr | 0.0 | 0.0 | 88.1 | 8.0 | 158.6 |
| CAIDI | hrs/no. | 0.0 | 0.0 | 5.0 | 1.4 | 1.7 |
| **Rural** | | | | | | |
| SAIDI | hrs/cust. yr | 0.0 | 0.0 | 206.5 | 4.8 | 283.3 |
| SAIFI | no./cust. yr | 0.0 | 0.0 | 123.6 | 4.9 | 165.2 |
| CAIDI | hrs/no. | 0.0 | 0.0 | 4.6 | 5.3 | 1.7 |

We used reliability numbers to estimate the amount of suppressed demand at the distribution level due to infrastructure barriers. As an example, 138.3 hours of outages per year reported in 2014 for metropolitan customers represents 1.6% of the time those customers could not use electricity due to the outages in the ECG network. However, the reliability indices vary significantly from year to year and thus would introduce a large degree of uncertainty in estimating the combined impact on distribution level demand.

#### *4.2.4.3 Combined GRIDCo and ECG Results*

Outages and low voltages have a dual effect on demand. Low voltages have negative impact on demand, since some appliances consume less during the low voltage periods and some could not be used or started at all. A secondary impact of persistent outages and supply problems is to delay the opening of new businesses or purchasing of additional equipment. The impact of each of the two components could only be accurately estimated by conducting surveys and studying the long-term impact on parts of the distribution network that had recent improvements removing those barriers. Without more accurate information, we estimated that the two components combined resulted in the reduction of existing demand by about 8%. Reduction represents only impact on existing customers, as impact on new customer connections are addressed in developing forecasting assumptions. Since this is only a rough estimate, our

[18] In 2010 the reliability indices was not categorized into Metropolitan, Urban & Rural. The Reliability indices represent the whole of ECG and not Metropolitan.

[19] In 2011 the reliability indices was not categorized into Metropolitan, Urban & Rural. The Reliability indices represent the whole of ECG and not Metropolitan.

forecast applied sensitivity analysis to analyze the impact that higher or lower estimates of the Infrastructure Barrier component would have on total demand.

Accounting for the reliability and outage information, that together represents about 2% of the current demand (e.g. 1.6% for distribution and 0.5% for transmission outages), we estimate that the combined Infrastructure Barrier component of the suppressed demand based on GRIDCo and ECG data accumulated over the last three years to be up to 10% or about 780 GWh of the combined demand at the distribution level (e.g. ECG and NEDCo demand). In other words, we estimate that the actual 2014 demand would be about 10% or 780 GWh higher if the system did not have any T&D constraints, low voltages or other reliability problems. However, the Infrastructure Barrier component does not have an immediate impact on 2014 demand (e.g. no full upward revision is made to historical 2014 demand to account for suppressed demand due to the infrastructure barrier, as it will take time and investments in the T&D network to remove all remaining constraints. Instead, it is assumed that this barrier will be removed over time.

For the forecasting analysis, we estimated that with increased funding and by applying all measures specified and planned by GRIDCo, ECG and NEDCo, the Infrastructure Barrier component of the Suppressed Demand could be eliminated and result in a 10% increase in demand over the next five years. Since this estimate includes a high degree of uncertainty, sensitivity analysis has been conducted on this assumption.

### 4.2.5 Estimate Suppressed Demand Using Historical Demand Data

Another way of estimating suppressed demand is to start from unconstrained historical demand data before the latest round of load shedding that started in 2012 (using demand from the 2000-2011 period) and forecast demand up to 2014 using the combination of the actual historical data with necessary adjustments (such as adjusted GDP and number of customers) to account for suppressed demand.

We will present this analysis in Section 5, as the first part of the forecasting analysis.

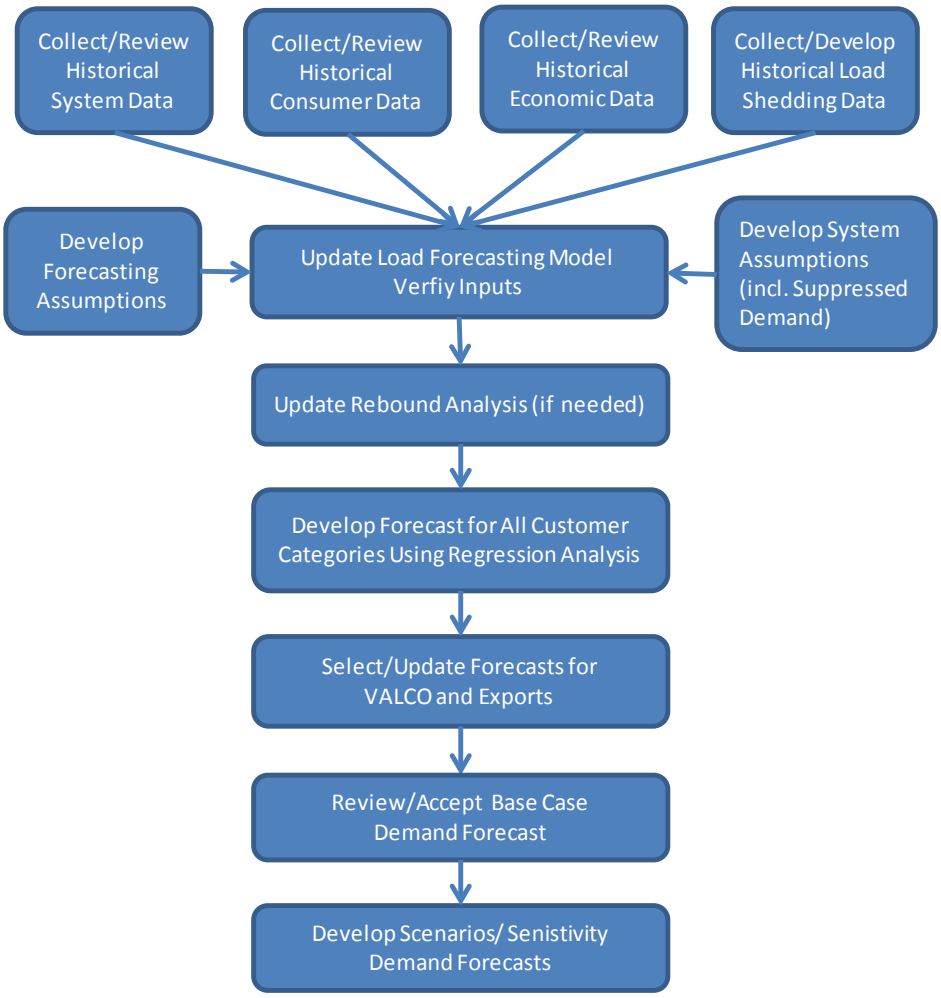
# Section 5 DEMAND FORECASTING

## 5.1 METHODOLOGY

### 5.1.1 Overview

This section describes the methodology and the key steps used to develop the demand forecasts (Refer to the User's Manual for detailed descriptions of the forecasting model use). Figure 5-1 presents an overview of the forecasting process and steps.

Figure 5-1: Forecasting Process and Steps




The key steps included in developing and validating the forecasts are:

1) Develop the general and specific model data inputs
2) Develop forecasting assumptions including suppressed demand estimates and rebound analysis

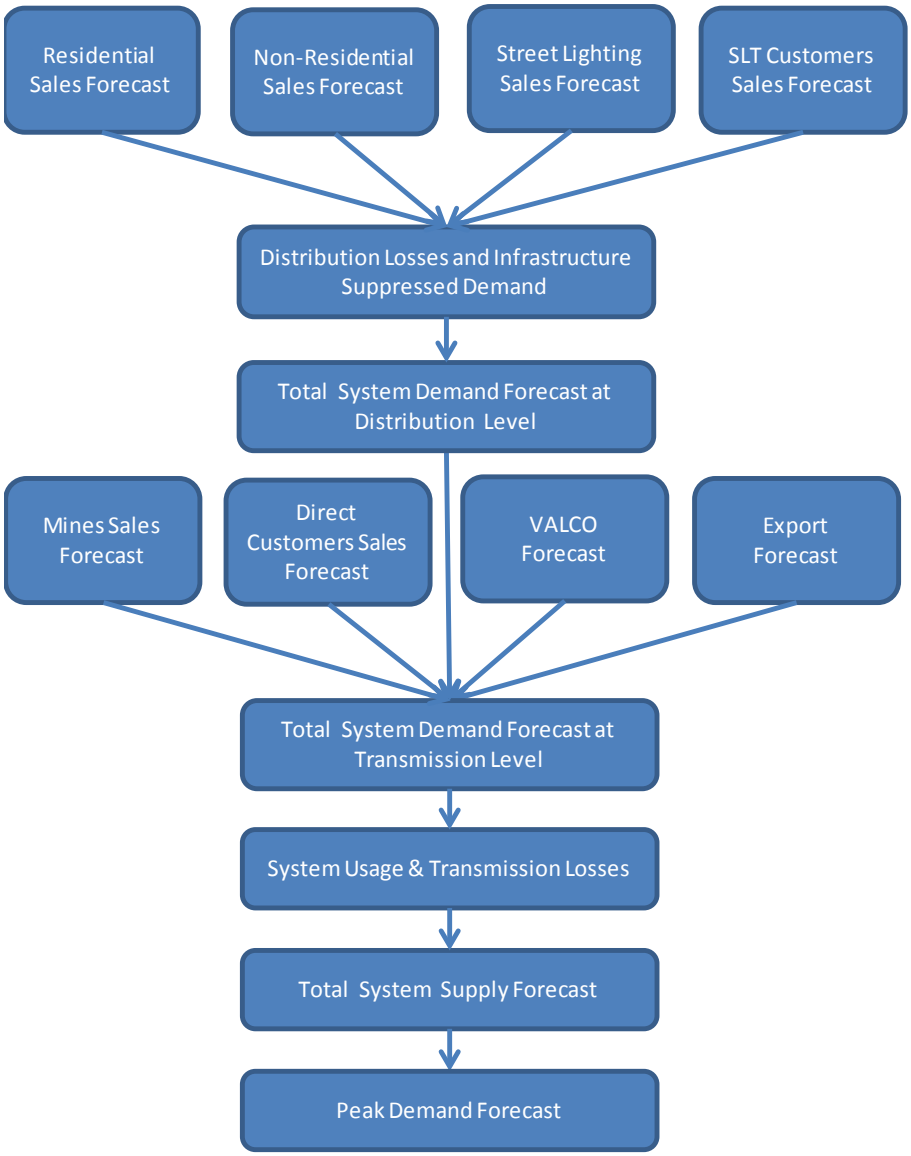
3) Specify, test, and validate regression models for each customer category. Validation includes comparison of direct estimates of suppressed demand in 2012-2014 with forecast estimates based on 2000-2011 data and the specified regression models
4) Select sales forecasts from available forecasts for customer categories that are not independently forecasted in the model (Mines, VALCO and Exports).
5) Verify the total energy forecast, including distribution and transmission losses, and develop the peak demand forecast derived from the total energy forecast
6) Conduct scenario/sensitivity analysis

Steps 1 and 2 as applied in this study are discussed in detail in Section 3 and 4 of this report. This section details the methodology used in steps 3-6, and presents the final set of forecasts and scenario results, as well as sensitivity analysis.

The reader should refer to the User's Manual for the Electricity Demand Forecasting Model that accompanies this report for details on how the forecasting model can be used to update or add additional historical data, modify scenario assumptions, to test and validate forecasting models, and to run sensitivity scenarios.

The individual component forecasts are the result of extensive data collection, independent variable identification, and regression modeling outlined in Figure 5-1. Figure 5-2 presents the forecasting components and how these components are used in developing total system demand.

Figure 5-2: Forecasting Components




The first step is to develop sales forecasts for all customer categories connected at the distribution system. This has been done in the final forecasting model, but users can update or add historical data and/or re-specify, validate, and run the regression models using different sets of independent variables. Distribution losses and Infrastructure Suppressed Demand (e.g. estimates related to distribution system constraints) as well as any estimated conversion of commercial losses to actual demand are added to the total distribution system sales forecast to arrive at the total demand forecast at the distribution level.

Residential, Non-residential, Street Lighting and Industrial customers (the Industrial category includes ECG & NEDCo SLT customers) are connected to the distribution system. Forecasts are developed for each of those customer categories via the regression modeling.

The forecasts can be linked via the selection of interacting independent variables (i.e. forecasting Non-residential demand as a function of Residential demand) if the testing of the

significance of the independent variables warrants their inclusion in the model. If so, the forecast of the included independent variable must first be developed independently.

Street Lighting has been fit to an S-Curve rather than a regression model because of the rapid historical growth observed during the 2000-2014 period. No reasonable regression based model fitting available historical values could be found. The S-Curve fit is based on the assumed long-term saturation level of Street Lighting demand, the period of growth, the mid-point year, and several other parameters, all of which can be changed by the User in the forecasting model

A forecast is also developed for the Direct Customers connected at the transmission system. Demand for Mines, VALCO and Exports is not independently forecasted in the model but is added to the total demand by selecting exogenous Government forecasts, which represent the best available consensus forecasts for these specific categories of demand.

The next step is to develop forecasts for all customers connected at the transmission system. This step includes developing sales forecasts for Direct Customers Sales as well as adding forecasted demand for Mines, VALCO and Export categories using exogenous inputs.

The final step is to review forecasting results at the distribution and total system levels. The Total System forecast is developed by adding the total demand forecast at the distribution level, sales to all customers connected at the transmission system, as well as System Usage & Transmission Losses. Analysis of all loss components was necessary to estimate and address the commercial and technical loss components and to derive the total system demand at the Net Generation level for use as an input to the Gas Market Study. The Peak Demand forecast is estimated by starting from the energy forecast and applying forecasted coincidence factors. Coincidence factors are inputs to the model and are based on historical data and future projections.

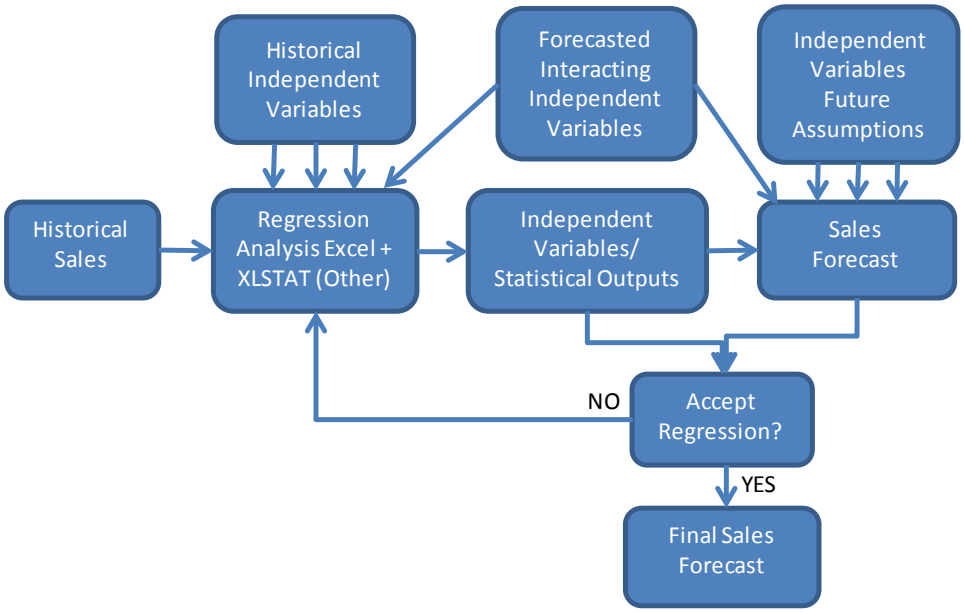
The remainder of this section describes the methodology by which the regression models were specified, tested, validated and used to develop the Total Demand forecasts.

## 5.2 FORECAST MODEL DEVELOPMENT

This study used linear multi-regression analysis to investigate historical relationships between electricity sales and the drivers for consumption (the independent variables) for each consumer category: Residential, Non-Residential, and SLT, as well as Direct Customers. As described in Section 3.3.8, exogenous Government forecasts for Mines, VALCO, and Exports were used in place of regression-based models, because these categories are highly dependent on project and condition specific assumptions. For Street Lighting, an S-curve was fit for the due to rapid historical growth and a presumed future saturation level of public lighting, as described in Section 5.2.6.

Figure 5-3 below presents the process for developing forecast for a single customer category.

Figure 5-3: Forecasting Flow Chart for a Single Consumer Category




For each customer category, the set of independent variables to be tested for model data quality and significance were selected from the full set of independent variables (as discussed in Section 3) based on hypothesized relationships. As an example, in the forecasting model, the Residential forecast includes a pre-selected list of variables for testing the potential impact on residential consumption, such as GDP, per capita income, population of active residential customers, number of households, and customer tariffs. Users have the flexibly to add additional independent variables for forecasting as well as for testing and validation.

The built-in capabilities of Microsoft Excel were used for regression modeling, in addition to a more advanced statistical commercial package called XLSTAT. The Ordinary Least Squares-based regression analysis in XLSTAT produces a set of statistical parameters and metrics (variable coefficients, $R^2$ statistics, P-values, and test statistics including multi-colinearity of independent variables, normality of residuals, serial correlation, and heteroscedasticity). Historical relationships having a high degree of statistical significance and data quality can be determined by analyzing the statistical output for each considered model.

Several primary statistical metrics are considered to determine the validity of historical relationships. Only those regressions having high $R^2$ values (indicating good correlation), and with coefficients which are of reasonable magnitude and sign and low P-values are generally accepted for inclusion in the model, as well as evaluation of the other statistical tests cited above. In a final step, the results obtained from the forecasts are analyzed to ensure that the growth rates are sensible within the context of overall expected energy sales and show limited volatility.

The final regression models for each consumer category are developed using the following process:

1) Application of statistical tests of the significance of the independent variables. Alternative models are considered iteratively that improve the statistical measures of data quality, model fit, and the statistical significance of each independent variable

2) Validating the forecasts by including load shedding over the period 2012-2014 from the direct estimate, as discussed in Section 4, and comparing with the regression based forecast for 2012-2014 including historical data revised to include suppressed demand
3) Evaluating the reasonableness of the long term forecasts relative to historical trends

For a given set of pre-selected independent variables, XLSTAT automatically generates the best model fit (based on Adjusted $R^2$ ) for 1, 2, …, up to the full set of variables. Each of these models was systematically evaluated relative to each other, following steps 2 and 3 above.

In addition, XLSTAT provides several additional automatic processes to guide model development. Models can be selected in a "forward" process in which variables are added sequentially with respect to a threshold value for significance, until a final model is specified. Models can also be selected in a "backwards" process, in which all independent variables are initially included, and then sequentially removed, again with respect to a threshold value of significance, again until a final model is specified. A "stepwise" process considers simultaneously adding and dropping variables. The forward, backward, and stepwise model selection options were used to validate the final model selected in the iterative and interactive process.

The regression models are structured using the logarithmic form of a standard econometric equation (as shown in the equation below):

The logarithmic econometric formula has the following form:

$$\text{Log}(y) = \log(a) + \beta 1 \log(X1) + \beta 2 \log(X2) + \beta 3 \log(X3) \ldots \text{etc}$$

Where:

y = Sector sales (dependent variable)

a = Constant

β = Elasticity of demand (coefficients)

X1, X2, X3 = Driving variables (independent variables)

As stated above, this process is carried out for each of the consumer categories, the final regression models are fit and validated, and the forecasts of each consumer category are added to generate the total system demand forecast.

The long term forecasts are developed by applying the independent variable forecasted inputs and regression coefficients for the entire forecasting period to the future values of the selected independent variables for each of the specified scenarios: Base, Low, and High. Variable inputs are based on the scenario assumptions or, in the case of interacting independent variables, data from other regression generated forecasts. The final validation step is to verify sales forecasts to make sure the results are reasonable and consistent with the historical trend.

As an additional validation check, the model also allows the option for developing independent forecasts for the combined categories. This includes developing a forecast for the NSLT category that includes combined Residential, Non-residential and Street Lighting demand (e.g. all ECG customers priced at the NSLT[20] tariff) as well as a forecast for the combined NSLT and

[20] NSLT is the category name used by ECG in the forecasting report to describe all customers having the NSLT tariff. We use the NSLT demand to describe demand for all ECG and NEDCo residential, non-residential and street lighting customers.

SLT categories (e.g. developing a forecast for the entire demand at the distribution level). This model feature, to compare individual forecasts with the combined forecast, is useful to gain additional insights and to spot any significant differences in two forecasting approaches. However, only the individual category forecasts are used for developing total system demand.

The following sections describes the full set of independent variables used in fitting each of the customer category demand forecasts, as well as the combined forecasts used for validation. Section 3 provided a full description of the data and assumptions applied to future growth of the variables.

### 5.2.1 Demand Categories

The abbreviations used for each forecasted category are repeated here, since these are used throughout this section:

- RES Residential
- NON_RES Non-Residential
- SL Street Lighting
- SLT Special Load Tariff Customers (Average Demand Exceeds 100 kVA)
- NSLT Non-Special Load Tariff Customers (Average Demand Below 100 kVA)
- MIN Mines
- DIR Other Direct Customers
- VAL VALCO
- EXP Exports

### 5.2.2 Independent Variables and Other Abbreviations

The following abbreviations are used for Independent variables and other abbreviations in the specification of the regression models.

- POP_TOT Total Ghana Population
- POP_SLT Population of Active Special Load Tariff Customers (SLT)
- POP_NON_RES Population of Active Non-residential Customers
- POP_RES Population of Active Residential Customers
- A_HOUSE Average Household Size
- GDP Total Gross Domestic Product
- GDPI Industrial Component of GDP
- GDPS Services Component of GDP
- GDPA Agriculture Component of GDP
- P_NSLT End User Tariff for Non SLT Customers
- P_SLT End User Tariff for SLT Customers
- S_SLT SLT Customer Sales
- S_NSLT NSLT Customer Sales

- PCI Per Capita Income (GDP/Population)

LN abbreviation was used for the Natural Log of all variables.

### 5.2.3 Lagged, or N-1 Variables

The N-1 data presents lagging variables (e.g. year before actual category sales) as input for forecasting. This variable, if selected for the regression analysis, represents the impact sales in earlier years have on current year sales. As such, formulas in N-1 inputs should always refer to the forecasting area N-1 log results (as an example input for year 2001 should be linked with the actual sales in year 2000).

### 5.2.4 Interacting Forecasts and Independent Variables

It may be the case that one category of historical and thus forecasted customer sales, such as Non-residential, could have a statistical relationship with another category, such as Residential sales. Independent variables for one category can be included in the specification of the regression model for another category. This is the case in the model for Non-residential sales, in which Residential sales was considered for inclusion as an independent variable[21].

If a forecasted value is to be included as an independent variable in another forecast, the regression model for the variable should first be specified, tested, and validated. Then, the historical and the forecast data for this variable can be evaluated for inclusion in the regression model for the second category.

### 5.2.5 Dummy Variable

The Potential Forecasting Input data also includes a “Dummy” variable input. In regression analysis, a dummy variable has the values 0 or 1 to indicate the absence or presence of some categorical effect that may be expected to shift the outcome. The use of a dummy variable usually improves the model fit (coefficient of determination), but at a cost of fewer degrees of freedom and loss of generality of the model.

If used as the input, the dummy variable acts like a switch that turns various parameters on and off in an equation. For example, if in one particular year electricity sales in one consumer category fell sharply due to an externality (such as load shedding) and the sales in that category recovered the following year (without load shedding) then a dummy variable could be used to ‘ignore’ that one year of sales data. In regression analysis, externalities (positive and negative) should be controlled so that the statistical outputs are not misleading and the resulting forecasts are too high or too low.

The Dummy variable was set to 1 for the year 2007 in all cases in which it was tested, to indicate the presence of load shedding which was not explicitly adjusted, and otherwise set to 0.

[21] Residential sales forecast was not included due to insufficient statistical evidence.

### 5.2.6 Street Lighting

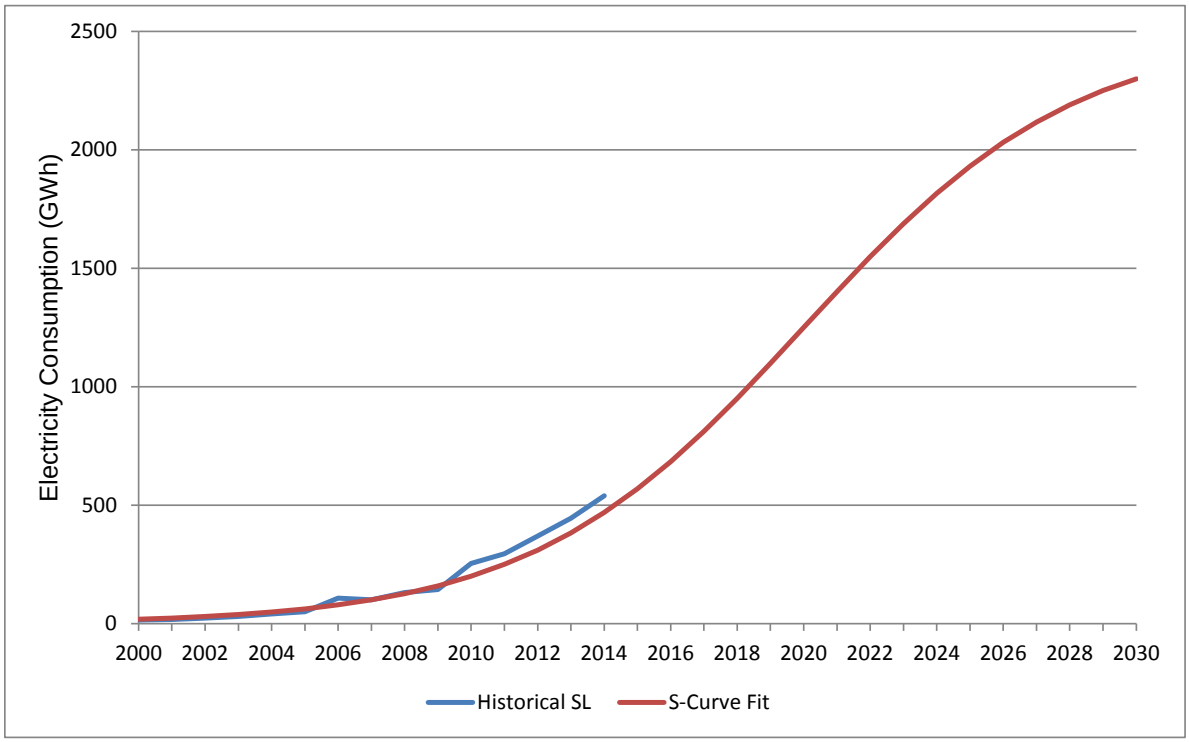
The S-Curve fit for Street Lighting is based on a fit of historical data, the upper limit or saturation level for demand, a mid-point parameter, and the time to grow from 10% to 90%. Parameters were set in order to derive a reasonable shape of the curve, based on the historical data. Users can adjust the parameter values to modify the Street Light curve fit and forecast. Table 5-1 and Figure 5-4 show the fit for Street Lighting and the comparison with historical demand.

Table 5-1: Street Lighting Historical and S-Curve Fit (GWh)

| Year | Historical | S-Curve Fit |
|---|---|---|
| 2000 | 15 | 19 |
| 2001 | 18 | 24 |
| 2002 | 23 | 30 |
| 2003 | 31 | 39 |
| 2004 | 41 | 49 |
| 2005 | 50 | 63 |
| 2006 | 108 | 79 |
| 2007 | 101 | 100 |
| 2008 | 132 | 127 |
| 2009 | 144 | 160 |
| 2010 | 254 | 200 |
| 2011 | 296 | 250 |
| 2012 | 369 | 311 |
| 2013 | 445 | 383 |
| 2014 | 540 | 469 |
| 2015 | | 570 |
| 2016 | | 684 |
| 2017 | | 812 |
| 2018 | | 951 |
| 2019 | | 1,098 |
| 2020 | | 1,250 |
| 2021 | | 1,402 |
| 2022 | | 1,549 |
| 2023 | | 1,688 |
| 2024 | | 1,816 |
| 2025 | | 1,930 |
| 2026 | | 2,031 |
| 2027 | | 2,117 |
| 2028 | | 2,189 |

| | | |
|---|---|---|
| 2029 | | 2,250 |
| 2030 | | 2,300 |

Figure 5-4: Street Lighting Historical and S-Curve Fit (GWh)




## 5.3 REGRESSION RESULTS

This section presents the final set of regression models specified for each category and shows the forecast results for the Base, Low and High scenarios for each category. Details on the process of model specification, comparisons of alternative models, and model statistics are provided in Section 8. An iterative process was used in combination with advanced capabilities in XLSTAT to generate and compare a series of regression models for each category guided by statistical metrics, magnitude and sign of the regression coefficients, validation of the model for the 2012-2014 period, and a resulting reasonable growth rate of the long term forecasts.

### 5.3.1 Residential

The best regression fit and 2012-2014 and long-term forecast model validation for the Residential consumer category was with the independent variables for GDP, the NSLT tariff, average household size, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression coefficient for average household size is negative because household size has historically decreased. The regression formula is:

**LN(RES) = -6.791 + 0.699 * LN(GDP) – 0.042 * LN(P_NSLT) – 1.261 * LN(A_HOUSE) – 0.049 * DUMMY**

Table 5-2 shows the statistical parameters for the final Residential model. Multi-colinearity is measured by the variance inflation factor, or VIF; smaller values indicate less correlation among independent variables.

Table 5-2: Statistics for Residential Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.987 |
| P-Value | LN(GDP) | <0.0001 |
| P-Value | LN(P_NSLT) | 0.441 |
| P-Value | LN(A_HOUSE) | 0.044 |
| P-Value | DUMMY | 0.146 |
| Multi-colinearity (VIF) | LN(GDP) | 6.732 |
| Multi-colinearity (VIF) | LN(P_NSLT) | 3.462 |
| Multi-colinearity (VIF) | LN(A_HOUSE) | 6.743 |
| Multi-colinearity (VIF) | DUMMY | 1.231 |

The 2015-2030 forecasts for the Residential category are shown in Table 5-3 and Figure 5-5 for the Base Case, Low, and High Growth scenarios.

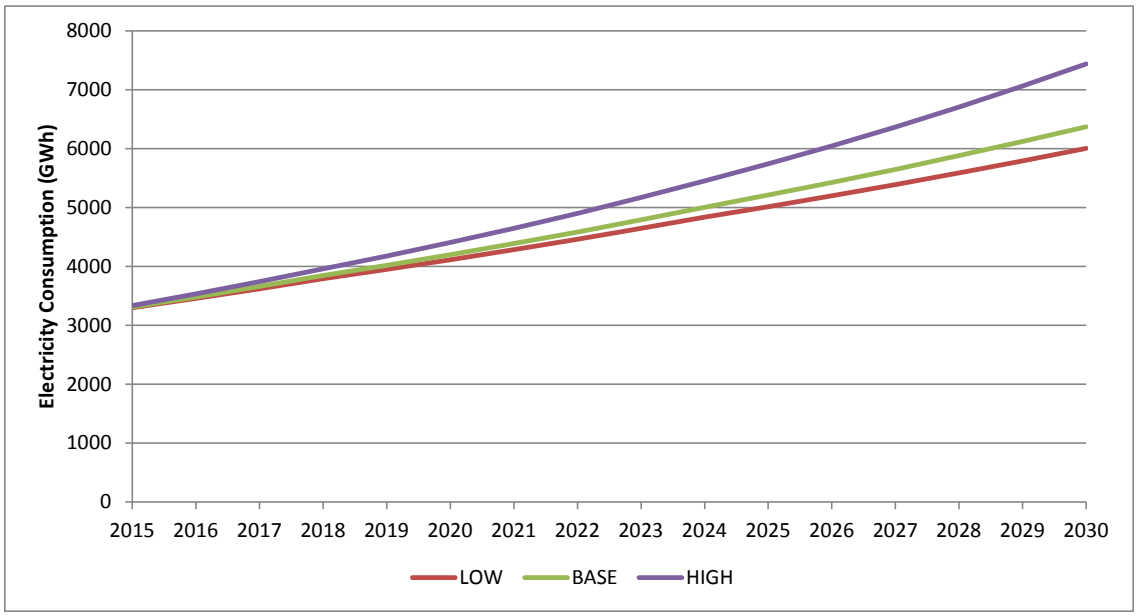
The growth rate observed in the three forecast scenarios is reasonable compared with the historical growth rate for this category.

Table 5-3: Residential Forecast for the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 3,075 | 3,075 | 3,075 |
| 2015 | 3,301 | 3,312 | 3,337 |
| 2016 | 3,458 | 3,481 | 3,533 |
| 2017 | 3,622 | 3,659 | 3,740 |
| 2018 | 3,793 | 3,845 | 3,959 |
| 2019 | 3,950 | 4,018 | 4,176 |
| 2020 | 4,113 | 4,199 | 4,405 |
| 2021 | 4,284 | 4,388 | 4,646 |
| 2022 | 4,461 | 4,585 | 4,900 |
| 2023 | 4,645 | 4,791 | 5,169 |
| 2024 | 4,837 | 5,006 | 5,452 |
| 2025 | 5,015 | 5,211 | 5,741 |
| 2026 | 5,199 | 5,425 | 6,046 |
| 2027 | 5,389 | 5,647 | 6,367 |
| 2028 | 5,587 | 5,879 | 6,706 |

| | | | |
|---|---|---|---|
| 2029 | 5,792 | 6,120 | 7,062 |
| 2030 | 6,004 | 6,370 | 7,437 |
| Annual Average Growth Rate (2014-2030) | 4.3% | 4.7% | 5.7% |
| Historical Growth Rate (2000-2014) | | 5.4% | |

Figure 5-5: Residential Forecast for the Base Case, Low and High Scenarios (GWh)




## 5.3.2 Non-Residential

The best regression fit and 2012-2014 and long-term forecast model validation for the Non-Residential consumer category was with the independent variables for GDP Services, the NSLT tariff, the 1-year lagged Non-Residential demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(NON_RES) = -16.634 + 0.931 * LN(GDPS) – 0.115 * LN(P_NSLT) + 0.382 * LN(NON_RES N-1) – 0.099 * DUMMY**

Table 5-4 shows the statistical parameters for the final Non-Residential model.

Table 5-4: Statistics for Non-Residential Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.973 |
| P-Value | LN(GDPS) | 0.013 |
| P-Value | LN(P_NSLT) | 0.389 |
| P-Value | LN(NON_RES N-1) | 0.353 |
| P-Value | DUMMY | 0.191 |
| Multi-colinearity (VIF) | LN(GDPS) | 23.23 |

| | | |
|---|---|---|
| Multi-colinearity (VIF) | LN(P_NSLT) | 3.019 |
| Multi-colinearity (VIF) | LN(NON_RES N-1) | 26.35 |
| Multi-colinearity (VIF) | DUMMY | 1.256 |

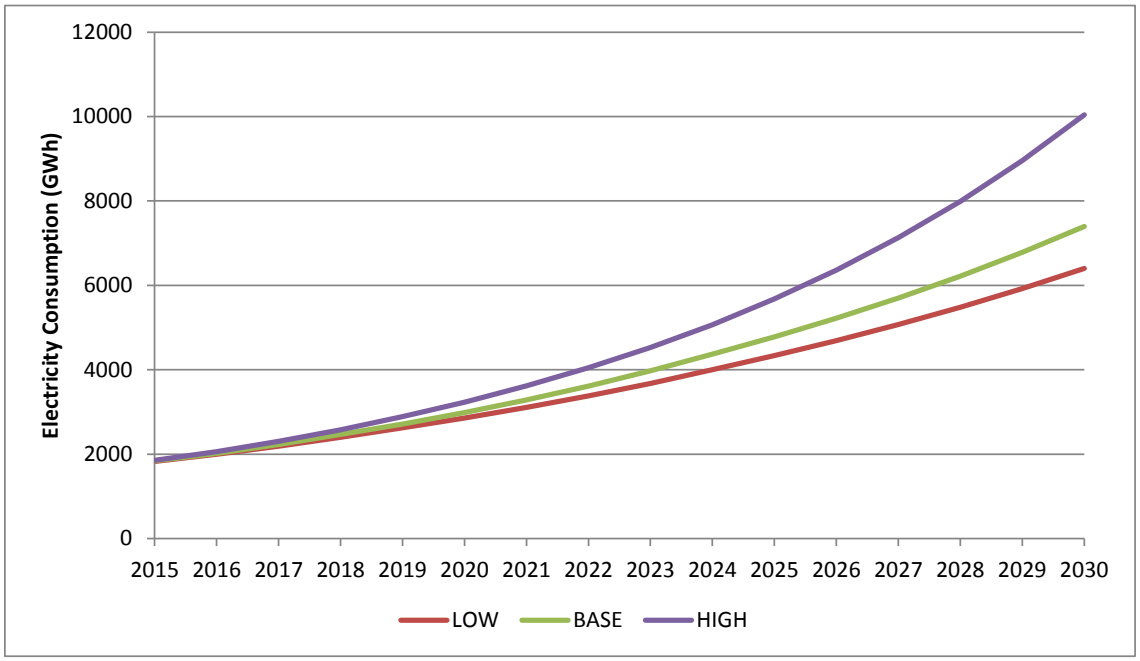
The 2015-2030 forecasts for the Non-Residential category are shown in Table 5-5 and Figure 5-6 for the Base Case, Low, and High Growth scenarios.

The growth rate observed in the three forecast scenarios is reasonable compared with the historical growth rate for this category.

Table 5-5: Non-Residential Forecast for the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 1,700 | 1,700 | 1,700 |
| 2015 | 1,830 | 1,839 | 1,854 |
| 2016 | 1,996 | 2,018 | 2,058 |
| 2017 | 2,187 | 2,228 | 2,301 |
| 2018 | 2,401 | 2,465 | 2,579 |
| 2019 | 2,622 | 2,716 | 2,888 |
| 2020 | 2,855 | 2,989 | 3,232 |
| 2021 | 3,107 | 3,287 | 3,617 |
| 2022 | 3,381 | 3,614 | 4,047 |
| 2023 | 3,677 | 3,973 | 4,528 |
| 2024 | 4,000 | 4,368 | 5,067 |
| 2025 | 4,334 | 4,779 | 5,676 |
| 2026 | 4,688 | 5,220 | 6,361 |
| 2027 | 5,069 | 5,697 | 7,129 |
| 2028 | 5,479 | 6,216 | 7,992 |
| 2029 | 5,922 | 6,781 | 8,958 |
| 2030 | 6,401 | 7,398 | 10,042 |
| Annual Average Growth Rate (2014-2030) | 8.6% | 9.6% | 11.7% |
| Historical Growth Rate (2000-2014) | | 8.4% | |

Figure 5-6: Non-Residential Forecast the Base Case, Low and High Scenarios (GWh)




## 5.3.3 NSLT

NSLT is a category that combines Residential, Non-Residential and Street Lighting into a single category, as used by ECG in its demand forecasts. NSLT is not used directly to develop the forecasts in this study, but rather is used as independent validation of the other combined categories. The 2015-2030 forecast validations are presented in Section 5.5.2 for the Base Case forecast, and in Sections 5.8.1.3 and 5.8.2.3 for the Low Growth and High Growth forecasts, respectively.

The best regression fit and 2012-2014 and long-term forecast model validation for the NSLT category was with the independent variables for GDP, the NSLT tariff, the 1-year lagged NSLT demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The final regression formula is:

**LN(NSLT) = -15.597 + 0.973 * LN(GDP) – 0.112 * LN(P_NSLT) + 0.137 * LN(NSLT N-1) – 0.054 * DUMMY**

Table 5-6 shows the statistical parameters for the final NLST model.

Table 5-6: Statistics for NLST Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.995 |
| P-Value | LN(GDP) | <0.0001 |
| P-Value | LN(P_NSLT) | 0.056 |
| P-Value | LN(NSLT N-1) | 0.105 |
| P-Value | DUMMY | 0.074 |

| | | |
|---|---|---|
| Multi-colinearity (VIF) | LN(GDP) | 3.182 |
| Multi-colinearity (VIF) | LN(P_NSLT) | 4.825 |
| Multi-colinearity (VIF) | LN(NSLT-1) | 2.043 |
| Multi-colinearity (VIF) | DUMMY | 1.145 |

The 2015-2030 forecasts for the NSLT category are shown in Table 5-7 for the Base Case, Low, and High Growth scenarios.

The NLST forecasts will be compared with the Base, Low and High forecasts for the individual component forecasts in Sections 5.5.2.1, 5.8.1.1, and 5.8.2.1, respectively. The individual component forecasts are 8%, 10%, and 2% higher than the combined forecast for the Base, Low and High scenarios. Given the 95% confidence levels for the two forecasts, the results provide a good validation of the forecasts using different models.

The growth rate observed in the three forecast scenarios is reasonable compared with the historical growth rate for this category.

Table 5-7: NSLT Forecast for the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 5,314 | 5,314 | 5,314 |
| 2015 | 5,736 | 5,769 | 5,834 |
| 2016 | 6,127 | 6,202 | 6,352 |
| 2017 | 6,535 | 6,660 | 6,909 |
| 2018 | 6,969 | 7,149 | 7,514 |
| 2019 | 7,379 | 7,622 | 8,138 |
| 2020 | 7,806 | 8,117 | 8,809 |
| 2021 | 8,257 | 8,644 | 9,534 |
| 2022 | 8,733 | 9,204 | 10,319 |
| 2023 | 9,237 | 9,801 | 11,169 |
| 2024 | 9,770 | 10,437 | 12,088 |
| 2025 | 10,280 | 11,066 | 13,062 |
| 2026 | 10,808 | 11,727 | 14,111 |
| 2027 | 11,362 | 12,426 | 15,244 |
| 2028 | 11,945 | 13,167 | 16,468 |
| 2029 | 12,557 | 13,951 | 17,791 |
| 2030 | 13,201 | 14,783 | 19,219 |
| Annual Average Growth Rate (2014-2030) | 5.9% | 6.6% | 8.4% |
| Historical Growth Rate (2000-2014) | | 7.1% | |

### 5.3.4 SLT

The best regression fit and 2012-2014 and long-term forecast model validation for the SLT category was with the independent variables for SLT Population, the 1-year lagged SLT demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(SLT) = 1.014 + 0.451 * LN(POP_SLT) + 0.434 * LN(SLT N-1) - 0.065 * DUMMY**

Table 5-8 shows the statistical parameters for the final SLT model.

Table 5-8: Statistics for SLT Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.978 |
| P-Value | LN(POP_SLT) | 0.014 |
| P-Value | LN(SLT N-1) | 0.066 |
| P-Value | DUMMY | 0.099 |
| Multi-colinearity (VIF) | LN(POP_SLT) | 1.248 |
| Multi-colinearity (VIF) | LN(SLT N-1) | 1.245 |
| Multi-colinearity(VIF) | DUMMY | 1.019 |

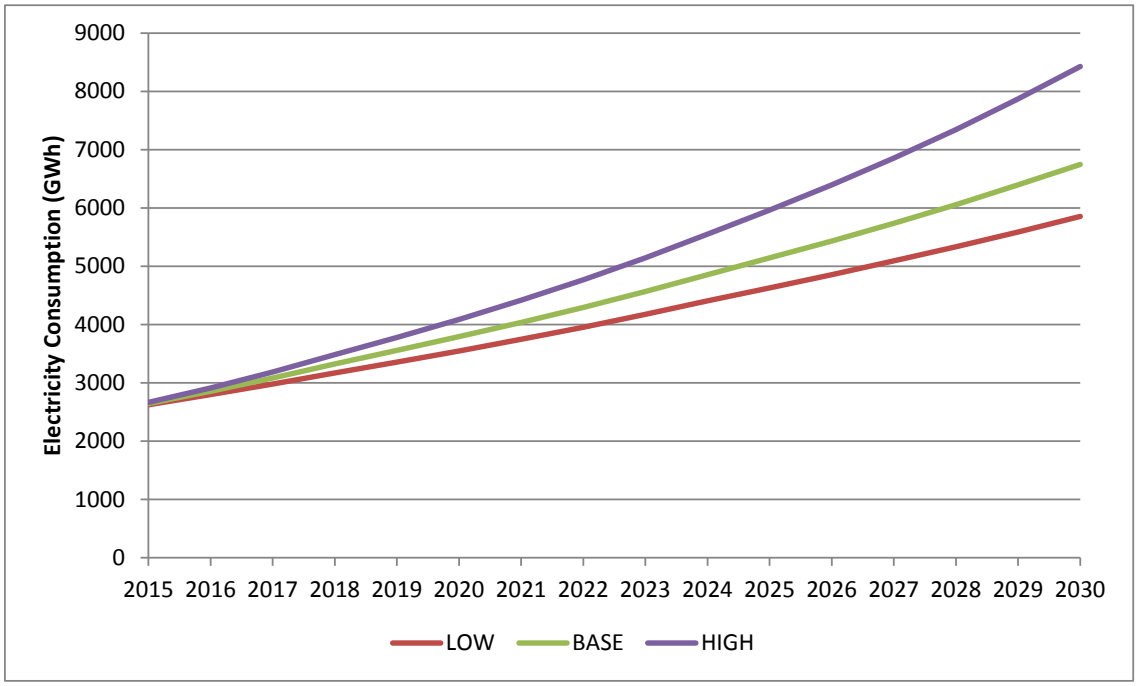
The 2015-2030 forecasts for the SLT category are shown in Table 5-94 and Figure 5-7 for the Base, Low, and High Growth scenarios.

Table 5-9: SLT Forecast the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 2,449 | 2,449 | 2,449 |
| 2015 | 2,623 | 2,644 | 2,666 |
| 2016 | 2,797 | 2,854 | 2,911 |
| 2017 | 2,978 | 3,080 | 3,183 |
| 2018 | 3,168 | 3,323 | 3,482 |
| 2019 | 3,355 | 3,556 | 3,780 |
| 2020 | 3,547 | 3,791 | 4,089 |
| 2021 | 3,746 | 4,036 | 4,416 |
| 2022 | 3,954 | 4,293 | 4,767 |
| 2023 | 4,174 | 4,566 | 5,144 |
| 2024 | 4,405 | 4,855 | 5,551 |
| 2025 | 4,630 | 5,141 | 5,964 |
| 2026 | 4,856 | 5,433 | 6,397 |

| | | | |
|---|---|---|---|
| 2027 | 5,090 | 5,737 | 6,856 |
| 2028 | 5,334 | 6,057 | 7,345 |
| 2029 | 5,588 | 6,393 | 7,868 |
| 2030 | 5,854 | 6,747 | 8,428 |
| Annual Average Growth Rate (2014-2030) | 5.6% | 6.5% | 8.0% |
| Historical Growth Rate (2000-2014) | | 5.6% | |

Figure 5-7: SLT Forecast the Base Case, Low and High Scenarios (GWh)




## 5.3.5 NSLT + SLT

NSLT + SLT is a combined forecast category that aggregates the NSLT and SLT categories. NSLT + SLT is not used directly to develop the forecasts, but rather is used as independent validation of the individual NSLT and SLT categories added together.

The best regression fit for 2012-2014 and long-term forecast model validation for the NSLT+SLT category was with the independent variables for GDP per Capita, number of SLT customers, the number of Residential customers, and the 1-year lagged SLT demand. The coefficients were of reasonable magnitude and expected sign. The final regression formula is:

**LN(NSLT+SLT) = -0.775 + 0.653 * LN(PCI) + 0.271 * LN(POP_SLT) + 0.189 * LN(POP_RES) + 0.031 * LN(SLT N-1)**

Table 5-10 shows the statistical parameters for the final NLST+SLT model.

Table 5-10: Statistics for NLST+SLT Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.995 |
| P-Value | LN(PCI) | 0.046 |
| P-Value | LN(POP_SLT) | 0.270 |
| P-Value | LN(POP_RES) | 0.029 |
| P-Value | LN(SLT N-1) | 0.317 |
| Multi-colinearity (VIF) | LN(PCI) | 88.171 |
| Multi-colinearity (VIF) | LN(POP_SLT) | 150.43 |
| Multi-colinearity(VIF) | LN(POP_RES) | 34.603 |
| Multi-colinearity (VIF) | LN(SLT N-1) | 1.683 |

The 2015-2030 forecasts for the combined NSLT+SLT category are shown in Table 5-11 for the Base Case, Low, and High Growth scenarios.

The growth rate observed in the three forecast scenarios is reasonable compared with the historical growth rate for this category.

Table 5-11: NSLT+SLT Forecast the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 7,763 | 7,763 | 7,763 |
| 2015 | 8,414 | 8,523 | 8,669 |
| 2016 | 8,624 | 8,852 | 9,160 |
| 2017 | 9,159 | 9,526 | 10,031 |
| 2018 | 9,727 | 10,252 | 10,985 |
| 2019 | 10,222 | 10,872 | 11,858 |
| 2020 | 10,740 | 11,527 | 12,797 |
| 2021 | 11,284 | 12,221 | 13,809 |
| 2022 | 11,855 | 12,955 | 14,900 |
| 2023 | 12,455 | 13,733 | 16,078 |
| 2024 | 13,086 | 14,557 | 17,348 |
| 2025 | 13,621 | 15,285 | 18,572 |
| 2026 | 14,175 | 16,046 | 19,879 |
| 2027 | 14,752 | 16,845 | 21,277 |
| 2028 | 15,351 | 17,683 | 22,773 |
| 2029 | 15,975 | 18,562 | 24,374 |
| 2030 | 16,623 | 19,485 | 26,087 |
| Annual Average Growth Rate (2014-2030) | 4.9% | 5.9% | 7.9% |

| | | | |
|---|---|---|---|
| Historical Growth Rate (2000-2014) | | 6.7% | |

### 5.3.6 Direct Customers

The best regression fit and long-term forecast validation for Direct Customers was with the independent variables for GDP Industrial and the 1-year lagged Direct Customer demand. The coefficients were of reasonable magnitude and expected sign. The final regression formula is:

**LN(DIR) = -6.278 + 0.353 * LN(GDPI) + 0.691 * LN(DIR N-1)**

Table 5-12 shows the statistical parameters for the final Direct Customers model.

Table 5-12: Statistics for Direct Customers Model

| Statistic | Variable | Value |
|---|---|---|
| Adjusted $R^2$ | | 0.861 |
| P-Value | LN(GDPI) | 0.158 |
| P-Value | LN(DIR N-1) | 0.035 |
| Multi-colinearity (VIF) | LN(GDPI) | 5.624 |
| Multi-colinearity (VIF) | LN(DIR N-1) | 5.624 |

The 2015-2030 forecasts for the SLT category are shown in Table 5-13 and Figure 5-8 for the Base, Low, and High Growth scenarios.

Table 5-13: Direct Customers Forecast the Base Case, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 339 | 339 | 339 |
| 2015 | 358 | 359 | 360 |
| 2016 | 382 | 383 | 386 |
| 2017 | 410 | 412 | 417 |
| 2018 | 442 | 445 | 453 |
| 2019 | 476 | 481 | 492 |
| 2020 | 512 | 519 | 536 |
| 2021 | 550 | 561 | 584 |
| 2022 | 592 | 606 | 637 |
| 2023 | 636 | 654 | 695 |
| 2024 | 684 | 707 | 759 |
| 2025 | 733 | 762 | 827 |

| | | | |
|---|---|---|---|
| 2026 | 785 | 819 | 900 |
| 2027 | 839 | 880 | 980 |
| 2028 | 897 | 945 | 1,065 |
| 2029 | 958 | 1,013 | 1,158 |
| 2030 | 1,022 | 1,087 | 1,258 |
| Annual Average Growth Rate (2014-2030) | 7.1% | 7.6% | 8.5% |
| Historical Growth Rate (2000-2014) | | 13.8% | |

Figure 5-8: Direct Customers Forecast the Base Case, Low and High Scenarios (GWh)

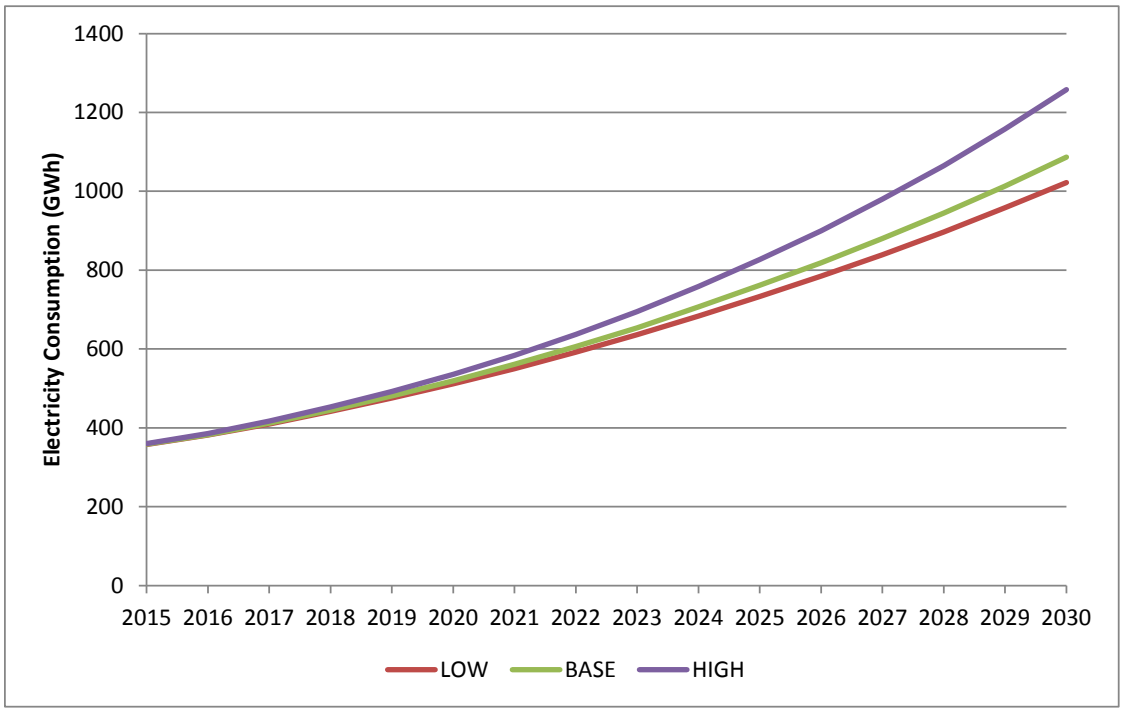



Table 5-14 shows the Direct Customer forecast as made by VRA for the same period, under their own assumptions for Low, Base, and High growth. As seen by comparing Table 5-9 with Table 5-14, the forecast cases largely overlap, and thus the regression based forecasts are used. Given the general similarity of the forecasts, and since Direct Customers constitutes a small percentage of the total demand, the accuracy of the Direct Customer forecast does not significantly impact the overall accuracy of the total demand forecast.

Table 5-14: VRA Direct Customers Forecasts for the Base Case, Low and High Scenarios (GWh)

| Year | Low | Base | High |
|---|---|---|---|
| 2015 | 394 | 434 | 494 |
| 2016 | 451 | 491 | 551 |
| 2017 | 505 | 545 | 605 |
| 2018 | 557 | 597 | 657 |
| 2019 | 608 | 648 | 708 |

| | | | |
|---|---|---|---|
| 2020 | 716 | 756 | 816 |
| 2021 | 770 | 810 | 870 |
| 2022 | 819 | 859 | 919 |
| 2023 | 870 | 910 | 970 |
| 2024 | 921 | 961 | 1,021 |
| 2025 | 929 | 969 | 1,029 |
| 2026 | 929 | 969 | 1,029 |
| 2027 | 931 | 971 | 1,031 |
| 2028 | 931 | 971 | 1,031 |
| 2029 | 931 | 971 | 1,031 |
| 2030 | 931 | 971 | 1,031 |

## 5.4 VALIDATION FOR 2012-2014 PERIOD

Forecasting analysis of the historical 2012-2014 period was conducted to determine if the Supply Constraint component of the suppressed demand could be estimated and verified by forecasting. The historical input data for the forecasting were adjusted to reflect no-supply constraint conditions (e.g. GDP and number of customers were increased to represent estimated levels without constraints). This independent forecasting was conducted for the combined Residential, Non-Residential and Street Lighting, NSLT, and SLT demand categories. The regression models for each category used the same set of independent variables as fit for the 2015-2030 period, but were re-fit using only the 2000-2011 historical data, in order to forecast and validate the 2012-2014 period. Results were then compared with the actual historical demand including the Supply Constraint component as presented in Section 4. Ideally, those two methods would produce similar results, which could then be used as a reliable starting point for future 2015-2030 period demand forecasting. An iterative process using the 2012-2014 validation forecasts to specify the final 2015-2030 models was also used, until a reasonable set of models were selected for the long term and validation forecasts. The regression models used in the 2012-2014 validation are presented in Section 8.

In summary of the results presented below, the validation analysis for the historical 2012-2014 period compare well with the results of the Supply Component of the suppressed demand. Consequently, results from analysis presented in Section 4 were used in developing the total demand forecasts for the 2015-2030 year period.

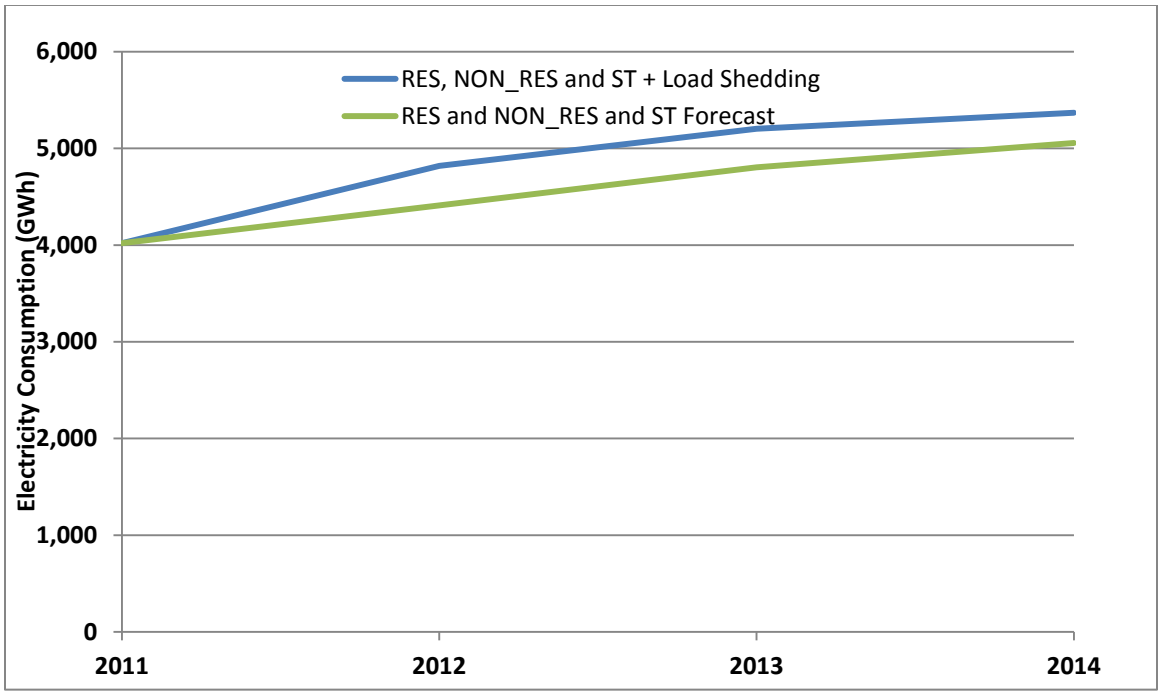
### 5.4.1 Residential, Non-residential, and Street Lighting Forecast

Table 5-15 and Figure 5-9 show the comparison of the forecasted and actual historical demand plus load shedding for the combined Residential, Non-Residential, and Street Lighting categories. The difference between the forecast and the actual plus load shedding in 2014, at about 6%, is reasonable in light of the assumptions about the rebound effect, and thus serves as a strong validation of the forecast results and models.

Table 5-15: 2012-2014 Validation of Res, Non-Res and SL Forecasts (GWh)

| Year | Forecast | Actual Plus Load Shedding | Actual |
|---|---|---|---|
| 2011 | 4,021 | 4,021 | 4,021 |
| 2012 | 4,411 | 4,819 | 4,737 |
| 2013 | 4,804 | 5,204 | 5,037 |
| 2014 | 5,057 | 5,368 | 4,841 |

Figure 5-9: 2012-2014 Validation of Res, Non-Res and SL Forecasts (GWh)




## 5.4.2 NSLT Forecast

An additional validation of the direct estimate of suppressed demand for the Residential, Non-Residential and Street Lighting category is made using the combined forecast for the NSLT category. This combined forecast validation is compared with the component forecast of Res, Non-res, and SL categories in Sections 5.5 and 5.8 for the Base case and the Low and High growth scenarios. As indicated in Section 5.3.3, the NSLT category is not directly used for developing the Total Demand forecast.

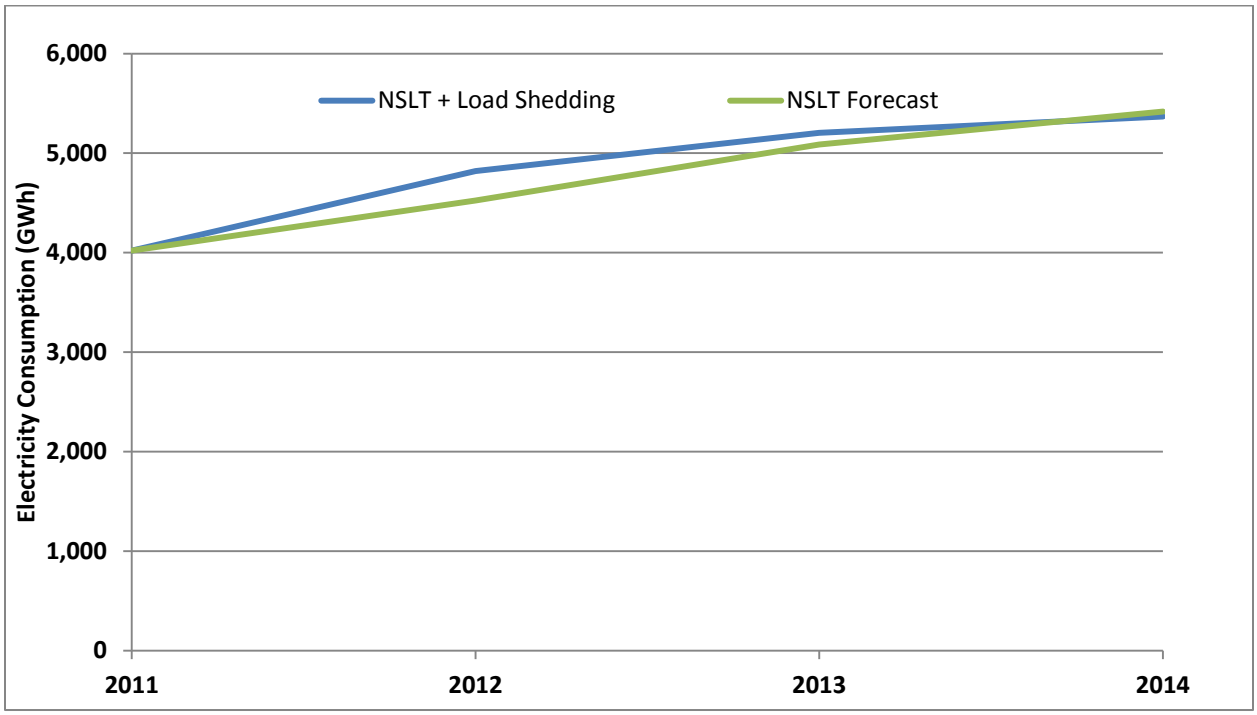
Table 5-16 and Figure 5-10 present NSLT forecasting results for the 2012-2014 period. The comparison includes analysis results using the actual sales and Supply Constraint component of the suppressed demand as described in Section 4.

The results show very similar trajectories - the final 2014 demand estimates, with the NSLT forecasting results, are slightly higher than the actual plus load shedding results in 2014. The historical forecasting validation thus provided another important independent estimate that confirmed results of our direct analysis of the Supply Constraint component of the suppressed demand.

Table 5-16: 2012-2014 Validation of NSLT Forecasts (GWh)

| Year | Forecast | Actual Plus Load Shedding | Actual |
|---|---|---|---|
| 2011 | 4,021 | 4,021 | 4,021 |
| 2012 | 4,525 | 4,819 | 4,737 |
| 2013 | 5,087 | 5,204 | 5,037 |
| 2014 | 5,418 | 5,368 | 4,841 |

Figure 5-10: 2012-2014 Validation of NSLT Forecasts (GWh)



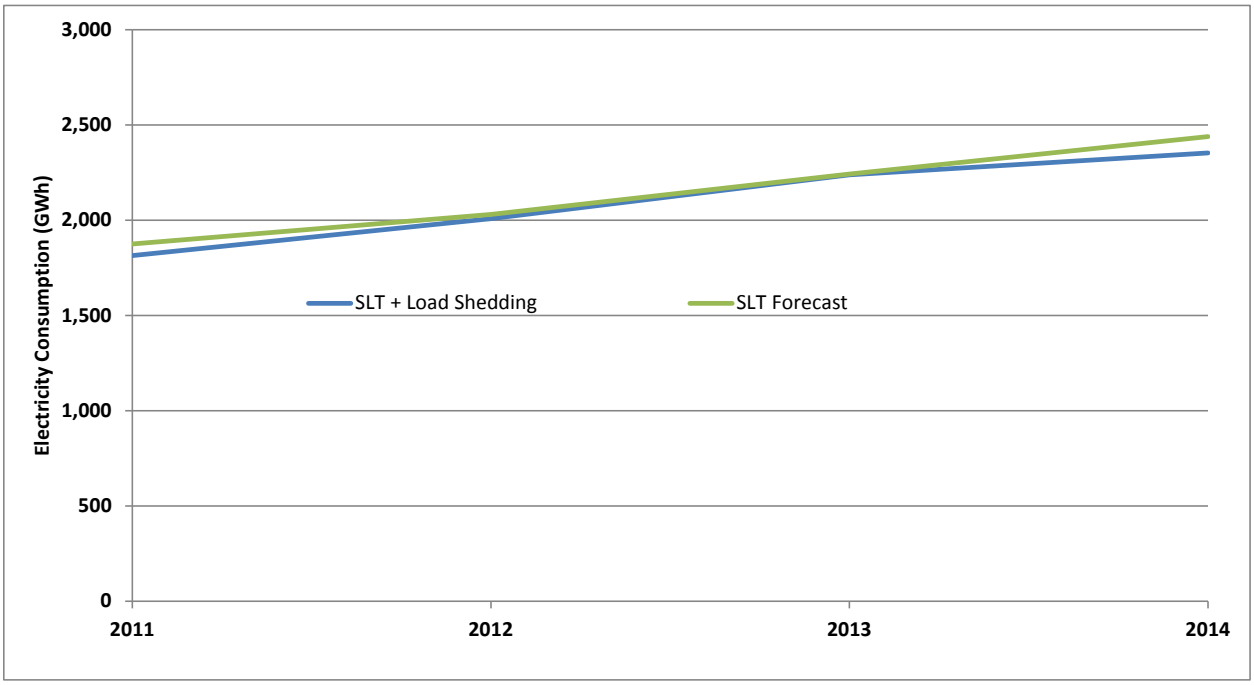

## 5.4.3 SLT Forecast for the 2012-2014 Period

Table 5-17 and Figure 5-11 show the comparison of the forecasted and actual historical demand plus load shedding for the SLT category. The difference between the forecast and the actual plus load shedding in 2014, at about 3%, given assumptions about the rebound effect, is a very strong validation of the forecast results and models.

Table 5-17: 2012-2014 Validation of SLT Forecast (GWh)

| Year | Forecast | Actual Plus Load Shedding | Actual |
|---|---|---|---|
| 2011 | 1,814 | 1,814 | 1,814 |
| 2012 | 2,031 | 2,008 | 1,980 |
| 2013 | 2,243 | 2,238 | 2,171 |
| 2014 | 2,439 | 2,353 | 2,125 |

Figure 5-11: 2012-2014 Validation of SLT Forecast (GWh)




## 5.4.4 NSLT+SLT Forecast for the 2012-2014 Period

An additional validation of the direct estimate of suppressed demand for the individually forecast NSLT and SLT categories is made using the combined forecast for the NSLT+SLT category.

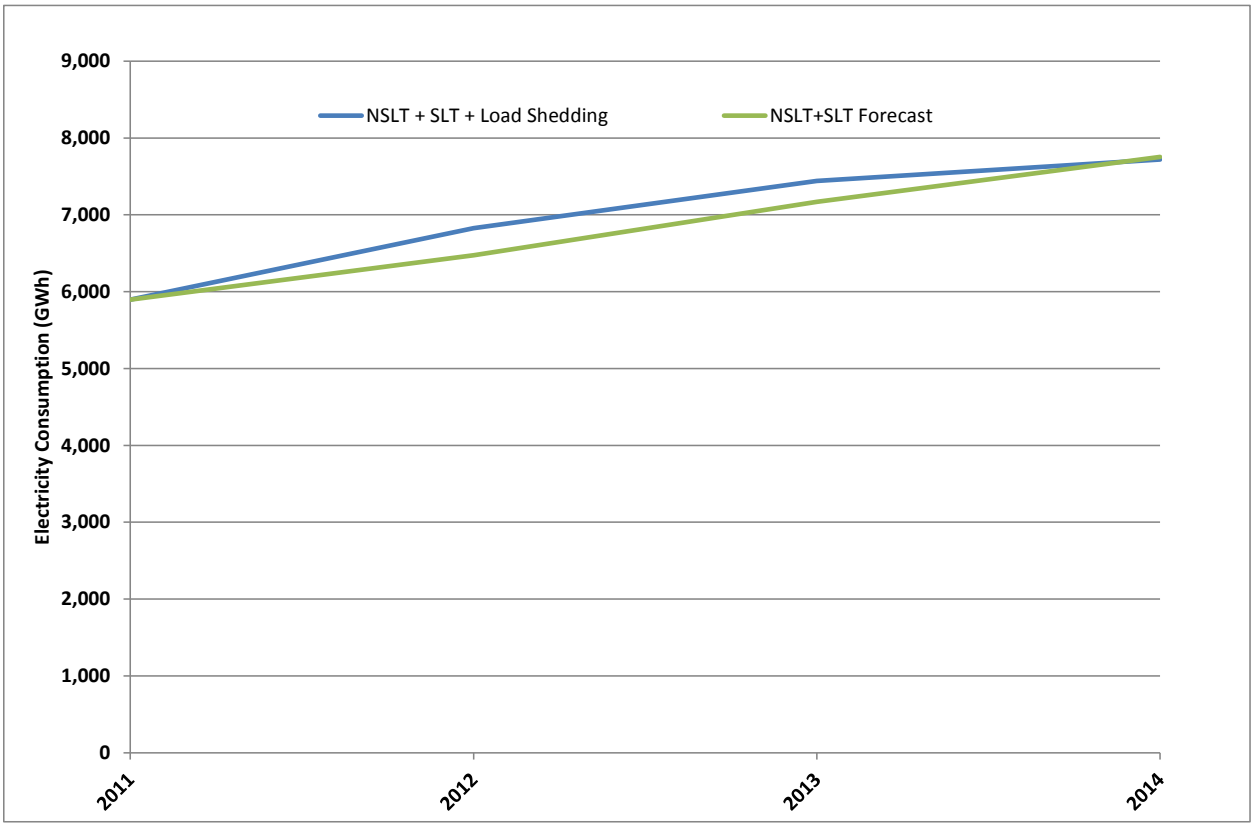
Table 5-18 and Figure 5-12 present NSLT+SLT forecasting results for the 2012-2014 period The comparison includes analysis results using the actual sales and Supply Component of the suppressed demand as described in Section 4.

Results again show very similar trajectories and the final 2014 demand estimates, with the forecast NSLT+SLT results slightly higher than the actual plus load shedding results in 2014. The historical forecast provides further independent validation of the methodology and results for estimating the direct analysis of the Supply Constraint component of the suppressed demand.

Table 5-18: 2012-2014 Validation of NSLT+SLT Forecast (GWh)

| Year | Forecast | Actual Plus Load Shedding | Actual |
|---|---|---|---|
| 2011 | 5,897 | 5,897 | 5,897 |
| 2012 | 6,474 | 6,827 | 6,773 |
| 2013 | 7,169 | 7,442 | 7,282 |
| 2014 | 7,753 | 7,721 | 7,062 |

Figure 5-12: 2012-2014 Validation of NSLT+SLT Forecast (GWh)




## 5.5 FORECAST AT THE DISTRIBUTION LEVEL AND VALIDATION

This section presents the forecasting results at the Distribution Level (e.g. forecast for the combined ECG and NEDCo demand), which includes Distribution Sales, Distribution Losses, and Suppressed Demand, and is developed from the independent component demands as presented in Sections 5.2.6 (Street Lighting), 5.3.1 (Residential), 5.3.2 (Non-Residential), and 5.3.4 (SLT). For validation, a comparison is made with a combined regression model for the NSLT and SLT categories as presented in Section 5.4.4 (NSLT+SLT), providing an internal validation of results. Base Case forecasting results at the Distribution Level are also compared with forecasts done by VRA and GRIDCo.

### 5.5.1 2015-2030 Distribution Level Forecasts

Table 5-19 shows the Distribution Level forecast developed from the individual component forecasts. The table presents total demand for the Res, Non-Res, SL categories combined, as well as forecasts for SLT, the adder accounting for Infrastructure Suppressed Demand, distribution losses, and the adder accounting for commercial losses assumed to be converted to paying demand.

The Base Case uses the ECG 2023 Loss Reduction target applied to the entire distribution network, e.g. losses in both ECG and NEDCo distribution networks. This is the loss target set by the ECG management for 2023. As year 2013 losses were around 23.2% of the total demand, the 2023 ECG loss target assumption means that losses will be reduced to 13.12% of the total demand in year 2023. This target also assumes that the entire commercial loss component,

estimated to be about half of the total distribution losses, will be converted into paying demand by year 2023. This loss component, called the Commercial Loss Adder, was added to the total demand at the distribution level. The Infrastructure Suppressed Demand Adder is estimated to increase only during the first 5 years, representing a gradual 5-year removal of distribution system constraints. After this initial period, the adder remains constant representing no further increase in demand, as all distribution constrains are already removed.

Table 5-19: Distribution Level Forecast for the Base Case (GWh)

| Year | Total (RES, NON_RES, SL) | SLT | Infrastructure Suppressed Demand Adder | Distribution Losses | Commercial Loss Adder (Per Year) | Total Incl. Losses and Adders |
|---|---|---|---|---|---|---|
| 2014 | 5,314 | 2,449 | 0 | 2,348 | 0 | 10,111 |
| 2015 | 5,721 | 2,644 | 155 | 2,373 | 113 | 11,006 |
| 2016 | 6,184 | 2,854 | 311 | 2,399 | 227 | 11,974 |
| 2017 | 6,699 | 3,080 | 466 | 2,422 | 340 | 13,007 |
| 2018 | 7,261 | 3,323 | 621 | 2,439 | 454 | 14,098 |
| 2019 | 7,833 | 3,556 | 776 | 2,434 | 567 | 15,166 |
| 2020 | 8,438 | 3,791 | 776 | 2,414 | 681 | 16,100 |
| 2021 | 9,076 | 4,036 | 776 | 2,380 | 794 | 17,063 |
| 2022 | 9,748 | 4,293 | 776 | 2,332 | 908 | 18,057 |
| 2023 | 10,453 | 4,566 | 776 | 2,268 | 1,021 | 19,083 |
| 2024 | 11,190 | 4,855 | 776 | 2,423 | 1,021 | 20,266 |
| 2025 | 11,921 | 5,141 | 776 | 2,577 | 1,021 | 21,435 |
| 2026 | 12,675 | 5,433 | 776 | 2,735 | 1,021 | 22,640 |
| 2027 | 13,461 | 5,737 | 776 | 2,899 | 1,021 | 23,895 |
| 2028 | 14,284 | 6,057 | 776 | 3,072 | 1,021 | 25,210 |
| 2029 | 15,151 | 6,393 | 776 | 3,253 | 1,021 | 26,594 |
| 2030 | 16,068 | 6,747 | 776 | 3,445 | 1,021 | 28,058 |

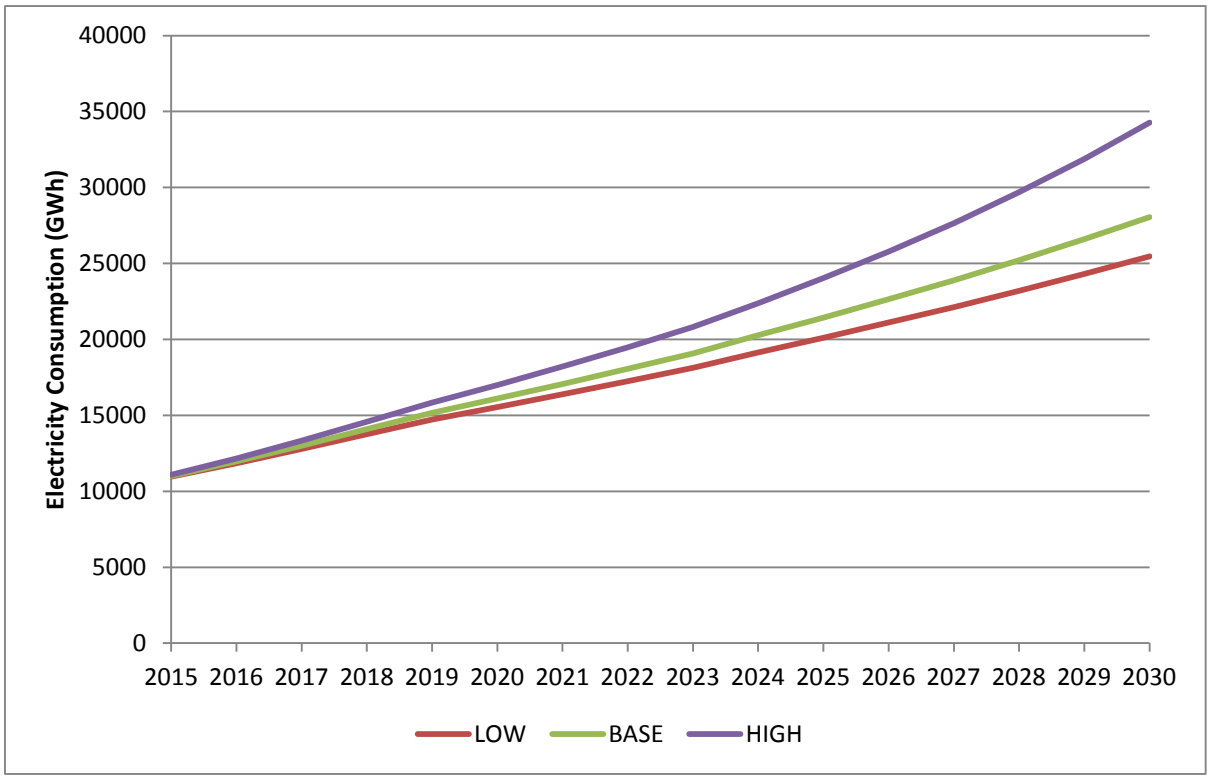
Table 5-20 and Figure 5-13 show the Distribution Level 2015-2030 period forecast for the Base Case, Low, and High Growth scenarios. The table also presents 2014 demand as adjusted for suppressed demand. Scenarios are derived from the High and Low Growth scenario forecasts for all customer categories presented earlier.

Table 5-20: Distribution Level Forecast, Base, Low and High Scenarios (GWh)

| Year | LOW | BASE | HIGH |
|---|---|---|---|
| 2014 | 10,111 | 10,111 | 10,111 |
| 2015 | 10,953 | 11,006 | 11,085 |
| 2016 | 11,843 | 11,974 | 12,161 |
| 2017 | 12,782 | 13,007 | 13,327 |

| | | | |
|---|---|---|---|
| 2018 | 13,766 | 14,098 | 14,575 |
| 2019 | 14,725 | 15,166 | 15,837 |
| 2020 | 15,545 | 16,100 | 16,994 |
| 2021 | 16,385 | 17,063 | 18,207 |
| 2022 | 17,245 | 18,057 | 19,482 |
| 2023 | 18,124 | 19,083 | 20,823 |
| 2024 | 19,130 | 20,266 | 22,383 |
| 2025 | 20,108 | 21,435 | 24,025 |
| 2026 | 21,105 | 22,640 | 25,778 |
| 2027 | 22,131 | 23,895 | 27,660 |
| 2028 | 23,194 | 25,210 | 29,689 |
| 2029 | 24,302 | 26,594 | 31,883 |
| 2030 | 25,461 | 28,058 | 34,264 |
| Annual Average Growth Rate (2014-2030) | 5.9% | 6.6% | 7.9% |

Figure 5-13: Distribution Level Forecast for the Base Case, Low and High Scenarios (GWh)



## 5.5.2 Validation of the 2015-2030 Base Forecast at the Distribution Level

### *5.5.2.1 Individual Component versus Combined Forecasts*

Table 5-21 shows the comparison between the individual component sales forecasts for Residential, Non-Residential and Street Lighting with the combined NSLT category. Distribution losses and infrastructure suppressed demand estimates are not included. The difference in the total 2030 demand is around 8%. Given confidence levels for the 15 year forecasts, we consider that the individual and combined categories compare very favorably, with very similar average annual growth rates.

Table 5-21: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast for the Base Case (GWh)

| Year | Res, Non-Res, SL | NSLT | Difference |
|---|---|---|---|
| 2014 | 5,314 | 5,314 | 0 |
| 2015 | 5,721 | 5,769 | -48 |
| 2016 | 6,184 | 6,202 | -19 |
| 2017 | 6,699 | 6,660 | 39 |
| 2018 | 7,261 | 7,149 | 112 |
| 2019 | 7,833 | 7,622 | 211 |
| 2020 | 8,438 | 8,117 | 321 |
| 2021 | 9,076 | 8,644 | 433 |
| 2022 | 9,748 | 9,204 | 544 |
| 2023 | 10,453 | 9,801 | 651 |
| 2024 | 11,190 | 10,437 | 754 |
| 2025 | 11,921 | 11,066 | 855 |
| 2026 | 12,675 | 11,727 | 948 |
| 2027 | 13,461 | 12,426 | 1,035 |
| 2028 | 14,284 | 13,167 | 1,117 |
| 2029 | 15,151 | 13,951 | 1,199 |
| 2030 | 16,068 | 14,783 | 1,285 |
| Annual Average Growth Rate (2014-2030) | 11.7% | 10.7% | |

### *5.5.2.2 Comparisons with other Forecasts at the Distribution Level for the Base Case*

The Distribution Level forecast includes the forecasts for ECG and NEDCo customers. Since our forecast is done using multiple customer categories that use total ECG and NEDCo demand and the number of customers (e.g. such as for residential, non-residential and street lighting

demand), we could not directly compare these forecasts on an individual utility level[22]. However, we could compare our forecast with the VRA and GRIDCo forecasts done on a same basis. We could not include a comparison with the EC forecast, since the EC forecasts provides the combined system forecast for all Services and Industrial customers. Table 5-22 shows this comparison including the GWh difference in each forecast. All three forecasts have similar results, with the Nexant forecast being slightly lower that the other two forecasts.

Table 5-22: Distribution Level Forecast Comparison (GWh)

| Year | Nexant (ECG and NEDCo) | VRA (ECG & NEDCo) | Difference from Nexant | GRIDCo (ECG & NEDCo) | Difference |
|---|---|---|---|---|---|
| 2014 | 10,111 | 10,111 | 0 | 10,360 | -249 |
| 2015 | 11,006 | 11,846 | -840 | 11,326 | -319 |
| 2016 | 11,974 | 12,533 | -559 | 12,187 | -213 |
| 2017 | 13,007 | 13,301 | -294 | 13,091 | -84 |
| 2018 | 14,098 | 14,455 | -357 | 14,118 | -20 |
| 2019 | 15,166 | 15,589 | -423 | 15,227 | -61 |
| 2020 | 16,100 | 16,727 | -627 | 16,427 | -327 |
| 2021 | 17,063 | 17,429 | -366 | 17,724 | -661 |
| 2022 | 18,057 | 18,541 | -484 | 19,126 | -1,069 |
| 2023 | 19,083 | 19,735 | -652 | | |
| 2024 | 20,266 | 21,031 | -765 | | |
| 2025 | 21,435 | 22,427 | -992 | | |
| 2026 | 22,640 | 23,882 | -1,242 | | |
| 2027 | 23,895 | 25,359 | -1,464 | | |
| 2028 | 25,210 | 26,893 | -1,683 | | |
| 2029 | 26,594 | 28,586 | -1,992 | | |
| 2030 | 28,058 | 30,384 | -2,326 | | |

## 5.6 TOTAL BASE CASE DEMAND FORECAST FOR THE 2015-2030 PERIOD

The Base Case Total Demand Forecast for 2015-2030 is developed by starting with the forecast at the Distribution Level and adding forecasts for all customer categories connected at the Transmission Level - Mines, Direct Customer Sales, VALCO, and Exports. System usage and transmission losses are also calculated based on the total consumption to derive the Total Demand Forecast, e.g. required net generation supply. The assumed transmission losses are

[22] One option to compare resulting forecasts with ECG and NEDCo individual forecasts is to assume the same historical demand ratios between ECG and NEDCo going forward. However, these due to the rapid increase in demand those ratios are likely to change, so we did not conduct this comparison.

consistent with the assumptions included in the GRIDCo forecast and take into account all system expansion and improvements needed over the next 10 year period. Losses are estimated to vary from year to year and increase slightly from 3.89% in 2014 to 3.92%% by 2025 as the system develops and new high voltage transmission lines are put into service. The 2025 loss factor is used through 2030. Coincident peak load factors are applied to derive the Peak Load forecast, as discussed in Section 3.3.7.

### 5.6.1 Mines, VALCO, and Export Forecasts

Forecasts for Mines, VALCO and Exports as performed by VRA, GRIDCo and the Energy Commission were selected as the best available forecasts to incorporate into the Total Demand forecast. Demand from these categories are project, government policy and contract specific, and are more accurately developed in a "bottoms-up" manner. Since forecasts are based on the exogenous inputs, a single set of forecasts are used in all of the forecasting scenarios[23].

Table 5-23 presents available VALCO forecasts for the 2015-2030 period, as estimated by GRIDCo and the Energy Commission. VALCO consumption is directly related to the number of pot-lines estimated in operation, with a single pot-line representing a demand of 625 GWh/year. The number of pot-lines operating at VALCO is dependent on availability of electricity supply in Ghana (as shows in the historical VALCO demand) and on the Ghana government policy and pricing for this specific large customer. Both the Energy Commission and GRIDCo assume VALCO long-term operations to include all 5 pot-lines, with a gradual increase to full production by year 2019.

Table 5-23: VALCO Forecast, from GRIDCo/EC (GWh)

| Year | GRIDCo/EC Forecast | Number of Pot-lines |
|---|---|---|
| 2015 | 625 | 1 |
| 2016 | 1250 | 2 |
| 2017 | 1250 | 2 |
| 2018 | 1875 | 3 |
| 2019 | 3125 | 5 |
| 2020 | 3125 | 5 |
| 2021 | 3125 | 5 |
| 2022 | 3125 | 5 |
| 2023 | 3125 | 5 |
| 2024 | 3125 | 5 |
| 2025 | 3125 | 5 |
| 2026 | 3125 | 5 |
| 2027 | 3125 | 5 |

[23] In our forecasting model, the User can modify inputs for each of these categories and study the impact of different assumptions on the total demand forecast.

| | | |
|---|---|---|
| 2028 | 3125 | 5 |
| 2029 | 3125 | 5 |
| 2030 | 3125 | 5 |

Forecast for Mines, shown in Table 5-24, is based on the VRA forecast. The VRA forecast is based on information gathered in interviews with the major mining companies and the Minerals Commission on the expected output from existing mines, including anticipated expansion plans; mines currently being planned and the availability of suitable ore deposits, the world market price of gold and the investment programs by the individual mines and on the relationship between mine production and electricity consumption. Similar end demand was also estimated by GRIDCo, but with the more rapid increase in early years. The Energy Commission forecast does not specify Mines as a separate category, and this demand is included in the overall Industry consumption.

Mines demand is estimated to nearly double during the next 15 year period.

Table 5-24: Mines Forecast (GWh)

| Year | VRA Base Forecast |
|---|---|
| 2015 | 1,618 |
| 2016 | 2,137 |
| 2017 | 2,179 |
| 2018 | 2,179 |
| 2019 | 2,241 |
| 2020 | 2,262 |
| 2021 | 2,404 |
| 2022 | 2,424 |
| 2023 | 2,565 |
| 2024 | 2,664 |
| 2025 | 2,826 |
| 2026 | 2,887 |
| 2027 | 2,948 |
| 2028 | 3,071 |
| 2029 | 3,101 |
| 2030 | 3,101 |

Source: VRA 2015-2030 Load Forecast, Final Report October 2014.

The GRIDCo/Energy Commission forecast for Exports is shown in Table 5-25. Exports are dependent on the supply conditions in Ghana and on the available supply to provide for the contractually specified amounts. The Export forecasts assume that supply will return to normal levels by 2016/2017 and show increases in exports from the existing 600 GWh/year level to at least meet the contractual obligations.

Table 5-25: Export Forecast (GWh)

| Year | CEB (Togo-Benin) | Sonabel (Burkina Faso) | CIE (Ivory Coast) | EDM (Mali) | Total Exports |
|---|---|---|---|---|---|
| 2015 | 1,000 | 70 | 18 | 0 | 1,088 |
| 2016 | 1,000 | 70 | 18 | 0 | 1088 |
| 2017 | 1,314 | 150 | 18 | 0 | 1,482 |
| 2018 | 1,314 | 690 | 18 | 300 | 2,322 |
| 2019 | 1,314 | 986 | 18 | 689 | 3,007 |
| 2020 | 1,314 | 986 | 18 | 689 | 3,007 |
| 2021 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2022 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2023 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2024 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2025 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2026 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2027 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2028 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2029 | 1,314 | 986 | 18 | 986 | 3,304 |
| 2030 | 1,314 | 986 | 18 | 986 | 3,304 |

Sources: VRA 2015-2030 Load Forecast, Final Report October 2014, forecast received from the Energy Commission of Ghana, December 2015.

### 5.6.2 Losses

System Uses and Transmission Losses, presented in Table 5-26, are based on GRIDCo estimates. Since GRIDCo conducts detailed transmission system planning and analysis, we consider their estimates to be the most accurate indicator of future transmission losses.

Table 5-26: Transmission Loss Estimates

| Year | GRIDCo Transmission Loss Factor |
|---|---|
| 2014 | 3.89% |
| 2015 | 4.01% |
| 2016 | 3.83% |
| 2017 | 3.78% |
| 2018 | 3.99% |
| 2019 | 3.93% |
| 2020 | 3.94% |
| 2021 | 3.90% |
| 2022 | 3.90% |
| 2023 | 3.91% |

| | |
|---|---|
| 2024 | 3.92% |
| 2025 - 2030 | 3.92% |

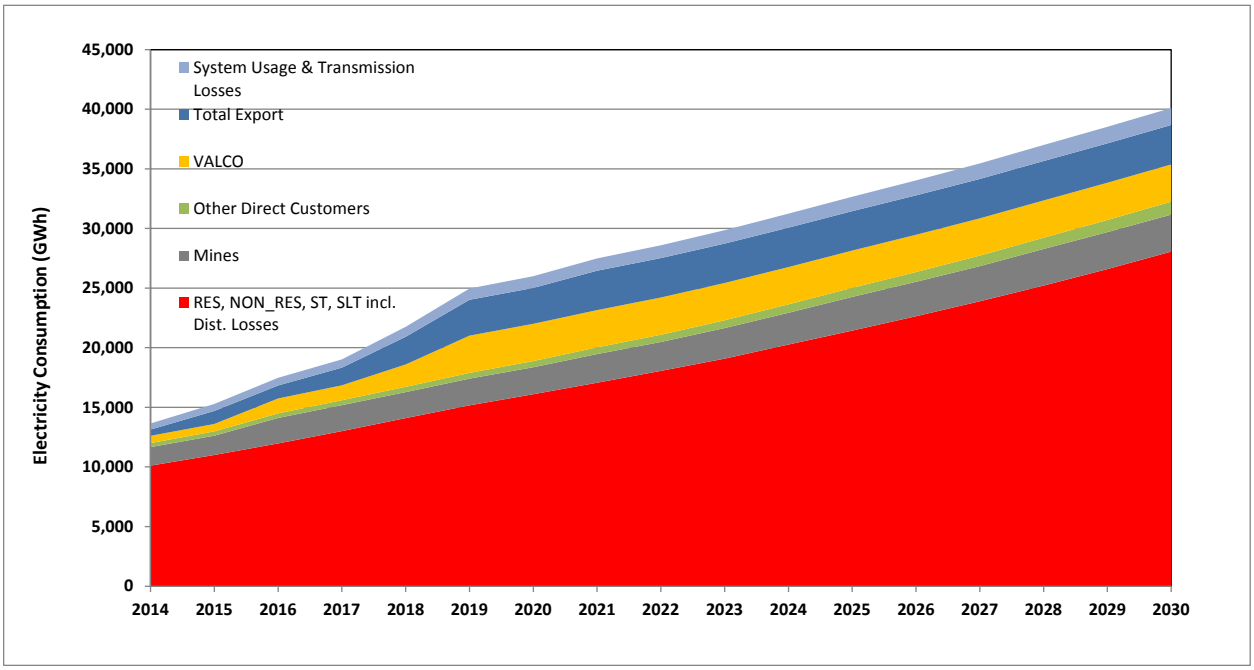
### 5.6.3 Total Demand Base Case Forecast

Table 5-27 shows the total Base Case demand for the 2015-2030 period. The Base Case total demand forecast for 2030 over 40,000 GWh and represents a 7.0% yearly growth rate over the 2014-2030 period. The table also presents growth rates for each demand component. Distribution losses are added to end-use categories forecasts at the distribution level. System usage and transmission losses are added to the demand in order to develop Net Generation Supply needed as an input to the Gas Market Study. In addition, Figure 5-14 presents the same results in graphical format showing the relative relationships and growth for all categories.

Table 5-27: Base Case Total Demand Forecast (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,006 | 1,618 | 359 | 12,983 | 625 | 1,088 | 589 | **15,285** |
| **2016** | 11,974 | 2,137 | 383 | 14,494 | 1,250 | 1,088 | 644 | **17,477** |
| **2017** | 13,007 | 2,179 | 412 | 15,598 | 1,250 | 1,482 | 692 | **19,022** |
| **2018** | 14,098 | 2,179 | 445 | 16,722 | 1,875 | 2,322 | 834 | **21,753** |
| **2019** | 15,166 | 2,241 | 481 | 17,888 | 3,125 | 3,007 | 944 | **24,964** |
| **2020** | 16,100 | 2,262 | 519 | 18,881 | 3,125 | 3,007 | 985 | **25,998** |
| **2021** | 17,063 | 2,404 | 561 | 20,028 | 3,125 | 3,304 | 1,031 | **27,487** |
| **2022** | 18,057 | 2,424 | 606 | 21,087 | 3,125 | 3,304 | 1,074 | **28,590** |
| **2023** | 19,083 | 2,565 | 654 | 22,303 | 3,125 | 3,304 | 1,123 | **29,855** |
| **2024** | 20,266 | 2,664 | 707 | 23,637 | 3,125 | 3,304 | 1,177 | **31,243** |
| **2025** | 21,435 | 2,826 | 762 | 25,023 | 3,125 | 3,304 | 1,207 | **32,660** |
| **2026** | 22,640 | 2,887 | 819 | 26,347 | 3,125 | 3,304 | 1,255 | **34,031** |
| **2027** | 23,895 | 2,948 | 880 | 27,723 | 3,125 | 3,304 | 1,302 | **35,454** |
| **2028** | 25,210 | 3,071 | 945 | 29,225 | 3,125 | 3,304 | 1,346 | **37,001** |
| **2029** | 26,594 | 3,101 | 1,013 | 30,709 | 3,125 | 3,304 | 1,388 | **38,526** |
| **2030** | 28,058 | 3,101 | 1,087 | 32,246 | 3,125 | 3,304 | 1,426 | **40,100** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 6.6% | 4.4% | 7.6% | 6.4% | 10.7% | 12.2% | 6.6% | 7.0% |

Figure 5-14: Base Case Total Demand Forecast by Category (GWh)



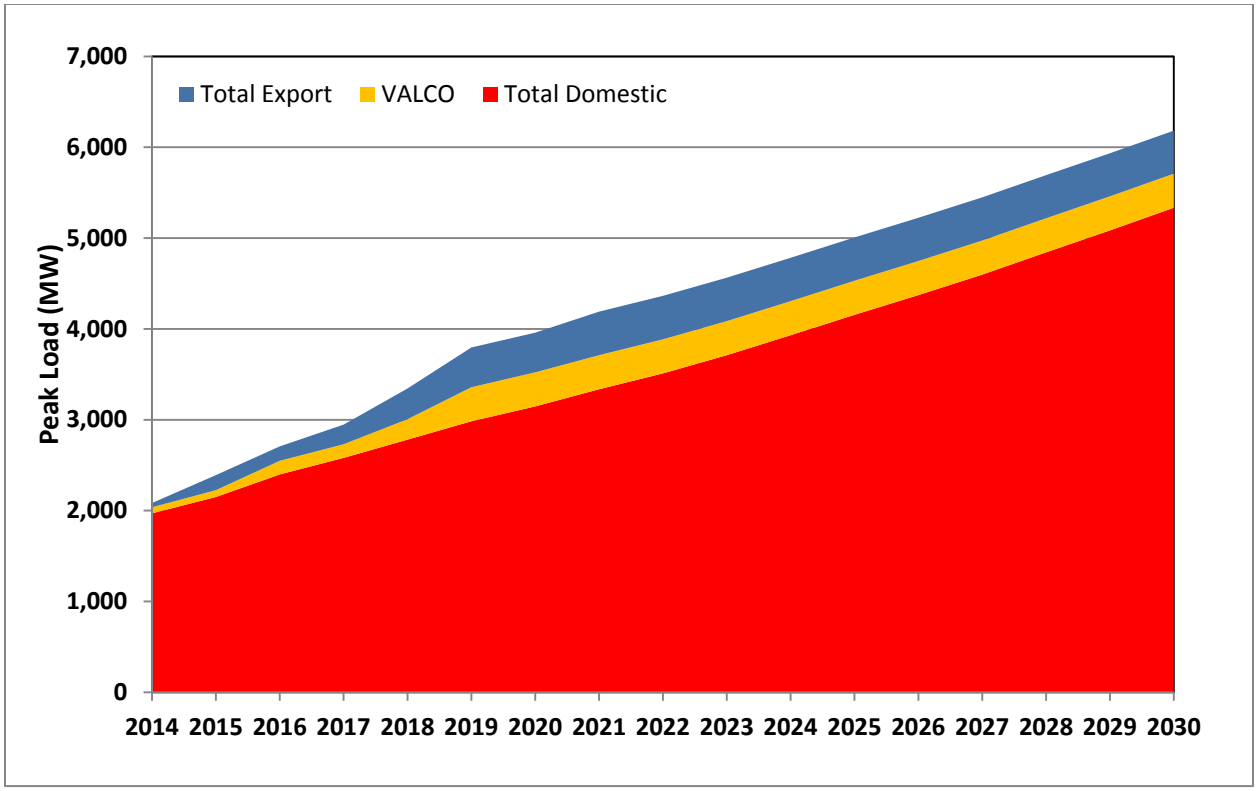

The corresponding Base Case peak load forecast was developed using the Base Case demand forecast and coincident factors consistent with the historical data and GRIDCo assumptions presented in Section 3.3.7. The GRIDCo forecast has the most accurate assumptions for coincidence factors due to their comprehensive historical database and their consistent use in developing peak load forecasts. The resulting total peak load forecast, presented in Table 5-28, for year 2030 is over 6,000 MW and represents a 7% yearly growth rate over the 2014-2030 period. The table shows coincident peak load forecasts and growth rates for the domestic, VALCO, and export categories. The peak load calculation assumes a constant load factor for domestic customers of 72.1%, consistent with the 2014 value, 95% load factor for VALCO representing full time operations, and the load factor for exports slightly increasing from 78% in 2015 to 80% in 2030, consistent with the load factor for exports assumed in the Energy Commission forecast. Figure 5-15 presents the same results in graphical format showing the impact each component has on the total peak demand.

Table 5-28: Base Case Peak Load Forecast (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,150 | 75 | 166 | 2,391 |
| 2016 | 2,398 | 150 | 159 | 2,707 |
| 2017 | 2,581 | 150 | 216 | 2,947 |
| 2018 | 2,781 | 225 | 338 | 3,345 |
| 2019 | 2,983 | 375 | 437 | 3,796 |
| 2020 | 3,147 | 375 | 437 | 3,959 |
| 2021 | 3,336 | 375 | 479 | 4,191 |
| 2022 | 3,511 | 375 | 479 | 4,365 |

| | | | | |
|---|---|---|---|---|
| 2023 | 3,711 | 375 | 478 | 4,564 |
| 2024 | 3,931 | 375 | 477 | 4,784 |
| 2025 | 4,156 | 375 | 477 | 5,007 |
| 2026 | 4,373 | 375 | 476 | 5,224 |
| 2027 | 4,598 | 375 | 476 | 5,449 |
| 2028 | 4,843 | 375 | 475 | 5,693 |
| 2029 | 5,085 | 375 | 474 | 5,934 |
| 2030 | 5,334 | 375 | 474 | 6,183 |
| Growth Rates | | | | |
| Average Annual 2014-2030 | 6.4% | 11.4% | 15.5% | 7.0% |

Figure 5-15: Base Case Peak Load Forecast (MW)




## 5.6.4 Base Case Forecast Comparison

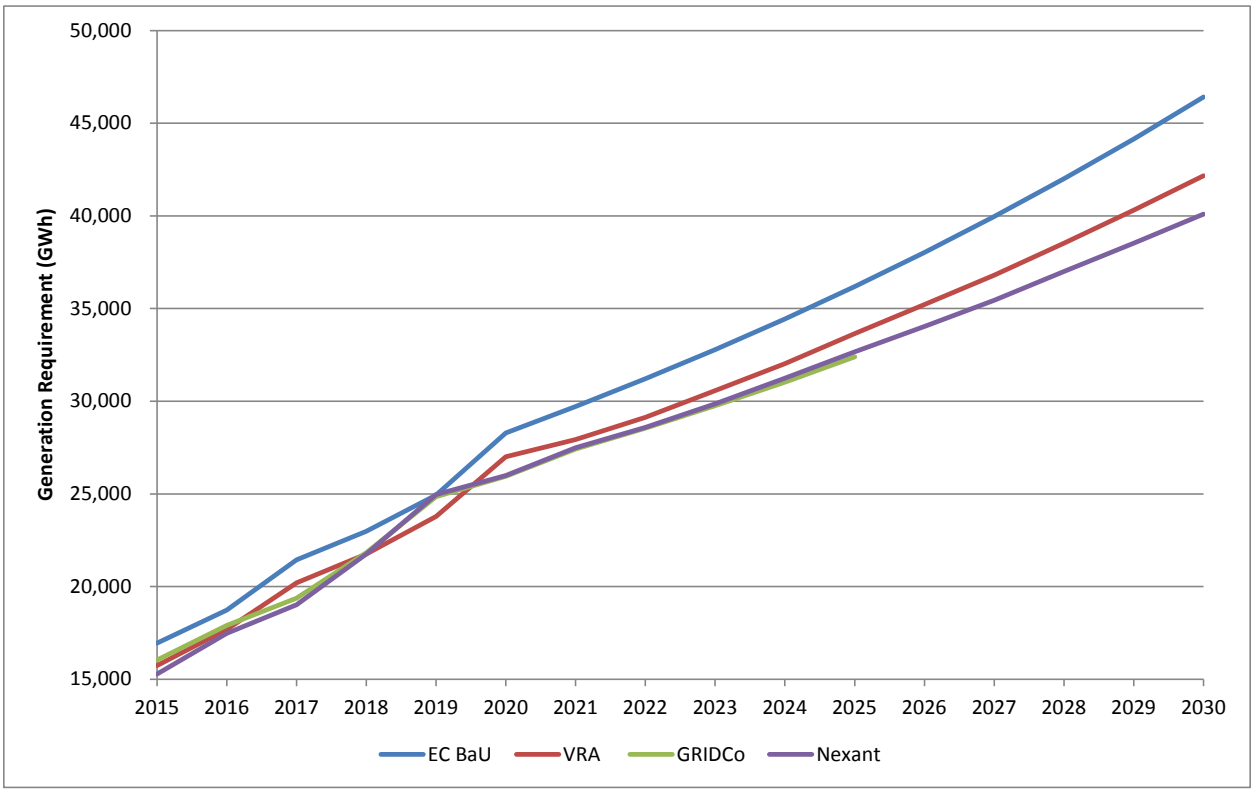
Table 5-29 shows the total Base Case demand for the 2015-2030 period compared with the Base Case forecasts done by the EC (Business as Usual), VRA and GridCo. The VRA forecast is presented by adjusting the forecast to include the same Export and VALCO assumptions as the other three forecasts. The Base total demand forecasts for VRA, GRIDCo and Nexant are all very close. The EC BaU forecast is higher in all years, primarily as the result of higher forecast for the household sector representing residential customers demand. The EC BaU forecast for the household sector reaches almost 15,000 GWh in year 2030, while Nexant forecast for the Residential sector is 6,350 GWh. The EC BaU forecast includes a more than 100% increase in

household demand from 2014 to 2015. We do not have details of the EC demand methodology and input, but realize that the EC household sales forecast includes commercial loss component.

Table 5-29: Base Case Total Demand Forecast Comparison (GWh)

| Year | EC BaU | VRA | GRIDCo | Nexant |
|---|---|---|---|---|
| 2015 | 16,956 | 15,743 | 16,038 | 15,285 |
| 2016 | 18,737 | 17,688 | 17,901 | 17,477 |
| 2017 | 21,443 | 20,198 | 19,371 | 19,022 |
| 2018 | 22,976 | 21,756 | 21,829 | 21,753 |
| 2019 | 24,942 | 23,788 | 24,851 | 24,964 |
| 2020 | 28,284 | 27,007 | 25,955 | 25,998 |
| 2021 | 29,711 | 27,935 | 27,417 | 27,487 |
| 2022 | 31,209 | 29,130 | 28,543 | 28,590 |
| 2023 | 32,785 | 30,565 | 29,751 | 29,855 |
| 2024 | 34,441 | 32,030 | 31,030 | 31,243 |
| 2025 | 36,183 | 33,649 | 32,398 | 32,660 |
| 2026 | 38,030 | 35,217 | | 34,031 |
| 2027 | 39,971 | 36,808 | | 35,454 |
| 2028 | 42,009 | 38,523 | | 37,001 |
| 2029 | 44,153 | 40,305 | | 38,526 |
| 2030 | 46,407 | 42,164 | | 40,100 |

Figure 5-16: Base Case Total Demand Forecast Comparison (GWh)



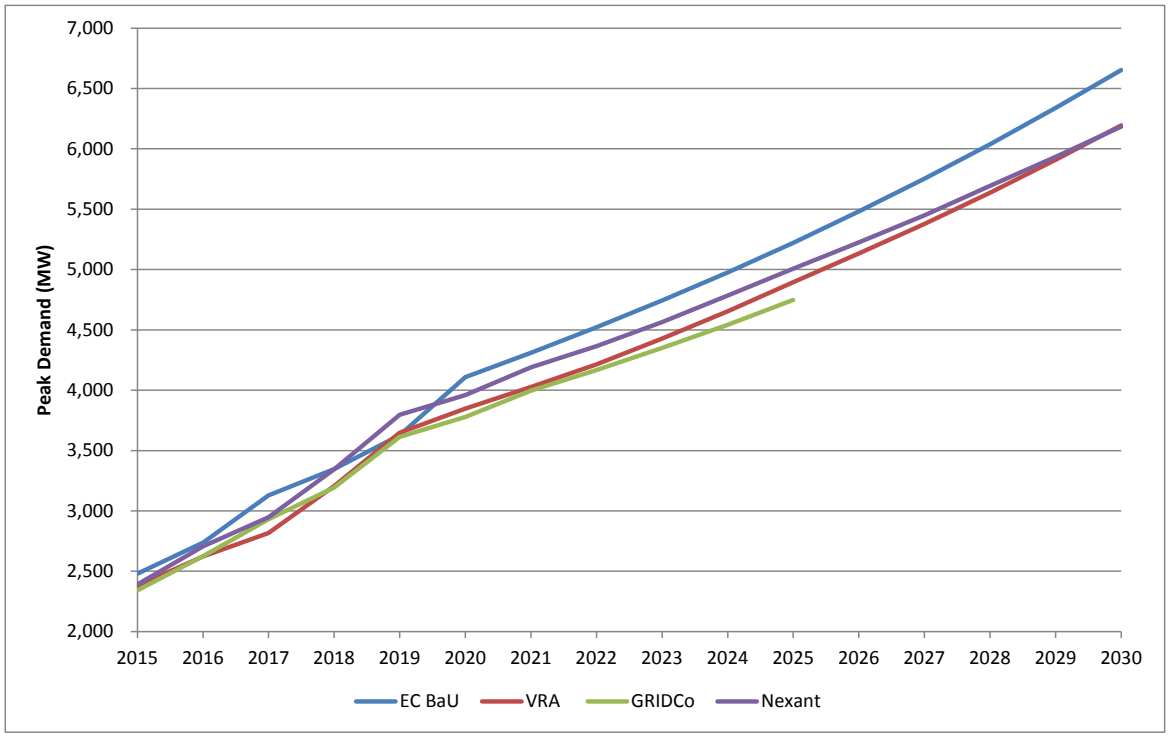
The corresponding Base Case peak load forecast comparison was developed using the Base Case peak load forecasts. Table 5-30 and Figure 5-17 presents those comparison results.

Similar to the energy forecast comparison, the Base Case total peak load demand forecasts for VRA, GRIDCo and Nexant are all close, while the EC BaU forecast is higher in all years. Differences between EC and the other three peak load forecasts are lower than what was observed for the energy forecasts. The EC peak demand forecast is lower as the EC assumes higher coincidence factors and higher resulting overall load factors in future years.

Table 5-30: Base Case Peak Load Forecast Comparison (MW)

| Year | EC BaU | VRA | GRIDCo | Nexant |
|---|---|---|---|---|
| 2015 | 2,479 | 2,379 | 2,342 | 2,391 |
| 2016 | 2,736 | 2,624 | 2,626 | 2,707 |
| 2017 | 3,127 | 2,816 | 2,931 | 2,947 |
| 2018 | 3,346 | 3,205 | 3,194 | 3,345 |
| 2019 | 3,628 | 3,648 | 3,613 | 3,796 |
| 2020 | 4,109 | 3,848 | 3,778 | 3,959 |
| 2021 | 4,310 | 4,027 | 3,997 | 4,191 |
| 2022 | 4,521 | 4,215 | 4,167 | 4,365 |
| 2023 | 4,743 | 4,428 | 4,350 | 4,564 |
| 2024 | 4,976 | 4,654 | 4,542 | 4,784 |
| 2025 | 5,221 | 4,895 | 4,748 | 5,007 |
| 2026 | 5,481 | 5,132 | | 5,224 |
| 2027 | 5,753 | 5,377 | | 5,449 |
| 2028 | 6,038 | 5,636 | | 5,693 |
| 2029 | 6,338 | 5,909 | | 5,934 |
| 2030 | 6,653 | 6,194 | | 6,183 |

Figure 5-17: Base Case Peak Load Forecast Comparison (MW)




# 5.7 BASE CASE SENSITIVITY ANALYSES

## 5.7.1 Increase the Suppressed Demand Attributed to Distribution System Constraints

In the Base Case, the Infrastructure Component of suppressed demand is estimated at 10% of current demand at the distribution level. The Infrastructure Component of the suppressed demand is attributed to Distribution System Constraints. Constraints are assumed to be removed over 5 years, resulting in the equivalent increase in demand. To study the impact of this assumption, we developed the Base Case sensitivity by increasing this estimate and model input to 20%. As seen in the total demand forecast for the year 2030 for both energy and peak load, presented in Tables 5-31 and 5-32, doubling the assumed contribution has a relatively small impact on the long term forecasts.

Table 5-31: Base Case Total Demand Forecast, with 20% Infrastructure Barrier Sensitivity (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,162 | 1,618 | 359 | 13,139 | 625 | 1,088 | 595 | **15,447** |
| **2016** | 12,284 | 2,137 | 383 | 14,805 | 1,250 | 1,088 | 656 | **17,799** |
| **2017** | 13,472 | 2,179 | 412 | 16,064 | 1,250 | 1,482 | 710 | **19,506** |
| **2018** | 14,719 | 2,179 | 445 | 17,343 | 1,875 | 2,322 | 859 | **22,399** |
| **2019** | 15,942 | 2,241 | 481 | 18,664 | 3,125 | 3,007 | 975 | **25,771** |
| **2020** | 16,876 | 2,262 | 519 | 19,658 | 3,125 | 3,007 | 1,015 | **26,805** |
| **2021** | 17,839 | 2,404 | 561 | 20,804 | 3,125 | 3,304 | 1,061 | **28,294** |
| **2022** | 18,833 | 2,424 | 606 | 21,863 | 3,125 | 3,304 | 1,104 | **29,396** |
| **2023** | 19,860 | 2,565 | 654 | 23,079 | 3,125 | 3,304 | 1,153 | **30,662** |
| **2024** | 21,042 | 2,664 | 707 | 24,413 | 3,125 | 3,304 | 1,207 | **32,049** |
| **2025** | 22,212 | 2,826 | 762 | 25,800 | 3,125 | 3,304 | 1,207 | **33,436** |
| **2026** | 23,416 | 2,887 | 819 | 27,123 | 3,125 | 3,304 | 1,255 | **34,807** |
| **2027** | 24,671 | 2,948 | 880 | 28,499 | 3,125 | 3,304 | 1,302 | **36,230** |
| **2028** | 25,986 | 3,071 | 945 | 30,002 | 3,125 | 3,304 | 1,346 | **37,777** |
| **2029** | 27,371 | 3,101 | 1,013 | 31,485 | 3,125 | 3,304 | 1,388 | **39,302** |
| **2030** | 28,835 | 3,101 | 1,087 | 33,022 | 3,125 | 3,304 | 1,426 | **40,877** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 6.8% | 4.4% | 7.6% | 6.5% | 10.7% | 12.2% | 6.6% | 7.1% |

Table 5-32: Base Case Peak Load Forecast, with 20% Infrastructure Barrier Sensitivity (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,176 | 75 | 166 | 2,416 |
| 2016 | 2,449 | 150 | 159 | 2,758 |
| 2017 | 2,657 | 150 | 216 | 3,024 |
| 2018 | 2,884 | 225 | 338 | 3,447 |
| 2019 | 3,111 | 375 | 437 | 3,924 |
| 2020 | 3,275 | 375 | 437 | 4,087 |
| 2021 | 3,464 | 375 | 479 | 4,318 |
| 2022 | 3,639 | 375 | 479 | 4,492 |
| 2023 | 3,839 | 375 | 478 | 4,692 |
| 2024 | 4,059 | 375 | 477 | 4,911 |
| 2025 | 4,279 | 375 | 477 | 5,130 |
| 2026 | 4,496 | 375 | 476 | 5,347 |
| 2027 | 4,721 | 375 | 476 | 5,572 |
| 2028 | 4,966 | 375 | 475 | 5,816 |
| 2029 | 5,208 | 375 | 474 | 6,057 |
| 2030 | 5,457 | 375 | 474 | 6,306 |

| Growth Rates | | | | |
|---|---|---|---|---|
| Average Annual 2014-2030 | 7.6% | 11.4% | 15.5% | 8.1% |

### 5.7.2 Sensitivity with No Loss Reduction

The Base Case uses the ECG 2023 Loss Reduction target applied to the entire distribution network, e.g. losses in both ECG and NEDCo distribution networks. This is the loss target set by the ECG management for 2023. As year 2013 losses were around 23.2% of the total demand, the 2023 ECG loss target assumption means that losses will be reduced to 13.12% of the total demand in year 2023.

The 2030 No Loss Reduction sensitivity assumes that losses will remain at historical levels through year 2030 and that the commercial losses will increase proportionally to the increase in demand. Consequently, there is no conversion of current commercial losses to paying demand and the Commercial Loss Adder is zero, as presented in Table 5-33. This sensitivity assumes that the efforts to reduce losses will not be successful and provides assessment of the impact on the system demand.

Table 5-33: Distribution Demand Forecast, Sensitivity with No Loss Reduction (GWh)

| Year | Total (RES, NON_RES, SL) | SLT | Infrastructure Suppressed Demand Adder | Distribution Losses | Commercial Loss Adder (Per Year) | Total Incl. Losses and Adders |
|---|---|---|---|---|---|---|
| 2014 | 5,314 | 2,449 | 0 | 2,348 | 0 | 10,111 |
| 2015 | 5,721 | 2,644 | 155 | 2,529 | 0 | 11,049 |
| 2016 | 6,184 | 2,854 | 311 | 2,732 | 0 | 12,080 |
| 2017 | 6,699 | 3,080 | 466 | 2,955 | 0 | 13,199 |
| 2018 | 7,261 | 3,323 | 621 | 3,198 | 0 | 14,403 |
| 2019 | 7,833 | 3,556 | 776 | 3,440 | 0 | 15,605 |
| 2020 | 8,438 | 3,791 | 776 | 3,693 | 0 | 16,698 |
| 2021 | 9,076 | 4,036 | 776 | 3,959 | 0 | 17,848 |
| 2022 | 9,748 | 4,293 | 776 | 4,239 | 0 | 19,056 |
| 2023 | 10,453 | 4,566 | 776 | 4,533 | 0 | 20,327 |
| 2024 | 11,190 | 4,855 | 776 | 4,842 | 0 | 21,663 |
| 2025 | 11,921 | 5,141 | 776 | 5,147 | 0 | 22,985 |
| 2026 | 12,675 | 5,433 | 776 | 5,462 | 0 | 24,346 |
| 2027 | 13,461 | 5,737 | 776 | 5,789 | 0 | 25,764 |
| 2028 | 14,284 | 6,057 | 776 | 6,133 | 0 | 27,249 |
| 2029 | 15,151 | 6,393 | 776 | 6,494 | 0 | 28,814 |
| 2030 | 16,068 | 6,747 | 776 | 6,876 | 0 | 30,468 |

The impact on total demand is presented in Table 5-34. Impact on total demand is significant, as the total demand, under his sensitivity assumption, would increase by 2,600 GWh. Table 5-35 shows the impact on peak load forecast. Approximately 400 MW of additional generation is required to accommodate these additional losses.

Table 5-34: Base Case Total Demand Forecast, Sensitivity with No Loss Reduction (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,049 | 1,618 | 359 | 13,026 | 625 | 1,088 | 591 | **15,330** |
| **2016** | 12,080 | 2,137 | 383 | 14,601 | 1,250 | 1,088 | 648 | **17,587** |
| **2017** | 13,199 | 2,179 | 412 | 15,790 | 1,250 | 1,482 | 700 | **19,222** |
| **2018** | 14,403 | 2,179 | 445 | 17,027 | 1,875 | 2,322 | 846 | **22,070** |
| **2019** | 15,605 | 2,241 | 481 | 18,327 | 3,125 | 3,007 | 962 | **25,420** |
| **2020** | 16,698 | 2,262 | 519 | 19,480 | 3,125 | 3,007 | 1,008 | **26,620** |
| **2021** | 17,848 | 2,404 | 561 | 20,812 | 3,125 | 3,304 | 1,061 | **28,303** |
| **2022** | 19,056 | 2,424 | 606 | 22,086 | 3,125 | 3,304 | 1,113 | **29,628** |
| **2023** | 20,327 | 2,565 | 654 | 23,547 | 3,125 | 3,304 | 1,172 | **31,147** |
| **2024** | 21,663 | 2,664 | 707 | 25,034 | 3,125 | 3,304 | 1,232 | **32,695** |
| **2025** | 22,985 | 2,826 | 762 | 26,573 | 3,125 | 3,304 | 1,294 | **34,296** |
| **2026** | 24,346 | 2,887 | 819 | 28,053 | 3,125 | 3,304 | 1,352 | **35,833** |
| **2027** | 25,764 | 2,948 | 880 | 29,592 | 3,125 | 3,304 | 1,412 | **37,433** |
| **2028** | 27,249 | 3,071 | 945 | 31,265 | 3,125 | 3,304 | 1,477 | **39,172** |
| **2029** | 28,814 | 3,101 | 1,013 | 32,928 | 3,125 | 3,304 | 1,543 | **40,900** |
| **2030** | 30,468 | 3,101 | 1,087 | 34,655 | 3,125 | 3,304 | 1,610 | **42,695** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 7.1% | 4.4% | 7.6% | 6.9% | 10.7% | 12.2% | 7.4% | 7.4% |

Table 5-35: Base Case Peak Load Forecast, Sensitivity with No Loss Reduction (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,157 | 75 | 166 | 2,398 |
| 2016 | 2,416 | 150 | 159 | 2,725 |
| 2017 | 2,612 | 150 | 216 | 2,979 |
| 2018 | 2,832 | 225 | 338 | 3,395 |
| 2019 | 3,056 | 375 | 437 | 3,868 |
| 2020 | 3,246 | 375 | 437 | 4,058 |
| 2021 | 3,465 | 375 | 479 | 4,320 |
| 2022 | 3,675 | 375 | 479 | 4,529 |
| 2023 | 3,916 | 375 | 478 | 4,769 |
| 2024 | 4,161 | 375 | 477 | 5,014 |
| 2025 | 4,415 | 375 | 477 | 5,267 |

| | | | | |
|---|---|---|---|---|
| 2026 | 4,658 | 375 | 476 | 5,510 |
| 2027 | 4,912 | 375 | 476 | 5,762 |
| 2028 | 5,187 | 375 | 475 | 6,037 |
| 2029 | 5,461 | 375 | 474 | 6,310 |
| 2030 | 5,745 | 375 | 474 | 6,594 |
| Growth Rates | | | | |
| Average Annual 2014-2030 | 6.9% | 11.4% | 15.5% | 7.5% |

# 5.8 SCENARIO RESULTS

## 5.8.1 Low Growth Scenario

### *5.8.1.1 Low Scenario Forecast at the Distribution Level and Validation*

The Low Growth scenario forecast at the distribution level is presented in Table 5-36. The table also shows validation results using the Low Growth scenario forecast for the combined NSLT category. The Individual Component versus Combination Forecasts column shows the differences between the individual component forecasts for Residential, Non-Residential and Street Lighting with the combined NSLT category.

The Low Scenario forecast assumptions, used as inputs in developing this forecast, are summarized in Section 3.3.6. Distribution losses and suppressed demand estimates are not included in the comparison. As stated in Section 5.3.3, given the confidence levels for the two forecasts, results provide a good validation of the forecasts using different models. The annual average growth rates for the two models compare favorably.

Table 5-36: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast, Low Growth Scenario (GWh)

| Year | Res, Non-Res, SL | NSLT | Difference |
|---|---|---|---|
| 2014 | 5,314 | 5,314 | 0 |
| 2015 | 5,701 | 5,736 | -35 |
| 2016 | 6,137 | 6,127 | 11 |
| 2017 | 6,620 | 6,535 | 85 |
| 2018 | 7,145 | 6,969 | 177 |
| 2019 | 7,670 | 7,379 | 290 |
| 2020 | 8,219 | 7,806 | 413 |
| 2021 | 8,793 | 8,257 | 536 |
| 2022 | 9,391 | 8,733 | 657 |
| 2023 | 10,011 | 9,237 | 774 |
| 2024 | 10,654 | 9,770 | 884 |
| 2025 | 11,279 | 10,280 | 1,000 |

| | | | |
|---|---|---|---|
| 2026 | 11,918 | 10,808 | 1,110 |
| 2027 | 12,575 | 11,362 | 1,213 |
| 2028 | 13,256 | 11,945 | 1,311 |
| 2029 | 13,964 | 12,557 | 1,407 |
| 2030 | 14,705 | 13,201 | 1,504 |
| Average Annual Growth Rates 2014-2030 | 5.8% | 5.7% | |

Table 5-37 shows the comparison between the individual component forecasts for Residential, Non-Residential and Street Lighting plus SLT forecasts, with the combined NSLT+SLT category under the Low Growth scenario assumptions. For this scenario, the individually forecasted components result in significantly higher total forecasted demand, suggesting that the combined forecast does not present a good fit for forecasting Low Growth scenario demand.

Table 5-37: Comparison of Res, Non-Res, and SLT + SLT Forecast with Combined NSLT+SLT Forecast, Low Growth Scenario (GWh)

| Year | Res, Non-Res, SL +SLT | NSLT +SLT | Difference |
|---|---|---|---|
| 2014 | 7,763 | 7,763 | 0 |
| 2015 | 8,323 | 8,414 | -90 |
| 2016 | 8,935 | 8,624 | 310 |
| 2017 | 9,599 | 9,159 | 439 |
| 2018 | 10,314 | 9,727 | 587 |
| 2019 | 11,025 | 10,222 | 804 |
| 2020 | 11,766 | 10,740 | 1,026 |
| 2021 | 12,538 | 11,284 | 1,254 |
| 2022 | 13,345 | 11,855 | 1,489 |
| 2023 | 14,185 | 12,455 | 1,729 |
| 2024 | 15,059 | 13,086 | 1,973 |
| 2025 | 15,909 | 13,621 | 2,288 |
| 2026 | 16,774 | 14,175 | 2,599 |
| 2027 | 17,666 | 14,752 | 2,914 |
| 2028 | 18,589 | 15,351 | 3,239 |
| 2029 | 19,552 | 15,975 | 3,577 |
| 2030 | 20,559 | 16,623 | 3,935 |
| Growth Rate | | | |
| Average Annual 2014-2030 | 6.2% | 4.6% | |

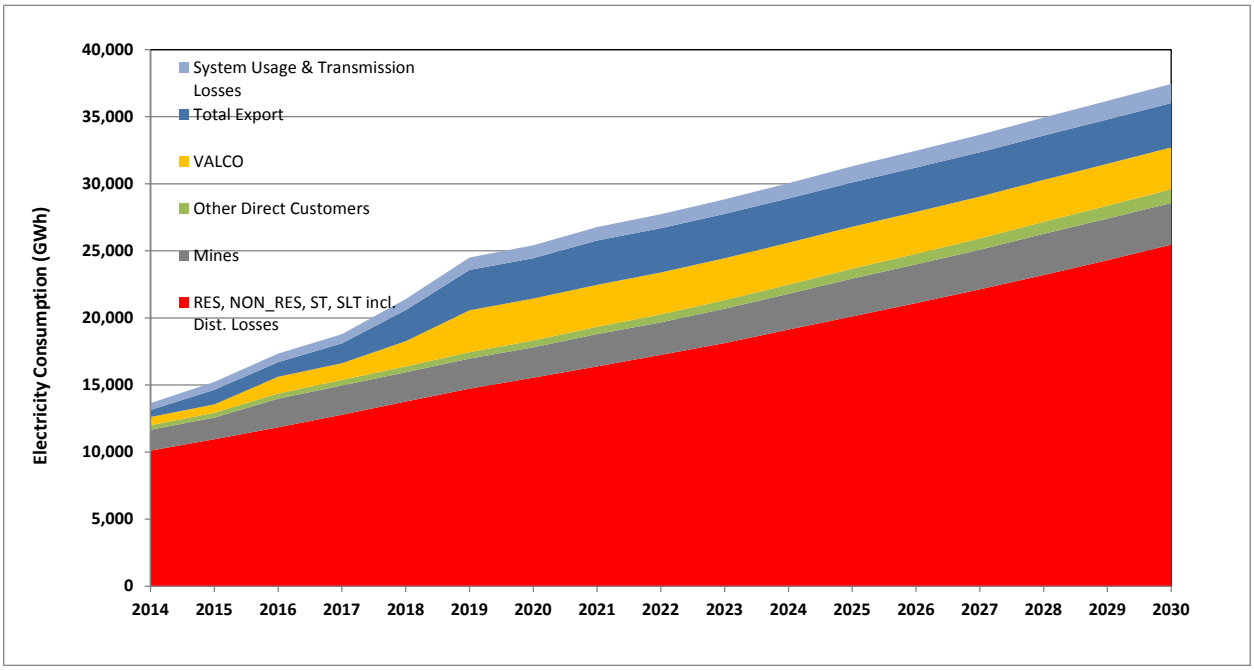
### 5.8.1.2 Total Low Growth Scenario Forecast

Table 5-38 shows the total Low Growth Scenario demand for the 2014-2030 period. The Low Growth total demand forecast at the generation supply level for 2030 is almost 37,500 GWh. This represents a 6.5% yearly growth rate over this period, and is about 2,600 GWh, or 6.4%, below the Base Case 2030 forecast. Table 5-38 also presents growth rates for each demand component. In addition, Figure 5-18 presents the same results in graphical format showing the relative relationships and growth for all categories.

Table 5-38: Total Low Growth Scenario Demand Forecast (GWh)

| | Domestic Consumption | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Year | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 10,953 | 1,618 | 358 | 12,929 | 625 | 1,088 | 587 | **15,229** |
| **2016** | 11,843 | 2,137 | 382 | 14,363 | 1,250 | 1,088 | 639 | **17,340** |
| **2017** | 12,782 | 2,179 | 410 | 15,371 | 1,250 | 1,482 | 684 | **18,787** |
| **2018** | 13,766 | 2,179 | 442 | 16,387 | 1,875 | 2,322 | 821 | **21,404** |
| **2019** | 14,725 | 2,241 | 476 | 17,442 | 3,125 | 3,007 | 927 | **24,500** |
| **2020** | 15,545 | 2,262 | 512 | 18,319 | 3,125 | 3,007 | 962 | **25,413** |
| **2021** | 16,385 | 2,404 | 550 | 19,339 | 3,125 | 3,304 | 1,004 | **26,772** |
| **2022** | 17,245 | 2,424 | 592 | 20,261 | 3,125 | 3,304 | 1,042 | **27,731** |
| **2023** | 18,124 | 2,565 | 636 | 21,325 | 3,125 | 3,304 | 1,085 | **28,839** |
| **2024** | 19,130 | 2,664 | 684 | 22,478 | 3,125 | 3,304 | 1,132 | **30,038** |
| **2025** | 20,108 | 2,826 | 733 | 23,668 | 3,125 | 3,304 | 1,207 | **31,304** |
| **2026** | 21,105 | 2,887 | 785 | 24,777 | 3,125 | 3,304 | 1,255 | **32,461** |
| **2027** | 22,131 | 2,948 | 839 | 25,918 | 3,125 | 3,304 | 1,302 | **33,649** |
| **2028** | 23,194 | 3,071 | 897 | 27,162 | 3,125 | 3,304 | 1,346 | **34,937** |
| **2029** | 24,302 | 3,101 | 958 | 28,361 | 3,125 | 3,304 | 1,388 | **36,178** |
| **2030** | 25,461 | 3,101 | 1,022 | 29,584 | 3,125 | 3,304 | 1,426 | **37,439** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 5.9% | 4.4% | 7.2% | 5.8% | 10.7% | 12.2% | 6.6% | 6.5% |

Figure 5-18: Total Low Growth Scenario Demand Forecast (GWh)




The corresponding Low Growth scenario peak load forecast, presented in Table 5-39, was developed using the same coincident factors as applied for the Base Case forecast. The resulting Low Growth scenario peak load forecast for year 2030 is around 5,760 MW and represents a lower 6.5% yearly growth rate over the 2014-2030 period (compared to 7.0% for the Base Case).

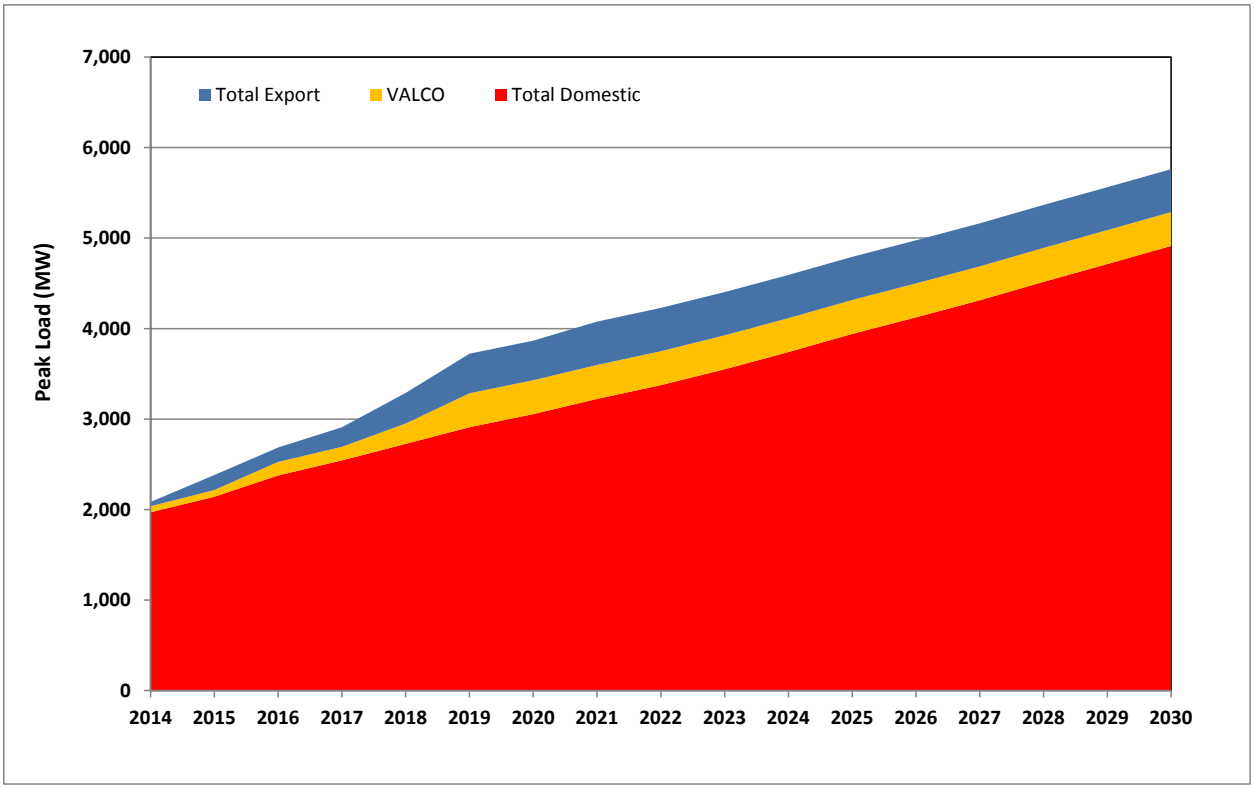
Table 5-39: Low Growth Scenario Peak Load Forecast (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,141 | 75 | 166 | 2,382 |
| 2016 | 2,377 | 150 | 159 | 2,686 |
| 2017 | 2,544 | 150 | 216 | 2,910 |
| 2018 | 2,726 | 225 | 338 | 3,289 |
| 2019 | 2,910 | 375 | 437 | 3,722 |
| 2020 | 3,055 | 375 | 437 | 3,866 |
| 2021 | 3,223 | 375 | 479 | 4,077 |
| 2022 | 3,375 | 375 | 479 | 4,229 |
| 2023 | 3,550 | 375 | 478 | 4,403 |
| 2024 | 3,740 | 375 | 477 | 4,593 |
| 2025 | 3,941 | 375 | 477 | 4,793 |
| 2026 | 4,124 | 375 | 476 | 4,975 |
| 2027 | 4,312 | 375 | 476 | 5,163 |
| 2028 | 4,516 | 375 | 475 | 5,366 |
| 2029 | 4,713 | 375 | 474 | 5,562 |

| | | | | |
|---|---|---|---|---|
| 2030 | 4,913 | 375 | 474 | 5,761 |
| Growth Rates | | | | |
| Average Annual 2014-2030 | 5.9% | 11.4% | 15.5% | 6.6% |

Figure 5-19 presents the same results in graphical format showing the impact each component has on the total peak load.

Figure 5-19: Low Growth Scenario Peak Load Forecast by Category (MW)




## 5.8.2 High Growth Scenario

### *5.8.2.1 Validation of the 2030 High Scenario Forecast at the Distribution Level*

The High Growth scenario forecast at the distribution level is presented in Table 5-40. The table also shows validation results using the High Growth scenario forecast for the combined NSLT category. The Individual Component versus Combination Forecasts column shows the differences between the individual component forecasts for Residential, Non-Residential and Street Lighting with the combined NSLT category.

The High Scenario forecast assumptions, used as inputs in developing this forecast, are summarized in Section 3.3.6. Distribution losses and suppressed demand estimates are not included in the comparison. As stated in Section 5.3.3, given the confidence levels for the two forecasts, results provide a good validation of the forecasts using different models. The average annual growth rates for the forecasts compare favorably as well.

Table 5-40: Comparison of Res, Non-Res and SL Forecast with NSLT Forecast, High Growth Scenario (GWh)

| Year | Res, Non-Res, SL | NSLT | Difference |
|---|---|---|---|
| 2014 | 5,314 | 5,314 | 0 |
| 2015 | 5,760 | 5,834 | -73 |
| 2016 | 6,275 | 6,352 | -77 |
| 2017 | 6,853 | 6,909 | -57 |
| 2018 | 7,489 | 7,514 | -25 |
| 2019 | 8,162 | 8,138 | 24 |
| 2020 | 8,887 | 8,809 | 78 |
| 2021 | 9,664 | 9,534 | 130 |
| 2022 | 10,496 | 10,319 | 177 |
| 2023 | 11,385 | 11,169 | 216 |
| 2024 | 12,334 | 12,088 | 246 |
| 2025 | 13,347 | 13,062 | 285 |
| 2026 | 14,438 | 14,111 | 326 |
| 2027 | 15,614 | 15,244 | 369 |
| 2028 | 16,887 | 16,468 | 419 |
| 2029 | 18,270 | 17,791 | 480 |
| 2030 | 19,779 | 19,219 | 560 |
| Growth Rates | | | |
| Average Annual (2014-2030) | 8.6% | 8.4% | |

Table 5-41 shows the comparison between the individual component forecasts for Residential, Non-Residential and Street Lighting plus SLT forecasts, with the combined NSLT+SLT category for the High Growth Scenario. For this scenario the individually forecasted components result in slightly higher total forecasted demand, suggesting that the combined forecast also presents a good fit for forecasting High Growth scenario demand and serves as an additional validation of individual component forecasts.

Table 5-41: Comparison of Res, Non-Res, and SL + SLT Forecast with Combined NSLT+SLT Forecast, High Scenario (GWh)

| Year | Res, Non-Res, SL +SLT | NSLT +SLT | Difference |
|---|---|---|---|
| 2014 | 7,763 | 7,763 | 0 |
| 2015 | 8,426 | 8,669 | -243 |
| 2016 | 9,186 | 9,160 | 26 |
| 2017 | 10,036 | 10,031 | 4 |

| | | | |
|---|---|---|---|
| 2018 | 10,971 | 10,985 | -13 |
| f2019 | 11,942 | 11,858 | 84 |
| 2020 | 12,975 | 12,797 | 178 |
| 2021 | 14,081 | 13,809 | 272 |
| 2022 | 15,263 | 14,900 | 363 |
| 2023 | 16,529 | 16,078 | 451 |
| 2024 | 17,885 | 17,348 | 537 |
| 2025 | 19,312 | 18,572 | 740 |
| 2026 | 20,835 | 19,879 | 955 |
| 2027 | 22,470 | 21,277 | 1,192 |
| 2028 | 24,232 | 22,773 | 1,459 |
| 2029 | 26,138 | 24,374 | 1,764 |
| 2030 | 28,207 | 26,087 | 2,120 |
| Growth Rates | | | |
| Average Annual (2014-2030) | 8.4% | 7.9% | |

#### *5.8.2.2 Total High Growth Scenario Forecast*

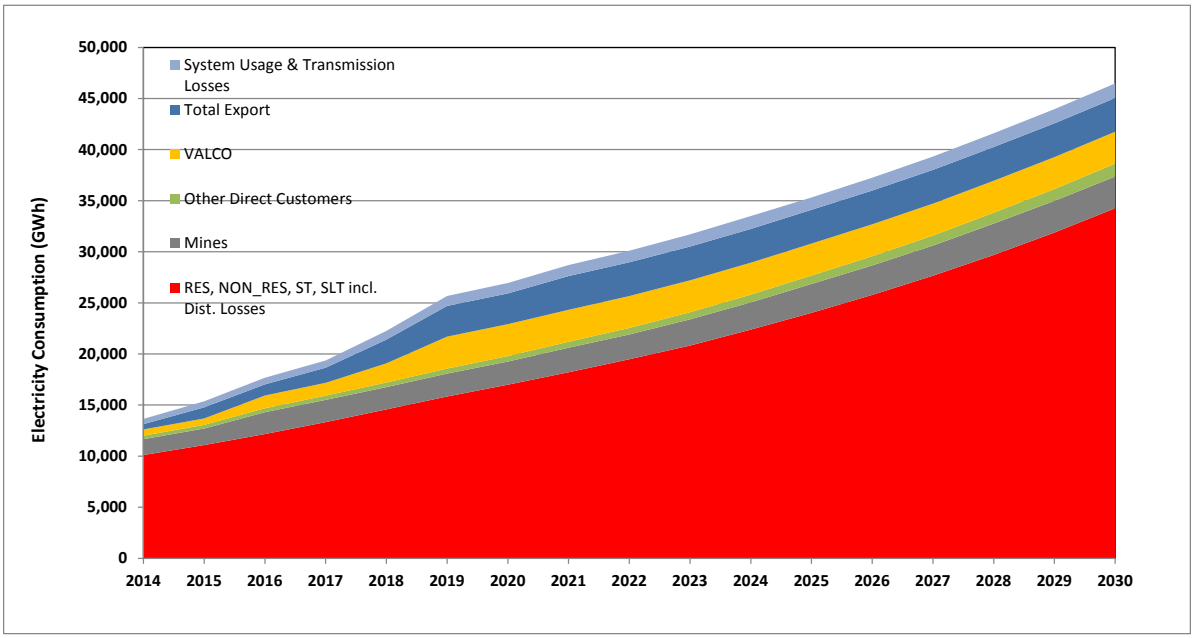
Table 5-42 summarizes the High Growth scenario forecast by customer category and also includes the System Usage and Transmission loss component.

Table 5-42: High Growth Scenario Total Demand Forecast (GWh)

| Year | Domestic Consumption | | | | VALCO | Total Export | System Usage & Transmission Losses | Net Generation Supply |
|---|---|---|---|---|---|---|---|---|
| | RES, NON_RES, ST, SLT incl. Dist. Losses | Mines | Other Direct Customers | Total Domestic | | | | |
| **2014** | 10,111 | 1,553 | 339 | 12,003 | 611 | 522 | 511 | **13,647** |
| **2015** | 11,085 | 1,618 | 360 | 13,062 | 625 | 1,088 | 592 | **15,368** |
| **2016** | 12,161 | 2,137 | 386 | 14,684 | 1,250 | 1,088 | 652 | **17,674** |
| **2017** | 13,327 | 2,179 | 417 | 15,923 | 1,250 | 1,482 | 705 | **19,360** |
| **2018** | 14,575 | 2,179 | 453 | 17,206 | 1,875 | 2,322 | 853 | **22,257** |
| **2019** | 15,837 | 2,241 | 492 | 18,571 | 3,125 | 3,007 | 971 | **25,674** |
| **2020** | 16,994 | 2,262 | 536 | 19,792 | 3,125 | 3,007 | 1,020 | **26,944** |
| **2021** | 18,207 | 2,404 | 584 | 21,196 | 3,125 | 3,304 | 1,076 | **28,701** |
| **2022** | 19,482 | 2,424 | 637 | 22,544 | 3,125 | 3,304 | 1,131 | **30,103** |
| **2023** | 20,823 | 2,565 | 695 | 24,083 | 3,125 | 3,304 | 1,192 | **31,705** |
| **2024** | 22,383 | 2,664 | 759 | 25,806 | 3,125 | 3,304 | 1,262 | **33,497** |
| **2025** | 24,025 | 2,826 | 827 | 27,678 | 3,125 | 3,304 | 1,207 | **35,314** |
| **2026** | 25,778 | 2,887 | 900 | 29,566 | 3,125 | 3,304 | 1,255 | **37,250** |
| **2027** | 27,660 | 2,948 | 980 | 31,588 | 3,125 | 3,304 | 1,302 | **39,318** |
| **2028** | 29,689 | 3,071 | 1,065 | 33,825 | 3,125 | 3,304 | 1,346 | **41,600** |
| **2029** | 31,883 | 3,101 | 1,158 | 36,142 | 3,125 | 3,304 | 1,388 | **43,959** |
| **2030** | 34,264 | 3,101 | 1,258 | 38,623 | 3,125 | 3,304 | 1,426 | **46,478** |
| Growth Rates | | | | | | | | |
| **2014-2030** | 7.9% | 4.4% | 8.6% | 7.6% | 10.7% | 12.2% | 6.6% | 8.0% |

The High Growth scenario forecast at the generation supply level for year 2030 is estimated to increase to around 46,500 GWh and represents a higher 8.0% yearly growth rate over the 2014-2030 period (vs 7.0% for the Base Case). Growth rates for each demand component are also presented in the table. Figure 5-20 presents the same results in graphical format showing relationships and growth for all categories.

Figure 5-20: High Growth Scenario Total Demand Forecast by Category (GWh)




The corresponding High Growth scenario peak load forecast, presented in Table 5-43, was developed using the same coincident factors as applied for the Base Case forecast. The resulting High Growth scenario peak load forecast for year 2030 is above 7,500 MW and represents a high 8.4% yearly growth rate over the 2014-2030 period (compared to 7.0% for the Base Case). Coincident peak load forecasts and growth rates for each demand component are also presented in Figure 5-19.

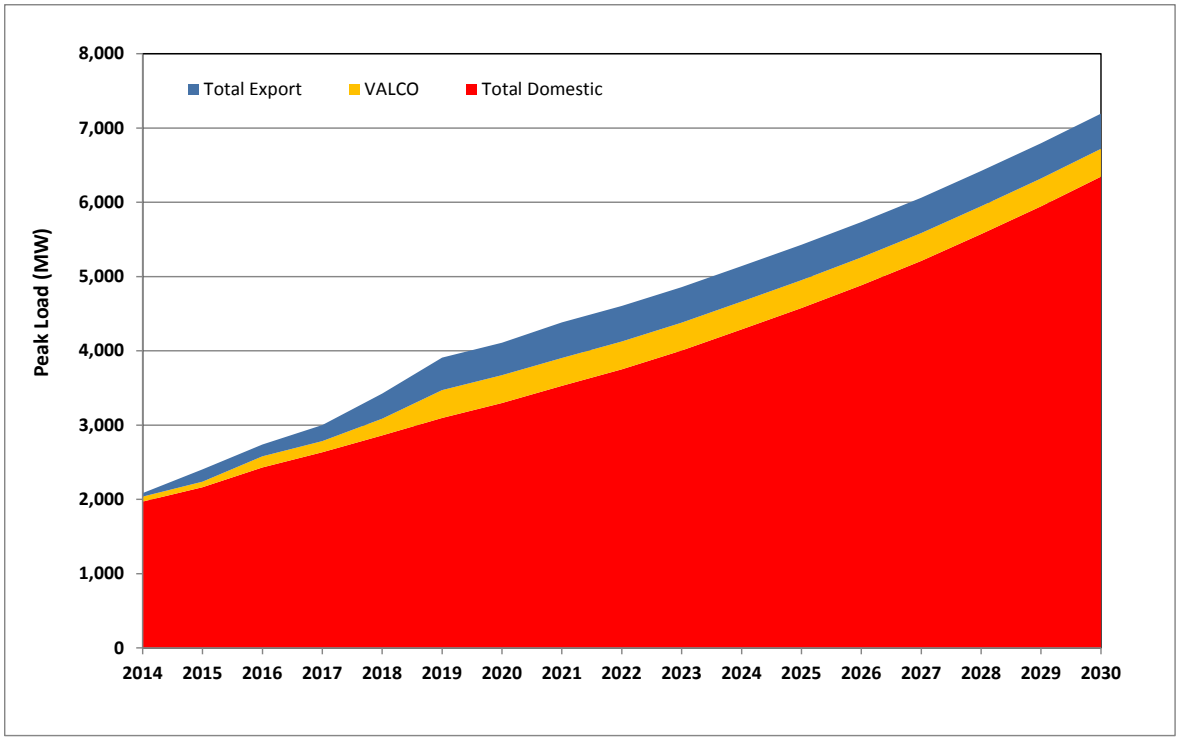
Table 5-43: High Growth Scenario Peak Load Forecast (MW)

| Year | Total Domestic | VALCO | Total Export | Total Peak Load |
|---|---|---|---|---|
| 2014 | 1,970 | 67 | 47 | 2,084 |
| 2015 | 2,163 | 75 | 166 | 2,404 |
| 2016 | 2,430 | 150 | 159 | 2,738 |
| 2017 | 2,634 | 150 | 216 | 3,000 |
| 2018 | 2,861 | 225 | 338 | 3,424 |
| 2019 | 3,096 | 375 | 437 | 3,908 |
| 2020 | 3,297 | 375 | 437 | 4,109 |
| 2021 | 3,528 | 375 | 479 | 4,383 |
| 2022 | 3,751 | 375 | 479 | 4,604 |
| 2023 | 4,004 | 375 | 478 | 4,857 |
| 2024 | 4,288 | 375 | 477 | 5,141 |
| 2025 | 4,576 | 375 | 477 | 5,428 |
| 2026 | 4,883 | 375 | 476 | 5,734 |
| 2027 | 5,211 | 375 | 476 | 6,061 |
| 2028 | 5,572 | 375 | 475 | 6,422 |
| 2029 | 5,946 | 375 | 474 | 6,795 |

| | | | | |
|---|---|---|---|---|
| 2030 | 6,345 | 375 | 474 | 7,193 |
| Growth Rates | | | | |
| Average Annual 2014-2030 | 7.6% | 11.4% | 15.5% | 8.1% |

Figure 5-21 presents the same results in graphical format showing the impact each component has on the total peak load.

Figure 5-21: High Growth Scenario Peak Load Forecast by Category (MW)




### *5.8.2.3 High Growth Scenario Forecast Comparisons*

Tables 5-44 and 5-45 present comparisons of the High Growth Scenario forecast with the EC Accelerated Economic Growth (AEG) forecast and the VRA High Case Scenario. Even though the EC forecast applies a different methodology and assumptions, it is interesting to compare all high growth forecasts to show the differences and the highest anticipated demand increase over the next 16 years.

Table 5-44: Demand Forecast Comparison for the High Growth Scenarios (GWh)

| Year | High Growth Scenario (GWh) | EC AEG Scenario (GWh) | VRA High Case Scenario (GWh) |
|---|---|---|---|
| 2015 | 15,368 | 18,559 | 17,437 |
| 2016 | 17,674 | 20,698 | 19,594 |
| 2017 | 19,360 | 23,794 | 22,557 |
| 2018 | 22,257 | 25,749 | 25,184 |
| 2019 | 25,674 | 28,171 | 26,882 |

| | | | |
|---|---|---|---|
| 2020 | 26,944 | 31,994 | 28,604 |
| 2021 | 28,701 | 33,987 | 29,996 |
| 2022 | 30,103 | 36,096 | 31,719 |
| 2023 | 31,705 | 38,330 | 33,769 |
| 2024 | 33,497 | 40,696 | 35,917 |
| 2025 | 35,314 | 43,210 | 38,309 |
| 2026 | 37,250 | 45,864 | 40,727 |
| 2027 | 39,318 | 48,674 | 43,252 |
| 2028 | 41,600 | 51,653 | 46,007 |
| 2029 | 43,959 | 54,811 | 48,934 |
| 2030 | 46,478 | 59,090 | 52,054 |

Table 5-45: Peak Load Forecast Comparison for the High Growth Scenarios (MW)

| Year | High Growth Scenario (MW) | EC AEG Scenario (MW) | VRA High Case Scenario (MW) |
|---|---|---|---|
| 2015 | 2,404 | 2,714 | 2,490 |
| 2016 | 2,738 | 3,023 | 2,776 |
| 2017 | 3,000 | 3,470 | 3,162 |
| 2018 | 3,424 | 3,750 | 3,532 |
| 2019 | 3,908 | 4,098 | 3,791 |
| 2020 | 4,109 | 4,647 | 4,063 |
| 2021 | 4,383 | 4,930 | 4,283 |
| 2022 | 4,604 | 5,229 | 4,561 |
| 2023 | 4,857 | 5,546 | 4,882 |
| 2024 | 5,141 | 5,880 | 5,226 |
| 2025 | 5,428 | 6,235 | 5,601 |
| 2026 | 5,734 | 6,610 | 5,980 |
| 2027 | 6,061 | 7,005 | 6,383 |
| 2028 | 6,422 | 7,424 | 6,820 |
| 2029 | 6,795 | 7,868 | 7,289 |
| 2030 | 7,193 | 8,471 | 7,790 |

The EC AEG forecast is consistently higher than the other two High Growth scenario forecasts in both energy and peak load estimates throughout the entire 2015-2030 forecasting horizon. Similarly to the Base Case comparison, the major reason for the difference seems to be a much higher forecast for the household sector in the EC AEG scenario (18,650 GWh in 2030) vs. the High Growth scenario forecast for the residential sector (7,450 GWh in 2030).

# Section 6 CONCLUSIONS AND RECOMMENDATIONS

## 6.1 CONCLUSIONS

The conclusions and observations are grouped into several categories. The conclusions and observations from the analysis of Ghana demand forecasts are as follows:

- Demand forecasting in Ghana is done on a yearly basis by several entities as part of the regular operations and planning cycle with forecasting details and time horizons corresponding to individual company needs and goals. The Energy Commission, GRIDCo, and VRA develop demand forecasts that cover the entire country including VALCO, mines, direct customers and exports, while the ECG demand forecast is done for its service territory and customers
- Demand forecasting is done using end use, econometric and regression methods at different levels of granularity. While forecasting methods are based on sound techniques, more emphasis should be placed on collecting and developing accurate and up-to-date inputs for forecasting
- Ghana forecasts don't explicitly include suppressed demand, e.g. all use actual historical demand as a starting point for forecasting. Local forecasts either use actual historical demand as a starting point and include suppressed demand in long-term forecasting applying higher initial growth rates, or based on the estimated amount of suppressed demand make adjustments to the actual demand in the first forecasted year.

Conclusions and observations from the suppressed demand analysis:

- The most recent load shedding is so severe as to significantly impact the country's overall economic development and growth. VALCO was the single customer most severely affected during the generation constrained years and consumption was significantly reduced in each of the shortage years
- The Supply Constraint component of the suppressed demand (e.g. load shedding for ECG and NEDCo customers) was estimated to be around 940 GWh. The Infrastructure Barrier component was estimated to be 776 GWh. With the additional impact on mining and direct customers, Suppressed Demand in 2014 was estimated to be around 16% of the total domestic consumption
- Impact on VALCO consumption is around 2,500 GWh (4 additional pot-lines) and the potential increase in exports is around 1,800 GWh. With those two demand categories included, total Suppressed Demand is estimated to be approximately 6,000 GWh or about 50% of the 2014 supply
- Income Barrier and Technology Barrier Impact are the two components of the Suppressed Demand not impacting 2014 demand. Their impact was addressed in developing the demand forecast over the forecasting horizon through assumptions for future growth rates for GDP, population, number of customers, and electricity prices.

Conclusions and observations from the demand forecasting analysis:

- Our forecasting methodology review found the inputs used by Ghana entities to be consistent and correct. Inputs such as electricity prices, customer population and GDP and its components were key parameters used in forecasting

- Our forecasting used the customer categories consistent with the historical sales information obtained from the Energy Commission. We further disaggregated industrial customer consumption at the distribution level, so the combined categories are consistent and could be compared with those used by VRA and GRIDCo.
- Independent forecasting was done for the following customer categories: Residential, Non-Residential, Street Lighting, ECG and NEDCo SLT Customers, and Direct Customers.
- We used exogenous Government consensus forecasts for the remaining customer categories: Mines, VALCO, and Exports
- Log-Log linear multivariate models are used for the forecasts, using Ordinary Least Squares (OLS) for parameter estimation, similar to the methods used by ECG, VRA, and GRIDCo for demand forecasting. Diagnostic tests showed that the results are a good fit for the final long term forecasting models
- Forecasts for the historical 2012-2014 period compare well with the results of the Supply Component of the suppressed demand. Historical forecasting for Residential, Non-Residential and SLT customer categories provided important independent estimates that confirmed results of our direct analysis of the Supply Constraint component of the suppressed demand
- The forecast at the Distribution Level network is similar to the forecasts developed by VRA and GRIDCo
- The total 2030 Base Case forecast is just over 40,000 GWh and is comparable with VRA and GRIDCo forecasts, representing a 7.0% yearly growth rate over the 2014-2030 period. Only the EC forecast is higher in all years, primarily due to the higher forecast for the household sector. The household category consumption in the EC forecast increases by more than 100% from 2014 to 2015, and thus the forecast begins from a much higher demand level.
- The total year 2030 Base Case peak demand forecast is estimated at 6,183 MW representing a 7% yearly growth rate over the 2014-2030 period
- Forecasting analysis showed the limited impacts of the Infrastructure Component of the suppressed demand. Sensitivity analysis showed that as demand increases, this component represents a relativity small percentage of the total demand
- Forecasting analysis showed large impacts of the loss reduction program. Sensitivity analysis showed that as demand increases, distribution system loss reduction efforts are the critical component in reducing overall demand. Without the reduction in distribution losses (primarily the commercial loss component), the system will need to supply significant additional energy in the future to cover both technical and commercial losses
- The total demand forecast under the Low Growth Scenario is estimated to be around 37,500 GWh by year 2030, and represents a 6.5% yearly growth rate over the 2014-2030 period
- The total demand forecast under the High Growth Scenario demand forecast is estimated to be around 46,500 GWh and represents a 8.0% yearly growth rate over the 2014-2030 period
- Some forecasting results, such as for the street lighting category, show the limit of using only the regression analysis based on historical data as a forecasting method

## 6.2 RECOMMENDATIONS

The following are key recommendations regarding future demand forecasting:

- As long as current conditions remain unchanged (high level of suppressed demand), forecasting should explicitly include suppressed demand analysis
- Forecasting inputs need to be adjusted to account for suppressed demand impacts
- Assumptions used for long-term demand forecasting should take into account growth associated with a more mature and larger power sector and the impact of relatively high electricity prices
- Forecasting should gradually improve and include more end use forecasting methods and the associated data collection efforts, such as those already in use by the Energy Commission
- Forecasting should be conducted or updated on a yearly basis to keep pace with the rapid development of the power sector

# Section 7 REFERENCES


1. Volta River Authority, 2015-2030 Load Forecast, Final Report, October 8 2014
2. Ghana Grid Company Limited, 2014 Electricity Supply Plan
3. Electricity Company of Ghana, 2014 ECG Energy Forecast Report, November 2014
4. Energy Commission of Ghana, National Energy Statistics 2000-2013, October 2014
5. Energy Commission of Ghana, 2014 and 2015 Energy Outlooks for Ghana, April 2014/2015
6. Ghana Statistical Service, Revised Gross Domestic Product 2014, January 2015
7. IMF, World Economic Outlook, April 2015
8. World Bank, Sub-Saharan Africa Region Outlook, 2015 http://www.worldbank.org/content/dam/Worldbank/GEP/GEP2015a/pdfs/GEP2015a_chapter2_regionaloutlook_SSA.pdf
9. World Bank, "Energizing Economic Growth: Making the Power and Petroleum Sectors Rise to the Challenge.", June 2013

# Section 8 FORECASTING MODELS AND TESTS

## 8.1 UNIT ROOT TEST FOR ECG MODELS

All historical data inputs were subjected to the Phillips Peron test, at a significance level of 5%, in order to verify that the time series data is stationary. The results, shown in Table 8-1 below, indicate that all of the time series data is stationary.

Table 8-1: Philips Perron Unit Root Test

| Variable | Tau (Observed Value) | P-value |
|---|---|---|
| LN(GDP) | 8.140 | <.0001 |
| LN(GPI) | -2.65 | <.0001 |
| LN(GDPS) | 7.679 | <.0001 |
| LN(P_NSLT) | 1.581 | <.0001 |
| LN(P_SLT) | 1.695 | <.0001 |
| LN(POP_TOT) | 17.679 | <.0001 |
| LN(PCI) | 4.126 | <.0001 |
| LN(A_HOUSE) | -3.881 | <.0001 |
| LN(POP_RES) | 20.394 | <.0001 |
| LN(POP_NON_RES) | 6.412 | <.0001 |
| LN(POP_SLT) | 5.875 | <.0001 |

## 8.2 PROCESS AND RESULTS OF THE MODEL ESTIMATION

The final log-log models, the resulting parameter estimation, model statistics, and the process used to examine alternative models using OLS for the Residential, Non-Residential, SLT, NSLT, the combined NSLT+SLT, and Direct Customer sales are descried below. The models derived for each category are based upon:

- Data for the 2000-historical period for each model were used to forecast 2015-2030 sales
- Data for the 2000-2011 historical period for each of the models were used to validate the direct estimates of suppressed demand vs actual 2012-2014 sales plus load shedding, as discussed in Section 4. The results from the corresponding 2012-2014 models were used in an iterative manner in developing and refining the 2015-2030 forecast models for each category.

Results for goodness of fit and diagnostic tests for each forecasting model are shown in Table 8-2.

For each customer category, the set of independent variables to be tested for model data quality and significance were selected from the full set of independent variables (as discussed in Section 3) based on hypothesized relationships.

The built-in capabilities of Microsoft Excel were used for regression modeling, as well the advanced statistical commercial package XLSTAT. XLSTAT produces a set of statistical parameters and metrics (variable coefficients, $R^2$ statistics, P-values, and test statistics including multi-colinearity of independent variables, normality of residuals, serial correlation, and heteroscedasticity). Historical relationships having a high degree of statistical significance and data quality can be determined by analyzing the statistical output for each considered model.

Several primary statistical metrics are considered to determine the validity of historical relationships. Only those regressions having high $R^2$ values (indicating good correlation), and with coefficients which are of reasonable magnitude and sign and low P-values are generally accepted for inclusion in the model, as well as evaluation of the other statistical tests cited above. In a final step, the results obtained from the forecasts are analyzed to ensure that the growth rates are sensible within the context of overall expected energy sales and show limited volatility.

The final regression models for each consumer category are developed using the following process:

1) Application of statistical tests of the significance of the independent variables. Alternative models are considered iteratively that improve the statistical measures of data quality, model fit, and the statistical significance of each independent variable
2) Validating the forecasts by including load shedding over the period 2012-2014 from the direct estimate, as discussed in Section 4, and comparing with the regression based forecast for 2012-2014 including historical data revised to include suppressed demand
3) Evaluating the reasonableness of the long term forecasts relative to historical trends

For a given set of pre-selected independent variables, XLSTAT automatically generates the best model fit (based on Adjusted $R^2$ ) for 1, 2, …, up to the full set of pre-specified variables. Each of these models was systematically evaluated relative to each other, and following steps 2 and 3 above. In addition, alternative models were developed in XLSTAT to specify and evaluate other specific combinations of variables, and these were compared with the models generated automatically by XLSTAT. The final version of the Electricity Demand Forecasting Model contains the results from all of these considered models.

In addition, XLSTAT provides several additional automatic processes to guide model development. Models can be selected in a “forward” process in which variables are added sequentially with respect to a threshold value for significance, until a final model is specified. Models can also be selected in a “backwards” process, in which all independent variables are initially included, and then sequentially removed, again with respect to a threshold value of significance, again until a final model is specified. A “step-wise” process both adds and removes variables at each step. The forward, backward and step-wise model selection options were used to validate the final model selected in the interactive process. These XLSTAT runs are also included in the final version of the Electricity Demand Forecasting Model.

Regression models were also specified manually in XLSTAT to evaluate specific combinations of variables to be compared with the automatically generated models. These comparisons are considered below in the specification section for each model. The final Electricity Demand Forecasting Model contains all XLSTAT models generated for model evaluation and selection.

The following sections describe the model specification process used for each consumer category and the combined categories, starting with a statement of the functional form of the final model, followed by a description of the automatically generated XLSTAT best-fit model for all combinations of variables, and the process of refinement of that model and the validation for 2012-2014.

## 8.2.1 Residential

### *8.2.1.1 2015-2030 Forecast based on 2000-2014 Data*

The best regression fit and 2012-2014 and long-term forecast model validation for the Residential consumer category was with the independent variables for GDP, the NSLT tariff, average household size, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The coefficient for average household size is negative because the average size decreases over time. The final regression formula is:

**LN(RES) = -6.791 + 0.699 * LN(GDP) – 0.042 * LN(P_NSLT) – 1.261 * LN(A_HOUSE) – 0.049 * DUMMY**

LN(RES) was tested with the independent variables LN(P_NSLT), LN(GDP), LN(PCI), LN(RES N-1), LN(POP_RES), LN(PCI), LN(A_HOUSE), and DUMMY.

Because PCI is a ratio of GDP and total population, either LN(GDP) or LN(PCI) were tested with the other variables.

The model label XLSTAT (Model) 2014 (Number) for all of the customer categories in this section refers to the XLSTAT output saved in the Electricity Demand Forecasting model.

- XLSTAT Res 2014 (1): This is the automatic output from run from XLSTAT to fit the best model with 1, 2, up to 7 variables. This first run tested LN(GDP) with the other variables, excluding LN(PCI). The best fit model included 4 variables: LN(P_NSLT), LN(GDP), LN(POP_RES), and DUMMY. LN(RES N-1) was not included until the 6 variable model. The P-values for the variables were acceptable, but there was a high multi-colinearity for LN(POP_RES).
- XLSTAT Res 2014 (2): This model removed LN(RES N-1) from consideration in order to test additional year 2000 data. The resulting best fit was with 3 variables: LN(GDP), LN(POP_RES), and DUMMY. In this case there was also a high colinearity for LN(A_HOUSE) and higher P-value for LN(P_NSLT). The next best fit with a similar $R^2$ added the price variable and replaced LN(POP_RES with LN(A_HOUSE), which is tested in the next model
- XLSTAT Res 2014 (3): Tested second best model from (2) Best fit of LN(P_NSLT), LN(GDP), LN(POP_RES), LN(A_HOUSE), DUMMY. High colinearity of LN(POP) and LN(A_HOUSE), and High P-values for the population and price variables.
- XLSTAT Res 2014 (4): Tested LN(PCI) and LN(P_NSLT). Best model included 5 variables: LN(P_NSLT), LN(POP_RES), LN(PCI), LN(A_HOUSE), and DUMMY. Colinearity for population variables was high, P-values for price and population high.
- XLSTAT Res 2014 Final: Fit of LN(P_NSLT), LN(GDP), LN(A_HOUSE), and DUMMY. Model has lower $R^2$, low P-values; reasonable signs and magnitudes of coefficients, good validation against 2012-2014 historical suppressed demand, and reasonable growth rate for 2015-2030 forecast.

#### *8.2.1.2 2012-2014 Validation based on 2000-2011 Data*

The corresponding regression for the 2012-2014 period is:

**LN(RES) = -2.896 + 0.573 * LN(GDP) – 0.033 * LN(P_NSLT) – 1.886 * LN(A_HOUSE) – 0.051 * DUMMY**

This model provided a good validation of the 2012-2014 directly estimated suppressed demand for the combined Residential, Non-Residential, and Street Lighting categories.

### 8.2.2 Non-Residential

#### *8.2.2.1 2015-2030 Forecast based on 2000-2014 Data*

The best regression fit and 2012-2014 and long-term forecast model validation for the Non-Residential consumer category was with the independent variables for GDP Services, the NSLT tariff, the 1-year lagged Non-Residential demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(NON_RES) = -16.634 + 0.931 * LN(GPS) – 0.115 * LN(P_NSLT) + 0.382 * LN(NON_RES N-1) – 0.099 * DUMMY**

LN(NON_RES) was tested with the independent variables LN(P_NSLT), LN(GDPS), LN(NON_RES N-1), LN(POP_NON_RES), LN(RES), and DUMMY. LN(RES) the forecast for the Residential category, and thus is an interacting independent variable.

- XLSTAT NonRes 2014 (1): This is the automatic output from run from XLSTAT to fit the best model with 1, 2, up to 7 variables. The best fit model included 3 variables: LN(GDPS), LN(POP_NON_RES), and DUMMY. There was a high colinearity for the populations variables and a high P-value for LN(POP_NON_RES). LN(P_NSLT) was not included as independent variable by XLSTAT until the 4 variable model, with a similar $R^2$. The interacting forecast variable LN(RES) was not selected until the 6 variable model and had a high P-value. LN(GPS) had a very large coefficient, with too much sensitivity to the independent variables.
- XLSTAT NonRes 2014 (2): Fit of LN(P_NSLT), LN(GDPS), LN(POP_NON_RES), DUMMY. Acceptable colinearity; although higher P-value with inclusion of LN(P_NSLT). Better adjusted $R^2$ than (1). The LN(POP_NON_RES) variable had a negative coefficient, which should not be expected, and is removed from the model.
- XLSTAT Non_Res 2014 Final Fit of LN(P_NSLT), LN(GDPS), LN(NON_RES N-1), and DUMMY. Acceptable colinearity. Better validation against 2012-2014 historical suppressed demand, reasonable signs and magnitudes of coefficients, good $R^2$ value. Smaller, less sensitive coefficient for LN(GDPS) than in (1) is more reasonable.

#### *8.2.2.2 2012-2014 Validation based on 2000-2011 Data*

The corresponding regression for the 2012-2014 period is:

**LN(NON_RES) = -17.189 + 1.001 * LN(GPS) – 0.061 * LN(P_NSLT) + 0.186 * LN(NON_RES N-1) – 0.068 * DUMMY**

This model provided a good validation of the 2012-2014 directly estimated suppressed demand for the combined Residential, Non-Residential, and Street Lighting categories.

## 8.2.3 SLT

### *8.2.3.1 2015-2030 Forecast based on 2000-2014 Data*

The best regression fit and 2012-2014 and long-term forecast model validation for the SLT category was with the independent variables for GDP Services, the number of SLT customers, the 1-year lagged SLT demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(SLT) = 1.014 + 0.451 * LN(POP_SLT) + 0.434 * LN(SLT N-1) - 0.065 * DUMMY**

LN(SLT) was tested with the independent variables LN(P_SLT), LN(GDPI), LN(POP_SLT), LN(SLT N-1), and DUMMY.

- XLSTAT SLT 2014 (1): This is the automatic output from run from XLSTAT to fit the best model with 1, 2, up to 5 variables. The best fit model included 4 variables: LN(P_SLT), LN(GDPI), LN(SLT N-1), and the DUMMY. There was a high colinearity of variables, higher P-values for most variables, and a positive coefficient for the price variable, which should not be expected. The next best fit model for 5 variables included LN(POP_SLT).
- XLSTAT SLT 2014 (2): Tested the 5 variable model from (1). The coefficient for price remained positive, and P-values were higher than in the 4 variable model.
- XLSTAT SLT 2014 (3): This model removes the price variable. Fit with LN(GDPI), LN(POP_SLT), LN(SLT N-1) and DUMMY. High P-value for LN(GDPI).
- XLSTAT SLT 2014 Final: Removed LN(GDPI). Low P-values, and reasonable signs and magnitudes of coefficients, good validation against 2012-2014 historical suppressed demand.

### *8.2.3.2 2012-2014 Validation based on 2000-2011 Data*

The corresponding regression for the 2012-2014 period is:

**LN(SLT) = 1.085 + 0.415 * LN(POP_SLT) + 0.458 * LN(SLT N-1) – 0.064 * DUMMY**

This model provided a good validation of the 2012-2014 directly estimated suppressed demand for the SLT category.

## 8.2.4 NSLT

### *8.2.4.1 2015-2030 Forecast based on 2000-2014 Data*

The best regression fit and 2012-2014 and long-term forecast model validation for the NSLT category was with the independent variables for GDP, the NSLT tariff, the 1-year lagged NSLT demand, and the dummy variable. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(NSLT) = -15.597 + 0.973 * LN(GDP) – 0.112 * LN(P_NSLT) + 0.137 * LN(NSLT -1) – 0.054 * DUMMY**

LN(NSLT) was tested with the independent variables LN(P_NSLT), LN(GDP), LN(POP_RES), LN(POP_NON_RES), LN(PCI), LN(TOT_POP), LN(NSLT N-1), and DUMMY.

- XLSTAT NSLT 2014 (1): This is the automatic output from run from XLSTAT to fit the best model with 1, 2, up to 7 variables. This first run included price and GDP but not the LN(PCI) for per capita income. The best fit model included 4 variables: LN(P_NSLT), LN(GDP), LN(POP_NON_RES), and DUMMY. High colinearity of population variables, negative coefficient for LN(POP_NON_RES), and a large coefficient for LN(GDP).
- XLSTAT NSLT 2014 (2): This model fits LN(PCI) and LN(P_NSLT). The best fit model included 5 variables: LN(P_NSLT), LN(POP_RES), LN(PCI), LN(TOT_POP) and DUMMY. Equivalent Adjusted $R^2$ to (1); high colinearity but lower P-values for price and PCI, positive coefficient for LN(POP_NON_RES) but negative coefficient for LN(TOT_POP).
- XLSTAT NSLT 2014 (3): Removed population variables. Fit of LN(P_NSLT), LN(PCI), LN(NSLT N-1) and, DUMMY. Low colinearity; lower P-values for all variables.
- XLSTAT NSLT 2014 Final: Comparison of (3) with LN(GDP) substituted for LN(PCI). Better-values, low colinearity, good 2012-2014 validated forecast; reasonable signs and magnitudes of coefficients.

#### *8.2.4.2 2012-2014 Validation based on 2000-2011 Data*

The corresponding regression for the 2012-2014 period is:

**LN(NSLT) = -11.061 + 0.693 * LN(GDP) – 0.808 * LN(P_NSLT) + 0.381 * LN(NSLT -1) – 0.058 * DUMMY**

This model provided a good validation of the 2012-2014 directly estimated suppressed demand for the NSLT category.

### 8.2.5 NSLT+SLT

#### *8.2.5.1 2015-2030 Forecast based on 2000-2014 Data*

The NSLT+SLT category is used as an internal validation for the independently forecast NSLT and SLT categories, and is not used in developing the final total demand forecast.

The best regression fit and 2012-2014 and long-term forecast model validation for the NSLT+SLT category was with the independent variables for LN(PCI), LN(POP_SLT), LN(POP_RES), and the 1-year lagged SLT demand. The coefficients were of reasonable magnitude and expected sign. The regression formula is:

**LN(NSLT+SLT) = -0.775 + 0.653 * LN(PCI) + 0.271 * LN(POP_SLT) + 0.189 * LN(POP_RES) + 0.031 * LN(SLT N-1)**

LN(NSLT+SLT) was tested with the independent variables LN(P_NSLT), LN(GDP), LN(POP_RES), LN(POP_NON_RES), LC(PCI), LN(TOT_POP), LN(P_SLT), LN(GDPI), LN(SLT N-1), LN(TOT_POP), LN(NSLT N-1), and DUMMY.

- XLSTAT NSLT+SLT 2014 (1): This is the automatic output from run from XLSTAT to fit the best model with 1, 2, up to 11 variables. This first run included price and LN(PCI) but not LN(GDP). The best fit model included 6 variables: LN(PCI), LN(POP_NON_RES), LN(POP_SLT), LN(SLT N-1), LN(TOT_POP), and LN(NSLT N-1). The population variables displayed high colinearity,

negative coefficients for LN(POP_NON_RES) and LN(NSLT N-1). Otherwise the P-values were low and other coefficients reasonable.

- XLSTAT NSLT+SLT 2014 (2): This model replaces LN(POP_NON_RES) with LN(POP_RES). LN(NSLT N-1) still had a negative coefficient.
- XLSTAT NSLT+SLT 2014 Final: Fit of LN(PCI), LN(POP_SLT), LN(POP_RES), LN(SLT N-1). Good P-values, reasonable coefficient magnitude and signs; reasonable validation between individual NSLT and SLT forecasts and combined forecast.; good validation of 2012-2014 NSLT+SLT forecast.

#### *8.2.5.2 2012-2014 Validation based on 2000-2011 Data*

The corresponding regression formula for the 2012-2014 period is:

**LN(NSLT+SLT) = 0.429 + 0.192 * LN(PCI) + 0.431 * LN(POP_SLT) + 0.164 * LN(POP_RES) + 0.187 * LN(SLT N-1)**

This model provided a good validation of the 2012-2014 directly estimated suppressed demand for the NSLT category.

### 8.2.6 Direct Customers

#### *8.2.6.1 2015-2030 Forecast based on 2000-2014 Data*

The best regression fit and long-term forecast validation for Direct Customers was with the independent variables for GDP Industrial and the 1-year lagged Direct Customer demand. The coefficients were of reasonable magnitude and expected sign.

There was a limited number of independent variables that were considered to be drivers of the Direct Customer category demand. LN(DIR) was tested against LN(GPI) and LN(DIR N-1). The regression formula is

**LN(DIR) = -6.278 + 0.353 * LN(GDPI) + 0.691 * LN(DIR N-1)**

- XLSTAT DCD 2014 Final: XLSTAT best included both LN(GDPI) and LN(DIR N-1). Low colinearity of variables and low P-values, but Adjusted $R^2$ relatively low at 86% due to limited relevant data available for forecast.

## 8.3 DIAGNOSTIC TESTS

Table 8-2 shows the results of goodness of fit tests for the final long term and validation year models, and associated model diagnostic tests.

The $R^2$ value for each model indicates that between 97.4% to 98.4% of the variations in the sales for the various categories are accounted for by the variations in the inputs used to model each category of sales. Low standard error for all models indicates low predictive errors.

The Jacque-Bera test indicates that the residuals of the regression were normally distributed in all models.

The Durbin-Watson test shows that no serial correlation is present in any of the models, implying that the error terms are independently distributed.

The White test for heteroscedasticity indicates that all models are homoscedastic, meaning that the variance of the error term is constant.

Table 8-2: Diagnostic Tests

| Model | $R^2$ | Standard Error | Normality (Jacque-Bera Test) Results | Autocorrelation (Durbin-Watson Test) Results | Heteroscedasticity (White Test) Rsults |
|---|---|---|---|---|---|
| Residential 2015-2030 | 0.991 | 0.027 | Normal | Not auto correlated, DW metric of 2.584 | Homoscedastic |
| Residential 2012-2014 | 0.989 | 0.028 | | | |
| Non-Residential 2015-2030 | 0.980 | 0.062 | Normal | Not auto correlated, DW metric of 1.7798 | Homoscedastic |
| Non-Residential 2012-2014 | 0.973 | 0.048 | | | |
| SLT 2015-2030 | 0.983 | 0.034 | Normal | Not auto correlated, DW metric of 2.116 | Homoscedastic |
| SLT 2012-2014 | 0.949 | 0.039 | | | |
| NSLT 2015-2030 | 0.996 | 0.022 | Normal | Not auto correlated, DW metric of 2.476 | Homoscedastic |
| NSLT 2012-2014 | 0.995 | 0.017 | | | |
| NSLT+SLT 2015-2030 | 0.995 | 0.022 | Normal | Not auto correlated, DW metric of 2.305 | Homoscedastic |
| NSLT+SLT 2012-2014 | 0.992 | 0.019 | | | |
| Direct Customers 2015-2030 | 0.882 | 0.149 | Normal | Not auto correlated, DW metric of 1.129 | Homoscedastic |

# Section 9 REBOUND ANALYSIS EXAMPLES

Figures 9-1 and 9-8 show sample comparisons for the eight sample days included in developing the rebound analyses impact results. Selected days are from July, August, October and December.

Figure 9-1: Daily Demand Comparison for the Second Friday in July

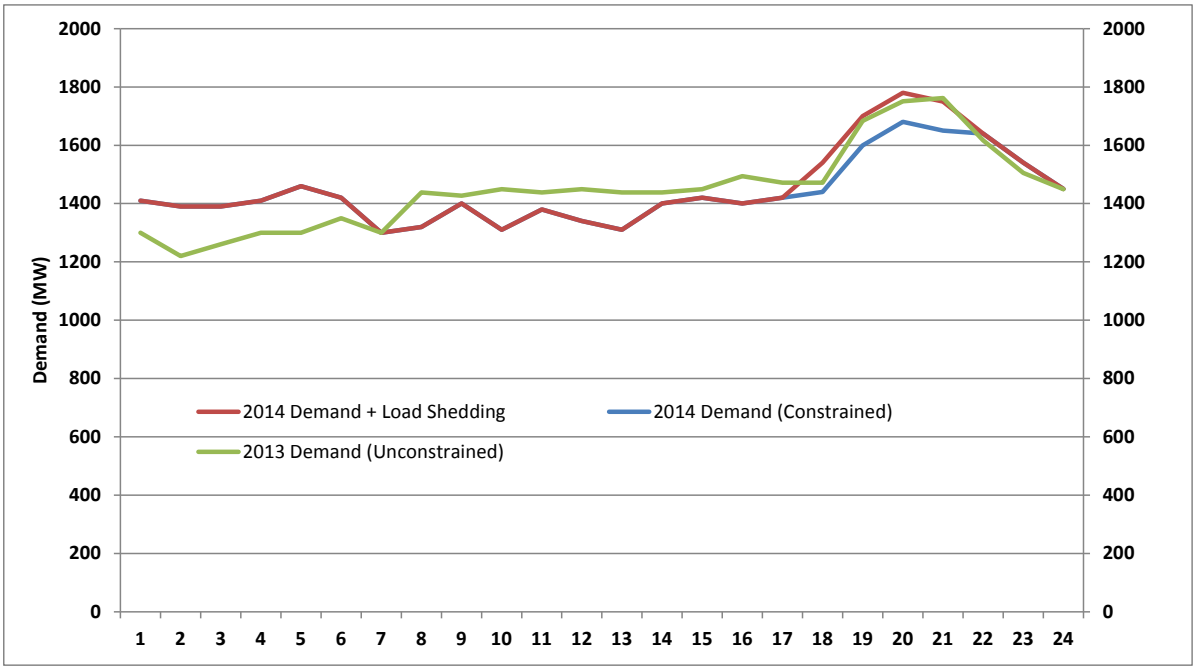



Figure 9-2: Daily Demand Comparison for the Second Saturday in July

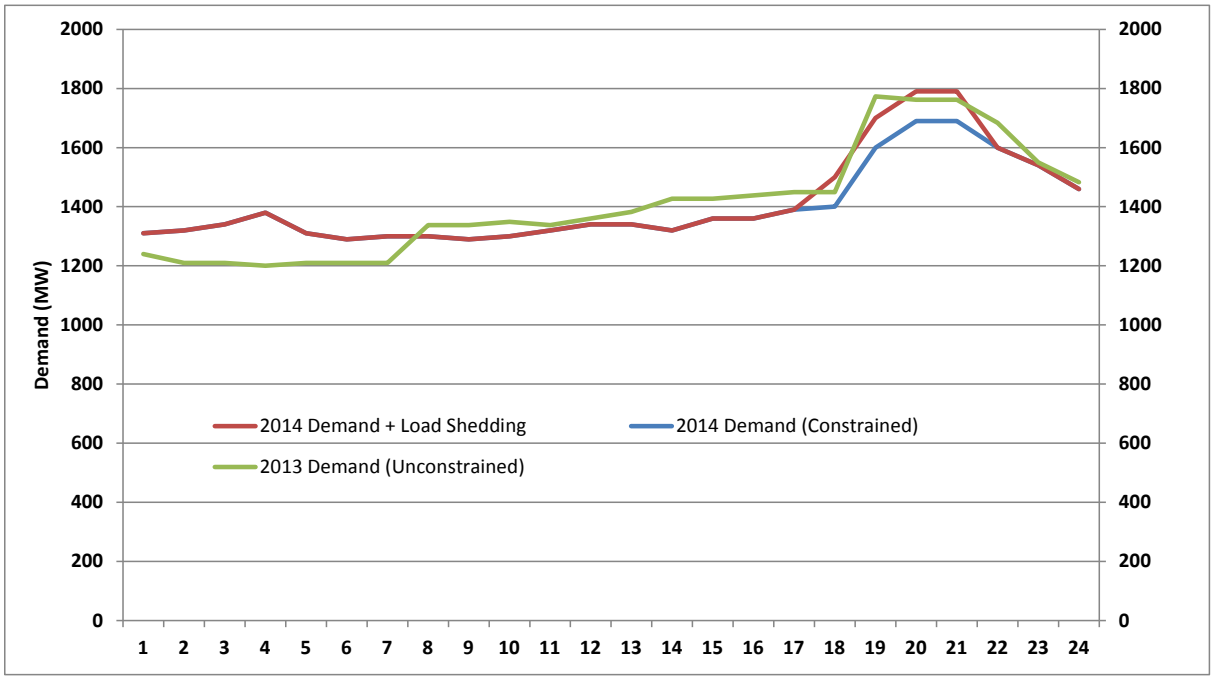


Figure 9-3: Daily Demand Comparison for the Second Monday in August

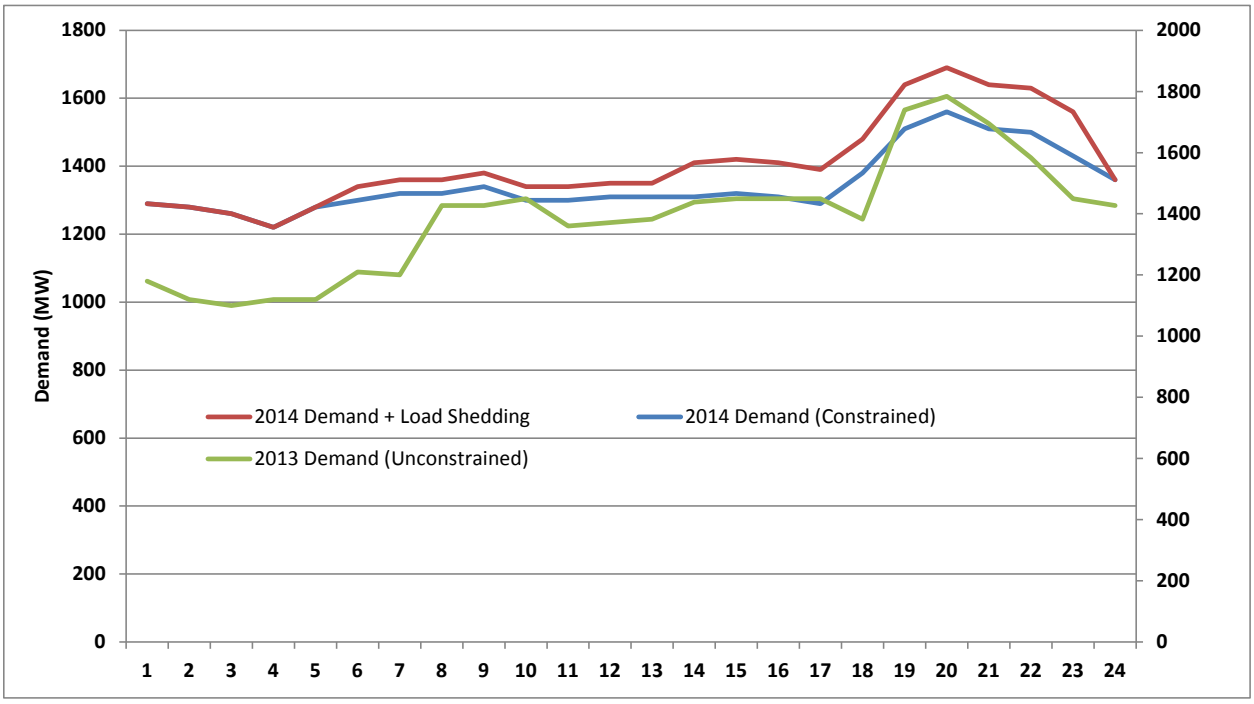



Figure 9-4: Daily Demand Comparison for the Second Tuesday in August

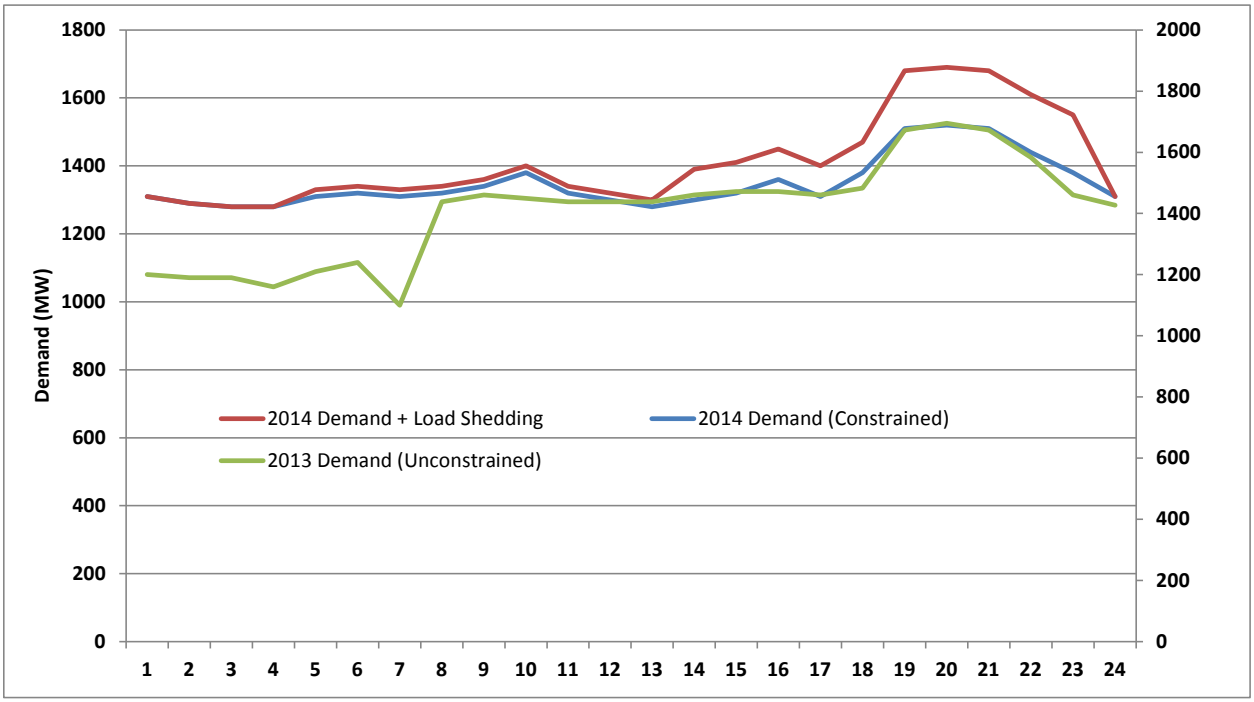


Figure 9-5: Daily Demand Comparison for the First Wednesday in October

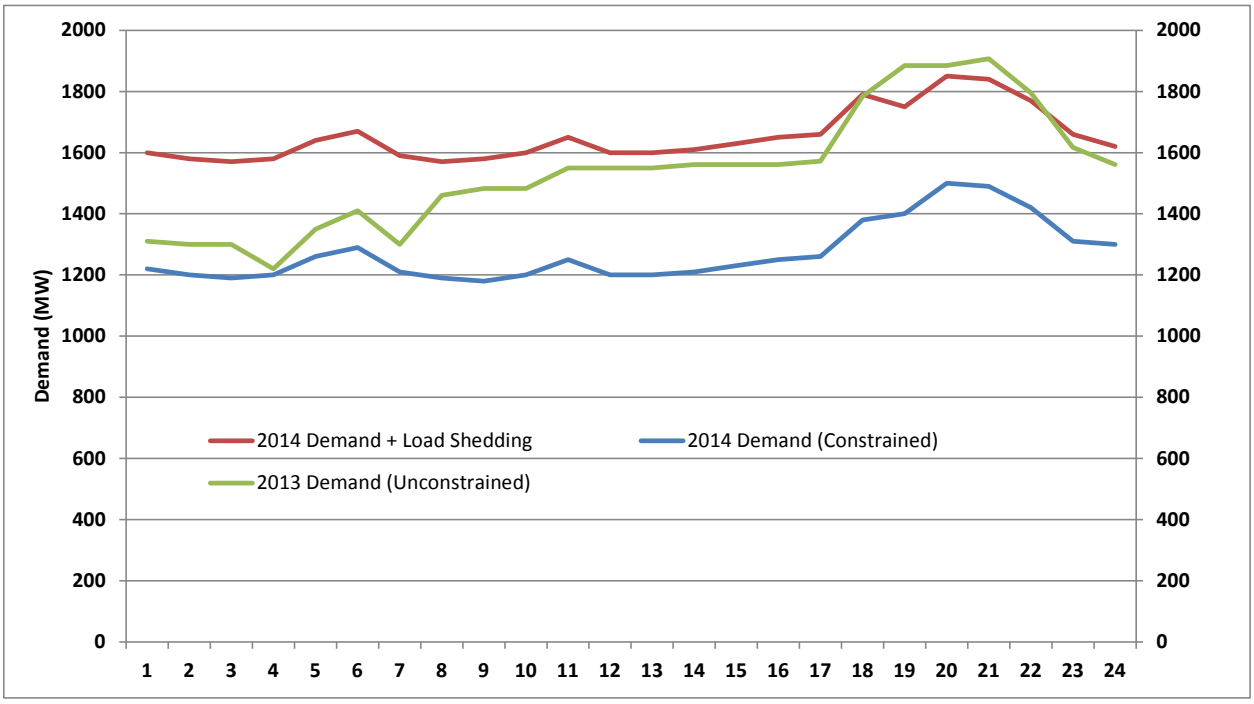



Figure 9-6: Daily Demand Comparison for the First Thursday in October

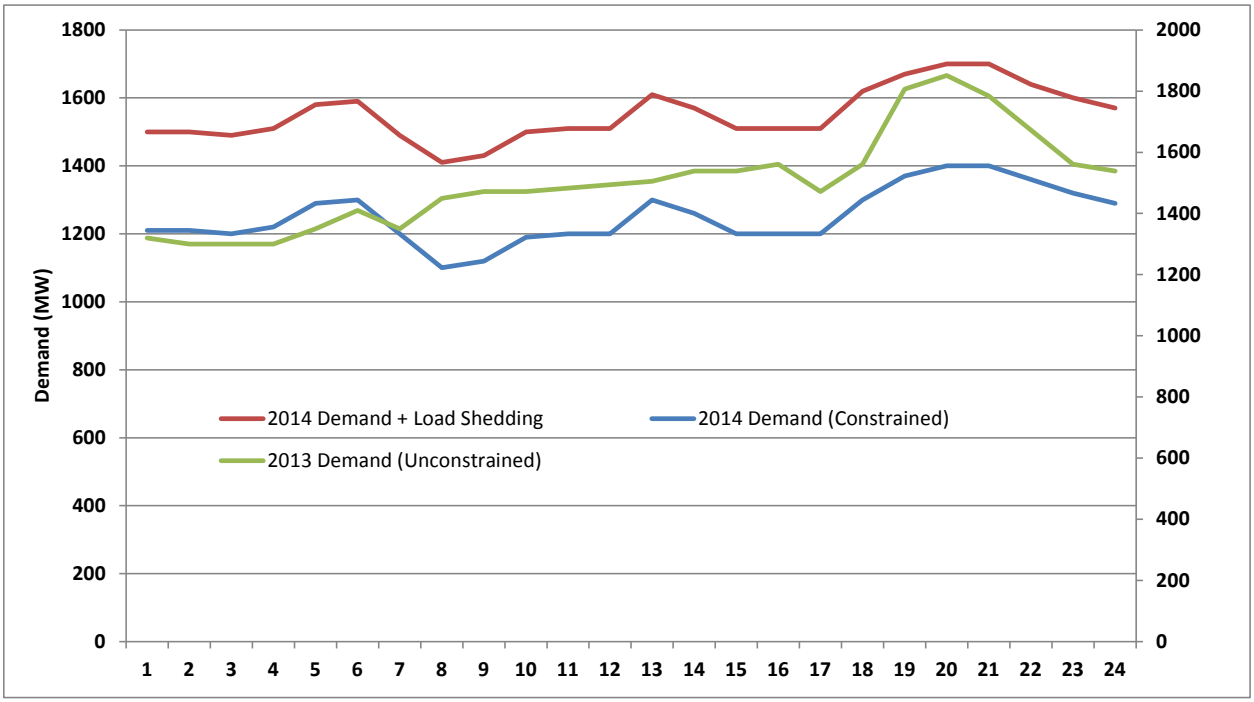


Figure 9-7: Daily Demand Comparison for the First Monday in December

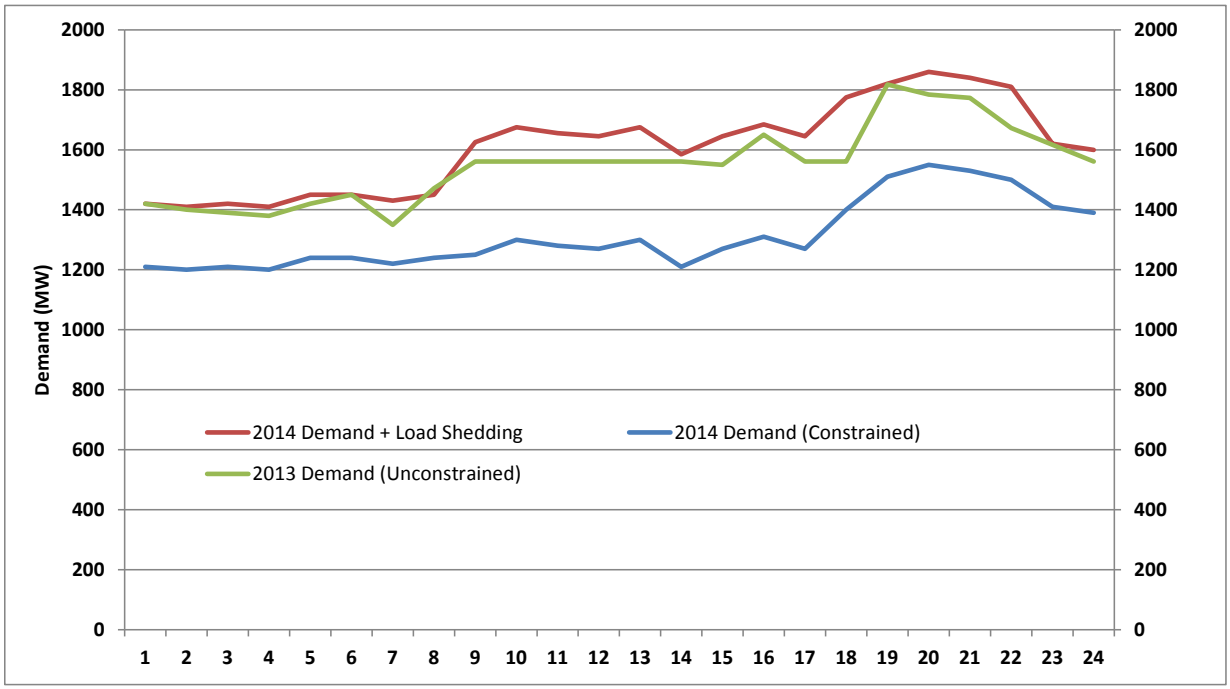
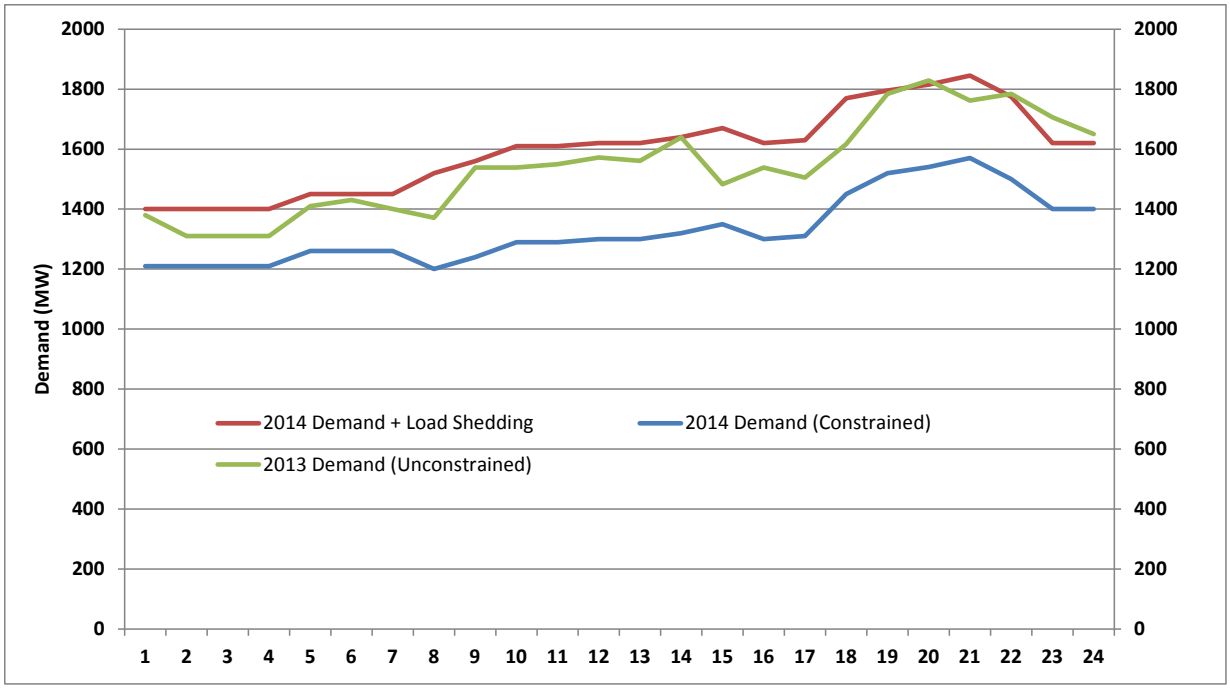



Figure 9-8: Daily Demand Comparison for the First Wednesday in December



U.S. Agency for International Development

www.usaid.gov