Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)

Submitted By: Midgard Consulting Inc.

Date: March 17, 2015

TABLE OF CONTENTS

1 Introduction 6
Forecasting: Art or Science? 7
Difference Between Capacity and Energy 8
2 Overview of Yukon's Electrical System and Historical Development 9
3 Forecasting Electrical Energy Need 11
3.1 Phase 1: Forecast Electrical Energy Demand (2035 to 2065) 12
3.1.1 Step 1 – Forecasting Yukon Population 13
3.1.2 Step 2 – Forecast Per Capita Electrical Energy Consumption 18
3.1.3 Step 3 – Forecasting Non-Industrial (Residential and Commercial) Electrical Energy Demand 22
3.1.4 Step 4 – Forecast Industrial Electrical Energy Demand 25
3.1.5 Step 5 – Forecast Total Electrical Energy Demand 26
3.2 Phase 2: Forecast Supply of Yukon's Future Electrical Energy Generation (2035 to 2065) 28
3.3 Phase 3: Calculating the Annual Electrical Energy Gap (2035 to 2065) 32
3.4 Phase 4: Translating Annual Electrical Energy Gaps into Monthly Gaps (2035 to 2065) 34
3.4.1 Step 1: Forecasting Monthly Electrical Energy Demand 34
3.4.2 Step 2: Forecasting Monthly Electrical Energy Supply 38
3.4.3 Step 3: Calculating Monthly Energy Gaps 39
4 Forecasting Electrical Capacity Need 43
4.1 Step A: Compile Historic Capacity Data 45
4.2 Step B: Capacity Demand – Forecast 45
4.3 Step C: Installed Generation Capacity 50
4.3.1 "N-1" Reliable Winter Capacity Forecast 51
4.4 Step D: Calculating the Capacity Gap (2035 to 2065) 53
5 Electrical Energy and Capacity Need Summary 55
Appendix A: Mining in Yukon 56
Appendix B: Forecasting Mining Impact upon Future Load in Yukon 58
Appendix C: Historic Non-Industrial Per Capita Demand for Electrical Energy 61
Appendix D: Supporting Tables for Monthly Electrical Energy Gaps 62
Appendix E: Scenario Analysis 64

FIGURES AND TABLES

Figure 2-1: Map of Yukon and its Electrical Infrastructure 9
Table 2-1: Legacy Hydroelectric Facilities with In-Service Dates & Associated Concurrent Events 10
Figure 3-1: Electrical Energy Gap (“Need”) 11
Figure 3-2: Electrical Energy Demand 12
Figure 3-3: Yukon Electrical Energy Demand Forecast Process 13
Figure 3-4: Graph of Historic and Forecast Baseline Population in Yukon (1977 – 2065)’ 14
Table 3-1: Table of Historic and Forecast Baseline Population in Yukon (1977 – 2065) 15
Table 3-3: Factors That May Contribute to a Low Population Case Scenario 16
Figure 3-5: Graph of Forecast Population in Yukon: Low, Baseline & High Scenarios (2026 – 2065) 17
Table 3-4: Table of Forecast Population in Yukon: High, Baseline & Low Scenarios (2026 – 2065) 18
Figure 3-6: Historic Yukon Industrial & Non-Industrial Load (1977 to 2013) 19
Table 3-5: Table of Historic Population, Historic Annual Energy Consumption, Industrial & Non-Industrial Load (1977-2013)’’’ 19
Figure 3-7: Historic Yukon Non-Industrial Electrical Energy Demand & Population (1977 to 2013) 20
Figure 3-8: Historic Non-Industrial Electrical Energy Demand & Forecast of Historic Non-Industrial Electrical Energy Demand 21
Table 3-7: Factors That May Decrease Per Capita Electrical Energy Consumption 22
Figure 3-9: Baseline Non-Industrial Electrical Energy Demand Forecast 23
Figure 3-10: Low, Baseline & High Non-Industrial Electrical Energy Demand Forecast 24
Table 3-8: Non-Industrial Load Forecast for Low, Baseline & High Electrical Energy Demand Scenarios 24
Table 3-9: Table of Projected Future Mining Load under High, Baseline & Low Scenarios 25
Figure 3-11: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2031 - 2065) 26
Figure 3-12: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2035 - 2065) 27
Table 3-10: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2035 - 2065) 27
Table 3-11: Generation Asset with Annual Electrical Energy Production & Retirement Date (Fish Lake Excluded): On-Grid’ 28
Figure 3-13: Annual Electrical Energy Generation per Facility: On-Grid (excluding Fish Lake Hydro) 30
Figure 3-14: Annual Electrical Energy Generation per Fuel Type: On-Grid[24] (Excluding Fish Lake Hydro) 30
Table 3-12: Annual Yukon Electrical Energy Generation Capability for Planning Purpsoes (2035 - 2065) (Excluding Fish Lake) 31
Figure 3-15: Low, Baseline & High Cases versus Forecast Supply of Electrical Energy (2014 to 2065) 32
Figure 3-16: Forecast Yukon Electrical Energy Gap (2035 to 2065) 33
Table 3-13: Table of Electrical Energy Gap in High, Baseline & Low Scenarios (2035 - 2065) 33
Figure 3-17: Translating Annual Electrical Energy Gaps into Monthly Electrical Energy Gaps 34
Figure 3-18: Monthly Electrical Energy Demand Forecast – Baseline Case (2035, 2045, 2055 & 2065) 35
Table 3-14: Table of Baseline Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065 35
Figure 3-19: Monthly Electrical Energy Demand Forecast – Low Case (2035, 2045, 2055 & 2065) 36

Table 3-15: Table of Low Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065 36
Figure 3-20: Monthly Electrical Energy Demand Forecast – High Case (2035, 2045, 2055 & 2065) 37
Table 3-16: Table of High Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065 37
Figure 3-21: Monthly Electrical Energy Supply Forecast - Existing & Committed less Retirements (2035 - 2065) 38
Table 3-17: Table of Monthly Electrical Energy Supply Capability (2035 - 2065) 38
Figure 3-22: Baseline Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065) 39
Figure 3-23: Baseline Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065) 40
Figure 3-24: High Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065) 40
Figure 3-25: High Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065) 41
Figure 3-26: Low Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065) 41
Figure 3-27: Low Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065) 42
Figure 4-1: Electrical Capacity Demand Duration Curve (December 2012 - January 2013) 44
Figure 4-2: Methodology for Forecasting Electrical Capacity Gaps 44
Table 4-1: Peak Electrical Capacity Demand : On-Grid (2004 - 2013) 45
Table 4-2: YEC Electrical Capacity Demand Forecast (2014 - 2030) 46
Figure 4-3: Historic & Forecast Baseline Case Electrical Capacity Demand (2004 - 2065) 47
Table 4-3: Table of Historic & Baseline Case Electrical Capacity Demand Forecast (2004 - 2065) 47
Figure 4-4: Electrical Capacity Demand Forecast for Low, Baseline & High Cases (2035 - 2065) 48
Table 4-4: Table of Electrical Capacity Demand Forecasts for Low, Baseline & High Cases (2035 - 2065) 48
Table 4-7: Contribution to Installed Electrical Capacity by Hydroelectric Generation Facilities 51
Figure 4-5: Yukon Grid – Reliable Winter Electrical Capacity Supply Forecast (excluding “New” Capacity Generation) 52
Table 4-8: Yukon Grid Electrical Capacity Supply Forecast (excluding “New” Capacity Generation) 53
Figure 4-6: High, Baseline & Low Case Electrical Capacity Demand & Electrical Supply Capacity (2014 - 2065) 53
Figure 4-7: Capacity Gaps for Low, Baseline & High Case Scenarios (2035 - 2065) 54
Table 4-9: Forecast Capacity Gap for Low, Baseline & High Cases (2035 – 2065) 54
Table 5-1: Summary of Electrical Energy (in GWh/year) and Capacity Gaps (in MW) for Low, Baseline & High Case Scenarios (2035-2065) 55
Table 5-2: Summary of Major Yukon Hydroelectric Generation Facilities and their Electrical Energy (in GWh/year) and Capacity (in MW) Capabilities 55
Table A-1: Historic Mines of Yukon - On-grid Mines″ 56
Table B-1: Historic Mining Load of Yukon″ 58

Figure C-1: Ex-Mining Historic Yukon Electrical Energy Demand per Capita 61
Table C-1: Historical annual per capita Electrical Energy consumption (Non-mining) 61

1 Introduction

The Yukon Development Corporation ("YDC") commissioned Midgard Consulting Incorporated ("Midgard") and its team of sub-consultants to complete Yukon *Next Generation Hydro and Transmission Viability Study*. The study, delivered through a series of technical papers, is intended to help inform the decisions necessary to identify and fill the territory's long term future electrical energy gap in order to support Yukon's continued economic growth and prosperity.

The goal of this report titled *Yukon Electrical Energy and Capacity Need Forecast (2035 to 2065)* is to forecast plausible scenarios of future Yukon electrical energy and electrical capacity requirements 20 to 50 years into the future (2035 to 2065). For each forecast scenario, Midgard will provide information regarding the forecast gaps that may exist between demanded electrical energy and electrical capacity and the then existing supply of electrical energy and electrical capacity. Gaps will be forecast for both electrical energy and electrical capacity.

The value of forecasting, as a planning exercise, is to devise plausible scenarios and help inform and prepare for a range of potential future outcomes. Although it is difficult to predict the future with accuracy and precision, there is value in forecasting long term trends that bound and inform expectations of future outcomes. For example, demographic predictions based upon repeatedly observed population change patterns and actuarial data support predictions that Canada's population will grow over the coming decades, and that Yukon will follow patterns that resemble overall Canadian trends.

In July 2012, the Yukon Energy Corporation ("YEC") published an electrical energy and electrical capacity need and requirement forecast for the years between 2011 and 2030. For the purposes of this report, YEC's data and conclusions provide the electrical energy and electrical capacity forecast for the period up to 2030. Midgard's forecast takes up where the YEC forecast ends, bridges the years from 2031 to 2034, and then forecasts the electrical need from 2035 to 2065.

The electrical energy and electrical capacity forecasts in this report predict future electrical energy and electrical capacity needs based upon expected future demand drivers which include historically significant factors such as Yukon population, per capita electrical energy consumption, and mining activity. Consideration is also given to future scenarios that could alter electrical energy and electrical capacity demand such as the impacts of climate, technological change, and changing electrical energy consumption patterns.

This report is organized into the following sections:

- **Section 2 - Overview of Yukon's Electrical System and Historical Development:** Provides an overview of the current Yukon electrical system, along with some historical context for YEC's electrical facilities;
- **Section 3 – Forecasting Electrical Energy Need:** Develops a forecast of future need for additional electrical energy generation in Yukon;

- **Section 4 – Forecasting Electrical Capacity Need:** Develops a forecast of future need for electrical capacity generation in Yukon;
- **Section 5 – Conclusions:** Summarizes the paper's findings.

Forecasting: Art or Science?

To careful observers, trends and patterns with historic precedents are discernible. Moreover, these trends and patterns occur because temporary points of balance exist within a world prone to disorderly change and discontinuities.

The science of forecasting equates to understanding when a trend is sustainable and when the trend is nearing a point of imbalance. Further, the science of forecasting encompasses knowledge of what the possible (and probable) replacement scenarios may be following a discontinuity.

The art of forecasting, on the other hand is making predictions without getting bogged down on timing or the specifics of the events while still providing forecasts that can still inform robust decision making.

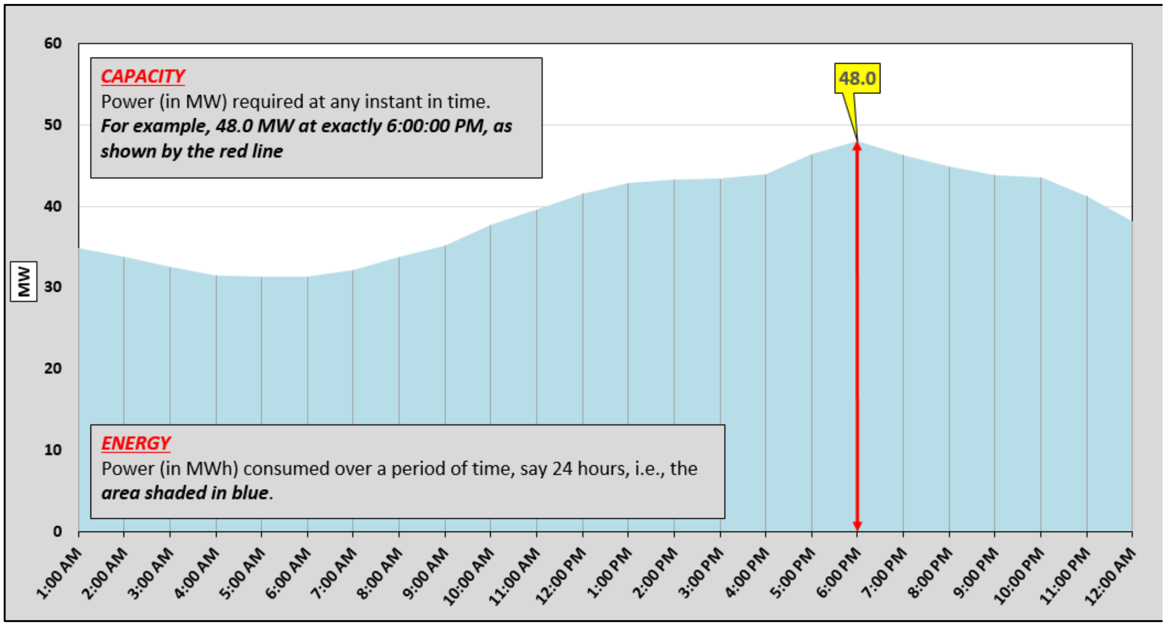
Midgard's Rules of Forecasting:

- Forecasting is doomed to be wrong. But the exercise is worthwhile, in terms of the actual process of identifying trends, the maturity of trends, and the alternatives. Many predictions turn out to be more true than not, but the timing is rarely perfect.
- Trends and equilibriums have remarkable staying power. The forces for change have to be substantially greater than the forces supporting the status quo in order to instigate change.
- Discontinuities do happen. But the greater the resistance to change, the greater the shock and disorder when change does arrive.
- Patterns repeat themselves. The best forecasting methodology often seeks out previous and similar scenarios in order to inform forecasts. History does not repeat itself, but it often rhymes.

"It's tough to make predictions, especially about the future." Yogi Berra

Difference Between Capacity and Energy

- Capacity = instantaneous need
- Energy = amount of electricity used over a period of time



2 Overview of Yukon's Electrical System and Historical Development

Figure 2-1 shows Yukon's current electrical system and transmission grid, including key generation sources and key industrial sites across the territory.

Figure 2-1: Map of Yukon and its Electrical Infrastructure

This report focuses on electrical activities that are "on-grid", referencing all electrical generation and consumption directly attached to the transmission grid that runs between Dawson City and Mayo (in the north) to Aishihik, Haines Junction, and the Southern Lakes just south of Whitehorse (in the south).

Yukon's first hydroelectric plant was the 1.2 MW Twelve-Mile River project developed to power the gold dredges near Dawson City, as well as Dawson City itself. The larger 11 MW North Fork power plant was constructed – in phases – and put into operation four (4) years later, also to serve the gold dredges of Dawson City. Twelve Mile River operated from 1907 until 1920, while North Fork operated from 1911 until 1966. The Mayo Hydroelectric Facility, built in 1951[1], was the first major modern hydroelectric generating asset in Yukon, closely followed by the Whitehorse Hydroelectric Facility in 1958 and the Aishihik Hydroelectric Facility in 1975. The facilities were constructed to support the needs of a growing Yukon.

Table 2-1 summarizes the major Yukon generation and transmission facilities as well as the in-service dates of key assets and associated concurrent events.

Table 2-1: Legacy Hydroelectric Facilities with In-Service Dates & Associated Concurrent Events

Year	Generation Facility	Turbine	Yukon Population	Concurrent Event
1951	Mayo Hydro A[2]	1	9,000	United Keno Hill Mine (1947-1989)
1956	Mayo Hydro A	2	12,000	United Keno Hill Mine (1947-1989)
1958	Whitehorse Rapids[3]	1 & 2	13,000	Growing Yukon population; Replace diesel generation
1969	Whitehorse Rapids[3]	3	16,000	Whitehorse Copper Mine (1967-1982)
1982	Whitehorse Rapids	4	24,465	Planned expansion of Faro Mine; Replace diesel generation
1975	Aishihik Hydro[4]	1 & 2	21,849	Faro Lead-Zinc Mine (1969-1985)
2011	Mayo Hydro B[2]	1	35,194	Alexco Bellekeno Mine (2011-2023); Growing Yukon population
	Aishihik Hydro[4]	3		

[1] Several other small hydroelectric facilities have been constructed in Yukon, including the 1.3 MW Fish Lake.

[2] "Mayo Hydro Facilities", Yukon Energy Corporation, https://www.yukonenergy.ca/energy-in-yukon/our-projects-facilities/hydro-facilities/mayo-hydro-facilities/ (accessed October 20, 2014)

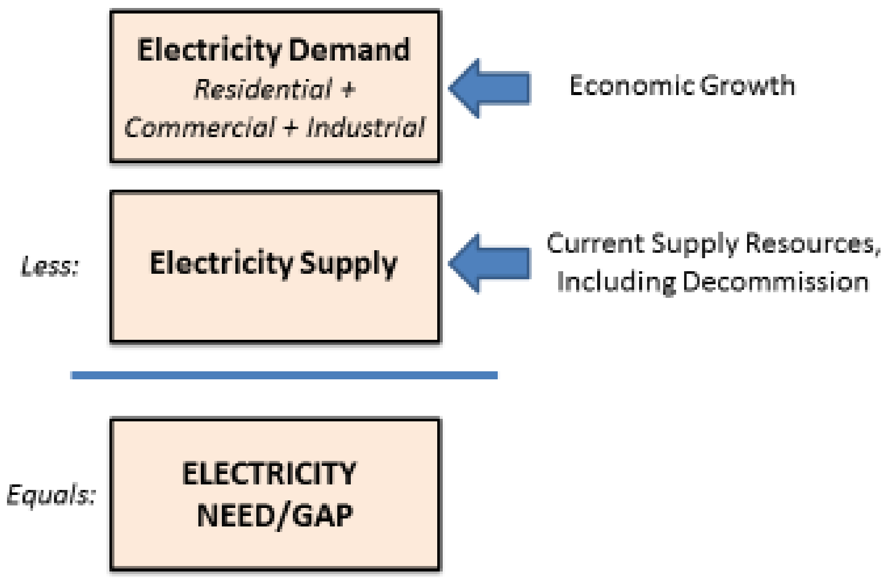
[3] "Whitehorse Hydro Facility", Yukon Energy Corporation, https://www.yukonenergy.ca/energy-in-yukon/our-projects-facilities/hydro-facilities/whitehorse-hydro-facility/when-was-it-done/ (accessed October 20, 2014)

[4] "Aishihik Hydro Facility", Yukon Energy Corporation, https://www.yukonenergy.ca/energy-in-yukon/our-projects-facilities/hydro-facilities/aishihik-hydro-facility/ (accessed October 20, 2014)

3 Forecasting Electrical Energy Need

The difference between electrical energy demand and electrical energy supply is the gap, or "Need", for additional electrical energy as shown in Figure 3-1.

Figure 3-1: Electrical Energy Gap ("Need")

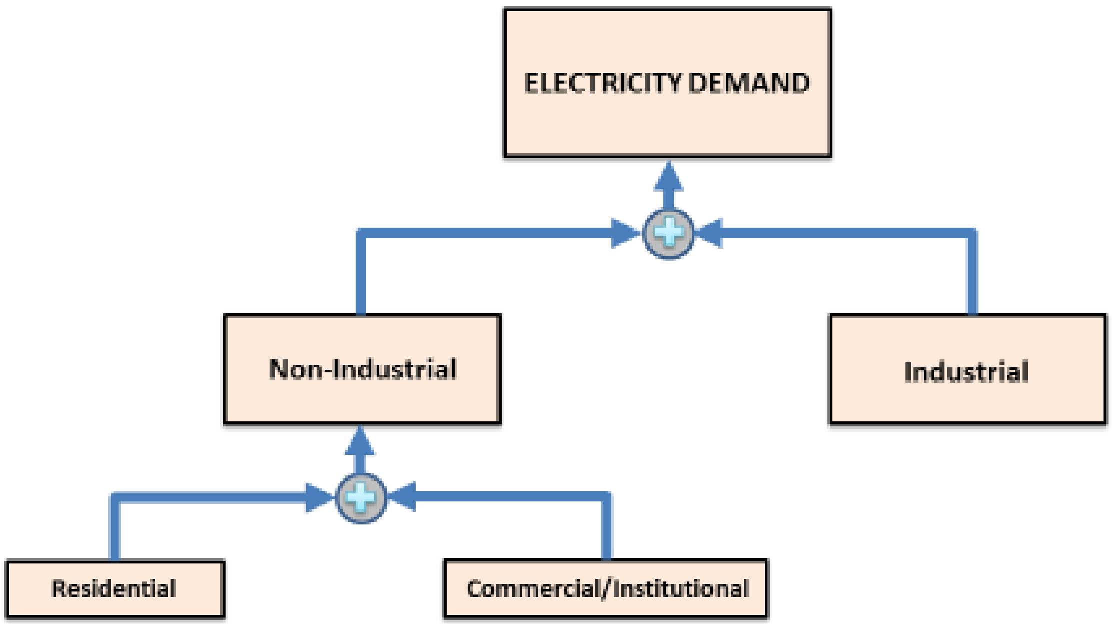


The following sections describe the process and methodology for forecasting electrical energy demand and the resultant electrical energy gap that defines the need for electrical energy generation from 2031 to 2065.

3.1 Phase 1: Forecast Electrical Energy Demand (2035 to 2065)

Electrical energy demand is the sum of two components as shown in Figure 3-2.

Figure 3-2: Electrical Energy Demand

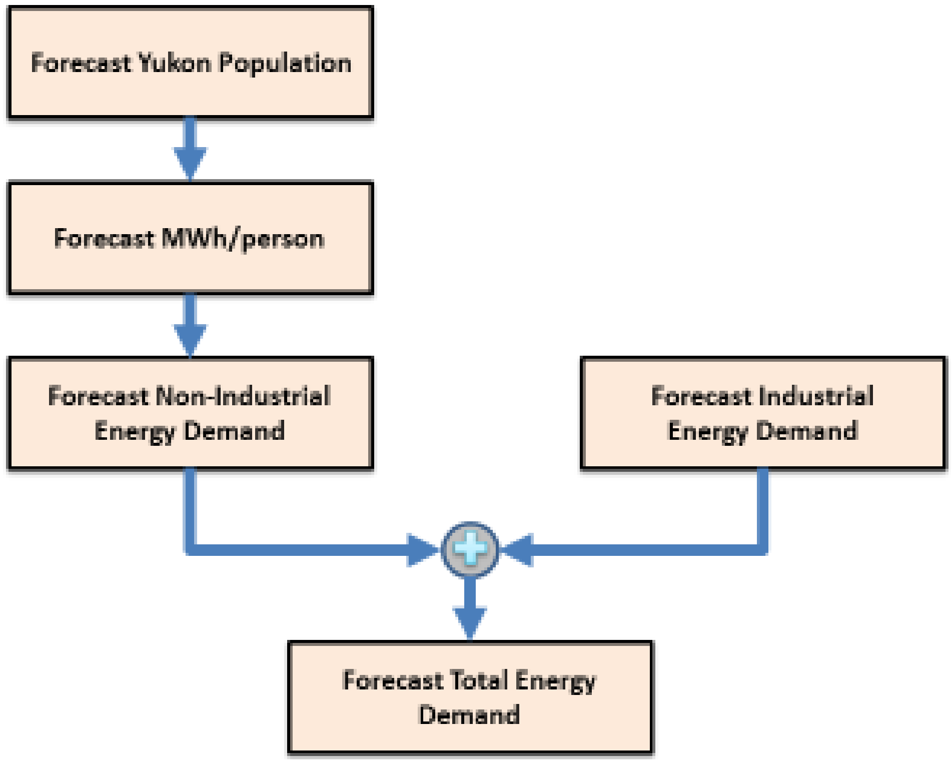


Residential and commercial/institutional demand are typically related to population factors such as population size, per capita electrical energy consumption, and the mix of commercial services needed to support the population (e.g. grocery stores, schools, shops, government services etc.). In Yukon, because residential demand and commercial demand are both related to population and population growth, residential and commercial demand was combined together into a common forecast element called Non-Industrial demand.

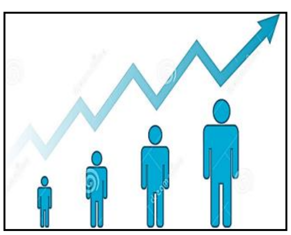
In terms of industrial demand, mining has historically played a significant role in Yukon's economic development, and accounts for the majority of the industrial activity in the territory. Although Yukon's economy continues to diversify, it is expected that mining will continue to play the prominent role in Yukon's industrial demand for the foreseeable future. As a result, the industrial demand forecast in Yukon is related primarily to forecast mining activity in Yukon.

In summary, the forecast electrical energy demand will be the sum of the forecast Non-Industrial demand and the forecast Industrial demand. The methodology for forecasting electrical energy demand (Non-industrial + Industrial) follows a multi-step process as summarized in Figure 3-3.

Figure 3-3: Yukon Electrical Energy Demand Forecast Process



3.1.1 Step 1 – Forecasting Yukon Population



Three population growth scenarios were developed in order to forecast a range of Non-Industrial electrical energy demand. The three population growth scenarios are Low Population Case scenario, Baseline Population scenario, and High Population Case scenario.

The data sources for Yukon population data are:

1) Historic Population Data (1977 to 2013): Statistics Canada CANSIM Table 051-0005
2) Forecast Population Data (2014 to 2025): Conference Board of Canada/Centre for the North, 2014 Fall/Winter Territorial Outlook for forecast population data from 2014 to 2025.[5]

[5] The Conference Board of Canada/Centre for the North forecast is a comprehensive and publicly available forecast of Yukon's long-term economic activity.

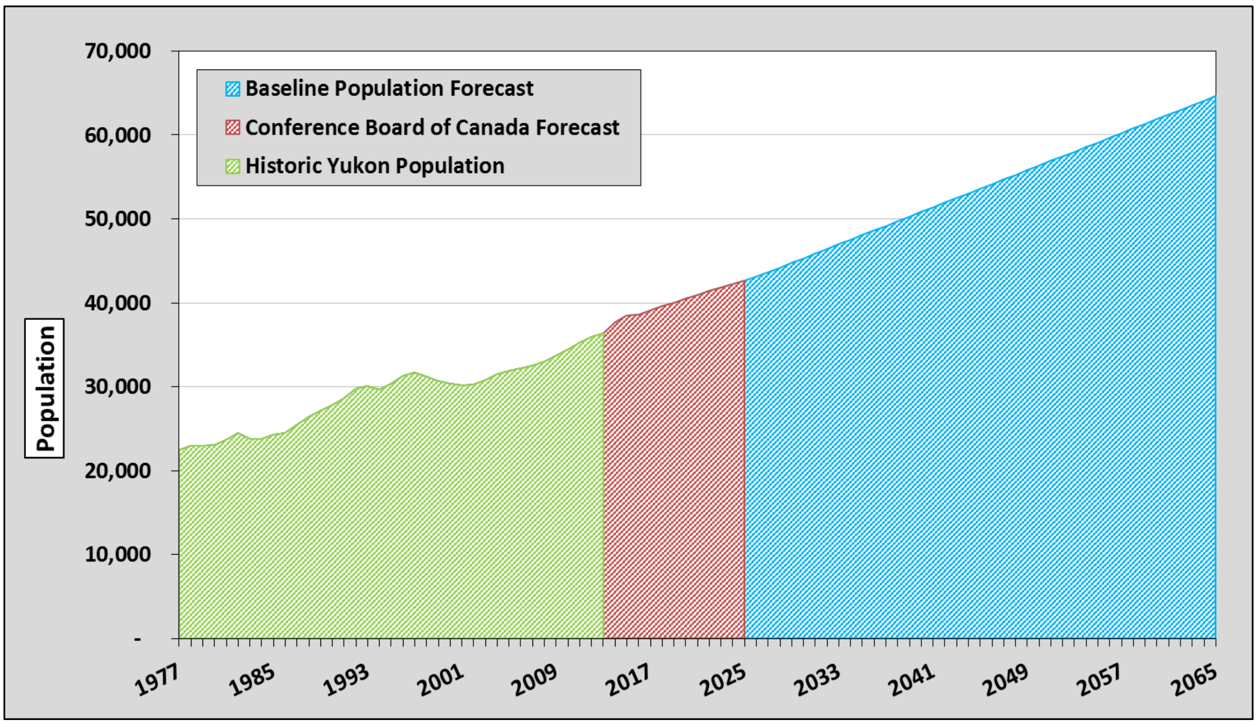
3.1.1.1 Baseline Population Forecast (2026 to 2065)

The following methodology is used to construct the Baseline population growth forecast.

1. Historic population data (1977 to 2013) and the forecast population data (2014 to 2025) were combined to create a single Yukon population data set from 1977 to 2025. This data set forms the starting point for the population forecast from 2026 to 2065.
2. Taking Yukon population data set from 2000 to 2025, a linear extrapolation was performed, and this linear extrapolation used to create the population forecast from 2026 to 2065. Based on this linear extrapolation, the forecast baseline population in Yukon is forecast to grow at a rate of approximately 550 people per year beyond 2026.

Figure 3-4 and Table 3-1 below display the results of the historic and forecasted baseline population scenario in Yukon for a time period ranging from 1977 until 2065.

Figure 3-4: Graph of Historic and Forecast Baseline Population in Yukon (1977 – 2065)[6,7]



[6] Conference Board of Canada / Centre for the North, 2014 Fall/Winter Territorial Outlook Population Forecast: Oct 2014 e-data excel sheet usage as per YDC e-mail permission grant.

[7] Historic Population (1977-2013) : Statistics Canada, CANSIM Table 051-0005

Table 3-1: Table of Historic and Forecast Baseline Population in Yukon (1977 – 2065)

Year	Historic Population[7]	Conference Board Canada Forecast[6]	Baseline Case Population Forecast
1977	22,445		
1980	23,027		
1985	24,309		
1990	27,852		
1995	30,336		
2000	30,401		
2005	31,913		
2010	34,408		
2014		37,707	
2016		38,567	
2018		39,564	
2020		40,474	
2025		42,659	
2030			45,300
2035			48,100
2040			50,800
2045			53,600
2050			56,400
2055			59,100
2060			61,900
2065			64,600

3.1.1.2 Low and High Case Population Forecast

The Baseline population forecast assumes that there are no major changes to the underlying population drivers in Yukon and that population growth continues on a path consistent with historic growth and forecasting patterns. However, over an extended forecasting period (e.g. 50 years), it is not un-reasonable to expect that Yukon conditions could change in a manner that will have a material impact on population growth. It is difficult to say with certainty which changes will arise in the future, and whether they will be positive or negative, but developing a range of potential population growth cases (i.e., Low Case & High Case) is warranted.

Nevertheless, the population scenarios serve as a **proxy for all high and low electrical energy scenarios.** A number of combinations of factors could result in high and low electrical energy scenarios that resemble the Midgard population-based electrical energy forecasts.

In developing the High Population Case scenario, a number of factors may affect growth. The factors, listed in Table 3-2 include:

Table 3-2: Factors That May Contribute to a High Population Case Scenario

Factors That May Contribute to High Population Case Scenarios

• Environment: Climate change impacts
  o Yukon's climate becomes warmer, which leads to larger population increases and/or increased job opportunities (e.g. commercial or industrial activity)
  o Opening of the Northwest Passage to commercial transportation; subsequent growth of population and commercial/industrial sectors to serve Arctic Ocean shipping.
  o Permafrost Retreat: Industrial and commercial projects become viable that once faced a permafrost barrier (e.g. agriculture, silviculture etc.)
• Technological change impacts:
  o Growing prosperity in Yukon due to reduced cost of living encourages immigration.
• Major Infrastructure Projects lead to an influx of direct and support jobs
  o Increased Mining Activity: Due to extended commodity boom.
  o Military Bases: Increased military activity due to Canadian sovereignty protection.
  o Energy Corridor Projects: Alaska Highway Pipeline construction & operations or similar type of energy corridor projects

In developing the Low Population case scenario, a number of factors may affect growth. The factors, listed in Table 3-3, include:

Table 3-3: Factors That May Contribute to a Low Population Case Scenario

Factors That May Contribute to Low Population Case Scenarios

• Climate change impacts:
  o For example, more extreme weather patterns lead to natural events that inhibit population growth
• Reduced Industrial Activity:
  o Multiple mine closures or no new mining activity.
• Government Policy Changes
  o Reduction in northern subsidies by Federal government leading to reduced economic input from government. De-emphasis of northern sovereignty and support.
• Demographics
  o Slowing of immigration to Yukon; aging of population and low natural birthrate.

The methodology for determining the Low Population Case and High Population Case is as follows:

1. **Historic Population Growth Rate:** From the historical population data from 1977 to 2013 (Statistics Canada CANSIM Table 051-0005), the year over year population growth rates are calculated as a percentage growth for each year.
2. **Population Growth Rate Forecast**
    a. *Low Population Case:*
        i. From historical population data from 1977-2013, year over year growth rates are derived.
        ii. The annual growth rates are sorted from lowest to highest.

iii. The five (5) lowest annual growth rates are discarded as potential outliers.
iv. The average of the next 15 lowest annual growth rates is calculated; the average of these 15 years corresponds to 0.68% per annum. This growth rate is used to predict the low case year-over-year population growth forecast from 2026 to 2065.

b. *High Population Case*

i. From historical population data from 1977-2013, year over year growth rates are derived.
ii. The annual growth rates are sorted from lowest to highest.
iii. The five (5) highest annual growth rates are discarded as potential outliers.
iv. The average of the next 15 highest annual growth rates is calculated; the average of these 15 years corresponds to 2.27% per annum. This growth rate is used to predict the high case year-over-year population growth forecast from 2026 to 2065.

The forecast Low, Baseline, and High population forecast curves and data are displayed in Figure 3-5 and Table 3-4 below.

Figure 3-5: Graph of Forecast Population in Yukon: Low, Baseline & High Scenarios (2026 – 2065)

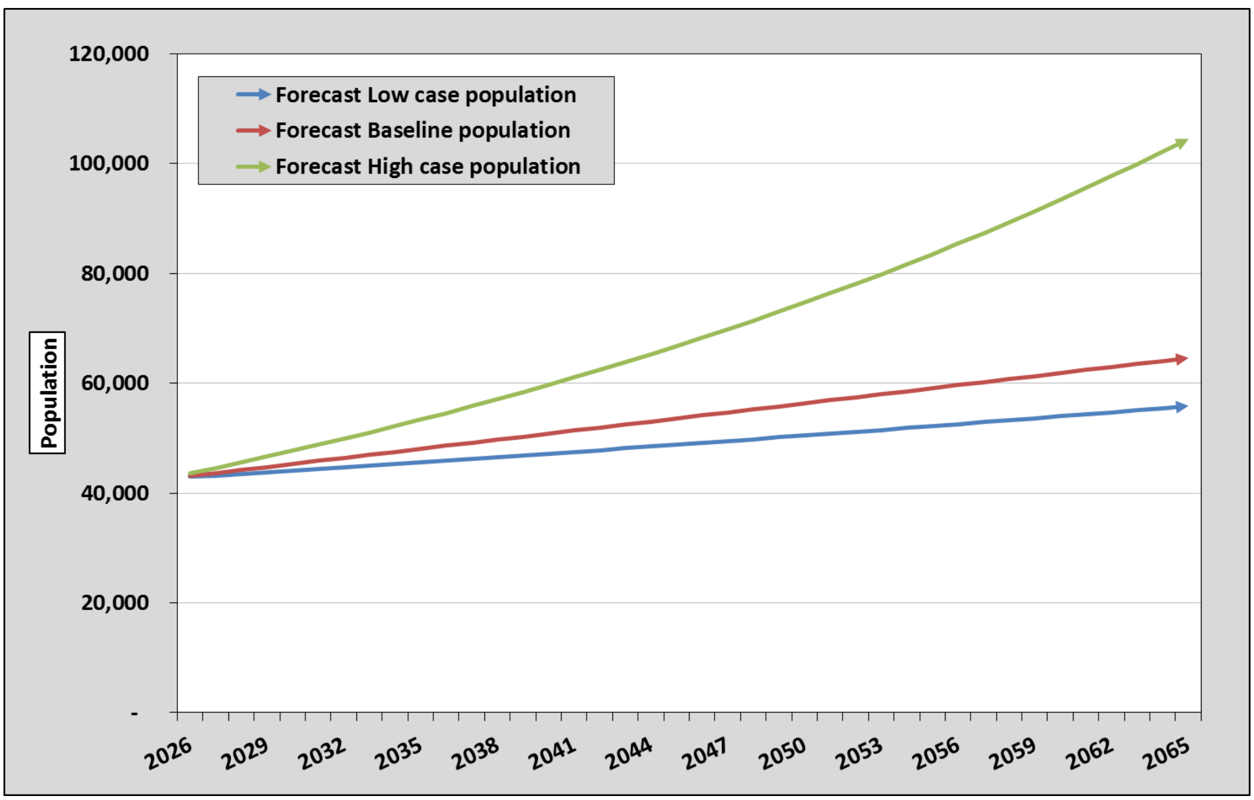


Table 3-4: Table of Forecast Population in Yukon: High, Baseline & Low Scenarios (2026 – 2065)

Year	Low Case Population Forecast	Baseline Population Forecast	High Case Population Forecast
2026	42,900	43,100	43,600
2030	44,100	45,300	47,700
2035	45,600	48,100	53,400
2040	47,200	50,800	59,700
2045	48,800	53,600	66,800
2050	50,500	56,400	74,700
2055	52,200	59,100	83,500
2060	54,000	61,900	93,500
2065	55,900	64,600	104,500

3.1.2 Step 2 – Forecast Per Capita Electrical Energy Consumption

The second step in the electrical energy need analysis is to determine forecast per capita electrical energy consumption patterns. The analysis looks at historic Yukon load, and differentiates between the Industrial (mining) load and the Non-Industrial (Residential & Commercial) load.

Figure 3-6 displays the historic annual demand for electrical energy in Yukon[8]. Within the total load, a distinction is made between the Industrial (mining) and Non-Industrial (Residential & Commercial) loads. For a more detailed discussion regarding the estimation of historic Industrial (mining) electrical load, see Appendix A: Mining in Yukon and Appendix B: Forecasting Mining Impact upon Future Load in Yukon.

[8] Midgard estimated mining loads (1977 - 2013) based upon publicly available information. Actual mining consumption figures may vary from the cumulative estimates used in the paper.

Figure 3-6: Historic Yukon Industrial & Non-Industrial Load (1977 to 2013)

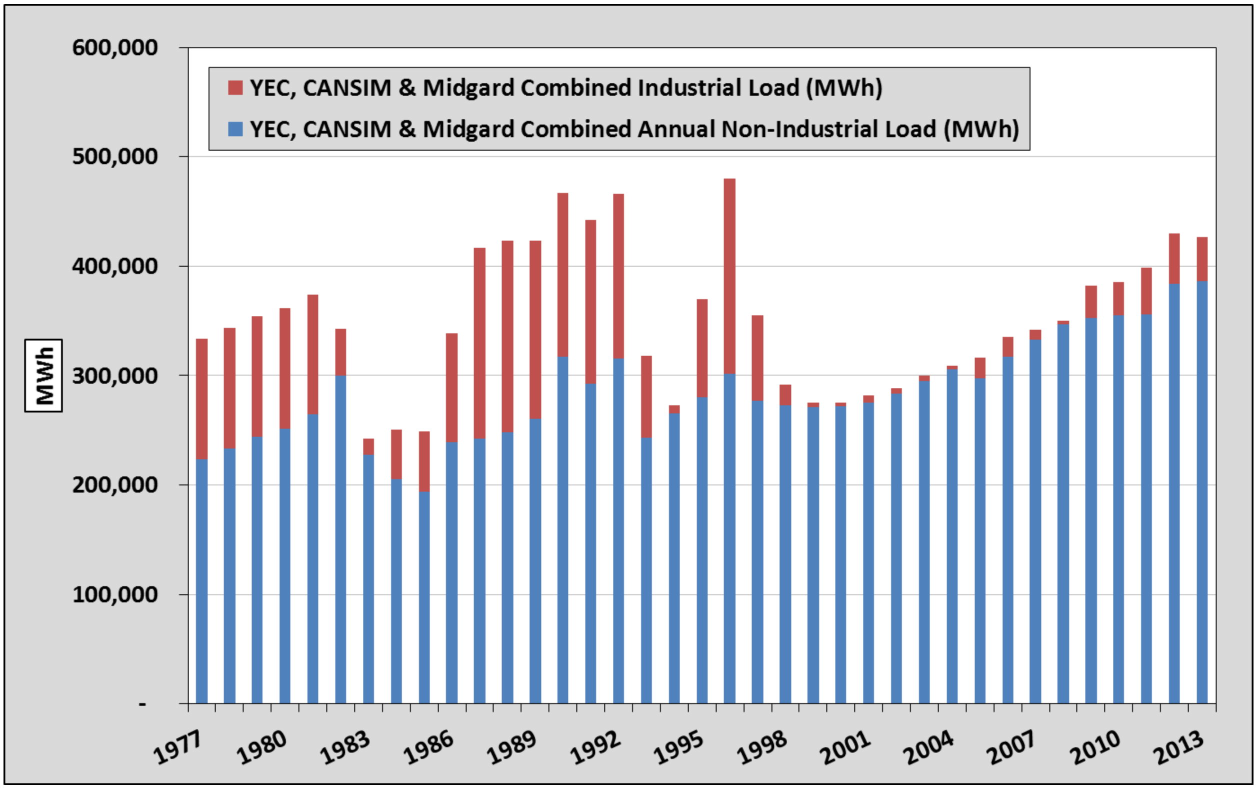


Table 3-5: Table of Historic Population, Historic Annual Energy Consumption, Industrial & Non-Industrial Load (1977-2013)[9,10,11,12,13]

Year	Historic Population	Historic Annual Electrical Energy Consumption (MWh/year)	Annual Non-Industrial Load (MWh/year)	Annual Industrial Load (MWh/year)
1977	22,445	333,300	223,300	110,000
1980	23,027	361,500	251,500	110,000
1985	24,309	248,800	193,800	55,000
1990	27,852	467,000	317,000	150,000
1995	30,336	369,850	280,316	89,534

[9] Mining Load (2005-2008) : "CANSIM 127-0008", Statistics Canada

[10] Mining Load (1994-2004 & 2013) : "Next Gen Hydro Information Request 06.10.14 - Attachment 3" , Tab : Re #4, 6 and 7 Historical Sales, Industrial Sales Column

[11] Annual Electricity Consumption : "Next Gen Hydro Information Request 06.10.14 - Attachment 3" , Tab : Request #1 Historical Gen

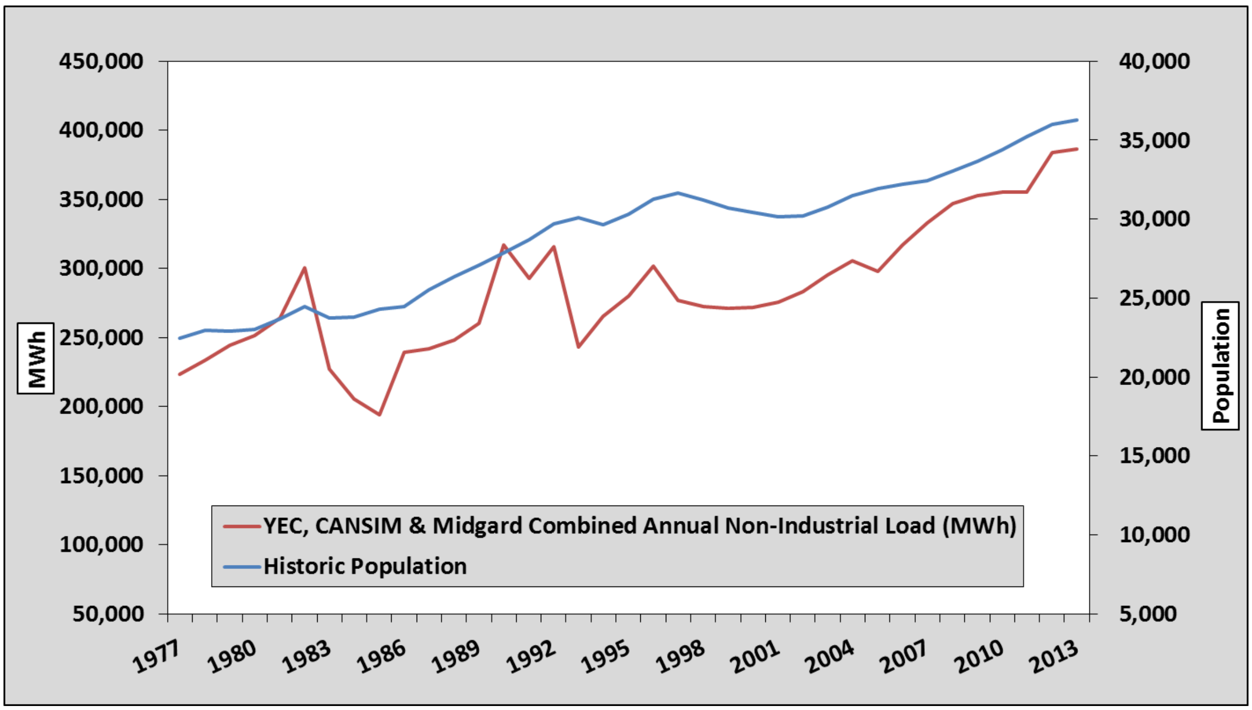
[12] Midgard estimated total mining loads (1977 - 1993) based upon the best publicly available individual mining information. Actual mining consumption figures may vary from the cumulative estimates used in the paper.

[13] Population (1977-2013) : "CANSIM Table 051-0005", Statistics Canada

Year	Historic Population	Historic Annual Electrical Energy Consumption (MWh/year)	Annual Non-Industrial Load (MWh/year)	Annual Industrial Load (MWh/year)
2000	30,401	275,498	271,633	3,865
2005	31,913	316,086	297,854	18,232
2010	34,408	385,643	355,388	30,255
2013	36,299	427,058	386,545	40,513

Figure 3-7 below plots the historic Yukon population and annual Non-Industrial demand for electrical energy. Figure 3-7 shows a good correlation between the historic population of Yukon and the Non-Industrial electrical energy demand. From 1977 to 2013 the average Non-Industrial electrical consumption per capita has remained relatively constant[14].

Figure 3-7: Historic Yukon Non-Industrial Electrical Energy Demand & Population (1977 to 2013)

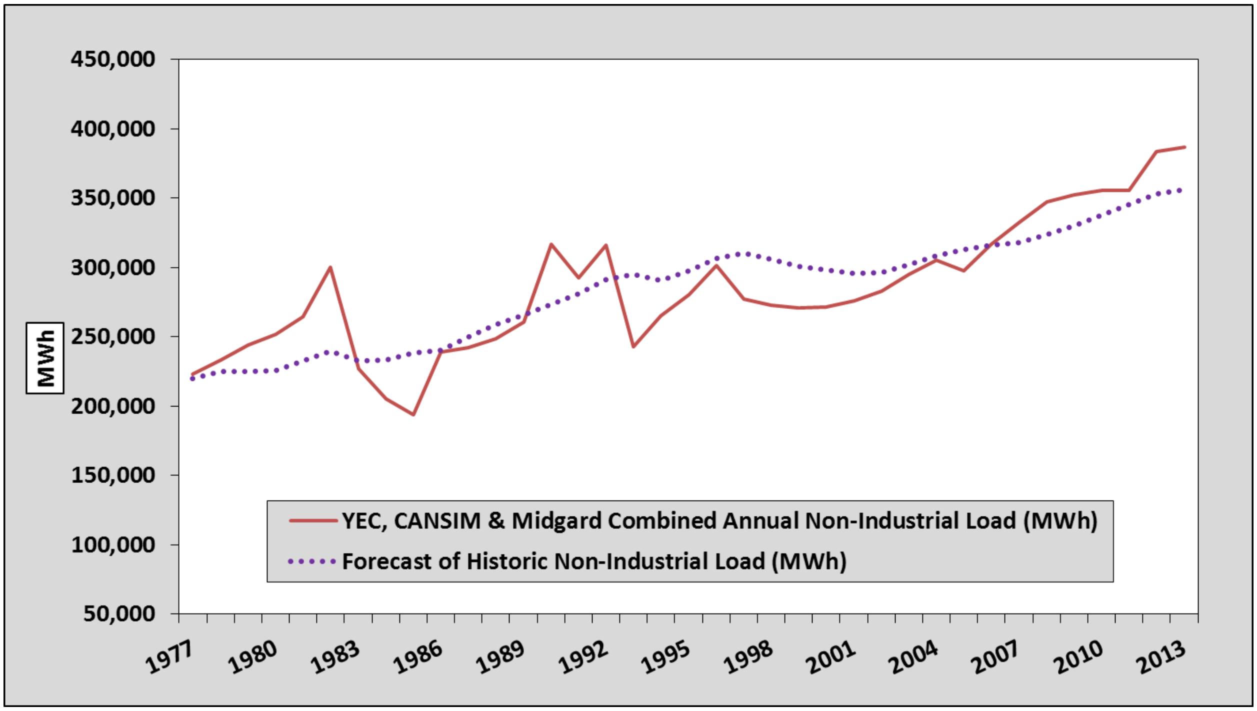


The dotted line in Figure 3-8 shows predicted historical electrical energy consumption based upon a constant per capita consumption of 9.8 MWh/year. Please note that the dotted line in Figure 3-8 is included for information purposes only as a demonstration of the correlation between actual electrical demand and a predicted electrical demand based upon a constant per capita consumption metric. For

[14] The change in per capita consumption of electrical is not statistically different than a constant value of 9.8 MWh/yr.

further discussion on the derivation of the historic per capita electrical consumption, please see Appendix C: Historic Non-Industrial Per Capita Demand for Electrical Energy.

Figure 3-8: Historic Non-Industrial Electrical Energy Demand & Forecast of Historic Non-Industrial Electrical Energy Demand



In order to take the historic per capita electrical energy consumption and translate it into forecast per capita electrical energy consumption, a number of factors that may increase per capita electrical energy consumption were considered as shown in Table 3-6, and factors that may decrease per capita electrical energy consumption were considered as shown in Table 3-7.

Table 3-6: Factors That May Increase Per Capita Electrical Energy Consumption

Factors That May Increase Per Capita Electrical Energy Consumption

• Fuel switching:
  ○ Increased use of electrical heating in Yukon, substitution away from fuel oil, propane and/or biomass (wood) as heating sources
  ○ Adoption of electric cars or battery powered commercial vehicles in Yukon
• Climate change impacts:
  ○ Extreme winters / weather: Greater number of heating degree days (and therefore increased load in winter)
• Technological change impacting consumer behavior:
  ○ Increase usage of electronic and electrical devices in Yukon homes and businesses
• Rising Real Incomes
  ○ Growing economic prosperity leading to larger disposable incomes, homes, and devices

that use electrical energy.

- Demographics
    - Changing of the age class distribution within Yukon population resulting is changing electrical energy consumption patterns.

Table 3-7: Factors That May Decrease Per Capita Electrical Energy Consumption

Factors That May Decrease Per Capita Electrical Energy Consumption

- Climate change impacts:
    - Warmer winters leading to lower electrical energy needs for heating
- Technological change:
    - Distributed electrical generation, e.g., wide adoption of rooftop solar panels that curtail electrical energy grid loads
    - Energy efficiency gains: Lowering of per capita electrical energy consumption in a variety of electrical devices such as TVs, lighting, electronics, appliances, portable electronics etc.
    - Smart Grid: Smart Grid devices that reduce peak electrical energy demand resulting in lower per capita transmission and distribution grid losses.
    - Demand Side Management: Successful demand side management programs that increase the overall efficiency of electrical energy usage across all usage areas (Residential, Commercial and Industrial).
- Regulatory Change:
    - Building code changes that increase thermal efficiency of residential and commercial buildings.
- Demographics:
    - Changing of the age class distribution within Yukon population resulting in changing electrical energy consumption patterns.

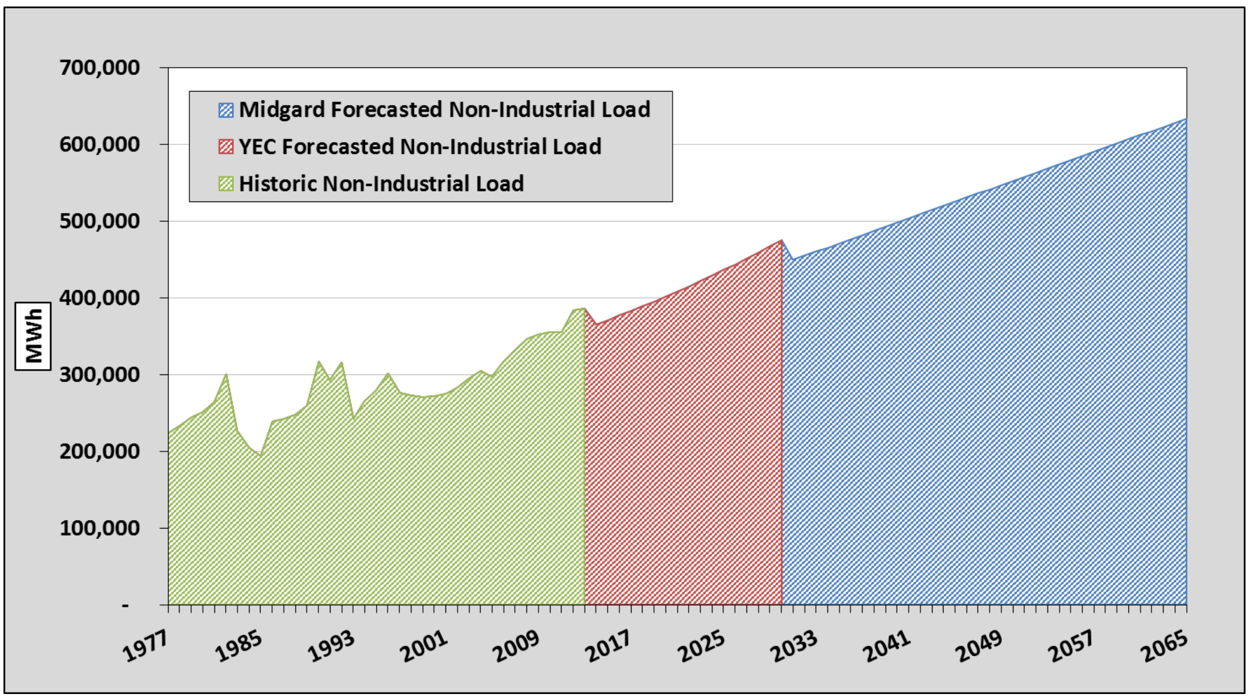
When the factors increasing per capita electrical energy consumption (Table 3-6) and reducing per capita electrical energy consumption (Table 3-7) are considered, it is not obvious which factors will dominate. Although the Non-Industrial per capita electrical energy consumption used to calculate the baseline, high and low scenarios is 9.8 MWh/yr., the potential high cases and low cases of per capita energy consumption changing are capture, by proxy, in the high and low population derived electrical energy forecasts. Appendix E: Scenario Analysis, discusses some alternative cases and how they fit within the high and low envelop outlined in Figure 3-11.

3.1.3 Step 3 – Forecasting Non-Industrial (Residential and Commercial) Electrical Energy Demand

Using the three population forecasts derived in 3.1.1 (Low, Baseline, and High), and the constant Non-Industrial per capita electrical energy consumption of 9.8 MWh/year, three forecasts for Non-Industrial energy demand were determined for the years 2031 to 2065. The Non-Industrial electrical energy demand forecasts are the multiplication of the population by the Non-Industrial per capita electrical energy consumption.

The results are for the Baseline Population scenario is displayed in Figure 3-9 along with actual Non-Industrial load for 1977 to 2013 and YEC's load projections for 2014 to 2030 taken from the "YEC 20-Year Resource Plan: 2011-2030". [15] Figure 3-10 and Table 3-8 below show the forecast Non-Industrial demand for the Low, Baseline, and High Population growth cases. Although the low and high scenarios for electrical energy consumption are forecast based on population growth, they are valid not only for low or high population growth scenarios, but also for other (non-population related) scenarios that result in low or high electrical energy requirements.

Figure 3-9: Baseline Non-Industrial Electrical Energy Demand Forecast[16]



[15] The YEC 20-Year Resource Plan Overview 2011-2030 is referenced multiple times in the analysis.

[16] YEC Non-Industrial Load Forecast : YEC 20-Year Resource Plan Overview 2011-2030: Appendix A, Table A-3, Base Case. Note that the Midgard forecasting methodology differs from the methodology employed by YEC. There is no single best methodology to forecast future load and different methodologies are selected for different time frames (e.g. 0-20 years vs. 20-50 years).

Figure 3-10: Low, Baseline & High Non-Industrial Electrical Energy Demand Forecast

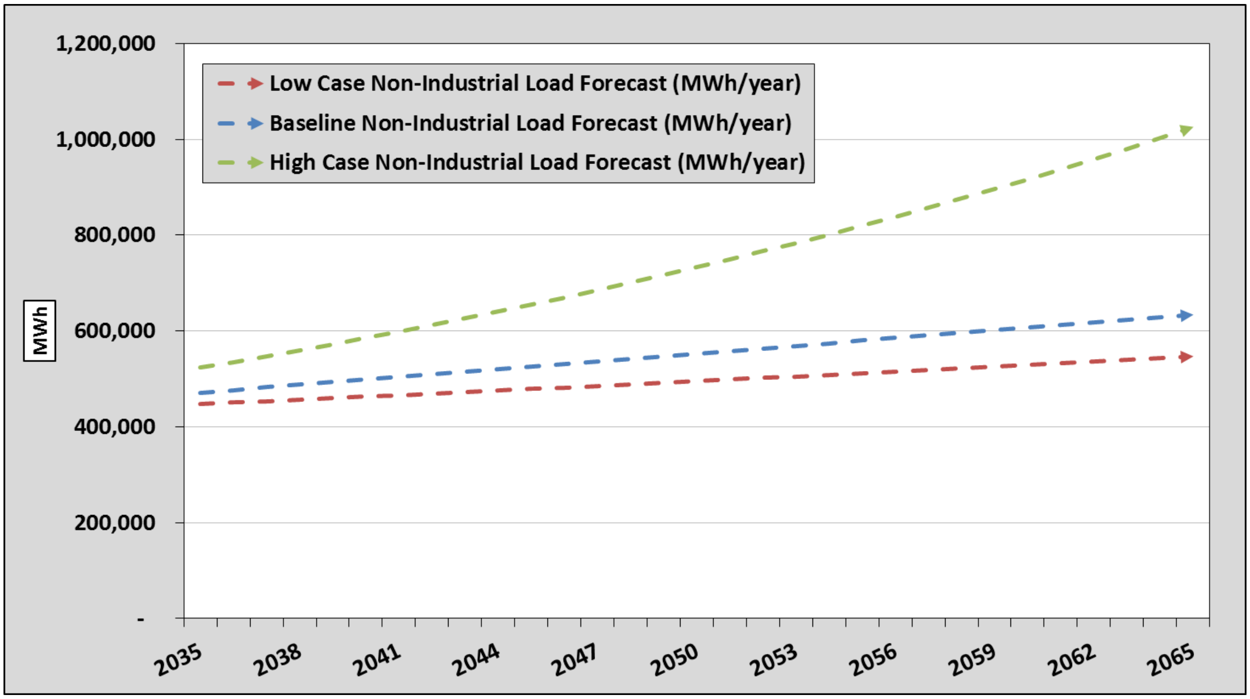


Table 3-8: Non-Industrial Load Forecast for Low, Baseline & High Electrical Energy Demand Scenarios

Year	Low Case Non-Industrial Load Forecast (MWh)	Baseline Non-Industrial Load Forecast (MWh)	High Case Non-Industrial Load Forecast (MWh)
2031	436,000	450,000	479,000
2035	448,000	472,000	524,000
2040	463,000	499,000	586,000
2045	479,000	526,000	655,000
2050	495,000	553,000	733,000
2055	512,000	580,000	820,000
2060	530,000	607,000	917,000
2065	548,000	634,000	1,025,000

3.1.4 Step 4 – Forecast Industrial Electrical Energy Demand

To begin the process of forecasting potential Industrial (mining) loads, historic data for the grid-connected Yukon mines was collected and analyzed to determine the electrical energy requirements of a typical mine in Yukon. The Industrial (mine) data used of the analysis is depicted in Figure 3-6.

Based upon the observation that the average on-grid connected mine consumed over 50 GWh/year,[17] and 1.2 mines were in operation (and connected to the grid) during the observation period from 1977 to 2014, it was determined that for Baseline forecasting purposes, on average, 1.5 grid connected mines will be in operations during the 2031-2065 period. The 1.5 operating mines will consume, in aggregate, 75 GWh/year. For details on how average mining activity and forecasted loads was derived, please see Appendix B: Forecasting Mining Impact upon Future Load in Yukon.

For the High case scenario, on average, two (2) grid connected mines were forecast during 2031 to 2065, consuming an aggregate 100 GWh/year. For the Low case scenario, on average, one (1) grid connected mine was forecast to be in operation during 2031 to 2065, consuming an aggregate 50 GWh/year. The mining load scenarios for 2031 to 2065 are shown in Table 3-9.

Table 3-9: Table of Projected Future Mining Load under High, Baseline & Low Scenarios

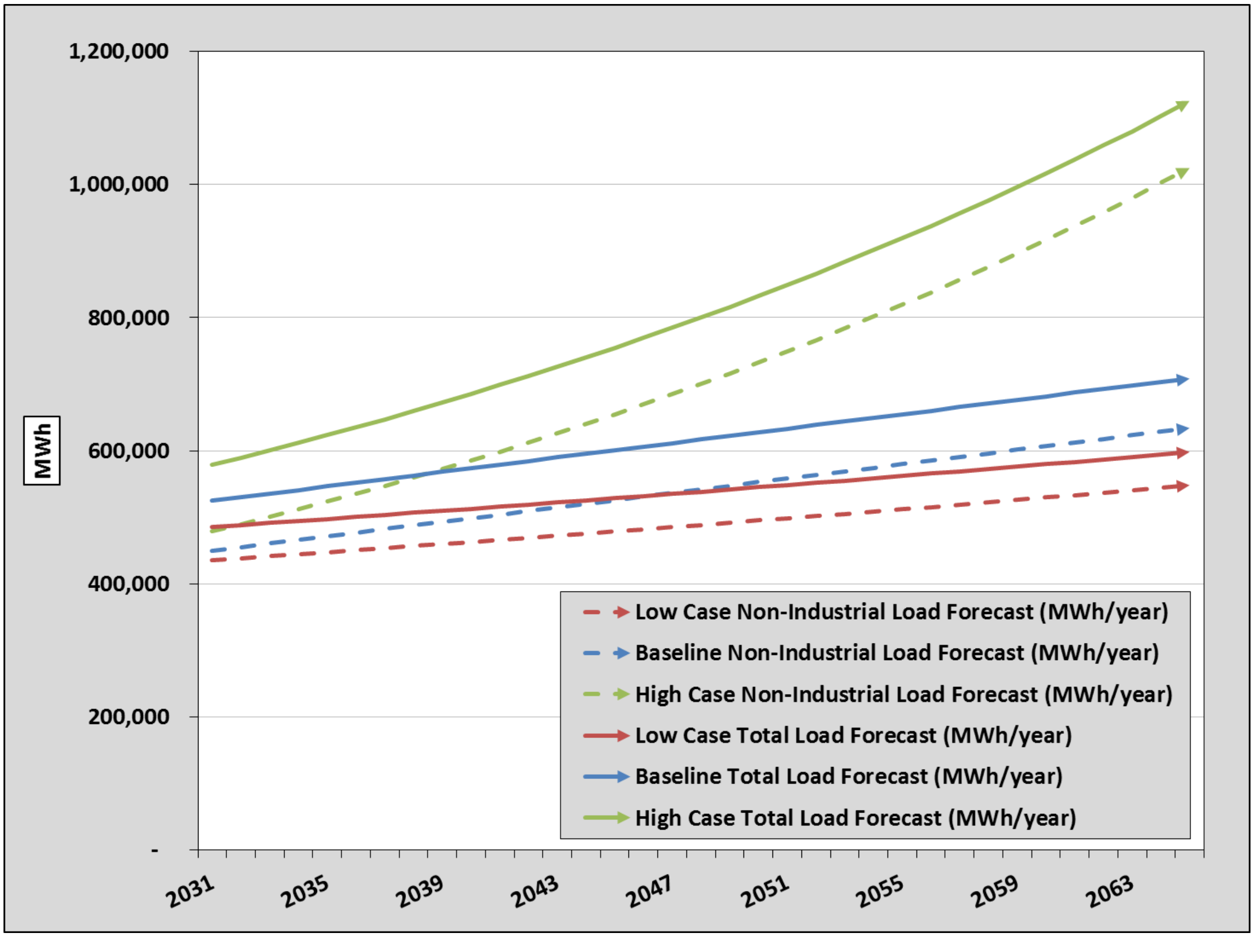
Scenarios	Mining Energy Demand
Low Case Scenario	50 GWh/year from 2031 to 2065
Baseline Scenario	75 GWh/year from 2031 to 2065
High Case Scenario	100 GWh/year from 2031 to 2065

[17] 1 GWh = 1,000 MWh

3.1.5 Step 5 – Forecast Total Electrical Energy Demand

Taking the Non-Industrial and Industrial electrical energy demand forecasts and adding them together, the forecast total electrical energy demand for 2031 to 2065 is as shown in Figure 3-11.

Figure 3-11: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2031 - 2065)



After removing the forecast bridge years (2031 to 2034) that link the end of the YEC 20 Year Energy Forecast[18] to the electrical energy demand forecast in this report, the forecast total electrical energy demand for 2035 to 2065 is as shown in Figure 3-12 and Table 3-10 below.

[18] YEC 20-Year Resource Plan Overview 2011-2030 : Appendix A, Table A-1, Base Case

Figure 3-12: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2035 - 2065)

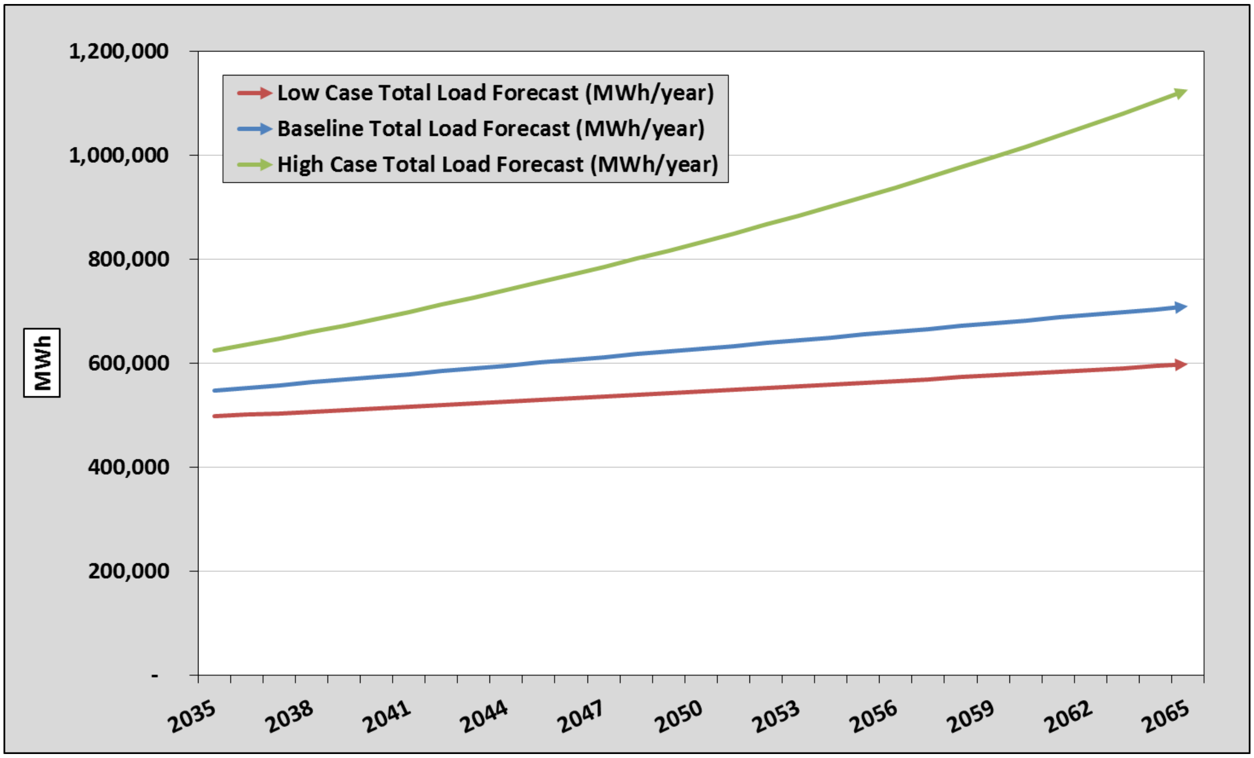
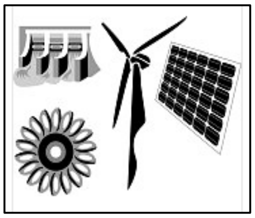


Table 3-10: Forecast Total Electrical Energy Demand (Low, Baseline & High Cases) (2035 - 2065)

Year	Low Case Total Load Forecast (MWh)	Baseline Total Load Forecast (MWh)	High Case Total Load Forecast (MWh)
2035	498,000	547,000	624,000
2040	513,000	574,000	686,000
2045	529,000	601,000	755,000
2050	545,000	628,000	833,000
2055	562,000	655,000	920,000
2060	580,000	682,000	1,017,000
2065	598,000	709,000	1,125,000

3.2 Phase 2: Forecast Supply of Yukon's Future Electrical Energy Generation (2035 to 2065)



The forecast supply of Yukon's electrical energy generation is based upon existing and committed generation assets, and is comprised of three components:

1) Existing Generation
2) PLUS: Committed Generation Additions
3) LESS: Generation Retirements

Existing Generation is the current electrical generation connected to Yukon's grid, and includes hydroelectric, wind, and diesel generation. Committed Generation Additions are generation assets that that have been committed to and shall be constructed and made operational. The only Committed Generation Addition at this time is the Whitehorse natural gas generation facility currently under construction adjacent to the Whitehorse hydroelectric facility. Generation retirements account for the retirement of generation assets that reach the end of their useful operating life and will be decommissioned.

The electric generation resources that exist or are committed to construction in Yukon include hydroelectricity, wind, diesel, and natural gas generation. Table 3-11 summarizes the on-grid generation resources in Yukon and their corresponding annual electrical energy production. It is important to note the role diesel generation and natural gas generation plays is to meet short term demand peaks (e.g. on the coldest winter days) and backup generation, such as when a transmission line is disabled or a hydro-electric plant is offline.

Table 3-11: Generation Asset with Annual Electrical Energy Production & Retirement Date (Fish Lake Excluded): On-Grid[19,20]

Generation resource	Type	Existing / Committed	Annual Electrical Energy Production (MWh)	Expected Retirement Year
Whitehorse	Hydro	Existing	250,200	Post-2065
Aishihik	Hydro	Existing	112,700	Post-2065
Mayo	Hydro	Existing	80,900	Post-2065
Whitehorse Diesel #1	Diesel	Existing	Backup & Peaking Generation	2014
Whitehorse Diesel #2	Diesel	Existing	Backup & Peaking Generation	2015
Whitehorse Diesel #3	Diesel	Existing	Backup & Peaking Generation	2021
Whitehorse Diesel #4	Diesel	Existing	Backup & Peaking Generation	2025

[19] Whitehorse, Aishihik and Mayo Annual Generations : YEC 2011-2030 Resource plan, Page 48, Figure 2-11 : YEC Grid Electricity Generation by Source : Mean Flows (Average of all water years) at 545 GWh/yr Grid Load Net of Fish Lake and Wind

[20] Retirement Years : YEC 2011-2030 Resource plan, Page 42, Table 2-3

Generation resource	Type	Existing / Committed	Annual Electrical Energy Production (MWh)	Expected Retirement Year
Whitehorse Diesel #5	Diesel	Existing	Backup & Peaking Generation	2025
Whitehorse Diesel #6	Diesel	Existing	Backup & Peaking Generation	2025
Whitehorse Diesel #7	Diesel	Existing	Backup & Peaking Generation	2026
Faro Diesel #1	Diesel	Existing	Backup & Peaking Generation	2021
Faro Diesel #3	Diesel	Existing	Backup & Peaking Generation	2019
Faro Diesel #5	Diesel	Existing	Backup & Peaking Generation	2020
Faro Diesel #7	Diesel	Existing	Backup & Peaking Generation	2027
Mayo	Diesel	Existing	Backup & Peaking Generation	2019
Dawson Diesel #1	Diesel	Existing	Backup & Peaking Generation	2018
Dawson Diesel #2	Diesel	Existing	Backup & Peaking Generation	2017
Dawson Diesel #3	Diesel	Existing	Backup & Peaking Generation	2020
Dawson Diesel #4	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Dawson Diesel #5	Diesel	Existing	Backup & Peaking Generation	2031
Carmacks	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Haines Junction	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Teslin	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Ross River	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Stewart Crossing	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Pelly Crossing	Diesel	Existing	Backup & Peaking Generation	*Pre-2035*[21]
Haeckel Hill	Wind	Existing	440[22]	*Pre-2035*[21]
Whitehorse LNG #1	Natural Gas	Committed	Backup & Peaking Generation	*2054*[23]
Whitehorse LNG #2	Natural Gas	Committed	Backup & Peaking Generation	*2054*[23]

The historic generation for the on-grid resources listed in Table 3-11 is displayed in Figure 3-13 and Figure 3-14.

[21] Retirement dates are assumed to be Pre-2035 for diesel generation facilities that are currently operating without planned retirement dates. Therefore, for analysis purposes they will be assumed to retire in 2034

[22] Haeckel Hill : "Next Gen Hydro Information Request 06.10.14 - Attachment 3", Tab : Request #1- Historical gen

[23] YEC: Application for Energy Project Certificate and an Energy Operation Certificate, Table 4-3: In the "Notes" section, statement #1 – mentions that, "All Capital costs are depreciated over 40 years". Hence, a 40-year life span was assumed.

Figure 3-13: Annual Electrical Energy Generation per Facility: On-Grid[24] (excluding Fish Lake Hydro)

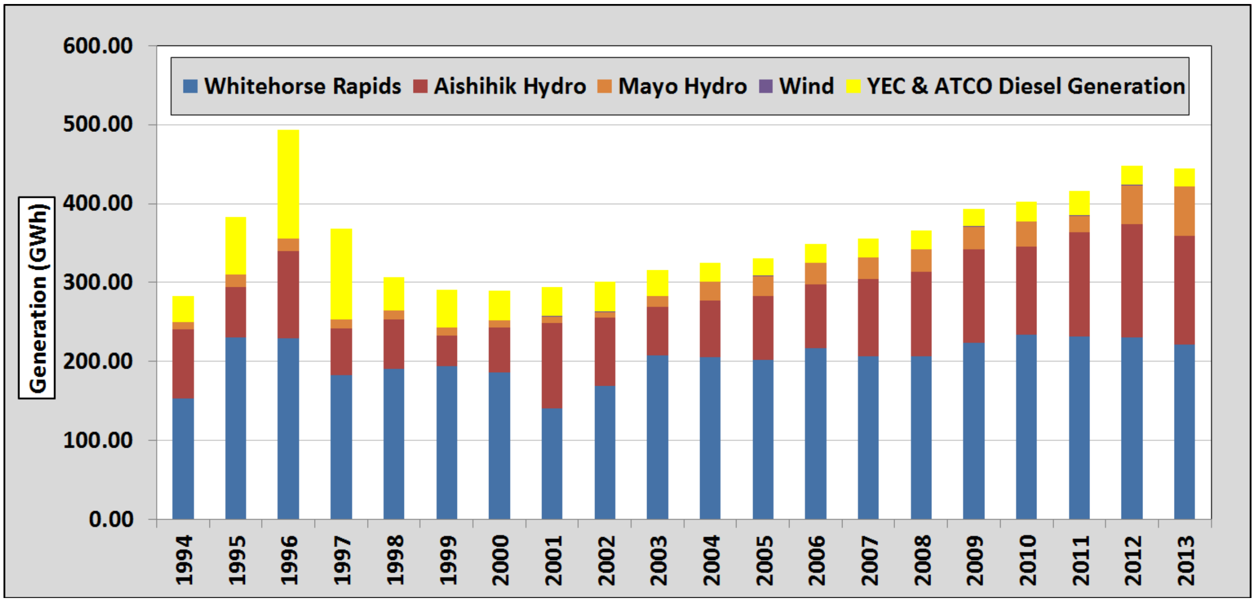
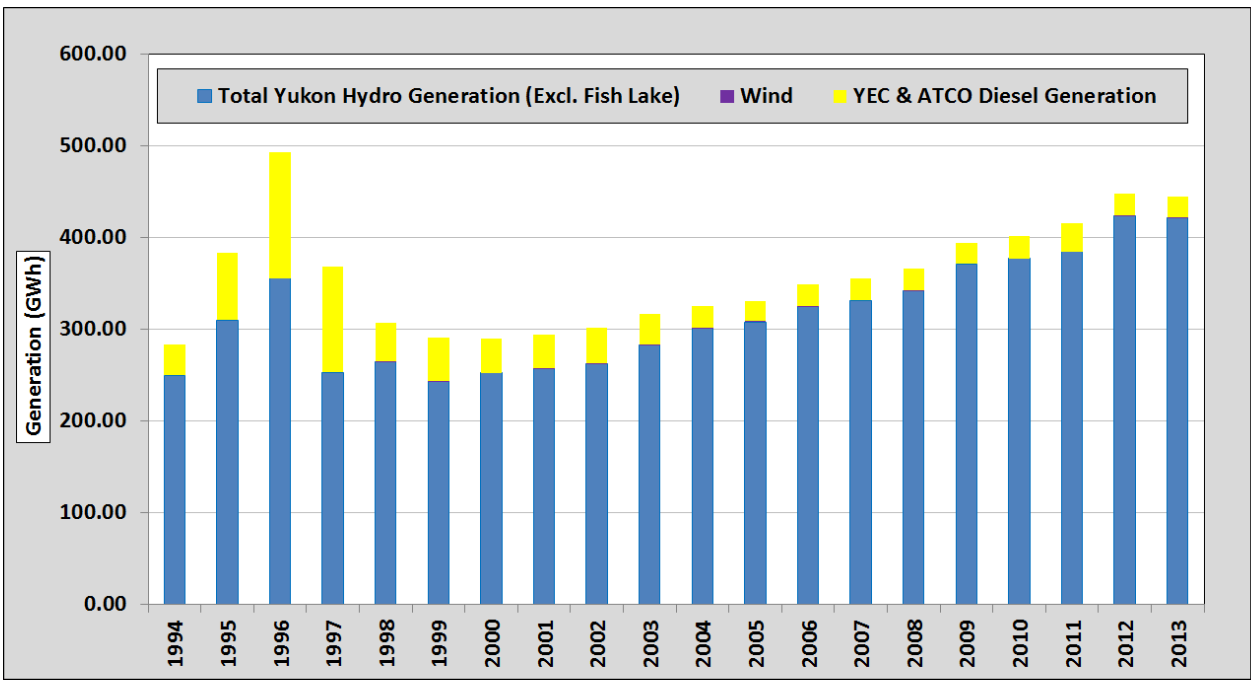


Figure 3-14: Annual Electrical Energy Generation per Fuel Type: On-Grid[24] (Excluding Fish Lake Hydro)



[24] Yukon Energy Corporation : "Next Gen Hydro Information Request 06.10.14 - Attachment 3 – Request #1- Historical gen"

Table 3-11 also includes the expected year of retirement for the existing and committed Yukon generation assets. Generally speaking, the rotating machinery and moving parts in diesel engines, natural gas reciprocating engines, and wind turbines need replacement approximately every 20 years (although life of equipment can be extended, especially if the machinery in not heavily used). Presumably diesel and natural gas generation will be used to address short and medium term electrical energy requirements as and when deemed appropriate to meet backup demands and peak generation demands. Similarly, the Haeckel Hill facility will provide electrical energy up to 2030. Thermal generation is anticipated to contribute modest amounts of electrical energy in future years, except during very high demand or emergency situations when output could be greater.

It is expected that Yukon's hydroelectric facilities will have operating lives to 2065 and beyond. The existing hydroelectric assets listed in Table 3-11 are the assets that are available for planning purposes between 2035 and 2065.

Table 3-12: Annual Yukon Electrical Energy Generation Capability for Planning Purpsoes (2035 - 2065)[25]
(Excluding Fish Lake)

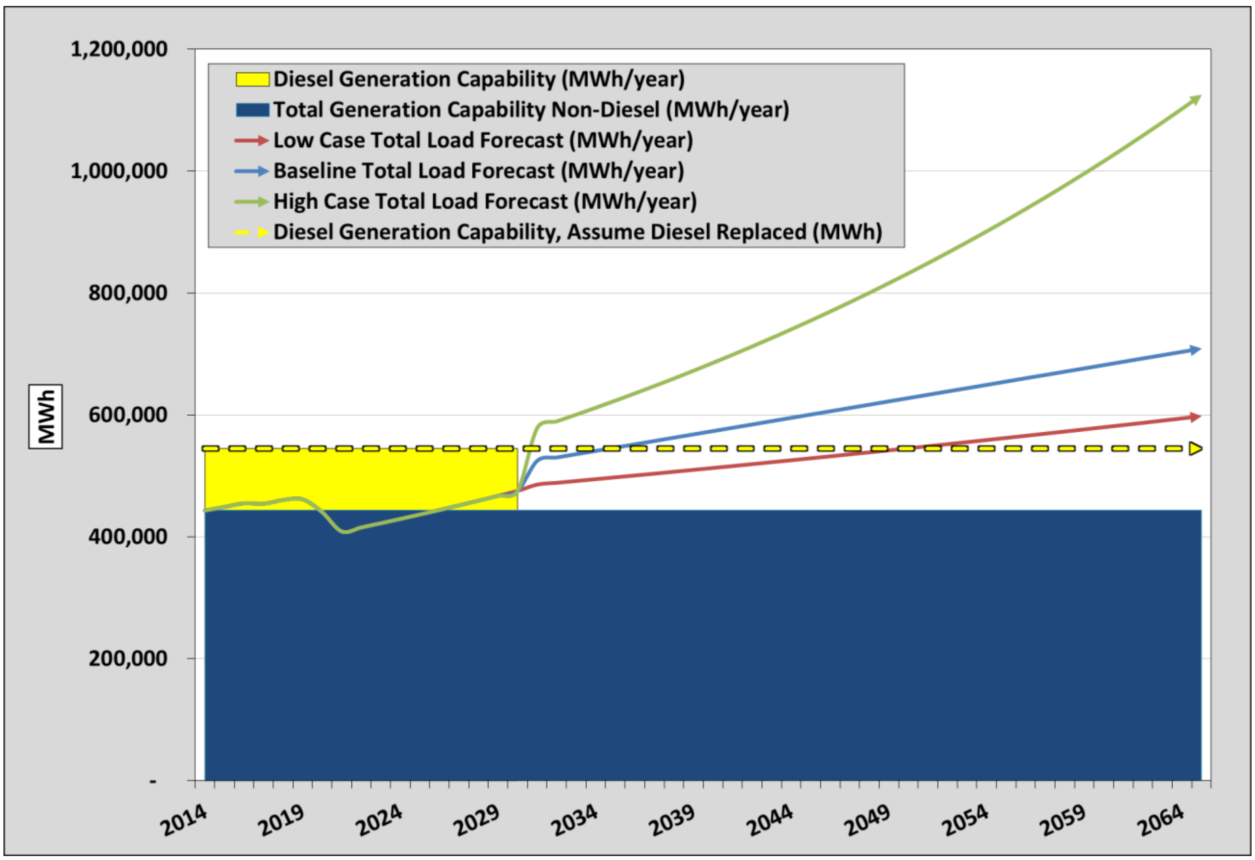
Facility	2035 to 2065 Annual Generation Capability (MWh)
Whitehorse Hydro facility	250,200
Aishihik Hydro Facility	112,700
Mayo Hydro Facility	80,900
Total Planning Generation	**443,800**

[25] Whitehorse, Aishihik, Mayo and Diesel Annual Generation Capability : YEC 2011-2030 Resource plan, Page 48, Figure 2-11 : YEC Grid Electricity Generation by Source : Mean Flows (Average of all water years) at 545 GWh/yr Grid Load Net of Fish Lake and Wind

3.3 Phase 3: Calculating the Annual Electrical Energy Gap (2035 to 2065)

Now that the annual demand and supply of electrical energy have been forecast for the years 2035 to 2065, all that remains is to calculate the gap between electrical energy demand (Low, Baseline and High cases) and supply. Figure 3-15 shows the Low, Baseline, and High Case load forecast scenarios, plotted with the forecasted supply of electrical energy.

Figure 3-15: Low, Baseline & High Cases versus Forecast Supply of Electrical Energy (2014 to 2065)



The annual electrical energy gaps between supply and demand, under the three cases are shown in Figure 3-16 and summarized in Table 3-13.

Figure 3-16: Forecast Yukon Electrical Energy Gap (2035 to 2065)

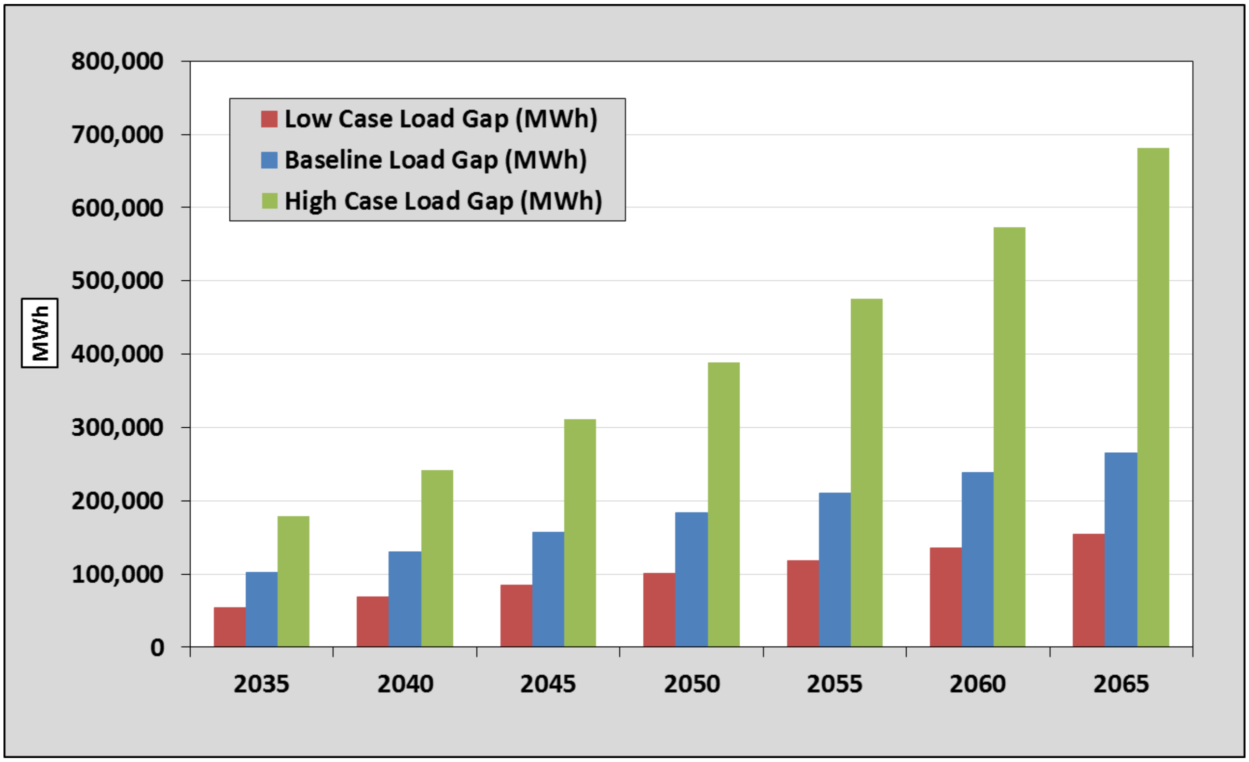


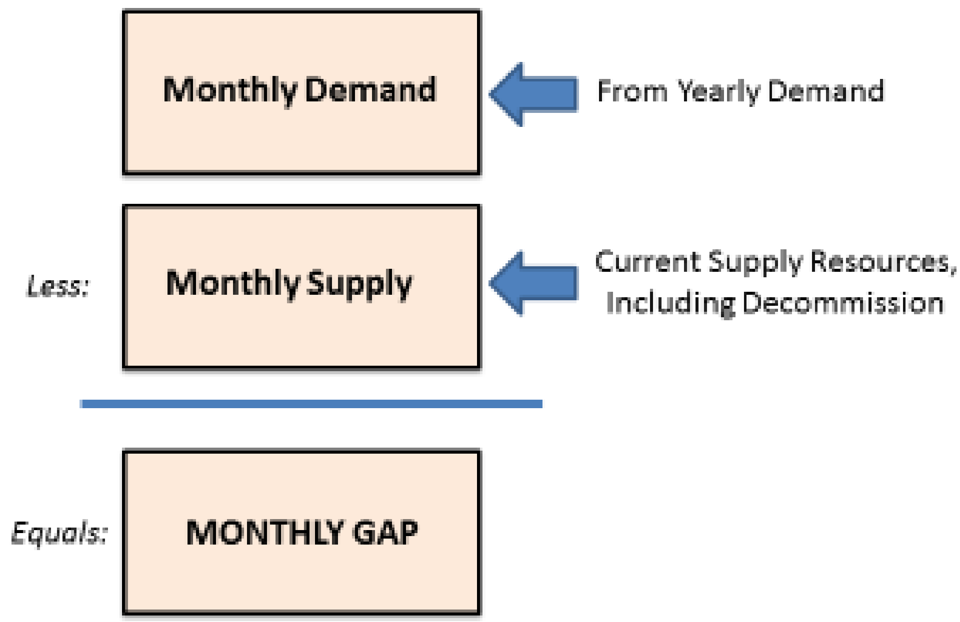
Table 3-13: Table of Electrical Energy Gap in High, Baseline & Low Scenarios (2035 - 2065)

Load Gap Scenario	2035	2040	2045	2050	2055	2060	2065
Low Scenario (MWh)	54,000	69,000	85,000	101,000	118,000	136,000	154,000
Baseline Scenario (MWh)	103,000	130,000	157,000	184,000	211,000	238,000	265,000
High Scenario (MWh)	180,000	242,000	311,000	389,000	476,000	573,000	682,000

3.4 Phase 4: Translating Annual Electrical Energy Gaps into Monthly Gaps (2035 to 2065)

In addition to forecasting the annual electrical energy gaps, electrical energy gaps were also determined on a monthly basis. The methodology for translating annual electrical energy gaps into monthly electrical energy gaps is done in three (3) steps as shown in Figure 3-17.

Figure 3-17: Translating Annual Electrical Energy Gaps into Monthly Electrical Energy Gaps



3.4.1 Step 1: Forecasting Monthly Electrical Energy Demand

The paper has discussed both historic annual loads and forecast annual load forecasts. In order to translate annual load figures into monthly load figures, Midgard derives a generic monthly load or electrical energy demand shape. The generic monthly electrical energy demand shape was calculated as follows:

I. Using YEC data, peak hourly demand (measured in megawatts) was compiled for years 2004 to 2012. A direct link between peak MW usage and electrical energy consumed within each respective hour was presumed.
II. The electrical energy usage for each individual hour was divided by the electrical energy usage for the average annual hour (for each respective year).
III. The electrical energy for each month was summed. The sum of the electrical energy demand of the twelve (12) months adds up to 100% of total annual electrical energy demand.

IV. Steps I through III was performed for each of the years 2004 to 2012. The average of all the Januaries (in percentage of annual usage) is used to represent the expected annual January usage for future years. The same process was repeated for each month of the year.

V. The result is an average monthly shape (% load by month) forms the generic shape of the annual load. Consumption patterns in the future should continue to resemble the average consumption patterns observed during the years 2004 to 2012.

Applying the generic monthly shape to future annual electrical energy forecasts results in monthly electrical energy demand for 2035, 2045, 2055, and 2065 are shown in Figure 3-18 (Baseline Case), Figure 3-19 (Low Case), and Figure 3-20 (High Case). Results are also shown in Table 3-14 (Baseline Case), Table 3-15 (Low Case), and Table 3-16 (High Case).

Figure 3-18: Monthly Electrical Energy Demand Forecast – Baseline Case (2035, 2045, 2055 & 2065)

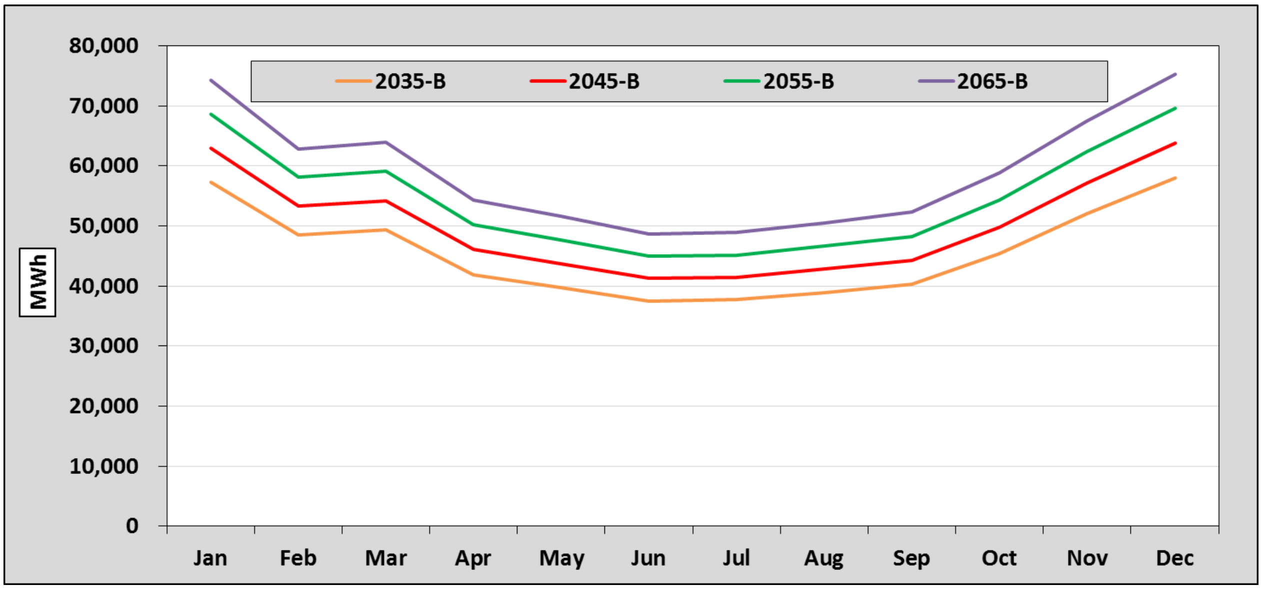


Table 3-14: Table of Baseline Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065

Month	2035 (MWh/Month)	2045 (MWh/Month)	2055 (MWh/Month)	2065 (MWh/Month)
Jan	57,200	62,900	68,600	74,300
Feb	48,500	53,300	58,100	62,900
Mar	49,300	54,200	59,100	64,000
Apr	41,900	46,000	50,200	54,300
May	39,800	43,700	47,600	51,600
Jun	37,500	41,200	45,000	48,700
Jul	37,700	41,400	45,200	48,900
Aug	38,900	42,800	46,600	50,500
Sep	40,300	44,300	48,300	52,300
Oct	45,300	49,800	54,300	58,800

Month	2035 (MWh/Month)	2045 (MWh/Month)	2055 (MWh/Month)	2065 (MWh/Month)
Nov	52,100	57,200	62,400	67,500
Dec	58,100	63,800	69,600	75,300

Figure 3-19: Monthly Electrical Energy Demand Forecast – Low Case (2035, 2045, 2055 & 2065)

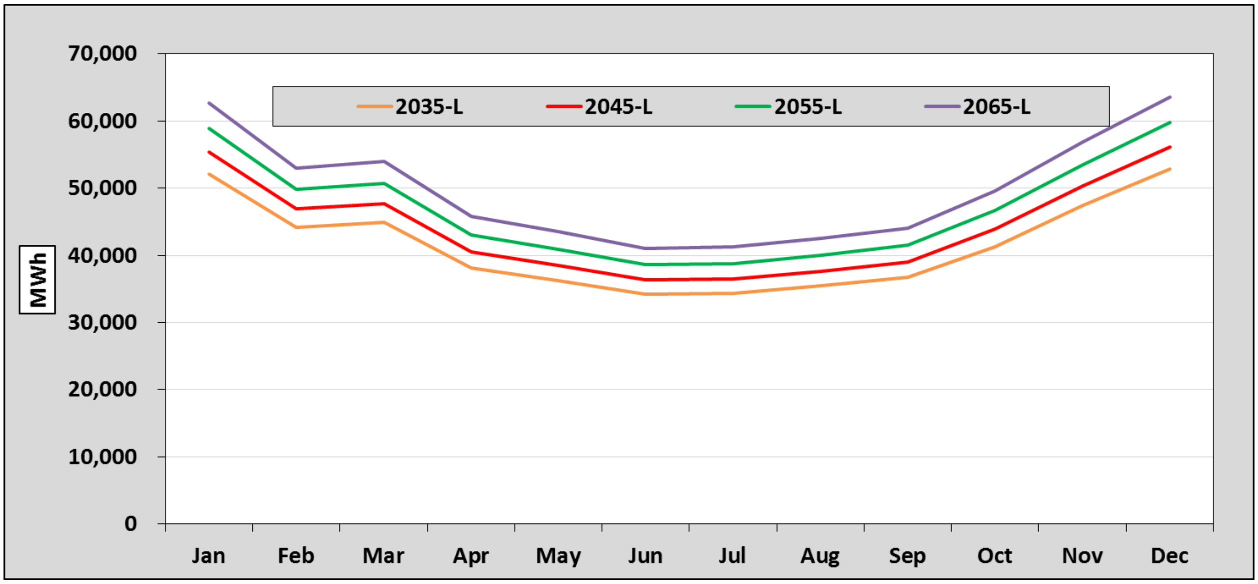


Table 3-15: Table of Low Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065

Month	2035 (MWh/Month)	2045 (MWh/Month)	2055 (MWh/Month)	2065 (MWh/Month)
Jan	52,100	55,400	58,900	62,600
Feb	44,100	46,900	49,900	53,000
Mar	44,900	47,700	50,700	54,000
Apr	38,100	40,500	43,100	45,800
May	36,200	38,500	40,900	43,500
Jun	34,200	36,300	38,600	41,000
Jul	34,300	36,500	38,800	41,200
Aug	35,400	37,700	40,000	42,600
Sep	36,700	39,000	41,500	44,100
Oct	41,300	43,900	46,600	49,600
Nov	47,400	50,400	53,500	56,900
Dec	52,900	56,200	59,700	63,500

Figure 3-20: Monthly Electrical Energy Demand Forecast – High Case (2035, 2045, 2055 & 2065)

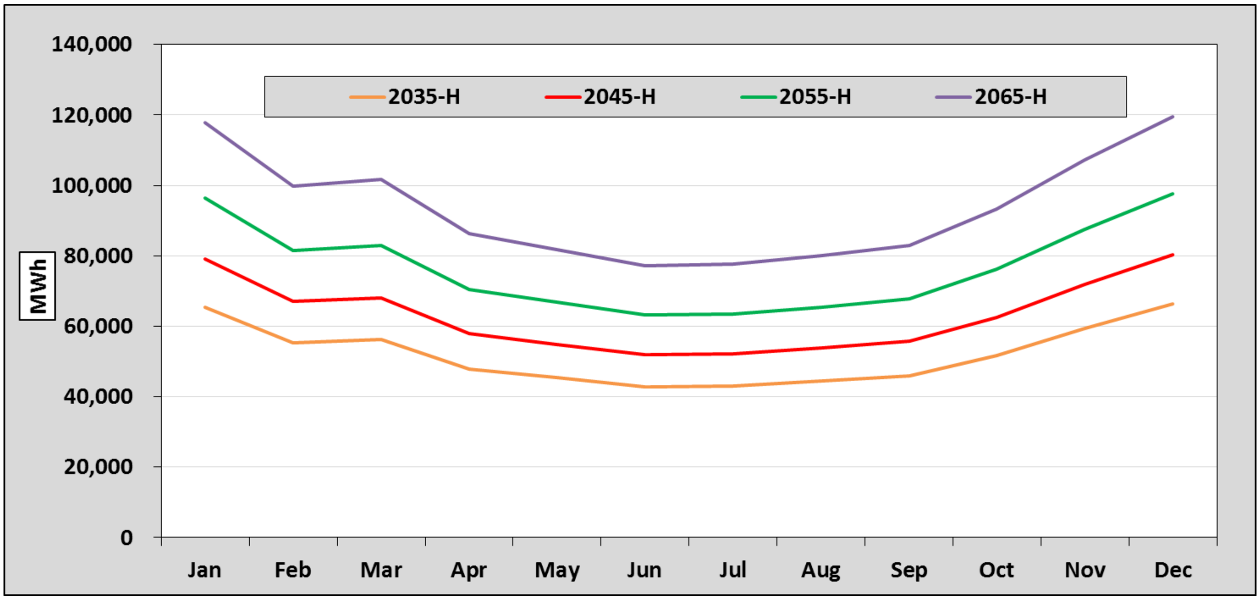


Table 3-16: Table of High Case Monthly Electrical Energy Demand Forecast for 2035, 2045, 2055 & 2065

Month	2035 (MWh/Month)	2045 (MWh/Month)	2055 (MWh/Month)	2065 (MWh/Month)
Jan	65,300	79,100	96,300	117,900
Feb	55,300	67,000	81,500	99,800
Mar	56,300	68,200	83,000	101,600
Apr	47,800	57,900	70,500	86,300
May	45,400	54,900	66,900	81,900
Jun	42,800	51,800	63,100	77,300
Jul	43,000	52,100	63,400	77,600
Aug	44,400	53,800	65,500	80,200
Sep	46,000	55,700	67,800	83,000
Oct	51,700	62,600	76,300	93,300
Nov	59,400	71,900	87,600	107,200
Dec	66,200	80,200	97,700	119,600

3.4.2 Step 2: Forecasting Monthly Electrical Energy Supply

As shown in Table 3-12, the existing and committed generation assets of Whitehorse, Aishihik, and Mayo are being used for planning purposes. From the YEC 20 Year Plan[26] these assets have a monthly electrical energy shape as shown in Figure 3-21 and Table 3-17.

Figure 3-21: Monthly Electrical Energy Supply Forecast - Existing & Committed less Retirements (2035 - 2065)

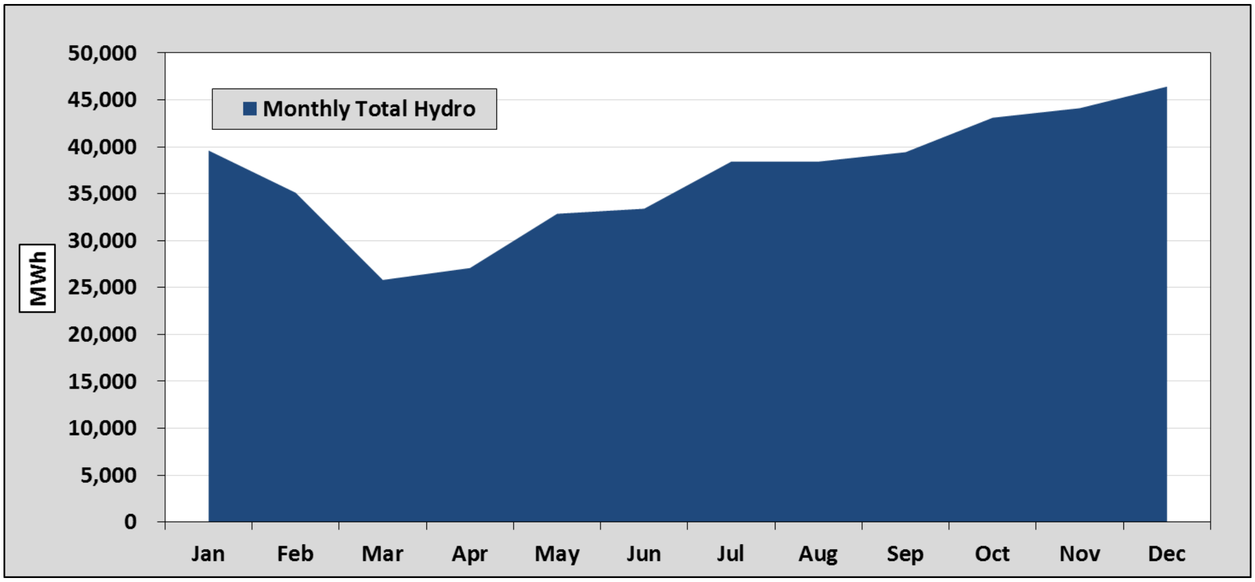


Table 3-17: Table of Monthly Electrical Energy Supply Capability (2035 - 2065)

Month	Monthly Hydro Capability (MWh/Month)
Jan	39,612
Feb	35,107
Mar	25,815
Apr	27,088
May	32,865
Jun	33,413
Jul	38,435
Aug	38,428
Sep	39,433
Oct	43,109
Nov	44,122
Dec	46,428

[26] Whitehorse, Aishihik and Mayo Annual Generations : YEC 2011-2030 Resource plan, Page 48, Figure 2-11 : YEC Grid Electricity Generation by Source : Mean Flows (Average of all water years) at 545 GWh/yr Grid Load Net of Fish Lake and Wind

3.4.3 Step 3: Calculating Monthly Energy Gaps

The results of plotting the Monthly Energy Demand and Monthly Supply Forecast on one graph for the Baseline, High case, and Low case are illustrated in Figure 3-22, Figure 3-24, and Figure 3-26 respectively. The three (3) figures show that in general the energy gap is larger in the colder weather months between November and May and grows with time across all months.

The monthly electrical energy gaps for 2035, 2045, 2055 & 2065 for the Baseline, High case, and Low cases are shown in Figure 3-22 respectively. There are electrical energy gaps in the first and last months of the year under all three scenarios. To give a fair idea, Yukon's current energy consumption is also represented in Figure 3-22.

Figure 3-22: Baseline Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065)

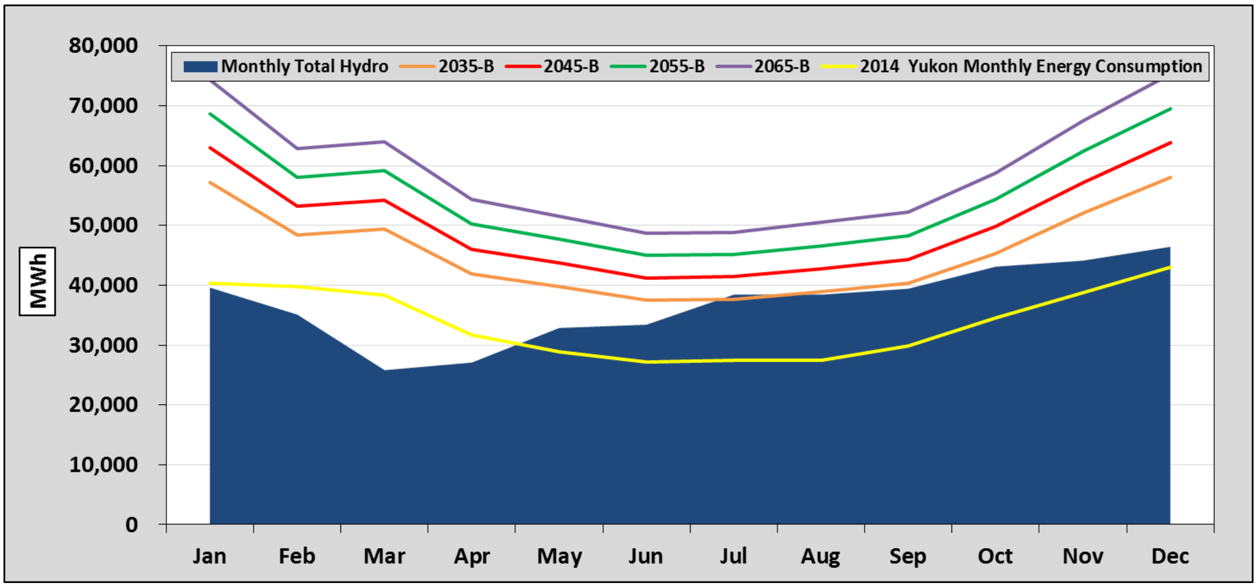


Figure 3-23: Baseline Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065)

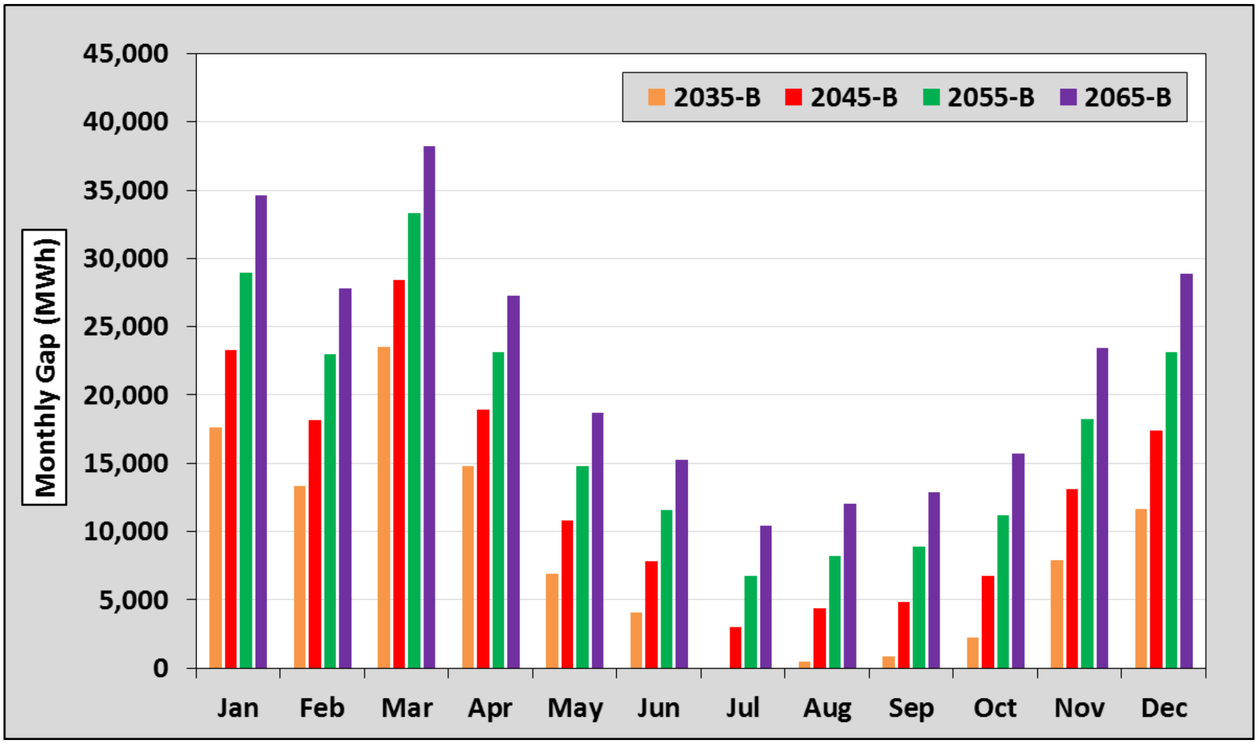


Figure 3-24: High Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065)

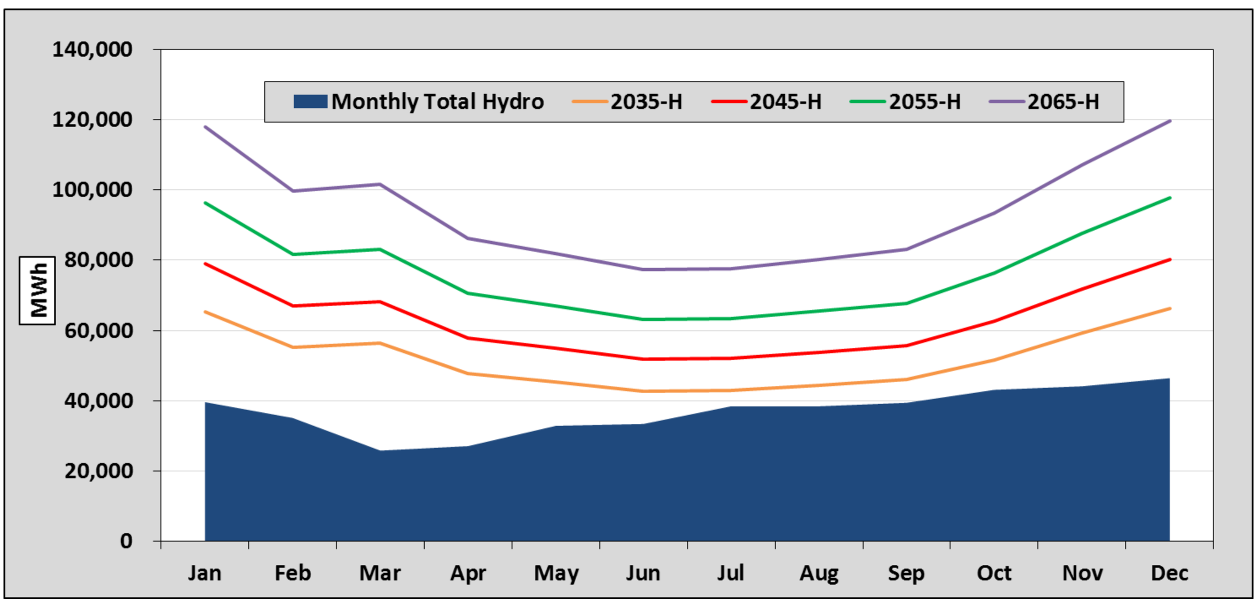


Figure 3-25: High Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065)

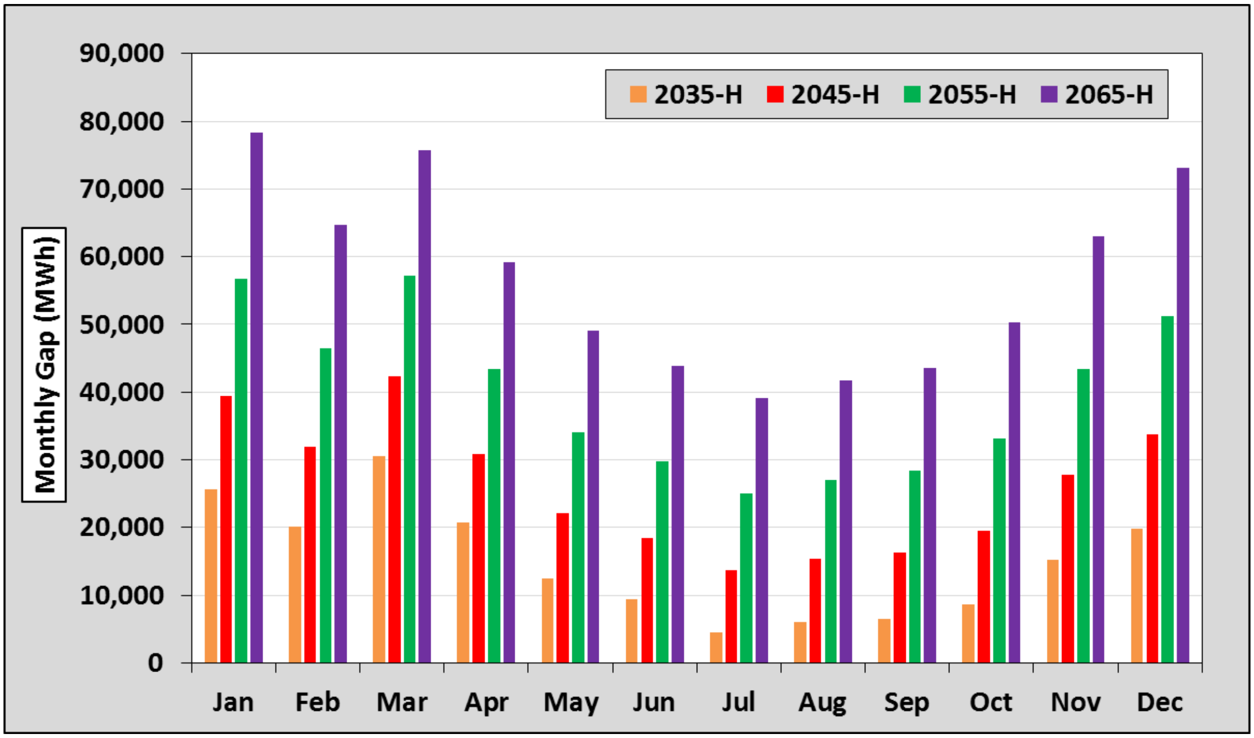


Figure 3-26: Low Case Monthly Electrical Energy Demand and Supply Forecast (2035, 2045, 2055 & 2065)

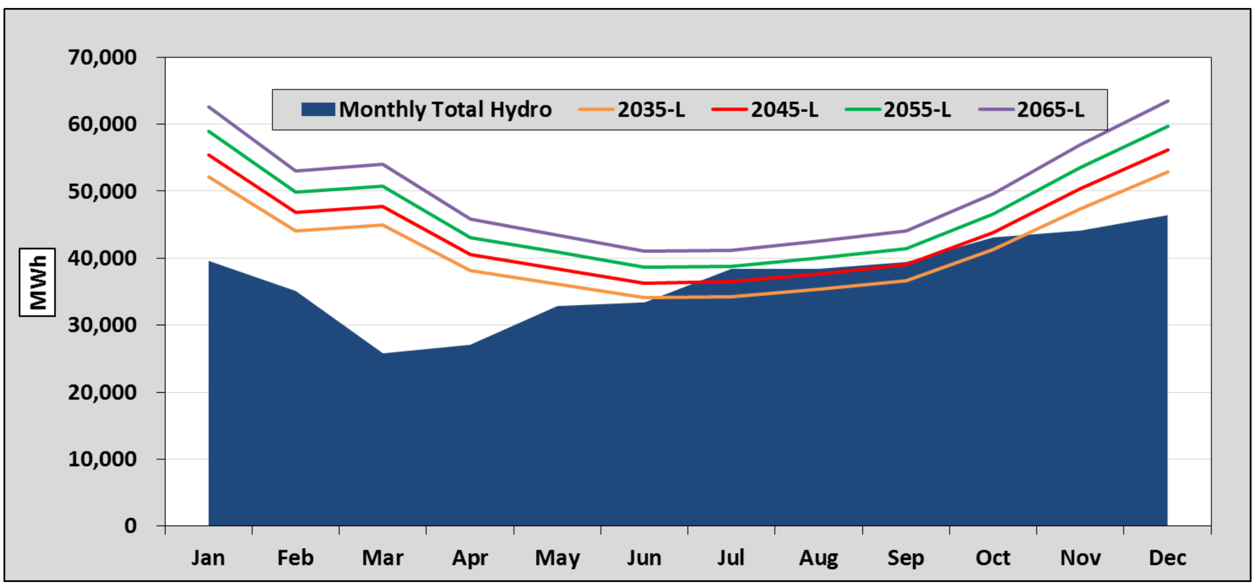
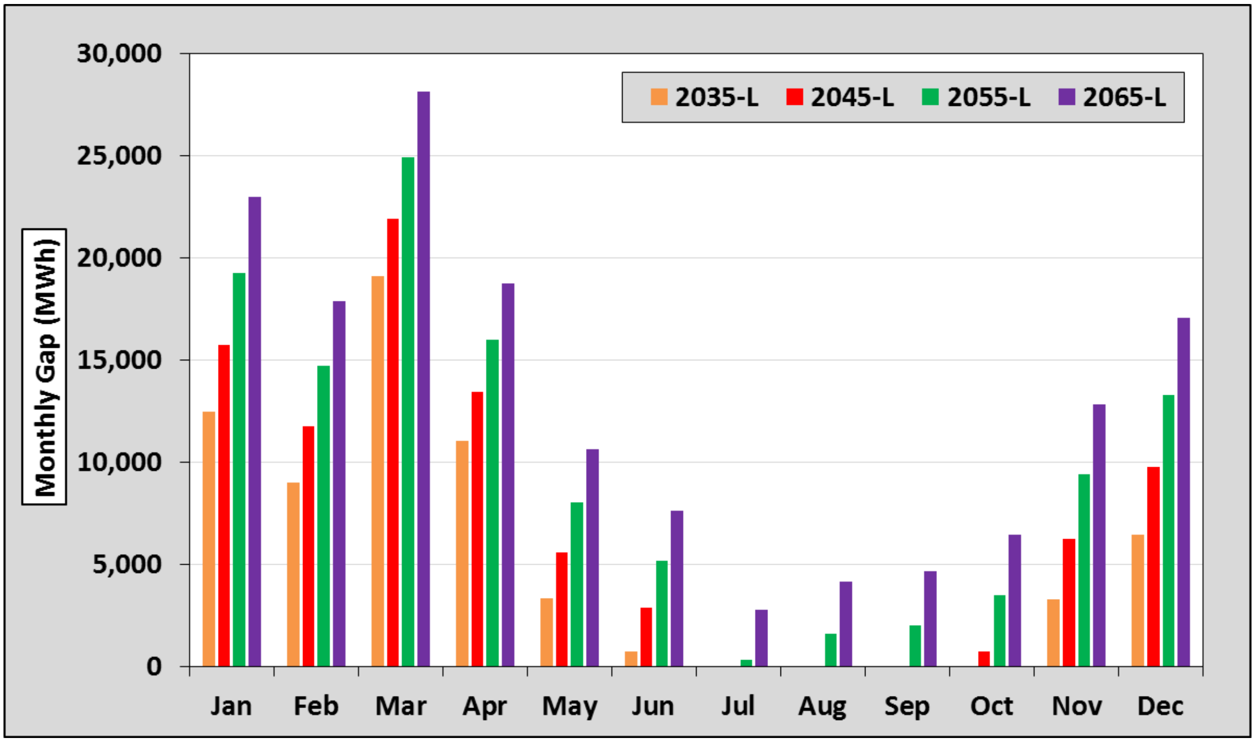


Figure 3-27: Low Case Monthly Electrical Energy Gap (2035, 2045, 2055 & 2065)



4 Forecasting Electrical Capacity Need

Electrical capacity is defined as the ability to produce a given amount of electrical energy to satisfy a demand at any given instant in time. In its simplest form, it is the ability to "turn your lights on" at any time and know that they will actually turn on at that moment.

Capacity is linked to the reliability of the electrical grid. Electrical capacity requirements comprise the sum of:

i) The electrical energy generation requirement during an extremely high demand event such as the coldest hour of the coldest day of the year

ii) Contingency or standby generation to address a major failure somewhere on the electrical system. This criterion is also known as the "N-1" Reliability Criterion and includes things such as transmission line failures, the loss of a generator or other similar failures which inhibit the normal supply of electrical energy.

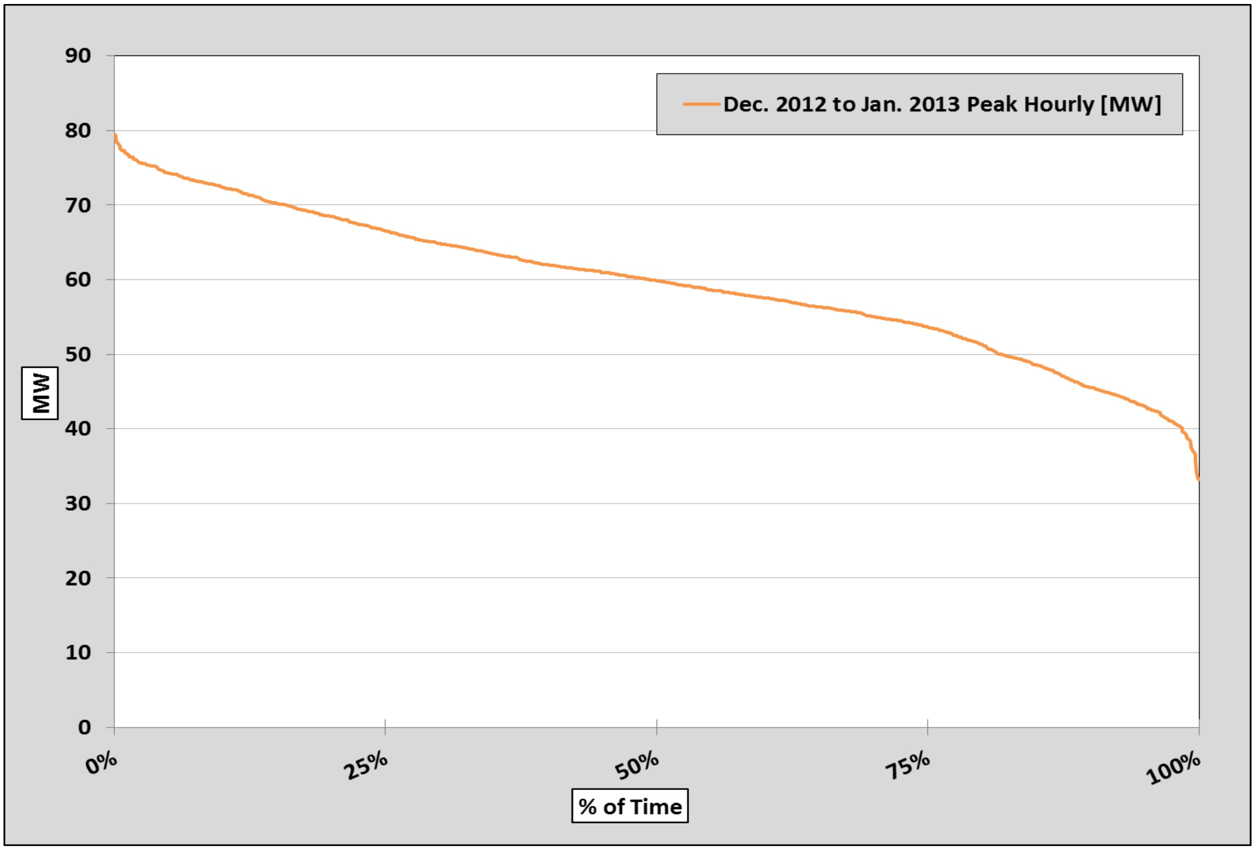
iii) Other ancillary reserve requirements such as spinning and regulating reserves.

In Yukon, hydroelectric facilities provide 63% of the installed electrical generation capacity[27]. However, if a hydroelectric generator trips off, cannot deliver its electrical energy due to a transmission line outage, or is otherwise out of operation, diesel generation (and soon natural gas generation) exists to meet capacity demands on the electrical grid.

The graph in Figure 4-1 below shows the duration curve of the hourly peak demand for electrical capacity for the period of time from December 2012 to January 2013. Yukon electrical capacity duration curve for this period shows that the demand for electrical capacity exceeds 70 MW approximately 12.5% of the time (i.e., 1 out of 8 hours), and exceeds 60 MW approximately 50% of the time (i.e., 1 out of 2 hours), and exceeds 50MW approximately 80% of the time (i.e., 4 out of 5 hours). This relatively flat capacity duration curve means that the generation facilities in Yukon are heavily used during the peak winter season and there is little respite from high capacity demands on the grid. As a result, in order to ensure that the grid does not black out or brown out, redundancy and dependability are particularly important factors needed to maintain the reliability of Yukon's electrical grid operations.

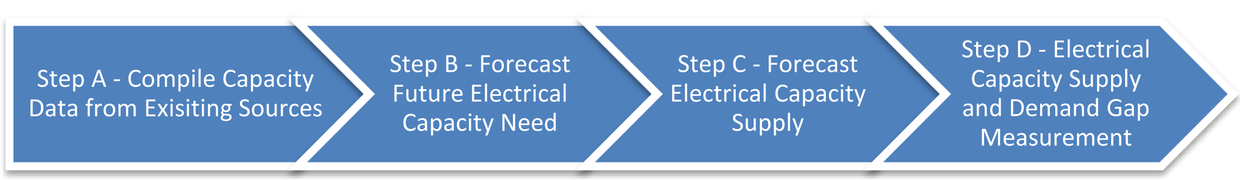
[27] "Yukon Energy Corporation: Annual Report 2013", Yukon Energy Corporation, page 69

Figure 4-1: Electrical Capacity Demand Duration Curve (December 2012 - January 2013)



In order to examine and forecast future capacity requirements in Yukon, Midgard investigated the historic electrical capacity demand trends of both the mining and non-mining sectors. The forecast Yukon electrical capacity demand and supply are derived by Midgard analysis of historic Yukon peak electrical capacity demand requirements and electrical generation patterns. The methodology for forecasting electrical capacity demand, supply, and future surplus or gaps is as follows:

Figure 4-2: Methodology for Forecasting Electrical Capacity Gaps



4.1 Step A: Compile Historic Capacity Data

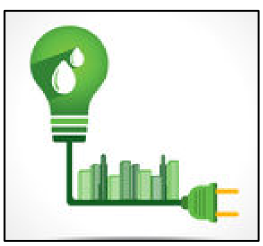
Historical peak electrical capacity (in megawatts) for Yukon grid was compiled starting from 2004. Yukon's historical on-grid monthly peak demands from 2004 to 2013 are listed in Table 4-1 below.

Table 4-1: Peak Electrical Capacity Demand : On-Grid (2004 - 2013) [28]

Year	Jan (MW)	Feb (MW)	Mar (MW)	Apr (MW)	May (MW)	Jun (MW)	Jul (MW)	Aug (MW)	Sep (MW)	Oct (MW)	Nov (MW)	Dec (MW)	% Increase of Peak Capacity
2004	**60.70**	51.21	45.35	42.05	38.60	37.50	34.80	37.56	40.52	44.53	50.07	58.55	
2005	**59.87**	53.08	44.20	41.97	38.97	38.15	37.76	37.20	40.87	46.27	53.31	55.24	*-1.37*
2006	57.66	53.77	56.29	44.68	41.65	40.59	37.62	42.21	41.08	47.90	**64.62**	58.00	*7.93*
2007	**62.44**	59.03	59.65	49.14	42.08	41.70	37.95	37.60	42.14	47.06	53.19	62.25	*-3.37*
2008	64.91	64.01	51.90	46.12	43.08	41.94	40.02	39.85	44.51	49.71	60.39	**66.76**	*6.92*
2009	**68.68**	64.32	58.37	55.09	47.27	44.00	43.50	42.91	50.59	53.67	61.75	67.28	*2.88*
2010	65.02	61.19	56.81	52.49	49.46	45.26	45.47	44.57	50.66	56.20	62.95	**71.64**	*4.31*
2011	**75.51**	69.24	68.59	52.75	50.11	45.88	45.86	47.86	53.50	55.21	74.79	69.99	*5.40*
2012	79.43	63.05	61.39	55.77	52.79	50.53	48.17	52.37	59.69	66.22	76.68	**79.45**	*5.22*
2013	**77.26**	63.43	67.45	61.75	56.66	45.58							

As indicated by the shaded boxes in Table 4-1 above, it can be seen that the highest peak demands for electrical capacity in Yukon occur during winter months, typical during either December or January, but peaks should also sometimes be expected in adjacent months such as in November 2006. The peak electrical demand increases during these months as a consequence of cold and dark Yukon winters which result in additional lighting, heating and general electrical energy usage (e.g. people are likely indoors more in the winter compared to the summer).

4.2 Step B: Capacity Demand – Forecast



Next, from the YEC's 2012 Resource Plan, a forecast of electrical capacity requirements for the years between 2011 and 2030 was created. For the purposes of this report, because historical data is available from 2011 to 2013, the results of the YEC forecast from 2014 to 2030 were taken and summarized in Table 4-2.

[28] Yukon Energy Corporation : "Next Gen Hydro Information Request 06.10.14 - Attachment 3 – Re #5"

Table 4-2: YEC Electrical Capacity Demand Forecast (2014 - 2030)[29]

Year	YEC Forecast Peak (MW)
2014	82.6
2015	83.7
2016	84.9
2017	85.2
2018	86.4
2019	87.7
2020	89.0
2021	81.2
2022	82.5
2023	83.9
2024	85.3
2025	86.7
2026	88.2
2027	89.7
2028	91.2
2029	92.8
2030	94.4

For 2031 to 2065 annual peak electrical capacity demand was forecast to grow at the same percentage rate as the forecast demand for electrical energy. It is recognized and acknowledged that if electrical energy consumption patterns change, actual peak capacity growth rates may be higher or lower than electrical energy growth rates. For example, if greater portions of homes begin to use electrical energy for heating purposes, peak winter capacity requirements may grow at a higher rate than the average growth in electrical energy demand. However, the opposite could also be true if Smart Grid technologies and Demand Side Management programs are successful at reducing capacity peaks. Similar to the electrical energy forecast scenarios, a Low case and High case scenario were also developed.

Figure 4-3 and Table 4-3 below display a combined historic and forecast peak electrical capacity demand from 2004 to 2065. Note that the figures are for total electrical capacity which includes both Non-Industrial and Industrial electrical capacity demand. The forecast in Figure 4-3 and Table 4-3 represent the Baseline Case for electrical capacity demand from 2035 to 2065.

[29] YEC : 20-Year Resource Plan Overview 2011-2030 : Appendix A, Table A-3, Base Case

Figure 4-3: Historic & Forecast Baseline Case Electrical Capacity Demand (2004 - 2065)[30]

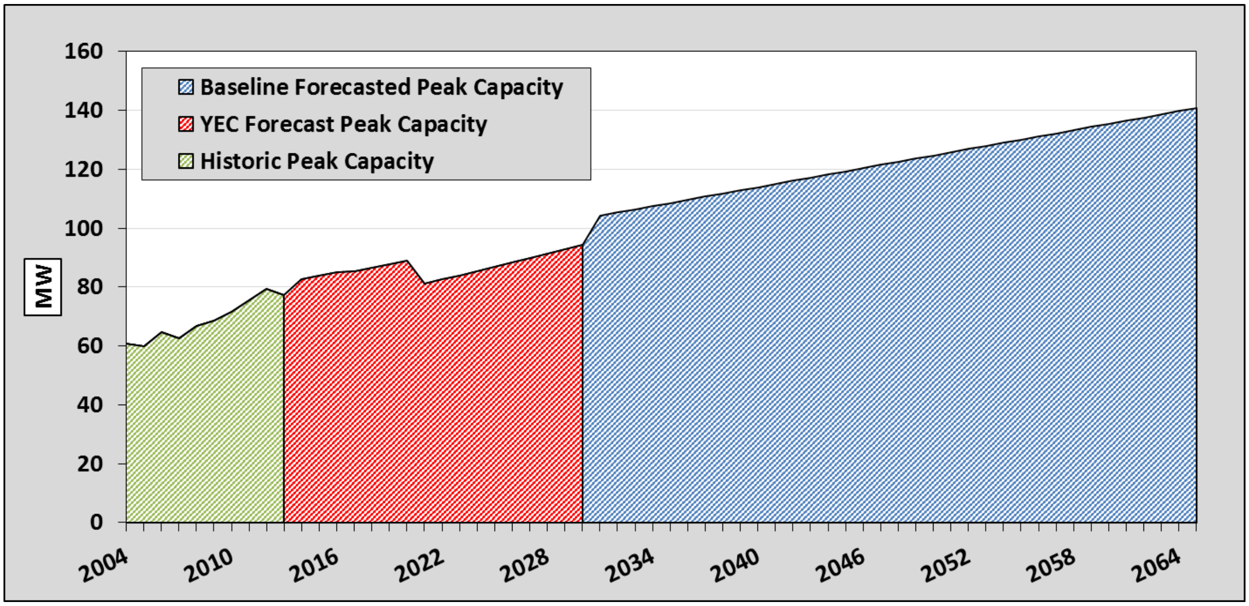


Table 4-3: Table of Historic & Baseline Case Electrical Capacity Demand Forecast (2004 - 2065)

Year	Historic Peak Capacity (MW)	YEC Forecast Peak Capacity (MW)	Baseline case Forecast Peak Capacity (MW)
2004	60.70		
2005	59.87		
2006	64.62		
2007	62.44		
2008	66.76		
2009	68.68		
2010	71.64		
2011	75.51		
2012	79.45		
2013	77.26		
2014		82.6	
2016		84.9	
2018		86.4	
2020		89.0	
2022		82.5	
2024		85.3	
2026		88.2	
2028		91.2	
2030		94.4	

[30] Midgard capacity forecasting methodology differs from YEC's capacity forecasting methodology; results however are similar.

Year	Historic Peak Capacity (MW)	YEC Forecast Peak Capacity (MW)	Baseline case Forecast Peak Capacity (MW)
2031			104
2035			109
2040			114
2045			119
2050			125
2055			130
2060			135
2065			141

In addition to the Baseline case peak demand forecast, Low case and High case peak capacity forecasts were also derived based upon the methodology that the peak demand for electrical capacity would grow at the same percentage rate as the forecast demand for electrical energy. Figure 4-4 graphs the peak electrical capacity demand forecast for all three scenarios for the years 2035 to 2065.

Figure 4-4: Electrical Capacity Demand Forecast for Low, Baseline & High Cases (2035 - 2065)

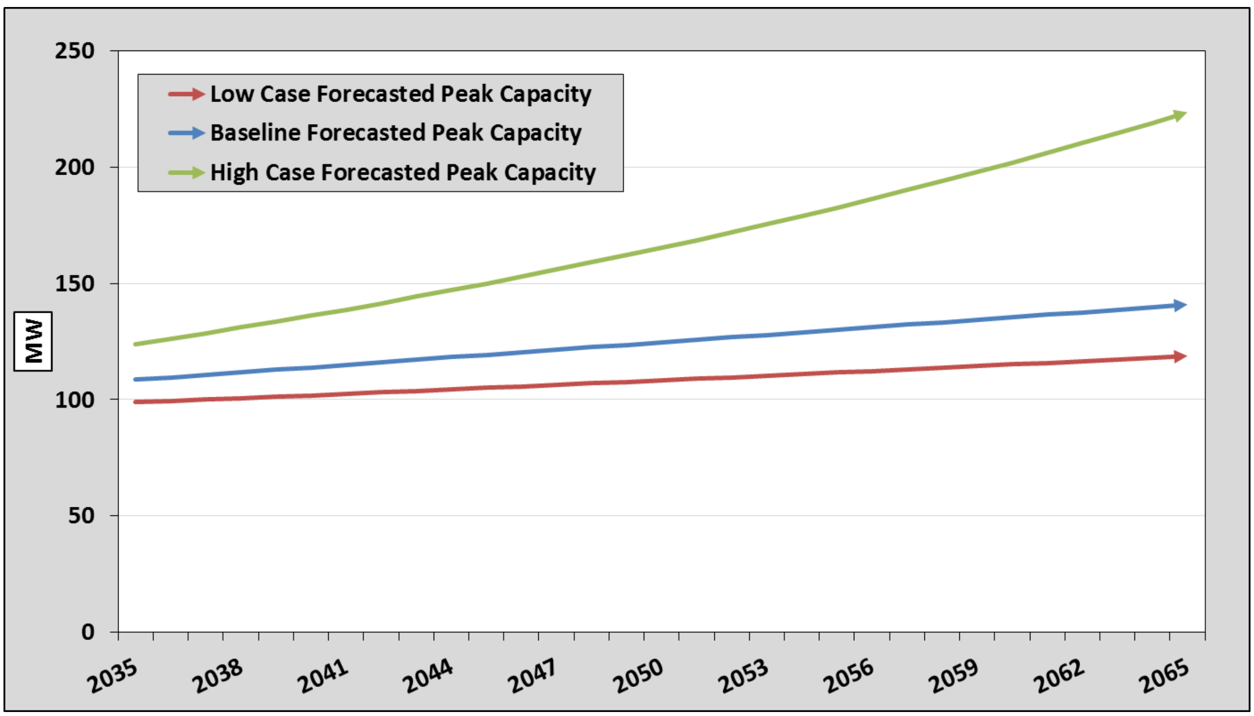


Table 4-4: Table of Electrical Capacity Demand Forecasts for Low, Baseline & High Cases (2035 - 2065)

Year	'N-1' Reliable Winter Capacity Non-Diesel/LNG	Low Case Peak Capacity (MW)	Baseline Peak Capacity (MW)	High Case Peak Capacity (MW)
2035	35	99	109	124
2040	35	102	114	136

Year	'N-1' Reliable Winter Capacity Non-Diesel/LNG	Low Case Peak Capacity (MW)	Baseline Peak Capacity (MW)	High Case Peak Capacity (MW)
2045	35	105	119	150
2050	35	108	125	165
2055	35	112	130	183
2060	35	115	135	202
2065	35	119	141	223

In developing the High and Low case scenario, a number of factors that could affect electrical capacity consumption growth rates were identified. Similar to the electrical energy growth rate forecasts it is difficult to forecast which factors would dominate. The potential factors that could increase capacity growth rates are outlined in Table 4-5 and the potential factors that could decrease capacity growth rates are outlined in Table 4-6.

Table 4-5: Factors That May Contribute to Increased Capacity Demand

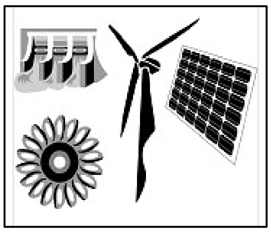
Factors That May Contribute to Increased Peak Capacity Demand
• Fuel switching: o Increased use of electrical heating in Yukon, substitution away from fuel oil, propane and/or biomass (wood) as heating sources • Climate change impacts: o Extreme winters / weather: Greater number of extreme heating degree days (and therefore increased peak load in winter) o Yukon's climate becomes much warmer, which leads to larger population increases and/or increased commercial or industrial activity o Opening of the Northwest Passage to commercial transportation; subsequent growth of population and commercial/industrial sectors to serve Arctic Ocean shipping • Technological change impacting consumer behavior: o Growing prosperity and penetration of electrical appliances and electronics in Yukon homes

Table 4-6: Factors That May Contribute to Decreased Capacity Demand

Factors That May Contribute to Decreased Peak Capacity Demand
• Climate change impacts: o Warmer "coldest" days in winter, therefore lower electrical peak for heating • Technological change: o Distributed electrical generation with peak capacity shaving enhancements such as thermal sinks (e.g. heat storage devices combined with solar panels) o Energy efficiency gains; Lowering of per capita electrical energy consumption in a variety of electrical devices such as TVs, lighting, electronics, appliances, portable electronics etc.

Factors That May Contribute to Decreased Peak Capacity Demand
o Smart Grid: Smart Grid technologies that reduce capacity peaks and shift electrical energy consumption into lower capacity demand times of day (e.g. nighttime) • Regulatory Change: o Building code changes that increase thermal efficiency of residential and commercial buildings, thereby reducing peak heating demands. • Demographics: o Changing of the age class distribution within Yukon population resulting in changing electrical energy consumption patterns.

4.3 Step C: Installed Generation Capacity



Different generation resources provide different capacity generating characteristics. As per the YEC 2013 Annual Report[31], approximately 62.5% of installed generation capacity in Yukon is hydroelectric generation, followed by diesel generation at 37% and wind generation at 0.5%. From the YEC 20-year Resource Plan 2011-2030:

> *"Current and committed generation capacity in Yukon includes approximately 138 MW of installed generation on the integrated grid (approximately 92 MW YEC hydro, 0.8 MW YEC wind, 37 MW YEC diesel, 1.3 MW YECL hydro, and 6.8 MW of YECL diesel) …."* [32]

When discussing installed capacity, it is important to differentiate between installed capacity and reliable (or firm) capacity. For example, for a hydroelectric facility with a specific installed capacity, the amount of reliable capacity is dependent on the amount of fuel / water available to be passed through the turbine, which varies from month to month and year to year. It is never assumed that dependable capacity would be run indefinitely (or for long periods of time) at its installed capacity level; rather dependable capacity is what can be counted upon under an extreme event or emergency.

More specifically, the reliable capacities of the three major Yukon hydroelectric facilities are dependent on the following:

- Whitehorse is operated as a Run-of-River facility but benefits from upstream storage such as that on the Southern Lakes; therefore reliable capacity is tied to natural flows on Yukon River and the storage capacity of upstream reservoirs such as the Southern Lakes,
- Aishihik and Mayo each have dedicated storage with seasonal flexibility; therefore reliable capacity is tied to both flows on the respective rivers as well as their adjacent storage reservoirs.

[31] "Yukon Energy Corporation: Annual Report 2013", Yukon Energy Corporation, page 69

[32] "Overview of 20 Year Resource Plan: 2011-2030", Yukon Energy Corporation, page 5

Table 4-7 lists the three Yukon hydroelectric facilities, their respective installed capacities, their reliable capacities (based on an average water year), and their reliable capacities as a percentage of total installed capacity.

Table 4-7: Contribution to Installed Electrical Capacity by Hydroelectric Generation Facilities[33]

Hydroelectric Facility	Installed Capacity (MW)	Reliable Winter Capacity (MW)	Reliable Capacity as % of Installed Capacity
Whitehorse Hydro Facility	40	24	60%
Aishihik Hydro Facility	37	37	100%
Mayo Hydro Facility	15.5	11	71%
Total	**92.5**	**72**	**78%**

4.3.1 "N-1" Reliable Winter Capacity Forecast

Under the YEC Planning stipulations:

> *"Grid capacity planning is required to not exceed a Loss of Load Expectation (LOLE) of 2 hours per year and, for non-industrial loads, to provide capacity adequate to accommodate loss of the system's largest generating or transmission-related generation resource (the "N-1" standard). Current capacity planning also provides for sufficient winter peak capacity reserve to accommodate loss of the Aishihik transmission line connection to Whitehorse."* [34]

Consequently, in accordance with the above stipulations, the "N-1" Reliability Criterion demands that the peak load must be satisfied when the largest generation resource is lost, where the reliable supply of electric capacity is the sum of the reliable winter capacity minus the largest generation resource. In Yukon, the largest generation resource is the Aishihik transmission line connection to Whitehorse which corresponds to a total loss of 37 MW[35].

The following methodology was implemented to construct the "N-1" Reliable Winter Capacity forecast for Yukon Grid.

- 2015 to 2030 (up to 2034) "N-1" Reliable Winter Capacity was based on generation retirement dates set by YEC[36].
- 2035 to 2065 is forecast by Midgard.

---

[33] YEC : "Next Gen Hydro Information Request 06.10.14 - Attachment 3"

[34] "Overview of 20 Year Resource Plan: 2011-2030", Yukon Energy Corporation, page 5

[35] If Haines Junction is included, the total lost generation is 38.75 MW (37 MW generated by the Aishihik Hydro facility and 1.75 MW generated by the Haines Junction diesel generator), however the Haines Junction load approximately offsets the installed diesel generation, consequently the paper treats the N-1 generation impact to be a loss of only 37 MW. See YEC's 2012 Resource Plan for more details on YEC's planning methodology.

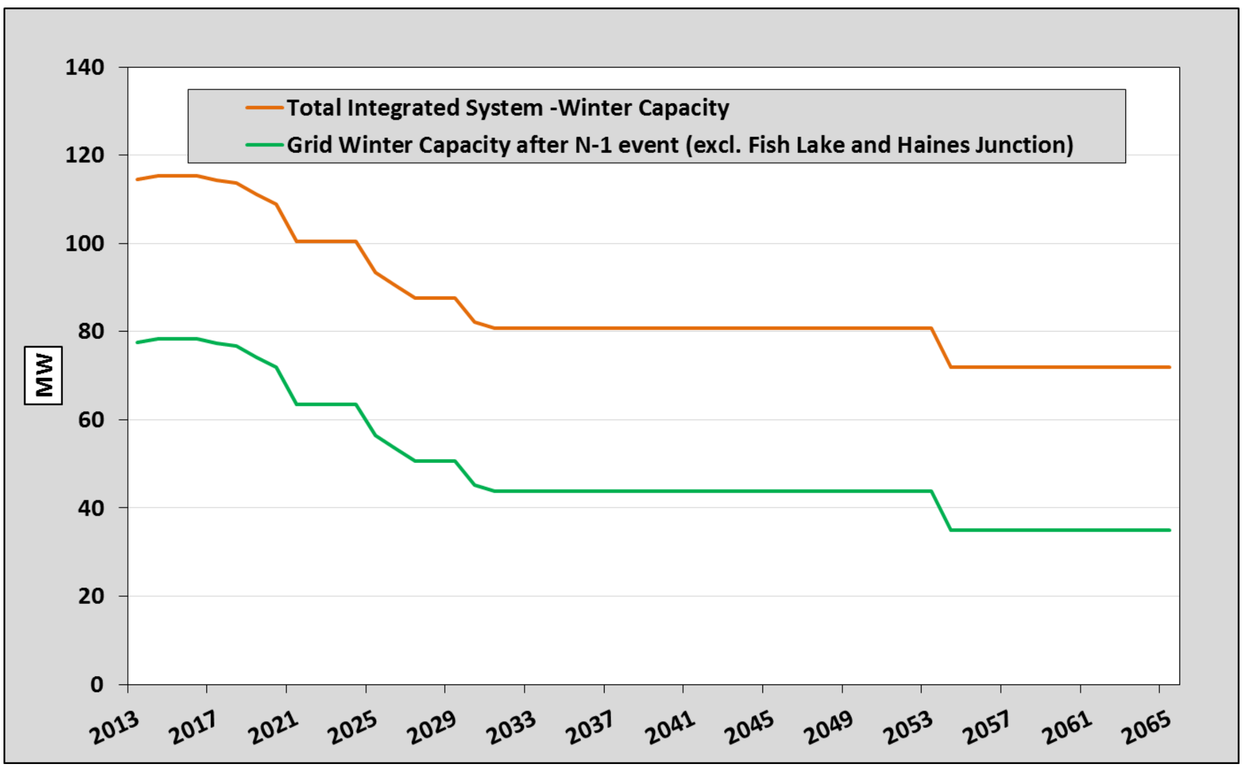
[36] YEC : 20-Year Resource Plan 2011-2030, Table 2-3, Page 42

- It is expected that the future supply of hydroelectricity will resemble that of the past; therefore the forecasted future supply of hydro powered electrical energy will remain consistent with the values in Table 3-12
- 37 MW - accounting for the "N-1" Reliability Criterion loss of the Aishihik transmission line - is subtracted from the total available hydroelectric winter capacity (which excludes Fish Lake and Haines Junction Diesel)[37] to produce the Reliable Winter Capacity forecast.

In this report the use of backup and peaking capacity resources with capacity characteristics equivalent to diesel and natural gas generation for the years beyond 2035 has been assumed. It is expected that a combination of diesel and natural gas generation will be used to address short and medium term (i.e. pre-2035) capacity requirements as deemed appropriate by YEC. The currently installed diesel generation is expected to be retired before 2035 and it is presumed that Yukon would replace the retired diesel and natural gas generation capacity with equivalent generation capacity using the appropriate generation technologies of the future. The Reliable Winter Yukon capacity forecast – excluding any replacement of retiring thermal generation - is displayed in Figure 4-5 and

Table 4-8 below.

Figure 4-5: Yukon Grid – Reliable Winter Electrical Capacity Supply Forecast (excluding "New" Capacity Generation)



[37] Yukon Energy Corporation : 20-Year Resource Plan 2011-2030, page 42, Table 2-3

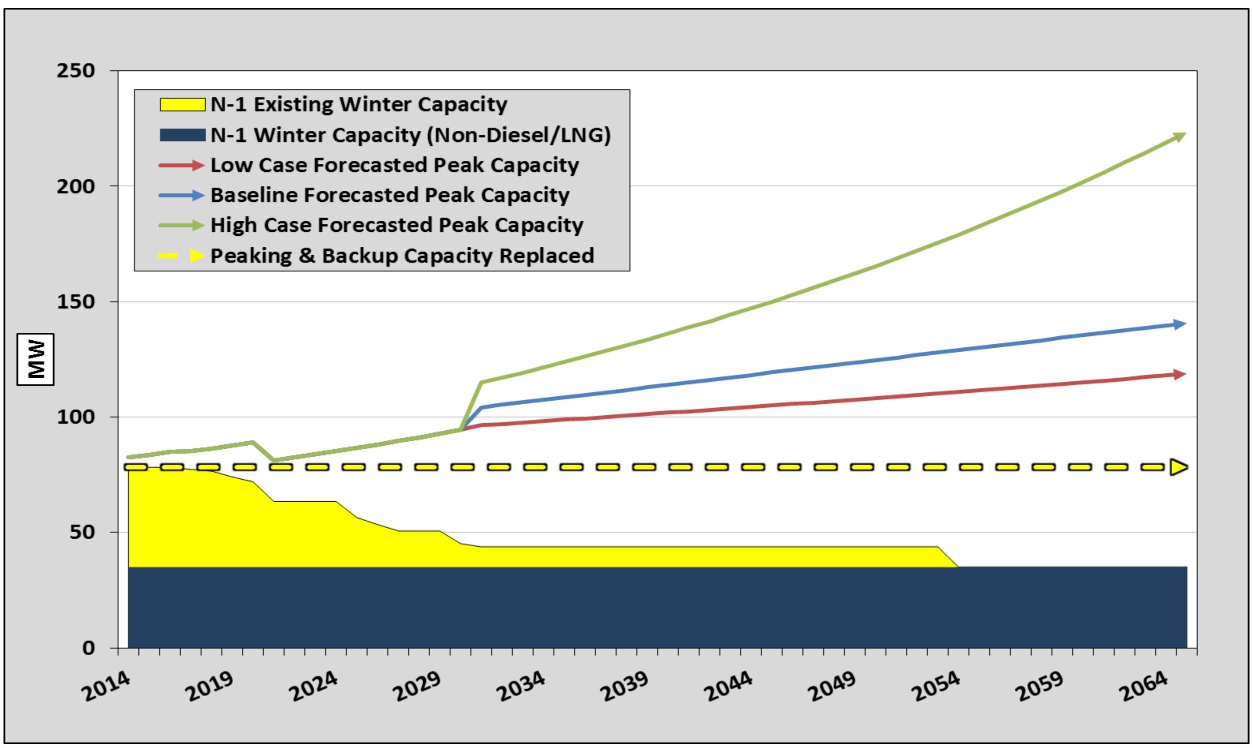
Table 4-8: Yukon Grid Electrical Capacity Supply Forecast (excluding "New" Capacity Generation)

Year	Total Available Winter Capacity (MW)	"N-1" Reliable Winter Capacity (MW)
2015	115.29	78.29
2025	93.48	56.48
2035	80.80	43.8
2040	80.80	43.8
2045	80.80	43.8
2050	80.80	43.8
2055	72	35
2060	72	35
2065	72	35

4.4 Step D: Calculating the Capacity Gap (2035 to 2065)

Now that the demand and supply of winter capacity have been forecast for the years 2035 to 2065, all that remains is to calculate the capacity gap between capacity demand (Low, Baseline and High cases) and capacity supply. Figure 4-6 plots the three capacity demand cases (Low, Baseline case & High) with the existing peak winter capacity for 2035 to 2065. This graph shows the requirement for new generation to maintain sufficient capacity on Yukon system.

Figure 4-6: High, Baseline & Low Case Electrical Capacity Demand & Electrical Supply Capacity (2014 - 2065)



Under all the cases studied, there is an increasing capacity gap from 2035 to 2065. The winter capacity gaps between supply and demand, under the three cases are shown in Figure 4-7 and summarized in Table 4-9.

Figure 4-7: Capacity Gaps for Low, Baseline & High Case Scenarios (2035 - 2065)[38]

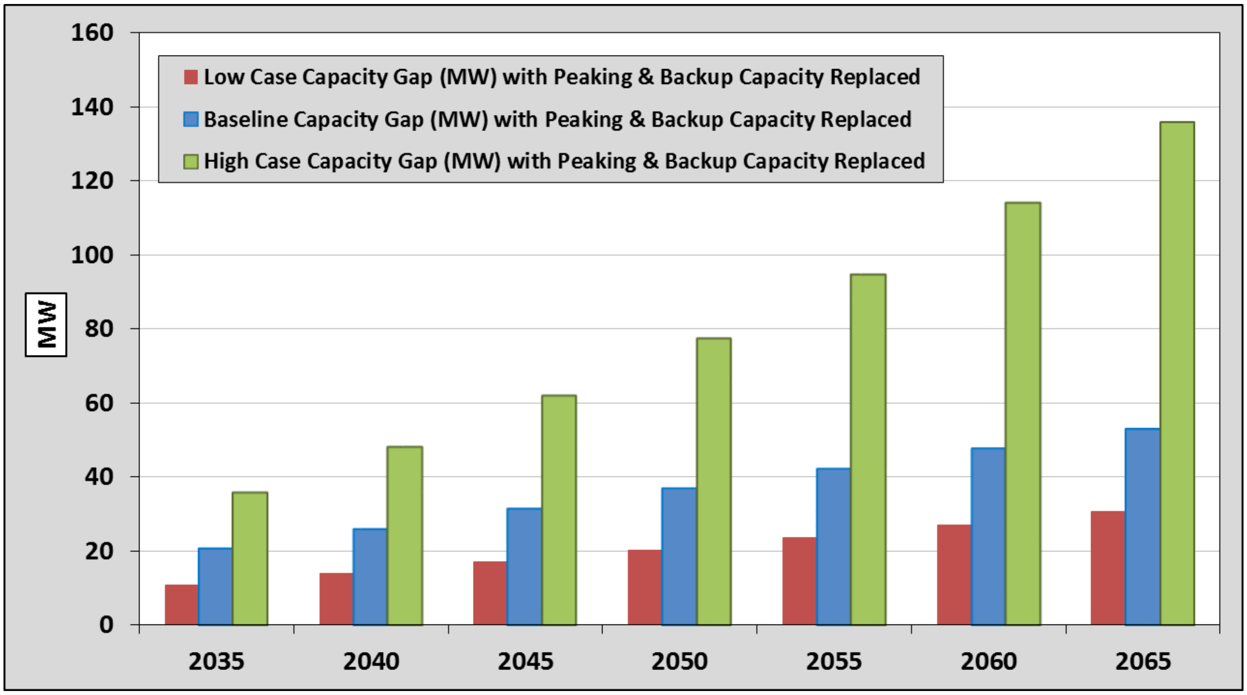


Table 4-9: Forecast Capacity Gap for Low, Baseline & High Cases (2035 – 2065)

	2035	2040	2045	2050	2055	2060	2065
Low Case Capacity Gap (MW)	11	14	17	20	24	27	31
Baseline Capacity Gap (MW)	21	26	31	37	42	47	53
High Case Capacity Gap (MW)	36	48	62	77	95	114	136

[38] Calculated Gap assumes that the capacity provided in 2014 by thermal generation is replaced at suitable periods of time to maintain peaking and/or back up capacity of 44.24 MW till 2054 and of 53.04 MW from 2055 onwards (given the potential retirement of 8.8 MW of LNG fired capacity in 2055).

5 Electrical Energy and Capacity Need Summary

Yukon is an islanded grid that must self-supply all its own electrical energy and capacity. The need for electrical energy and capacity is growing and is expected to continue growing through to the end of 2065 and beyond. As a result, Yukon must meet the monthly electrical energy gaps and capacity gaps for 2035 to 2065 as shown in Table 5-1. It is important to note that Yukon capacity requirements are largest in the winter months, as are the energy gaps. See Figure 3-23, Figure 3-25 and Figure 3-27 for illustrations of the energy gaps – which are highest in the months of November, December, January, February and March.

Table 5-1: Summary of Electrical Energy (in GWh/year) and Capacity Gaps (in MW) for Low, Baseline & High Case Scenarios (2035-2065)

	2035	2045	2055	2065
Low Case Scenario	11 MW 54 GWh	17 MW 85 GWh	24 MW 118 GWh	31 MW 154 GWh
Baseline Case Scenario	21 MW 103 GWh	31 MW 157 GWh	42 MW 211 GWh	53 MW 265 GWh
High Case Scenario	36 MW 180 GWh	62 MW 311 GWh	95 MW 476 GWh	136 MW 682 GWh

Table 5-1 shows that the Yukon should plan for additional generation that addresses both the forecast electrical energy gaps and capacity gap.

For reference purposes, Table 5-2 lists the three major Yukon hydroelectric generation facilities and their electrical energy and winter capacity characteristics.[39]

Table 5-2: Summary of Major Yukon Hydroelectric Generation Facilities and their Electrical Energy (in GWh/year) and Capacity (in MW) Capabilities

Facility	Whitehorse Hydro Facility	Mayo Hydro Facility	Aishihik Hydro Facility
Dependable Capacity (MW) & Electrical Energy (GWh/year)	24 MW 250 GWh[40]	11 MW 81 GWh[41]	37 MW 113 GWh[42]

[39] Yukon's peak capacity requirements arise during the winter months; hence it is each facility's dependable winter capacity (not installed capacity) that is relevant.

[40] Average winter (Nov-Mar) electrical energy generation for Whitehorse Hydro Facility is 86 GWh.

[41] Average winter (Nov-Mar) electrical energy generation for Mayo Hydro Facility is 70 GWh.

[42] Average winter (Nov-Mar) electrical energy generation for Aishihik Hydro Facility is 31 GWh.

Appendix A: Mining in Yukon

Throughout Yukon's history, mining has had a large impact on electrical energy consumption. The opening of new mines has frequently resulted in increases to electrical energy demand. Similarly, the closing of mines has resulted in decreases to electrical energy demand. Table A-1 and Table A-2 show the historical electrical energy consumption of Yukon on-grid and off-grid mines, as well as the operation periods. Certain mines had multiple operation periods. Placer gold mining activities are on-going; however, accurate information on their total electrical energy consumption, on-grid or off-grid, is not available.

Table A-1: Historic Mines of Yukon - On-grid Mines[43,44,45]

Mines	First Open	Close	Consumption (GWh/yr.)	Status
Placer Gold Mining (started with 140 active locations)	1900	Not Available	Not Available	Active
Whitehorse Copper 1	1910	1920	25	Inactive but Potential mine
United Keno Hill Mines 1	1920	1942	25	Inactive but Potential mine
United Keno Hill Mines 2	1947	1989	25	Inactive but Potential mine
Whitehorse Copper 2	1967	1982	25	Inactive but Potential mine
Faro mine 1	1969	1985	150	Inactive
Faro mine 2	1986	1993	150	Inactive
Faro mine 3	1995	1998	150	Inactive
Minto Copper Gold Mine	2006	2022	32.5	Active
Alexco's Bellekeno Silver Mine	2011	2023	17.4	Currently Inactive
Carmacks Copper	2015	2020	54.4	Potential mine
Victoria Gold - Eagle Gold	2015	2024	103.3	Potential mine

Table A-2: Historic Mines of Yukon - Off-grid Mines

Mines	First Open	Close	Consumption (GWh/yr.)	Status
Clinton Creek Asbestos Mine	1967	1978	Not Available	Inactive
Mount Nansen Gold Mine 1	1968	1969	6.2	Inactive
Mount Nansen Gold Mine 2	1975	1976	6.2	Inactive
Ketza River Gold Mine	1986	1988	12	Inactive but Potential mine
Mount Skukum Mine	1986	1988	16	Inactive

[43] Yukon Economic Development : HYDRO document, Page 11 & 12

[44] YEC 20-Year Resource plan overview – 2006 – Faro Consumption

[45] YEC : Application for an Energy Project Certificate and an Energy Operation Certificate , Appendix C, Page C-2

Mines	First Open	Close	Consumption (GWh/yr.)	Status
Sa Dena Hes Lead-Zinc Mine	1991	1992	30	Inactive
Mount Nansen Gold Mine 3	1996	1997	6.2	Inactive
Mount Nansen Gold Mine 4	1998	1999	6.2	Inactive
Cantung Tungsten Mine 2	2001	2003	Not Available	Active
Cantung Tungsten Mine 3	2005	2009	Not Available	Active
Cantung Tungsten Mine 4	2010	2015	Not Available	Active
Brewery Creek mine	1997	2007	25	Inactive but Potential mine
Yukon Zinc's Wolverine Lead-Zinc Mine	2011	2022	37	Active

Faro Mine has been Yukon's largest mine to date with a peak annual consumption of 180 GWh (as per "YEC 20 year resource plan overview – 2006"). Changes to the Faro Mine load explain the large increases and decreases in the electrical energy demand during years seen in 1969, 1986 and 1995.

Appendix B: Forecasting Mining Impact upon Future Load in Yukon

Table B-1 lists the historic mining load in Yukon. Of the mines listed below, Minto mine is actively consuming electrical energy from Yukon grid whereas the other mines are inactive (but have potential for future operation). Alexco Bellekeno mine is shut down temporarily and is planned to re-open in 2015. The consumption estimates under "Midgard Mining Numbers" column indicate the estimated total mining electrical energy consumption in Yukon from years 1977 to 1993. Figures in columns "YEC Industrial Sales" and "CANSIM Mining Numbers" are reported values.

Table B-1: Historic Mining Load of Yukon[46,47,48]

Year	Bellekeno (GWh)	Faro Mine (GWh)	Minto (GWh)	UKHM (GWh)	Whitehorse Copper (GWh)	Midgard Mining Numbers (GWh)	YEC Industrial Sales (GWh)	CANSIM Mining Numbers (GWh)
1977		60		25	25	110		
1978		60		25	25	110		
1979		60		25	25	110		
1980		60		25	25	110		
1981		60		25	25	110		
1982		20		10	12.5	42.5		
1983		10		5		15		
1984		30		15		45		
1985		30		25		55		
1986		75		25		100		
1987		150		25		175		
1988		150		25		175		
1989		150		12.5		162.5		
1990		150				150		
1991		150				150		
1992		150				150		
1993		75				75		
1994		*7.95*					7.952	
1995		*89.53*					89.534	
1996		*178.77*					178.773	
1997		*78.49*					78.491	

[46] 1977 – 1993 : Midgard estimated mining numbers based on YEC 2012-2030 resource plan, Page A-1 and A-2, Yukon Economic Development : HYDRO document, Page 11 & 12

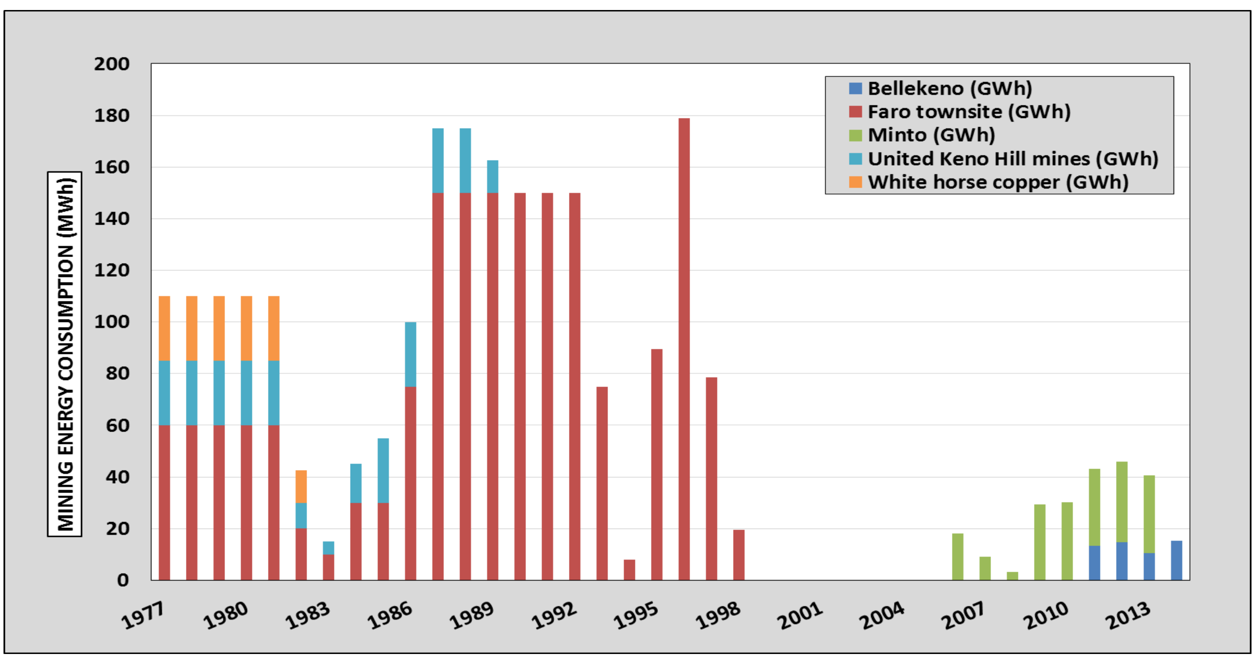
[47] 1994 – 2004 & 2013 : YEC Industrial sales data, "Next Gen Hydro Information Request 06.10.14 - Attachment 3"

[48] 2005 – 2012 : Mining Load (2005-2008) : "CANSIM 127-0008", Statistics Canada

Year	Bellekeno (GWh)	Faro Mine (GWh)	Minto (GWh)	UKHM (GWh)	Whitehorse Copper (GWh)	Midgard Mining Numbers (GWh)	YEC Industrial Sales (GWh)	CANSIM Mining Numbers (GWh)
1998		*19.38*					19.381	
1999							3.809	
2000							3.865	
2001							6.393	
2002							4.904	
2003							4.280	
2004							3.459	
2005								18.232
2006			*18.11*					18.112
2007			*9.031*					9.031
2008			*3.20*					3.200
2009			*29.36*					29.355
2010			*30.26*					30.255
2011	*13.23*		*30.03*					43.259
2012	*14.61*		*31.41*					46.023
2013	*10.56*		*29.96*				40.513	

The Figure B-1 below is a representation of the annual mining consumption data presented in the table above, in accordance with respective operational timelines.

Figure B-1: Quantum of Electrical Energy Consumed by Operating Mines – Historic perspective



Incremental Load Associated with Future Industrial / Mining Load

It is not unreasonable to posit that the number of future mines in Yukon will follow a pattern similar to the historical number of operational mines in Yukon. There will be booms and busts, but it can be forwarded that the long-term average mining load will adhere to similar patterns as those of the past.

In forecasting future mining load in Yukon, the following methodology was employed in interpreting the historical data.

1. Placer Gold operations are excluded from the analysis
2. Electrical energy consumption patterns are not categorized by mine type (i.e., precious metal mine versus base metal mine)
3. The future will resemble the past;
    a. Average annual electrical energy consumption per mine will be similar to the average historic annual electrical energy consumption
4. Industrial loads and non-industrial loads are considered independent of one another (i.e., there is no positive feedback between new mines and new jobs/population/non-industrial electrical energy consumption growth)

Using the historical mining load and the above approach, the results in Table B-2 suggests that, on an average, Yukon has had 1.2 (on-grid) mines per year actively operating, and the aggregate annual on-grid mining load was 67 GWh/yr. Each mine therefore consumes on an average 55 GWh/yr., which corresponds to approximately 7 MW of peak capacity (i.e., 55 GWh per year / 7884 operating hours per year).

There are many factors that will influence the amount of electrical energy a mine will require; such as, how much of that supply will come from the transmission grid, and how much of the electrical energy and capacity will be self-supplied, and other factors. For the purposes of the analysis, Midgard rounded the average mine usage to 50 GWh per mine per year. This figure is conservative relative to the calculated 55 GWh per year average, although the difference does not materially impact the results of the analysis.

Table B-2: Historical Data from Mines in Operation

Historical Mining Facts	1977-2013
Average Number of Operational Mines per Year	1.2
Average Mining Load per Year (MWh/yr)	67,130
Average Load per Mine per Year (MWh/yr)	55,382.5
Average Hourly Load / Capacity Requirement (MW)	7

Appendix C: Historic Non-Industrial Per Capita Demand for Electrical Energy

Historically, the average per capita electrical energy consumption (non-mining i.e., with the mining load data removed) has been in the range of 8 – 12 MWh/yr. (see Table C-1) with an average of 9.81 MWh/yr. as seen in the Figure C-1.

Figure C-1: Ex-Mining Historic Yukon Electrical Energy Demand per Capita[49,50]

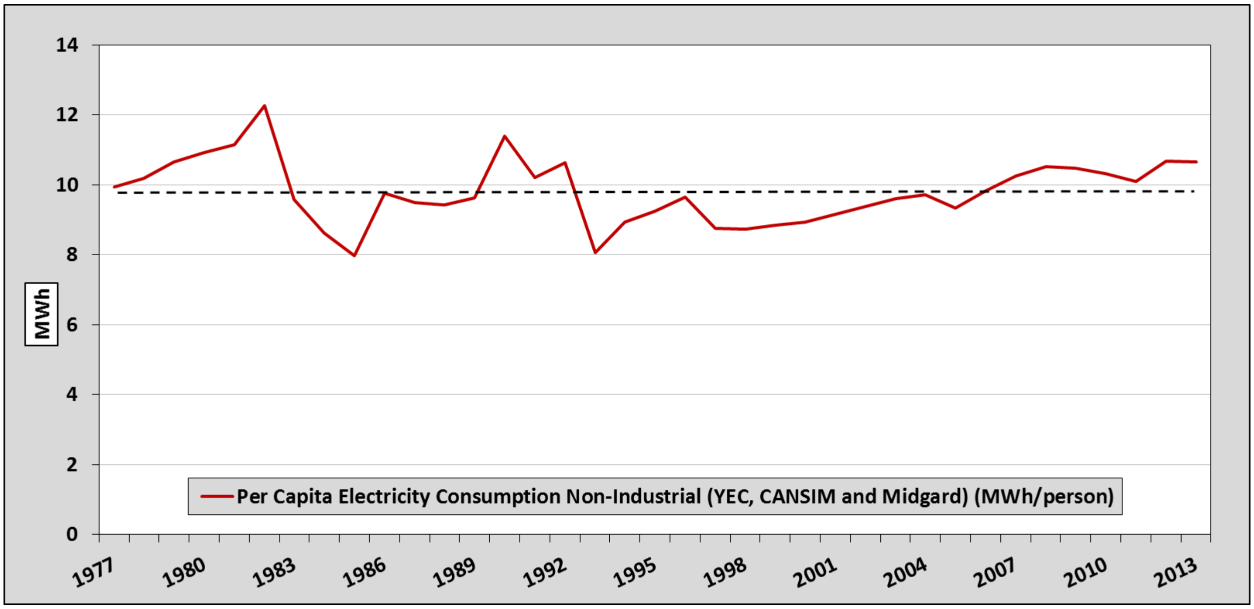


Table C-1: Historical annual per capita Electrical Energy consumption (Non-mining)

Year	1980	1985	1990	1995	2000	2005	2010	2013
Per Capita Electrical Energy Consumption (MWh/yr.)	10.92	7.97	11.38	9.24	8.94	9.33	10.33	10.65

[49] Annual Electricity Consumption : "Next Gen Hydro Information Request 06.10.14 - Attachment 3" , Tab : Request #1 Historical Gen

[50] Population : "CANSIM Table 051-0005", Statistics Canada

Appendix D: Supporting Tables for Monthly Electrical Energy Gaps

Table D-1: Table of Monthly Electrical Energy Gap for Low Case Scenario (2035, 2045, 2055 & 2055)

Month	2035	2045	2055	2065
Jan	12,503	15,771	19,269	23,008
Feb	9,017	11,783	14,745	17,911
Mar	19,101	21,917	24,932	28,154
Apr	11,046	13,437	15,996	18,732
May	3,328	5,597	8,026	10,623
Jun	746	2,888	5,181	7,632
Jul	-	-	329	2,791
Aug	-	-	1,609	4,151
Sep	-	-	2,029	4,662
Oct	-	744	3,514	6,475
Nov	3,267	6,238	9,419	12,819
Dec	6,434	9,748	13,296	17,089

Table D-2: Table of Monthly Electrical Energy Gap for Baseline Scenario (2035, 2045, 2055 & 2055)

Month	2035	2045	2055	2065
Jan	17,635	23,312	28,978	34,655
Feb	13,362	18,168	22,965	27,771
Mar	23,524	28,416	33,299	38,192
Apr	14,801	18,954	23,100	27,254
May	6,892	10,834	14,769	18,711
Jun	4,110	7,831	11,545	15,265
Jul	-	2,991	6,721	10,458
Aug	498	4,358	8,210	12,070
Sep	878	4,876	8,866	12,863
Oct	2,221	6,715	11,202	15,697
Nov	7,934	13,095	18,248	23,409
Dec	11,639	17,397	23,144	28,902

Table D-3: Table of Monthly Electrical Energy Gap for High Case Scenario (2035, 2045, 2055 & 2055)

Month	2035	2045	2055	2065
Jan	25,700	39,472	56,701	78,265
Feb	20,189	31,850	46,437	64,694
Mar	30,474	42,344	57,192	75,778
Apr	20,702	30,779	43,386	59,165
May	12,492	22,057	34,021	48,997
Jun	9,396	18,423	29,716	43,850
Jul	4,563	13,630	24,972	39,169

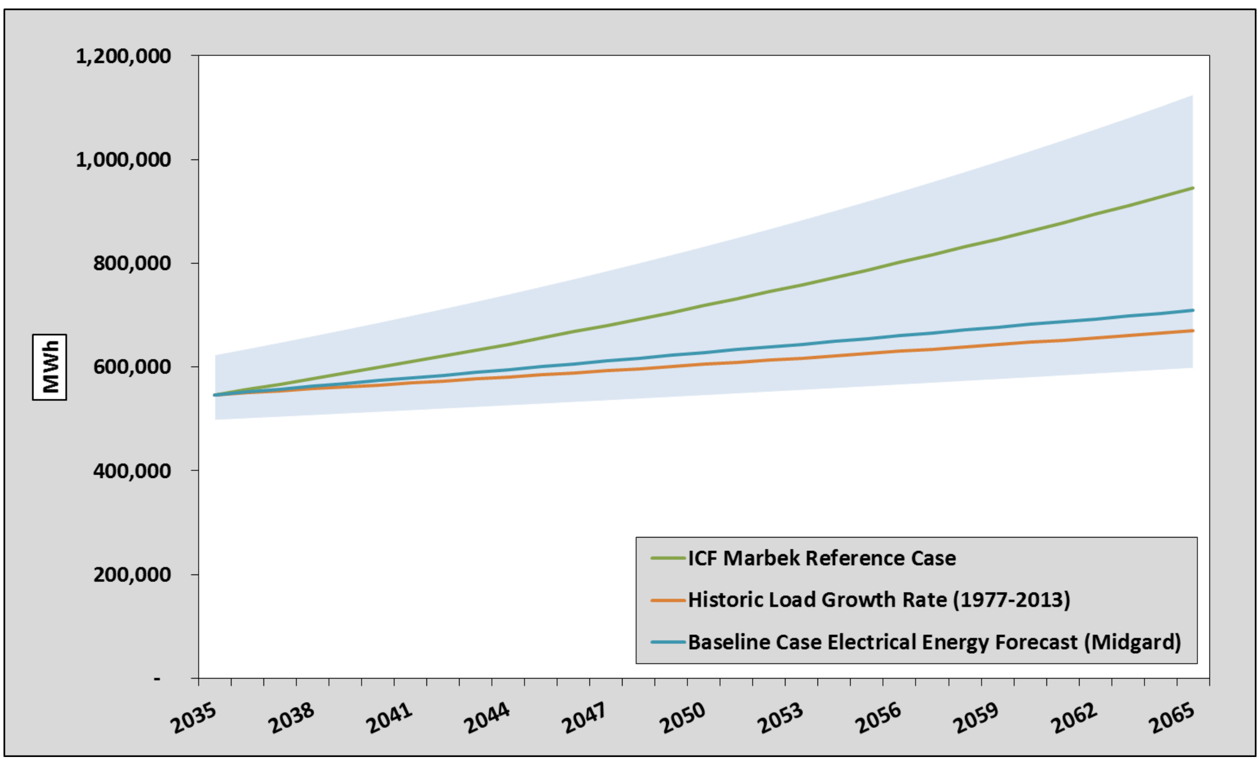
Aug	5,981	15,346	27,061	41,724
Sep	6,557	16,255	28,387	43,572
Oct	8,606	19,512	33,154	50,229
Nov	15,267	27,790	43,456	63,066
Dec	19,819	33,789	51,264	73,137

Appendix E: Scenario Analysis

Midgard's forecasting methodology used a top-down single variable model to estimate a range of potential future outcomes. Midgard's forecast provides high and low scenarios that in turn provide an envelop of plausible future electrical energy consumption over the long-term. Figure E-1 below provides three examples of potential electrical energy load paths. Each of these load paths fall within Midgard's high and low scenarios' envelop.

- Example scenario I: The Baseline Case Midgard forecast, as presented in this paper.
- Example scenario II: The ICF Marbek Reference Case (with demand side management or DSM).[51] The ICF Marbek Reference Case assumes that 75% of new Yukon housing units use electricity heating for space heating. The DSM adjustment is the "lower Achievable Potential" case.
- Example scenario III: Yukon's historic compounded electrical consumption growth rate for the period between 1977 and 2013.

Figure E-1: Examples of Growth Scenarios (2035-2065)



[51] ICF Marbek: Yukon Electricity Conservation and Demand Management Potential Review (CPR 2011) - Summary Report, 9 Jan 2012, page 12, Exhibit 3