Yukon Energy
2016 Resource Plan

March 31, 2017

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Executive Summary

2016 Resource Plan: Key Findings and Recommendations

Yukon Energy Corporation (YEC) prepares an update to its 20-Year Resource Plan every five years. The following document is an update of the 2006 and 2011 Plans. The purpose of this plan is to provide recommendations as to how to cost-effectively meet the electricity needs of the Yukon Energy's customers over the next 20 years. Consistent with the values of these customers, environmental protection and low cost were key drivers in shaping the recommendations of this plan.

A key component of the 2016 Resource Plan (the Plan) is a recommended Action Plan for meeting customer electricity demands. The document does not seek approval for specific future projects. While the Plan identifies resources of interest, the development of future resources will be managed through YEC's stagegate process for project development and approval, and will require engagement with First Nations and stakeholders, as well as regulatory reviews and permitting.

In the development of the Resource Plan, YEC did not speculate with respect to future government policies or transformative technological developments. The analysis undertaken for the Plan included the social cost of carbon, which is consistent with pending national carbon policies. Overall, the Plan was grounded in a conservative future outlook, based on reasonably foreseeable trends.

Yukon Energy spent approximately 18 months, from September 2015 to February 2017, working with First Nations, stakeholders, and the Yukon public on the Resource Plan. During the third round of engagement with Yukoners in early 2017, YEC shared the 2016 Resource Plan key learnings. These are summarized as follows:

- In the development of resource portfolios, YEC analyzed a wide range of potential future industrial activity scenarios. Informed by the analysis undertaken on these scenarios and the stakeholder engagement, Yukon Energy is recommending a Short Action Plan and Long Term Action Plan.
- YEC currently needs new capacity to meet requirements under the single contingency (N-1) criterion and this need will increase in the near future. Given the lead time in constructing new resources, the expected peak demand under the N-1 criterion for all the industrial activity scenarios is expected to exceed YECs generating capacity until the year 2021.
- There may be an energy deficit in the future depending on the level of future economic activity. If so, more renewable energy will be needed to fill the gap between future needs and current capabilities;
- Different stakeholders expressed different values with respect to resource and portfolio attributes, making compromise often challenging. The Electricity Values Survey showed that the priorities of the Yukoners were ranked in the following order: environmental protection, cost,

reliability of energy supply and social responsibility. The recommended Action Plan is an attempt to balance a wide range of stakeholder inputs while maintaining affordability;

- Resource planning inevitably requires compromise. Every resource option and every portfolio reviewed by YEC featured less preferred attributes, whether financial, environmental or social. The development and selection of the Action Plan was a tradeoff between tangible numbers and often less tangible values;
- In terms of alignment of the portfolios with public values, YEC believes that the resource portfolios proposed in the Action Plan are environmentally responsible, with portfolios providing on average between 92 and 99 percent of annual YEC energy generation from renewable resources over the 20 year planning period. The portfolios are also cost effective, meet reliability criteria, and socially responsible;
- A portfolio consisting of only renewable future resources was reviewed. This portfolio was determined to be significantly more expensive than the corresponding mixed portfolio including thermal resources, requiring an additional capital investment of $486 million, or 2.5 times greater than that of the mixed portfolio. In addition, the renewable portfolio did not meet YEC's capacity needs until 2024. Finally the renewable portfolio provided only marginally more renewable energy generation than the mixed portfolio including thermal. YEC's current portfolio is already more than 98% renewable, among the highest in the world;
- YEC's Resource Plan incorporates the need for flexibility to deal with risks such as major and sudden changes in loads, and the inability to develop a preferred resource proposed in the Action Plan. In light of ongoing uncertainties, the Action Plan needs to be resilient and robust under various potential load scenarios and regulatory, financial and development outcomes. A portfolio of relatively small, scalable and modular assets, as proposed in the Action Plan presents a lower risk than a single large asset, in terms of regulatory approvals, financing, fuel diversity and resourcing. As an example of scalability, YEC's LNG facility completed in 2015 was built with the expansion potential for a third unit, which is now recommended in the Action Plan as an attractive capacity option. YEC will consider the balance between potential lower costs of larger solutions due to economies of scale, versus the ability of smaller, incremental supply solutions to more closely match growth.
- The recommended Short Term Action plan is common for all the analyzed industrial activity scenarios until 2022. The common resources recommended for the Short Term Action Plan are presented in Table 1.

Table 1: Resource Options Recommended in the Short Term Action Plan

Year	Resource Option
2018	DSM (conservation)
2019	LNG Third Engine (4.4 MW)
2020	Aishihik Hydro Plan Uprate
2020	Whitehorse Hydro Plant Uprate
2020	Batteries (4 MW)
2020	Southern Lakes Enhanced Storage Project
2021	Diesel (20 MW)

2022	Mayo A Refurbishment
2022	Mayo Lake Enhanced Storage Project
2022	Standing Offer Program

- The recommended Long Term Action Plan consists of two components: 1) continued implementation of the resource options included in the short term Action Plan, and 2) development of additional resource options which are dependent on the specific industrial activity scenario that develops over time.
- The Action Plan was developed assuming no constraints to accessing to the required debt and equity to finance the assets included in the plan. The Action Plan considered only existing government policies, including for example the application of the social cost of carbon. YEC has finite resources available to both plan and manage the construction of new resources. The timing of projects included in the Action Plan may be adjusted in response to potential internal resource constraints.

To meet the challenges of execution of the recommended Action Plan, collaboration with First Nations and stakeholders will be critical to the success of these projects. YEC will continue to work on different aspects of planning and execution of new energy projects with:

- First Nations;
- Yukon Territorial Government;
- ATCO Electric Yukon;
- Municipal governments;
- Potential IPP proponents; and
- Consumer, business, community and environmental advocacy groups.

The Resource Plan is a living process and is updated every five years with the energy and peak demand forecasts scheduled for updating in 2018.

1 The Planning Environment

Yukon Energy Corporation is a public electric utility owned by the Yukon Government through the Yukon Development Corporation, a Crown Corporation. YEC's mandate is to plan, generate, transmit and distribute a continuing and adequate supply of cost-effective, sustainable, clean and reliable electricity for customers in Yukon.

YEC owns and operates the Yukon's integrated transmission system, generates almost 100% of the power on this isolated predominantly hydro grid, and is the electric utility with the primary responsibility for planning and development of new generation and transmission resources in Yukon. The Yukon Utilities Board (YUB) regulates the costs to be recovered through YEC rates, focusing on need, justification, and the reasonableness of costs incurred.

YEC has prepared 20-year resource plans at least every five years since 2006. The purpose of the resource plan is to provide recommendations on how to meet the needs of Yukon's electrical customers over a 20-year horizon. This plan follows utility best practice of prudent planning to ensure YEC is able to maintain a reliable and adequate supply of electricity, both energy and capacity. Resource planning in a living process and the plans are updated on a regular five year basis and as required in response to significant changes in the elements of the plan. The resource planning process involves the following steps:

1. Forecast future electricity load;
2. Create an inventory of existing energy supplies;
3. Determine potential shortfalls;
4. Create an inventory of potential energy supplies and conservation options;
5. Forecast future fuel cost and social cost of carbon;
6. Assess risks and uncertainties relevant to the Plan;
7. Analyze the portfolio of options;
8. Draft an action plan; and
9. Finalize the Plan.

The finalized plan will be included and/or referenced in future Yukon Energy submissions to the YUB to provide context that supports the justification for specific major new generation and transmission capital projects under review by the YUB. If and when an energy project is chosen for development, a separate planning, design, assessment and review process is followed that is specific to that project.

The 2011 Resource Plan was reviewed prior to the completion of the 2016 Resource Plan, with the intent of preserving its best elements, while making improvements if justified and feasible. The changes in the 2016 Plan relative to the 2011 Resource Plan can be grouped into the following categories: planning principles and methodologies, key inputs and assumptions, and conclusions and recommendations. The most significant changes include:

- Load forecasting methodology. The 2016 Resource Plan load forecast used a more sophisticated econometric approach that integrated demographic, economic, and technological trends. It also considered a broader range and scope of scenarios than the previous YEC Plan;
- The resource portfolio analysis. The 2016 Resource Plan portfolio analysis applied sophisticated optimization modeling to select the lowest cost resource solution, while meeting required planning criteria;
- Engagement methodology. The 2016 Resource Plan applied a broader, and more comprehensive public consultation approach, specifically enabled through the Electricity Values Survey;
- Social Cost of Carbon. The 2016 Resource Plan used the social cost of carbon in evaluation of resource options in the portfolio analysis;
- Existing unit capabilities. Updates to existing unit capabilities and expected retirement dates were made in the 2016 Resource Plan to reflect current information; and
- Conclustions and recommendations. Both the 2016 and 2011 Resource Plans identified industrial (specifically mining) electricity demand as a key uncertainty facing YEC, and this was the primary theme of the load scenarios analysis undertaken. The 2016 Resource Plan provided recommendations that included Short and Long Term Action Plans that identified preferred resources and the optimum development timing for these resources under different scenarios. The need for additional capacity today, and the portfolio of resources necessary to fill this need, are the primary outcome and recommendation of the 2016 YEC Resource Plan.

There are a number of territorial and federal orders, policies and objectives that YEC is accountable to follow. Key territorial policies and objectives include: Micro-Generation Policy, Independent Power Producer Policy, and Yukon Climate Action Plan.

The key federal policy is the Pan-Canadian Framework on Clean Growth and Climate Change, which Yukon Premier Sandy Silver joined on December 9, 2016. This framework indicates a pending national carbon tax, a development which was incorporated into this Resource Plan.

2 Electricity in Yukon

YEC is the main generator and transmitter of electrical energy in Yukon. Working with its parent company, the Yukon Development Corporation, YEC's provides Yukoners with a reliable, affordable and sustainable (both economically and environmentally) power. YEC's focus is on renewable sources of power and energy solutions that complement our legacy hydro assets.

There are almost 15,000 electricity consumers (accounts) in the territory. YEC directly serves about 2,100 of these, most of whom live in and around Dawson City, Mayo and Faro. Indirectly, YEC provides power to many other Yukon communities including Whitehorse, Carcross, Carmacks, Haines Junction, Ross River and Teslin, through ATCO Electric Yukon (ATCO). ATCO buys wholesale power from YEC and sells it to retail customers in the Yukon.

At present, the electrical system in Yukon is comprised of:

- One large hydro-based grid called the Yukon Integrated System (YIS);
- One medium-sized diesel-based grid serving Watson Lake; and
- Three smaller isolated communities with diesel generation (Old Crow, Beaver Creek and Destruction Bay/Burwash Landing).

YEC is mandated to provide Yukoners with an adequate supply of electricity every day of the year, every year. YEC must control assets that are required to cover extreme events that could include an outage at a hydro plant or a transmission line, or extreme cold or drought conditions. YEC must supply both energy and capacity to meet customer demands.

YEC has the maximum capacity to generate about 132 MW. In the summer, up to 92 MW can be produced from hydro and wind combined, with the remainder coming from thermal back-up (diesel and natural gas). During the winter, when electricity demand peaks, YEC hydro facilities have less water available, reducing hydro generation capacity to just over 70 MW. On December 15, 2016, a cold winter day, YEC's reached its highest electricity demand at 88 megawatts (MW). In the late spring and summer months the demand for power drops to a little more than half of the winter demand. YEC typically has more water available during the summer than is required to meet customer demands, which refills its hydro reservoirs and ultimately leads to spilled water.

Non-controllable factors, such as water inflows, demand variability, and demand growth have a significant influence on YEC and its planning. Another key planning risk is the potential for electricity demand growth, which is driven by population growth and economic expansion. A single new large industrial customer, such as a new mine, could cause a significant increase in YEC demand (25% or more), over a relatively short timeframe.

The seasonal mismatch between potential electricity production from hydro generation and the timing of maximum customer demands is a key planning constraint for YEC. In addition to the seasonal mismatch between winter demand and winter supply, electricity demand in the Yukon is highly variable, and changes considerably over the course of a day and year. Not all sources of electricity generation can respond to these demands.

Another important way of meeting future electricity demands is through Demand Side Management (DSM). This involves using incentives, rate structures, building and appliance codes and standards to encourage customers to reduce the amount of electricity they use. This could have the benefit of avoiding or delaying the construction of new electricity generation. DSM is often less expensive and has a lower environmental impact than the construction of new electricity supply infrastructure to meet growing load.

The YIS is an islanded grid. Most other areas of the North American continent are part of a large electricity system that connects power producers and consumers through a series of transmission and distribution wires, supplied by numerous electricity generation facilities. But the Yukon is not a part of that or any other system. It needs to be self-sufficient, which imposes challenges when it comes to maintaining and planning for the electricity needs of the Territory.

The key challenge is that the Yukon must produce all of its own power. Islanding imposes financial impacts to its ratepayers. The requirement for total self-reliance creates higher costs, relative to connected systems, due to the need for additional backup infrastructure. The inability of an islanded grid to export excess electricity makes it risky to build/generate electricity in anticipation of increased demand, as this future demand may not materialize in Yukon's commodity-dependent economy. Lastly, in the event of unexpected demand growth, the Yukon cannot simply import electricity, making growth in local generation capacity crucial to future economic and population growth.

3 Stakeholder Engagement

Yukon Energy spent approximately 18 months, from September 2015 to February 2017, working with First Nations, stakeholder groups, and the Yukon public obtaining feedback to guide the 2016 Resource Plan. The goals of Yukon Energy's engagement with First Nations, stakeholders, and the public during the preparation of the 2016 Resource Plan were:

- To ensure openness and transparency at every stage of the process; and
- To substantively incorporate the ideas, suggestions and values of Yukoners from every part of the Territory representing many different viewpoints related to resource planning.

A key stakeholder engagement element in the Resource Plan was the Electricity Values Survey. The goal of the survey was to gain information regarding Yukoners' preferences with respect to potential future electricity generation in the territory. The survey also sought to understand Yukoners' preferences and values relating to energy use. The survey results helped Yukon Energy in analyzing portfolios and creating the Action Plan.

A stratified random sample of more than 4,500 Yukon households, approximately one-third of total households, was selected to complete the survey. Respondents were asked to provide input on four thematic areas related to the development of new electricity sources:

- Environment protection;
- Cost;
- Reliability; and
- Social responsibility.

These themes aligned with the attributes considered during the portfolio analysis portion of the resource plan work.

Yukon First Nations were consulted on public meeting dates and received personalized invitations to the public meetings. Offers were made to have separate meetings with Chiefs and Councils. In cases where

Yukon Energy has regular meetings with a First Nation, the 2016 Resource Plan was included in the agenda. On several occasions, Yukon Energy's President and Vice-President met with the Chiefs and Councils of Carcross-Tagish First Nation, Kwanlin Dun First Nation, and Little Salmon/Carmacks First Nation to brief them on the 2016 Resource Plan.

Engagement with the Yukon public was completed in part through three rounds of public meetings, each round taking place in six Yukon communities: Whitehorse, Dawson City, Mayo, Teslin, Carcross and Haines Junction. These communities were chosen based on population, connection to the Yukon grid, and proximity to potential energy projects. Throughout each phase, the Yukon public was informed and engaged through the interactive resource planning website, social media, Electricity Values Survey, four mailers sent to every home in the territory, phone calls, and emails.

Once the draft resource plan was completed in February 2017, Yukon Energy invited the public to review the draft report, and to provide their comments directly on the interactive website, via email, social media, by phone, or a face-to-face visit

The available public comments were considered in the draft plan, while the comments received after the draft plan was publicized will be considered in the final version of the Resource Plan.

In addition to the results of the Electricity Values Survey, the consultation feedback can be summarized as follows:

- First Nations governments expressed appreciation at having received information at regular intervals about the resource planning work, and appreciated the sensitivity shown by Yukon Energy to potential projects within First Nation traditional territories;
- When considering new energy options, environmental protection is most valued by Yukoners, followed by cost, reliability, and social responsibility;
- There is strong support for energy conservation/efficiency measures;
- While the values survey indicated low support for the use of thermal resources, by the end of the engagement process most Yukoners understood why Yukon Energy is proposing thermal resources to meet capacity needs under the N-1 criterion.
- Yukoners are pleased that under the Action Plan proposed by Yukon Energy, between 92 – 99 percent of the average annual power produced would be renewable over the 20 year planning period;
- Yukoners are supportive of the social cost of carbon being included in the evaluation of resource projects;
- Several smaller energy projects are preferred over one large energy project;
- There is interest in energy self-sufficiency among a number of rural Yukon communities;
- There is broad interest in a variety of energy technologies; and
- There appears to be strong support for wind and solar resources.

4 Electricity and Peak Demand Forecast

Energy and peak demand forecasts are a critical input into YECs planning processes. The energy and peak demand forecast developed for this Resource Plan presents YEC's predicted electricity needs over the 20 year (2016 to 2035) planning period.

Energy refers to the amount of electricity that is produced or used over a period of time. Peak demand refers to the maximum customer electricity demand within a defined timeframe, usually the highest single hour demand within a year. The ability of YEC to serve peak demand is referred to as capacity. On a utility-scale, energy demands are expressed in gigawatt-hours (GWh) and peak demand (and capacity) is expressed in megawatts (MW).

The forecast was developed in a two stages. In the first stage, an economic forecast was developed for the Yukon, which was a key input for the energy and peak demand forecasts. Economic activity is one of the main drivers of electricity use. A detailed economic and demographic model was developed to forecast future economic activity in the Territory such as Gross Domestic Product (GDP), as well as population and employment trends. In the second stage, the economic indicators from this model were used as inputs to a statistically adjusted end-use (SAE) model. The SAE model was used to forecast energy and peak demand in the residential (including street lighting) and commercial customer classes. In addition to the economic indicators, the SAE model used past electricity sales data, ambient temperatures, end-use saturations and efficiencies, electricity prices and price elasticity as inputs. An industrial forecast was generated by a generalized economic model using forecasts for specific proxy mines. This industrial and residential forecasts were combined to generate the total load forecast.

To cover a range of potential future economic possibilities, fourteen economic scenarios were developed. Four major scenarios were selected to cover a range of future industrial activity. Ten additional sensitivity scenarios layer on government spending and economic activity in other sectors, such as tourism and the development of a domestic forestry sector. Economic indicators such as GDP were developed for all fourteen scenarios through an econometric model, and energy and peak demand forecasts were produced using these inputs. The range of results allowed YEC to prudently plan to meet future customer electricity needs through an improved understanding of future uncertainties and risks.

A key conclusion of the updated load forecast is that YEC load continues to be highly dependent on the mining sector, with a wide range of potential outcomes, depending on global economic activity and commodity prices that are out of the control of YEC. Residential and commercial load growth is relatively steady. In addition, demographic factors and electricity conservation activities tend to flatten out load growth in the long-term. This has key implications for long-term resource development. From this forecasting, five main industrial activity scenarios were brought forward as the base scenarios throughout the rest of the Plan. These five base scenarios are: Very Low Industrial Activity, Low Industrial Activity, Low with Early Minto Closure, Medium Industrial Activity, and High Industrial Activity.

The potential effects of climate change on electricity needs was modelled and found to have a relatively small impact on expected future demands, slightly reducing peak and energy demand. Given the small impact and the risks involved in planning to meet customer peak demand, the forecast did not assume a load reduction due to climate change.

The 2016 YEC load forecast indicates an annual growth of 0. 7% per annum over the 20-year in energy requirements, and 1.7% for peak demand under the Medium Industrial Activity scenario.

YEC's existing resources include YEC's legacy hydroelectric, wind and thermal (diesel- and natural gas-fired) generators. The thermal generators owned and operated by ATCO in the communities connected to the YIS also fall within this category, and are included in the list of existing resources for capacity planning purposes.

Comparing the reserve margin determined using the N-1 criterion to the Effective Load Carrying Capability (ELCC), the N-1 criterion was adopted as more conservative and consequently was used in the portfolio analysis.

The capabilities of YEC's existing reseources in terms of firm energy and dependable capacity were compared to forecast loads for the five major industrial activity scenarios: Very Low, Low, Low with Early Minto Closure, Medium and High. The remaining nine industrial scenarios were eliminated as being redundant/similar to the five major scenarios. The selected scenarios are expected to cover a plausible range of future energy and capacity requirements. The selected industrial activity scenarios were paired with an inventory of existing and committed YEC resources to construct the Load Resource Balance (LRB) for energy and peak demand for the YEC Power System. The peak demand LRB showed that there is a capacity gap under the N-1 criterion at the current time. The energy LRB showed that there was an energy deficit for the High Industrial Activity scenario, while there was no energy deficit for the remaining scenarios as long as YEC relied on existing thermal assets, both natural gas and diesel, to meet the forecasted energy requirements. Using thermal resources to that extent would lead YEC to incur material fuel costs and would not be aligned with Yukoner's values related to electricity.

The energy and peak demand forecasts for the major industrial activity scenarios analyzed in the portfolio analysis are presented along with the inventory of the existing resources under the N-1 criterion in Figure 1 and Figure 2 respectively.

Figure 1: Comparison of Energy Forecast for All Major Industrial Activity Scenarios and Existing System Firm Energy

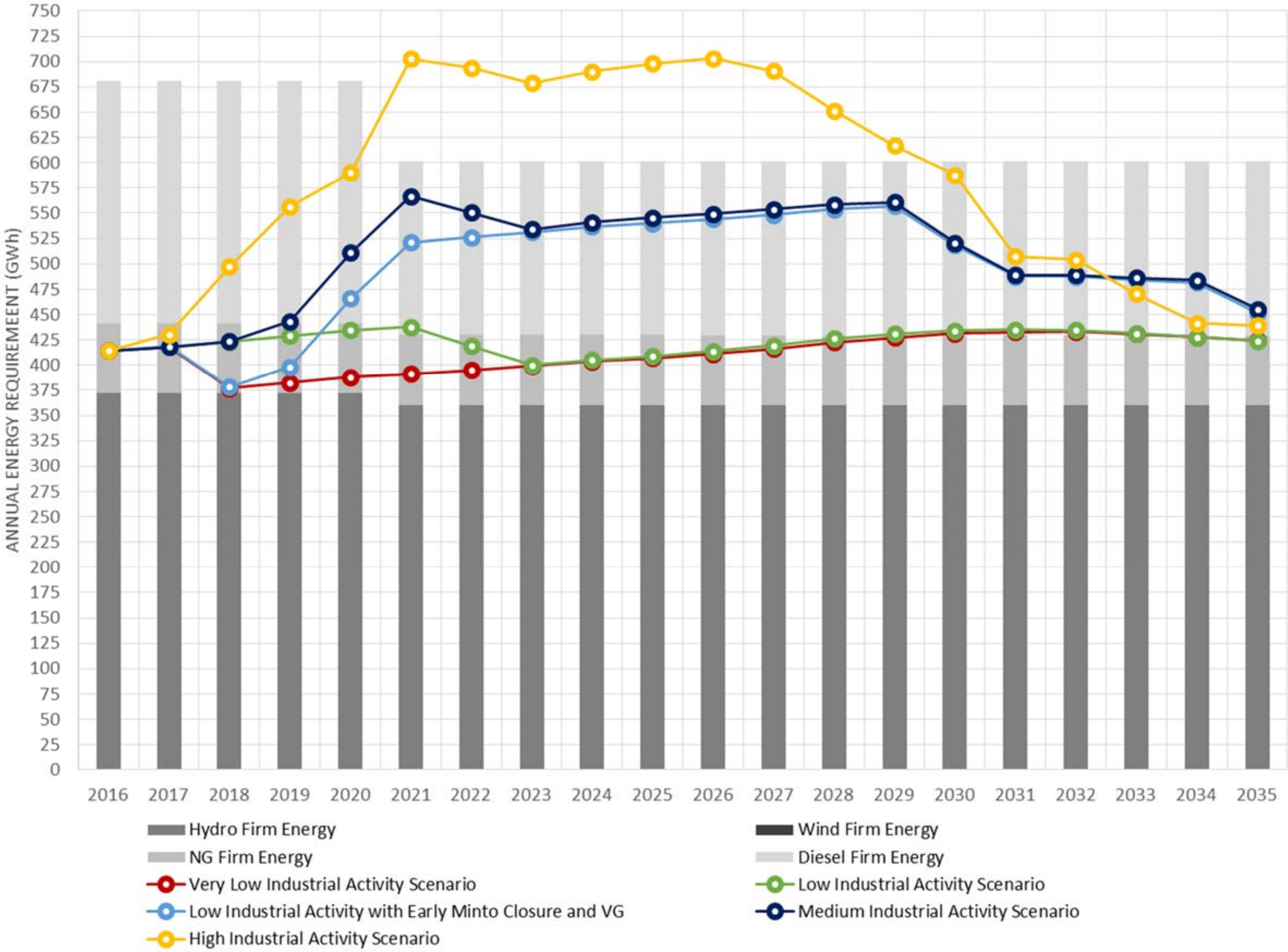
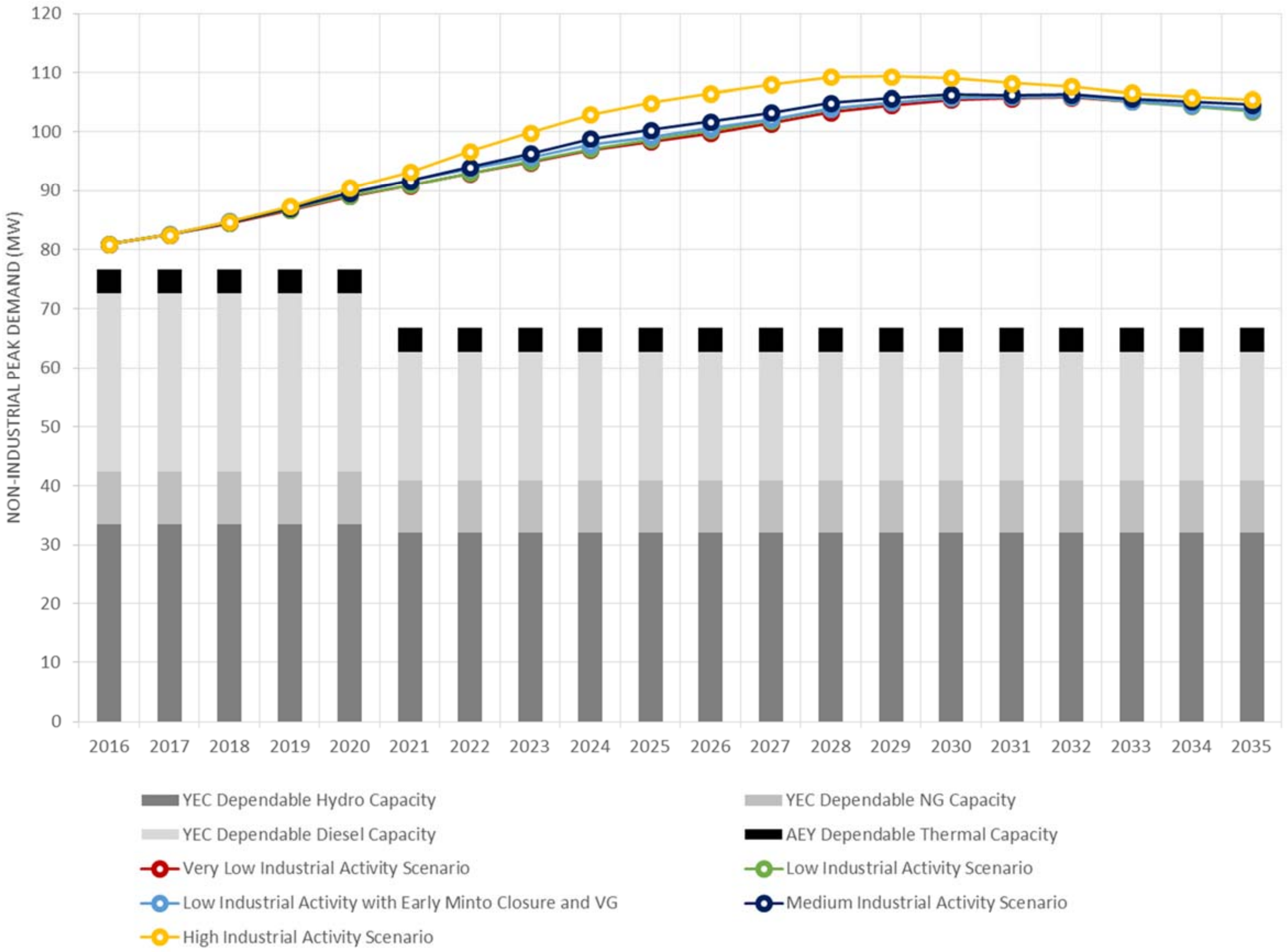


Figure 2: Comparison of Non-Industrial Peak Demand Forecast for All Major Industrial Activity Scenarios and System Dependable Capacity under single contingency (N-1) criterion



5 Resource Options

For the Resource Plan, fifteen resource options were assessed for their technical, financial, environmental, social and economic attributes at the prefeasibility level. The resource options assessed include:

- Hydro storage enhancements;
- Hydro uprating and refurbishments;
- Small hydro;
- Wind;
- Geothermal;
- Solar;
- Biomass;
- Biogas;
- Waste to energy;
- Natural gas;
- Diesel;
- Pumped storage;
- Energy storage;
- Demand side management; and
- Transmission.

Prefeasibility level studies were completed for each resource option and a list of best potential projects for each resource identified. These studies identified the technical and financial attributes of the potential projects.

The technical attributes assessed included:

- Monthly average energy;
- Monthly firm energy;
- Installed capacity;
- Dependable capacity;
- Project life (useable lifespan);
- In-service lead time associated with the resource development; and
- Resource dispatchability.

The financial attributes assessed included:

- Levelized cost of energy (LOLE); and
- Levelized cost of capacity (LOLC).

A high level assessment of the environmental, social and economic attributes of each potential energy projects was also completed. The attributes selected for assessment followed best practice for project assessment and were consistent with those used to develop the Electricity Values Survey. The attributes were presented to stakeholders for feedback during the first round of public meetings. The assessment focused on effects of the projects locally in the Yukon, with the exception of the impact of greenhouse gas (GHG) emissions, which were assessed on a full lifecycle basis for each resource option. The assessment of resource options against the attributes highlighted the key differences between resource options. Each attribute was assigned a low, medium or high preference ranking for each resource option. The attributes assessed are listed below. Each attribute has a number of indicators that were used to conduct the assessment.

The environmental attributes assessed included:

- Fish and fish habitat;
- Water quantity and quality;
- Terrestrial species and habitat
- Terrestrial footprint and land use; and
- Air quality.

The social attributes assessed included:

- First Nations lands;
- Traditional lifestyle;
- Heritage resources;
- Cultural and community wellbeing; and
- Tourism, Recreation and other resources and land use.

The economic attributes assessed included:

- Local economic impacts (positive effects); and
- Climate change risk affecting resources.

6 Fuel Forecast and Social Cost of Carbon

The cost of hydrocarbon fuels (diesel and LNG) is a major component in the cost of electricity delivered from thermal-based generation, and therefore this is a key factor in electricity generation resource decisions. YEC’s 2016 Resource Plan implemented a rigorous and detailed approach, in which the key components of diesel and LNG fuel price were analyzed, and specific escalation factors were applied separately to each of the cost components. These separate cost forecasts were then summed to generate a total diesel and LNG price forecast.

The prices of diesel and LNG delivered to YEC’s thermal generation facilities are comprised of a few key components. For example, the price of delivered diesel includes the following:

- Fuel cost (crude oil);

- Refining costs (crude oil converted to diesel);
- Marketing;
- Shipping; and
- Taxes.

In undertaking the forecast, the above costs were grouped into two categories. The forecasts were generated for each category separately and then added together to generate the final forecast. Those categories were as follows:

1. Fuel Costs: The feedstocks for diesel and LNG are crude oil and gas respectively. Therefore price forecasts for oil and gas are key forecast inputs. Oil prices are largely driven by global forces of supply and demand, with some degree of producer market power. Natural gas prices are set on a continental basis, as imports and exports of natural gas as LNG are relatively small. Processing and shipping costs for both fuels are largely cost-based, and generally track inflation; and
2. Other Non-fuel Costs: this grouping includes all other costs such as shipping, liquefaction for natural gas, refining for diesel, and taxes. In the forecasts, these are escalated at a rate consistent with the supplier cost of providing the service.

Long-term fuel price forecasts for oil and natural gas were adopted from a 2016 study by the National Energy Board of Canada.

The social cost of carbon (SCC) was introduced and applied to the economics of current and potential future resource options. Recent federal developments with respect to the application of a carbon tax require that YEC prudently apply the SCC. At the time of the SSC development, the exact magnitude and timing of a federal carbon tax was not known. Therefore, as a starting point for the SSC to be used in the 2016 Resource Plan, YEC used the most recent forecast from the US Environmental Protection Agency (EPA). Given the uncertainty in social cost of carbon outlooks, YEC conservatively adopted the low range of the EPA forecast for its SCC at $60/tonne in 2016 and $91/tonne in 2035 (2016$CA).

7 Risks and Uncertainties

In planning to meet customer demands, it is important to separate consequences, uncertainties, and risks. To provide clarity, these concepts are defined as:

- Consequence is an outcome or impact of relevance to the planning process. Consequences are usually tied to business of planning objectives and can be positive or negative, easily measurable or difficult to quantify;
- Uncertainty is the state of not knowing which one of several potential future consequences could occur;
- Risk is the potential of losing something of value if a consequence occurs. The key risks to utilities are usually thought of as negative impacts such as: financial losses, damage to infrastructure, reduced reliability, or loss of reputation.

YEC adopted a robust risk identification and mitigation process in this Resource Plan. The two key risks identified and to be addressed by the YEC Resource Plan are:

- Inadequate electricity supply, which reduces YEC's ability to 'keep the lights on', and leads to reduced reliability; and
- Over-building or over-procuring electricity supply, which could lead to higher rates. Capital intensive projects pose major risks to ratepayers if the future load projections used to justify these projects do not materialize.

The major uncertainties identified in the 2016 Resource Plan are related to the following four broad categories:

- Resources;
- Regulatory and Policy;
- Load Forecast; and
- Climate Change.

The major uncertainties and related risks are:

- **Resource uncertainties** such as fuel price volatility, water availability, project feasibility, equipment reliability, IPP supply, and capital availability can result in higher rates and/or insufficient energy and/or capacity supply;
- **Regulatory and policy uncertainties** such as proposed electricity supply projects being disallowed or delayed in legal or regulatory venues, or specific generation types become disadvantaged can result in an increased portfolio cost and/or insufficient energy and/or capacity supply;
- **The load forecast uncertainties** such as reduced future federal transfer payments to the Territory, increased economic growth due to rapidly developing new industrial loads, and fuel switching from oil and propane to electricity can result in increased rates and/or insufficient energy and/or capacity supply; and
- **Climate change uncertainties** such as hydrology patterns, temperature increase, or major economic and demographic changes can result in over/under energy and/or capacity supply, reduced load or increased load respectively.

The primary risk mitigation approaches adopted to deal with these risks included:

- **Development and analysis of scenarios:** Faced with the uncertainties inherent in the load forecasts, YEC's forecast approach focused on constructing and assessing a range of industrial-related load scenarios. The five industrial activity scenarios reviewed in the portfolio analysis covered a wide but plausible range of industrial sector outcomes. Additional sensitivity scenarios were constructed and analyzed to address uncertainties in the diesel and LNG price forecasts, and uncertainties with respect to the future social cost of carbon. Resource plans tested and developed for these scenarios allowed YEC to balance the tradeoff between risk and cost with respect to future possible outcomes;

- **Prudent planning criteria:** As an example, YEC adopted the N-1 criterion. When applied by YEC throughout the planning period, this criteria allows for customer reliability in the case of major generation and transmission equipment failures;
- **Monitoring and Updates:** YEC is constantly monitoring developments with respect to new large potential loads. This includes ongoing communications with potential industrial development proponents, particularly with respect to potential mining projects, as well as with the Yukon Government. YEC will update elements of the Resource Plan in the event of a material change. This could include major changes to government policy, transformative new technologies, climate change effects, or major new customer demands;
- **Plan Flexibility and Replacement Resources.** YEC's Resource Plan will incorporate the need for flexibility to deal with risks such as major and sudden changes in grid loads, and the inability to develop a preferred resource proposed in the Action Plan. In light of ongoing uncertainties, the Action Plan needs to be resilient under various potential industrial activity scenarios and regulatory, financial and development outcomes. For example, a portfolio of relatively small and modular assets presents a lower risk than a single large asset, in terms of regulatory approvals, financing, fuel diversity and resourcing; and
- **Rate Risk Mitigation.** In relation to industrial customers, to protect remaining customers, the servicing of large new industrial loads will require project-specific negotiations and joint planning to determine if mutually acceptable arrangements and opportunities can be concluded, including appropriate risk management and mitigation measures to protect all other grid-served customers from unacceptable rate risks.

8 Portfolio Analysis

The goal of portfolio analysis is to select an optimum basket of resources that best meets the future energy and capacity needs of YEC and its customers. A portfolio is a set of resource options, such as energy conservation, wind power, hydroelectricity and thermal generation, and the associated transmission lines required to bring generated electricity to customers. Each portfolio may contain a unique mix of conservation and generation assets, and these assets may have unique optimum development timelines. That is, each portfolio will contain specific assets developed over a given timeline, some early, and some near the end of the 20-year planning horizon. Each portfolio is an attempt to meet the technical, financial, environmental, social and economic objectives of YEC and its customers.

Energy planning is an exercise in tradeoffs, the tradeoffs being cost, reliability, and environmental, social and economic considerations. Some of these factors are easier to quantify, such as the strict costs arising from the procurement and ongoing operations of generation assets. Some environmental impacts, such as the cost of greenhouse gas (GHG) offsets can also be quantified. However, many remaining factors cannot be easily quantified, or an agreement among different stakeholders struck with respect to these values.

The future is far from certain and responsible planning requires YEC to consider and address future uncertainties, such as electricity demand, fuel prices, government policies, and/or capital availability. Therefore, an approach was use in which scenarios were developed, and then portfolios were assembled and tested.

The portfolio analysis was performed in two sequential steps: the first being a quantitative technical and financial evaluation, and the second being a primarily qualitative environmental, social and economic evaluation. The goal was to create portfolios that meet technical, financial, environmental, social and economic requirements, while minimizing total capital as well as operations and maintenance costs. To emphasize, for each of the tested scenarios, each portfolio was required to fulfill future customer energy and capacity needs.

In the first step, the portfolio technical and financial evaluation recommended a set of resource options that meets the planning criteria at the lowest cost. In the second step, an assessment was undertaken for each portfolio with respect to social, environmental and economic impacts.

Portfolio optimization is an exercise similar to filling in a series of puzzles (the portfolio) with the puzzle pieces representing different resource options; the puzzle size grows yearly due to forecast load changes. Filling the portfolio in every year is mandatory in order to meet expected load growth. There is nearly an infinite number of possible solutions, due to different resource options, the ability to scale up or down the size of resources, the timing of the resources, and their locations.

The portfolio modeling exercise was targeted at minimizing the sum of capital investments and operating & maintenance expenditures. The costs were expressed as the net present dollar value of the entire portfolio over the 20-year planning horizon. Operating costs and the resource potential assumed average conditions for each resource. For example, for operational purposes, hydro energy generation was modelled under average water inflow conditions, while for firm energy planning criterion, hydro energy generation is modelled under lowest water conditions. In converting future to present costs, a real discount rate of 3.38% was used, consistent with YEC's cost of capital.

Given the complexity of the exercise, a sophisticated computer model, the System Optimizer, was used for the portfolio analysis. This product is the industry-wide accepted capacity expansion optimization model developed by the vendor Ventyx/ABB. This modeling was a more sophisticated approach than that used by YEC in previous resource plans. For the first time, a rigorous analytical optimization approach was used, consistent with large-utility best-practices.

Figure 3 presents the energy requirement for the Medium Industrial Activity scenario as a line, existing energy capability under average water conditions as bars in the shades of gray and future energy of new resources selected in the portfolio analysis shown in different colored bars.

Figure 4 presents the peak demand requirement for the Medium Industrial Activity scenario under the N-1 criterion as a line, dependable capacity existing resources as bars in shades of gray and future dependable capacity of new resources shown in colours.

Figure 3: Medium Industrial Activity Portfolio, Energy

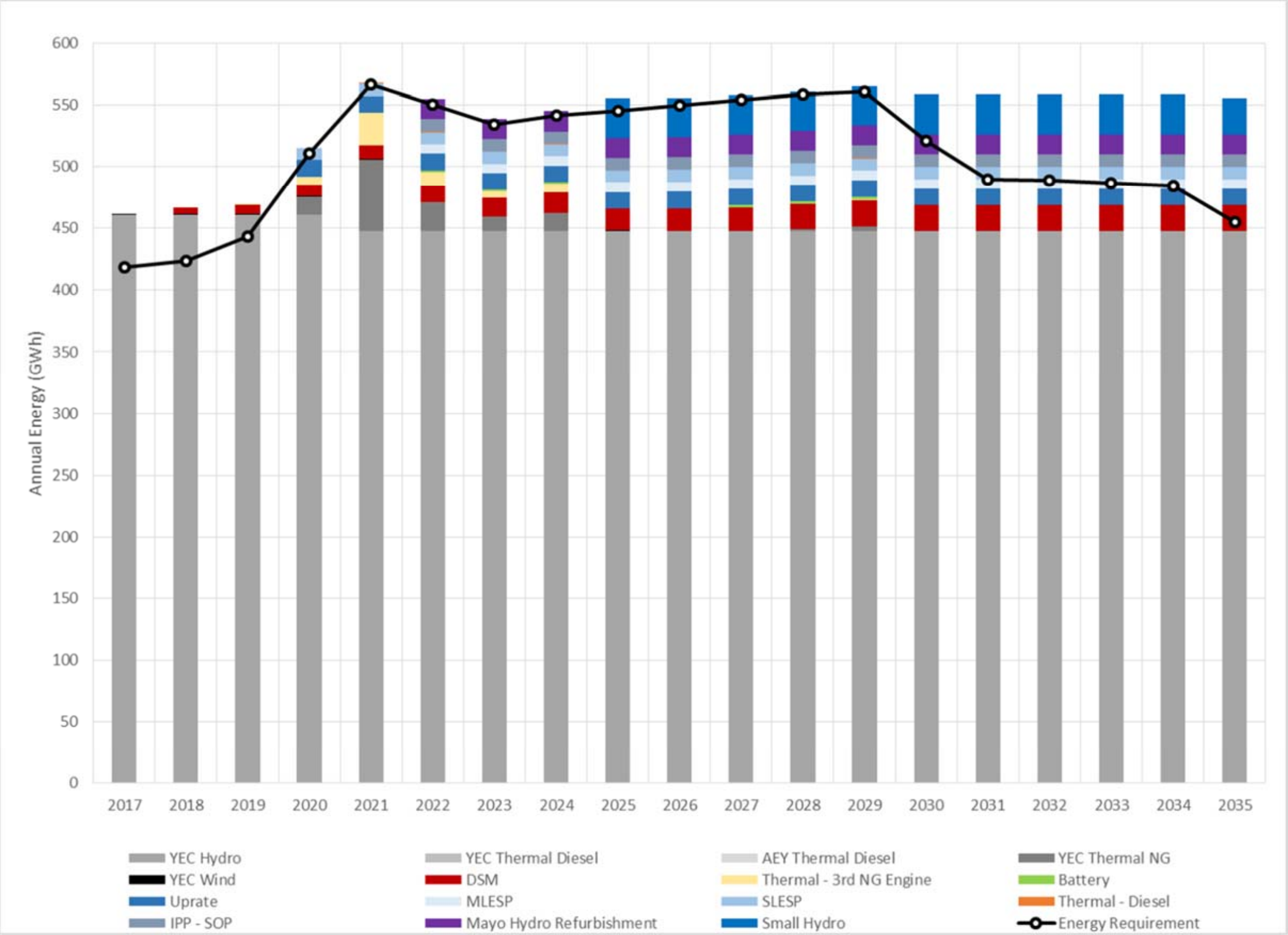
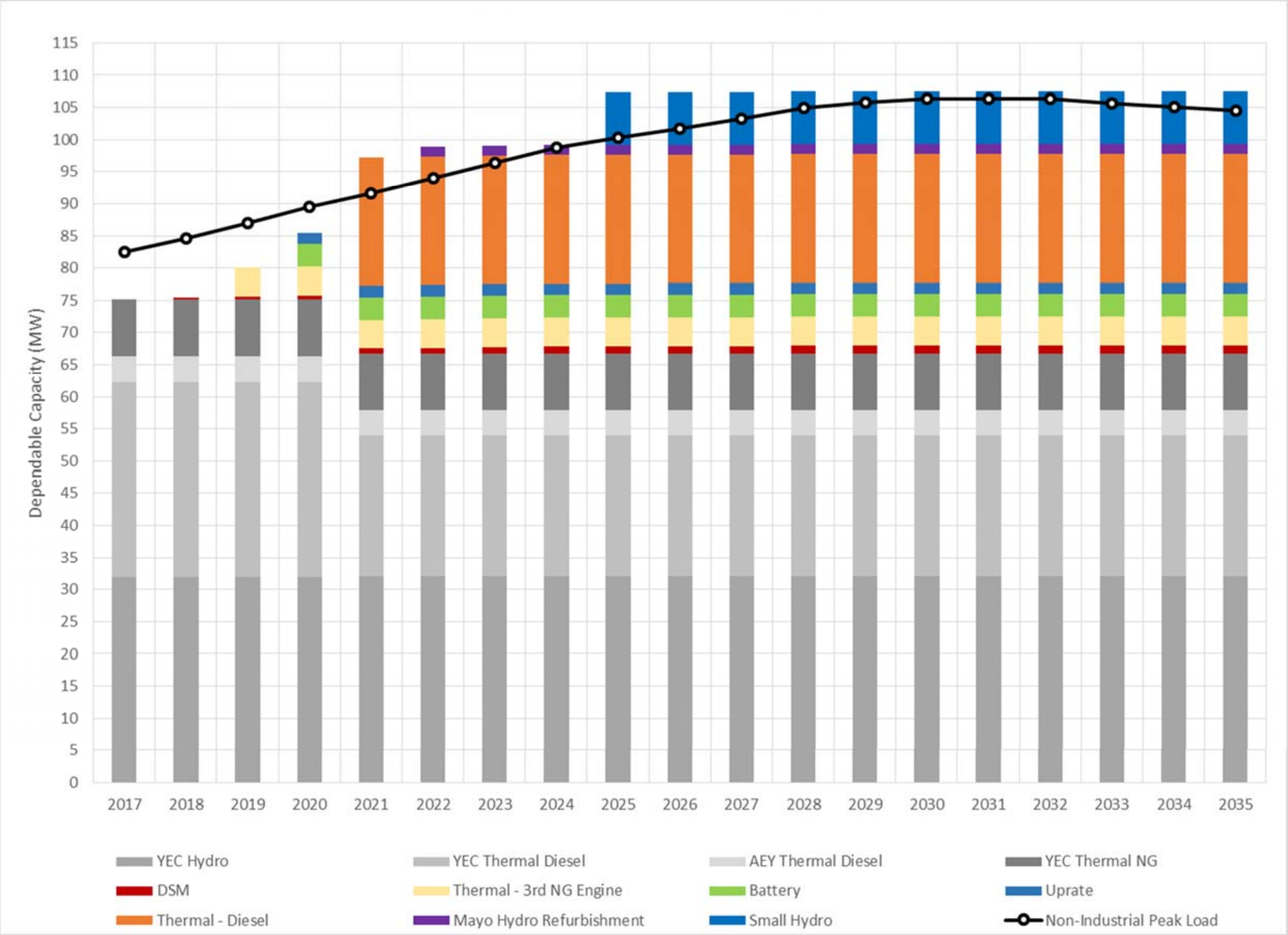


Figure 4: Medium Industrial Activity Portfolio, Capacity



The selection of the various environmental, social and economic attributes for each resource option was based on an understanding of stakeholder interests, including those commonly included in project impact assessments and permitting processes. Attributes were also selected from an understanding of industry best practices, knowledge gained from previous resource planning exercises and from the public interests identified in the Electricity Values Survey. A strong correlation between these sources was observed.

Each resource portfolio generated by the System Optimizer model was examined with respect to environmental, social, and economic characteristics. The first test was to examine a portfolio for adverse effects that could not be mitigated. If this test was passed, each resource option included in the portfolio would be examined in detail to understand the overall benefits, challenges and potential effects of the portfolio. In addition, an analysis was conducted to determine whether there were environmentally, socially, or economically comparable options available that were not strictly output from the technical and financial modelling. By doing so, those resources options excluded for technical or financial reasons could be reconsidered for inclusion if the options selected in the technical and financial evaluation could not be pursued for various reasons, such as geotechnical problems for a small hydro project discovered in the next, more detailed, project stage.

To facilitate assigning the importance (weight) to attributes, YEC conducted the Electricity Values Survey focused which on the same environmental, social and economic attributes that each resource was assessed against.

Once the resource portfolios were generated by the System Optimizer model, each was examined with respect to environmental, social, and economic characteristics.

The key conclusions of the evaluation of the technical and financial attributes were:

- YEC currently needs new capacity to meet requirements under the N-1 criterion. Given the lead time in constructing new resources, the expected electricity demand under all load cases is expected to exceed YECs generating capacity until the year 2021.
- For the Very Low, Low, Low with Early Minto Closure and Medium industrial activity scenarios, YEC is expected to have sufficient firm energy without introducing new resources, as long as it is acceptable to run YECs existing thermal resources. Despite the fact that there is sufficient firm energy under those scenarios, new renewable resources that are cheaper than thermal resources are proposed to provide a lower cost energy. The increased load of the high industrial activity scenario would require incremental new energy resources.
- Thermal assets are included in most portfolios to meet capacity requirements. However, these thermal assets are not expected to be operated frequently for energy production over the 20-year planning period. Therefore, all of the portfolios contain a high percentage of renewable energy, most in excess of 95% on the average over the 20-year planning period.
- All of the five industrial activity portfolios have common resources for first five years, which makes developing a consistent and sequential action plan possible, reducing the implementation

risk of stranded investments if the future unfolds somewhat differently than under the base assumptions

- The LNG third engine is common for all the base scenarios. It is the cheapest source of incremental capacity as it is an addition to an existing plant. For additional capacity beyond this, if thermal resources were needed, diesel was preferred over LNG because of its lower levelized cost of capacity (LCOC).
- Grid-scale battery storage is included in each portfolio as a near-term solution to address the capacity gap under the N-1 criterion. While batteries have a higher LCOC than diesel, they are included in all portfolios due to a shorter construction lead time than diesel.
- Intermittent renewables such as wind provide energy but not capacity. Wind was included in the portfolio for the high industrial activity scenario, as there is a significant energy deficit under this scenario.
- Small hydro is a part of the Low Industrial Activity Scenario with Early Minto Closure, Medium Industrial Activity Scenario and High Industrial Activity Scenario portfolios even though its use for energy generation is low during late last several years of the planning period. This is because it is a lower cost solution over the 20-year planning period for meeting both energy and capacity needs than a combination of thermal resources and intermittent renewable resources.
- In all of the reviewed portfolios, there is a drop-off in load near the end of the 20-year planning period as grid-connected mines reach end-of-life, and expected population growth change reduces non-industrial loads. In portfolio planning, there always exists the risks and associated cost that capital expenditures required to service customer demand growth may ultimately be stranded if load disappears. The Yukon economy is cyclical, with the potential for a load growth resurgence after the end of the 20-year Plan horizon. Thus, the recommended Action Plan needs to be robust to respond to a surge in future electricity demands. YEC's portfolio analysis incorporated this reduction in energy demand, which is reflected in the costs implications to YEC and its customers.
- The preferred portfolios were not materially sensitive to the social cost of carbon, the global warming potential, fuel prices, or low-cost new transmission lines.
- The portfolio containing only new renewables was significantly more expensive than the corresponding portfolio including thermal. In addition, the renewable portfolio did not meet YECs capacity needs until 2024. Finally the renewable portfolio provided only marginally more renewable energy generation overall than the portfolio including thermal.

The key conclusions of the evaluation of the environmental, social and economic attributes were:

- All resource options, and all portfolios represent trade-offs with respect to the potential for environmental, social and economic impacts. Consistent with the compromises inherent in resource planning, there was no portfolio without some less preferred attributes.
- The least-cost portfolios selected in the portfolio analysis were relatively balanced and positive from an environmental, social and economic perspective. This outcome made the environmental, social and economic attribute trade-off screening less challenging. The least cost portfolios identified did not contain onerous negative attributes that would cause them to be disqualified early.

- Most portfolios generated a high percentage of (92% to 98%) energy from renewable sources over the 20-year planning period. This indicates that the portfolios were aligned with the findings of the Electricity Values Survey, which showed that Yukoners have a strong preference for renewable sources of energy.
- A portfolio containing only new renewables was reviewed. The resources contained in that portfolio featured some degree of environmental, social and economic impacts and on balance the overall attribute scorings of the renewable portfolio were relatively close to those of the mixed portfolio that contained some thermal resources .The renewable portfolio substitutes any future potential thermal resources with all renewables, for an overall increase of 1% renewable energy. Despite a modest change in the environmental, social and economic attributes, the renewable portfolio requires the capital investment of $785 million, which is 2.5 times greater than that of the mixed portfolio. This significant cost difference is too great to recommend the all-renewables option in the Action Plan.
- The Action Plan does not preclude the option to substitute additional renewable resources in the future, but this substitution could incur potentially significant additional costs with potentially little gain in the overall renewable energy percentage.

9 Action Plan

The development of the Action Plan was based on the resource portfolios generated for the five major industrial activity scenarios: Very Low, Low, Low with Early Minto Closure, Medium and High. The Low with Early Minto Closure and Medium industrial activity scenarios are considered more likely to occur than the remaining three scenarios.

Portfolios were selected to cost-effectively meet expected load growth, and the subsequent analysis demonstrated that these portfolios were well aligned with Yukoners values as laid out in the Electricity Values Survey.

The content of the portfolios related to the five major industrial activity scenarios presented in Table 2 indicated that there were commonalities among the portfolios. The common resources for each portfolio at the beginning of the planning period helped develop the Action Plan in the following two stages:

1) Short Term Action Plan (present to 2022): The Short Term Action Plan is a recommendation based on common resources.
2) Long Term Action Plan (2022 to 2035): The Long Term Action Plan is a recommendation based on the continuation of the Short Term Action Plan recommendations and are matched with specific future load scenarios, for which time can reveal the outcome. The Long Term Action Plan consists of four different paths depending on the future industrial activity scenarios.

Table 2: Portfolios for Five Major Industrial Activity Scenarios

Scenario	Very Low	Low	Early Minto Closure	Medium	High
2018	DSM	DSM	DSM	DSM	DSM
2019	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine
2020	Battery (Takhini) Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP
2021	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)
2022	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP Wind 20 MW (Thulsoo Mt.)
2023			Small Hydro (Drury Lake)		Small Hydro (Drury Lake)
2025	Aishihik re-runnering			Small Hydro (Drury Lake)	
2026	Diesel 10 MW (Takhini)	Diesel 10 MW (Takhini)			Diesel 10 MW (Takhini)

9.1 Short Term Action Plan

The portfolio analysis presented in Table 2 recommended the following common resources for all the portfolios until 2022: DSM (conservation), LNG Third Engine, Battery, Diesel Plant, Whitehorse hydro plant uprate, Mayo refurbishment, and the Standing Offer Program (SOP). Consequently, those resources are common recommendations in the Short Term Action Plan. The SOP is a part of the Yukon Territorial Government Independent Power Producer (IPP) Policy that stipulates that 10 GWh/year of the energy will be supplied by independent power producers. YEC introduced this energy allocation for all the load scenarios starting in 2022.

In addition to the common resources, three more resources were recommended in the Short Term Action Plan: the Southern Lakes Enhanced Storage Project, Mayo Lake Enhanced Storage Project, and Aishihik Hydro plant uprate. The reason for this introduction was that these resources were required in the portfolios under a majority of the scenarios, particularly under the more probable ones: Medium and Early Minto Closure Industrial Activity scenarios.

The resources recommended in the Short Term Action Plan and their in service years are presented in Table 3. Those resources are common for all the load scenarios.

Table 3: Resource Options recommended in the Short Term Action Plan

Year	Resource Option
2018	DSM
2019	LNG Third Engine (4.4 MW)
2020	Aishihik Hydro Plant Uprate
2020	Whitehorse Hydro Plant Uprate
2020	Batteries (4 MW)
2020	Sothern Lakes Enhances Storage Project
2021	Diesel (20 MW)
2022	Mayo A Refurbishment
2022	Mayo Lake Enhances Storage Project
2022	Standing Offer Program

9.2 Long Term Action Plan

The recommended Long Term Action Plan consists of two components:

1) Continued implementation of the resource options included in the Short Term Action Plan, and
2) Development of additional resource options which are dependent on the specific industrial activity scenario that develops over time.

Therefore, specific additional resource recommended in the Long Term Action Plan were identified for each scenario. Growth in energy use and peak demand will be closely monitored to help guide the utility on which long term actions are required. An updated load forecast scheduled for 2018 should provide better insights into the load scenario unfolding in the future and for sufficient time to develop the resources to meet the load.

Table 4 presents the resource options recommended in the Long Term Action Plan, and the projected in-service years.

Table 4: Resource Options Recommended in the Long Term Action Plan

Scenario	**Very Low and Low**	**Early Minto Closure**	**Medium**	**High**
2022				Wind 20 MW (Thulsoo Mt)
2023		Small Hydro (Drury Lake)		Small Hydro (Drury Lake)
2025			Small Hydro (Drury Lake)	
2026	Diesel 10 MW			Diesel 10 MW

9.3 Constraints

There are several constraints that could potentially impact the execution of both the recommended short and long term Action Plans. These constraints could not be addressed formally in the portfolio analysis or the development of the recommended Action Plans. These constraints are:

- Access to Capital: an assumption was made in the development of the recommended short and long term Action Plans that YEC will have access to the required debt and equity to finance the assets included in the plan.
- New Government Policy: existing government policies over the planning period were considered in the development of the Action Plan, including for example the application of a social cost of carbon in the determination of the economics resources. The recommended short and long term Action Plans did not speculate with respect to future government policies.
- Internal Resource Constraints: as a small utility, YEC has finite resources available to both plan and manage the construction of new resources. Consequently, the timing of projects included in the Action Plan may be adjusted in response to potential internal resource constraints.

9.4 Next Steps

Following the completion of the 2016 Resource Plan and submission to the YUB, detailed planning will begin for the studies, design, and permitting required to implement the resource options presented in the recommended Short Term Action Plan. The development of future resources will be managed through YEC’s stagegate process for project development and approval. As collaboration with First Nations and stakeholders will be critical to the success of these projects, YEC will continue to work on different aspects of planning and execution of new energy projects with:

- First Nations;
- Yukon Territorial Government;
- ATCO Electric Yukon;
- Municipal governments;
- Potential IPP proponents; and
- Consumer, business and environmental advocacy groups.

The Resource Plan is a living process and is updated every five years with the energy and peak demand forecasts scheduled for updating in 2018.

Planning Environment: Table of Contents

1 Planning Environment

1.1 Purpose and Scope of the Submission

Yukon Energy Corporation (YEC) is a public electric utility owned by the Yukon Government through the Yukon Development Corporation, which is a Crown Corporation. Its mandate is to plan, generate, transmit and distribute a continuing and adequate supply of cost-effective, sustainable, clean and reliable electricity for customers in Yukon.

YEC owns and operates the Yukon's integrated transmission system, generates almost 100% of the power on this isolated hydro grid, and is the electric utility with primary responsibility for planning and development of new generation and transmission facilities in Yukon. YEC is incorporated under the Business Corporations Act and regulated by the Public Utilities Act and the Yukon Waters Act.

The Yukon Utilities Board (YUB) regulates the costs to be recovered through YEC rates, focusing on need, justification, and the reasonableness of costs incurred – and with a clear objective to minimize the costs required to serve electricity customers today and in the future.

The 2006 YEC 20-Year Resource Plan (the Plan) addressed major electrical generation and transmission requirements and options in Yukon over a 20-year planning period, focusing on the two Yukon grids existing at the time. It was reviewed and recommended by the YUB in its January 2007 Report to the Minister. The Board recommended that the Resource Plan be updated at least every five years, with the expectation that stakeholders be consulted in the preparation of the next plan. Pursuant to this, the 2006 Plan was updated in 2011.

The current 2016 Resource Plan follows the 5-year update schedule. The Plan explores and provides recommendations with respect to the requirements of YEC customers over the period 20-year horizon: 2016 to 2035. As with previous resource plans, this Resource Plan is intended to provide direction and recommendations with respect to the Yukon Integrated System (YIS).

1.2 Resource Planning Fundamentals

1.2.1 Plan Elements and Process

Fundamentally, this Plan addresses broad questions of how much, where, when and what new resources should be advanced to meet customer electricity needs. The planning methods used by YEC are good utility practice. This includes prudent and responsible practices and methods that are used by a significant portion of the electric utility industry in North America. This Plan has drawn upon planning practices and processes used by BC Hydro, which in turn has historically drawn upon broader industry best practices.

An example of prudent planning practice involves the adoption and adherence to planning criteria that are used to evaluate when additional infrastructure and resources are required to maintain a reliable and adequate supply of electricity, both energy and capacity, to customers. Planning criteria are critical in achieving the potentially conflicting objectives of maintaining reliability while minimizing rates. Absolute reliability is impossible to achieve due to the wide range and somewhat unpredictable nature of failures that may occur in the electricity system. These failures may occur at generation plants, on the transmission wires connecting the plants to the customers, or on the lower voltage wires close to the customer meter. Increasing reliability is costly, with costs generally inflating exponentially with increasingly marginal reliability gains. The balance between cost and reliability has been subject to intense scrutiny and cost-benefit analysis in the electricity industry.

YEC's planning criteria are generally consistent with those used in the rest of the industry and considered good utility practice. Special consideration is given to the harsh winter climate of Yukon, and the isolation of the Yukon grid from other electricity grids in North America. These criteria, or how YEC plans to strike the optimum balance between cost and reliability, are covered in detail in Chapter 4.

The Resource Plan involves the following steps:

1. Forecast future electricity load (demand);
2. Create an inventory of existing energy supplies;
3. Determine potential shortfalls;
4. Create an inventory of potential energy supplies and conservation options;
5. Forecast future fuel and carbon prices;
6. Assess risks and uncertainties relevant to the Plan;
7. Analyze the portfolio of options;
8. Draft an action plan; and
9. Finalize the Plan.

These steps are explained in more detail following:

1. Forecasting Load: This step is completed to obtain as accurate a prediction as possible of the future electricity needs (load) of Yukon, over a range of plausible scenarios. YEC's electricity loads are forecast over a 20-year horizon, under a variety of plausible scenarios. The forecast is undertaken for both energy and capacity (referred to as peak demand). The inputs and process involved in forecasting load are discussed in details in Chapter 4.
2. Create an Inventory: An inventory of current electricity supplies is created, including both physical electricity generation and electricity conservation and efficiency measures. This inventory indicates the ability of current YEC supplies to provide for energy and capacity. The details of the inventory are discussed in details in Chapter 4.
3. Determine shortfalls: A gap, or shortfall, is forecasted if customer load exceeds the existing and committed resources available to serve such load. Conversely, there is a surplus if available resources exceed forecasted load. A Load Resource Balance (LRB) is calculated for each load scenario, which quantifies the difference between YEC's load forecast and the supply from existing resources. The LRB is calculated for both energy and capacity, as discussed in detail in Chapter 4.
4. Future supplies: An inventory of possible future electricity supplies is created, including physical electricity generation and electricity conservation and efficiency measures. A wide range of electricity generation options (including wind, solar, thermal-based) are reviewed and documented, as discussed in detail in Chapter 5.

5. Forecast of fuel prices and social cost of carbon: This refers to an outlook for future natural gas and diesel prices for both YEC's current thermal generation, and future thermal options. An outlook for the future social cost of carbon (taxes or offsets) also needs to be created, as this cost would affect the cost of future generation. The details on the fuel price forecast and social cost of carbon are discussed in detail in Chapter 6.
6. Assess risks and uncertainties. This refers to an assessment of current and future risks to the Plan, including but not limited to: hydrology, climate change, asset outages and failures, and regulatory risks. YEC has developed a process to assess and appropriately deal with risk in the Plan, as discussed in detail in Chapter 7.
7. Analyzing the portfolio: All the possible energy options identified in the inventory are reviewed and analyzed based on a consistent set of criteria including risk. Combinations, or portfolios of energy options that make the most sense financially, technically, economically, environmentally and socially are identified, as discussed in details in Chapter 8.
8. Draft the Plan: A recommended Action Plan is prepared for review and comment. This review includes input from the public, and formal approval by the YEC Board of Directors. The details of the recommended Action Plan are discussed in Chapter 9.
9. Finalize the Plan: The 2016 Resource Plan is finalized, released to the public and included and/or referenced in future YEC submission to its rate regulator, the Yukon Utilities Board (YUB). The YUB regulates the costs to be recovered through rates, focusing on need, justification, and the reasonableness of costs incurred, and with a clear objective to minimize the costs required to serve customers today and in the future.

It should be noted that YEC has implemented a number of channels for First Nations and stakeholders to comment on the key findings of the Plan, through a series of public and First Nations engagement sessions completed over the duration of the planning process, as discussed in detail in Chapter 3.

In executing the recommended Action Plan, the development of future resources will require subsequent detailed technical, financial, environmental and socio-economic analysis as well as engagement with First Nations and stakeholders. In addition, certain projects and programs may require a review by the YUB. As YEC is required to meet customer electricity demands over all future timeframes, lead-time requirements is a critical input, and plays a major role in the processes and timelines of the recommended Action Plan.

As electricity planning recommendations often involve the construction of expensive, complex and contentious physical assets, such as generation plants and transmission wires, the time between planning and execution in the electricity industry is among the most lengthy in any industry.

The following outlines the steps in the planning and construction of a relatively small generation or transmission assets:

1. Planning: The general steps in the planning process were highlighted previously. These steps included the determination of electricity needs and how best to meet those needs. This also includes a consideration of affordability, reliability, and other factors such as environmental, economic and social impacts.

2. Baseline review: This step involves a determination of the current environmental and socio-economic conditions, and how they might be affected by the project. Depending on the number and type of studies required, this work could take up to five years.
3. Engineering: This step involves a determination of technical solution and methods needed to design and construct the project and it consists of the following phases: prefeasibility, feasibility, preliminary design, and detailed design. Each phase further refines previously selected engineering solutions to provide details for all the project components. The detailed engineering phase provides deliverables required for project construction and implementation.
4. Consultation: This involves communicating out the attributes of the project to affected First Nations and stakeholders, and listening to their concerns, in an attempt to find an acceptable solution to the electricity supply challenge. This phase also involves working with Yukon First Nations to reach protocol and/or project agreements. This phase could take 2 years.
5. Permitting: Federal and territorial statutes could require that numerous reviews, approvals, and/or permits that have to be obtained before construction can commence. These could include the Yukon Environmental and Socio-economic Assessment Board, the Yukon Utilities Board and the Yukon Water Board among others. Permitting could take in excess of 2 years.
6. Procurement: Electricity generation and transmission hardware is typically not an ‘on the shelf’ inventory item. Generators and turbine components are usually custom made, and then have to be shipped long distances. From ordering to delivery could exceed 2 years.
7. Construction: the construction and commissioning of a utility generation or transmission project could take in excess of 2 years.

YEC follows the stagegate project development framework to define and develop new assets. The framework covers the full set of activities from project conception to construction and commissioning. The framework is a consistent standard industry approach in which large projects are divided into stages, with appropriate authorization gates between the stages. Decision gates, positioned at the end of project stages, ensure the appropriate oversight and control by YEC management and YEC Board.

Regardless of the fact that some of these steps could be run in parallel, a small-scale generation or transmission asset could take 5 years from planning to commissioning.

Larger generation assets (such as storage hydro) could take significantly longer to realize, an example being BC Hydro’s Site C hydroelectric facility. Consultation, planning and regulatory work on the project took 7 years. Legal challenges to the project progressed from the lower courts ultimately to the BC and Federal Supreme Courts. Construction on the project has started, with the in-service date being 2024. Due to the long lead times for the commissioning of electricity infrastructure, YEC is prudent to consider a 20 year planning horizon, and under a range of plausible future scenarios.

1.3 Regulatory Context: Yukon Utilities Board Processes and Proceedings

1.3.1 Yukon Energy Mandate & Regulatory Context

YEC is incorporated under the Business Corporations Act and regulated by the YUB under the Public Utilities Act and the Yukon Water Board (YWB) under the Yukon Waters Act. The YUB is primarily an economic regulator that reviews and approves all utility rates to ensure rates charged are just and reasonable and that utility decisions are made prudently, with only assets considered “used and useful” are included in rates. The YWB issues water use licenses for all of YEC's hydroelectric generation facilities.

Major new generation and transmission capital projects developed by YEC normally require the prior approval of the Yukon Government, and are subject to regulatory review under the Yukon Environmental and Socioeconomic Assessment Act and, where relevant, the Yukon Waters Act.

The YUB does not directly approve YEC's capital projects – but does review and approve the costs for these projects that may be included in YEC's rates. In setting rates, the YUB proceeds in accordance with the Public Utilities Act (PUA) and Order in Council (OIC) directives under the PUA, including OIC 1995/90 which provides directives regarding equalized rates throughout Yukon (including the same rates for both utilities) for non-government retail and industrial rate classes, the requirement that major industrial customer rates at least recover cost of service to these customers (such costs to be determined on a Yukon wide basis), and directives to set rates for retail customers to encourage economy and efficiency in the use of electricity. As a result of these rate setting directives, new YEC generation and transmission projects on the isolated Yukon grid ultimately affect rates for all non-government customers of both electric utilities throughout Yukon.

1.3.2 Yukon Energy Resource Plans

YEC’s Resource Plans have been prepared once every five years since 2006 to address generation and transmission priorities in Yukon for a 20-year planning horizon.

Each Plan update focuses on (a) resource options for implementation over the first five years of each Plan and (b) planning activities during the first five years to define longer-term resource development options for potential construction later in the 20-year planning period.   These plans focus on the YIS.

1.3.3 YUB Review of Resource Plans and Capital Projects

There is currently no regulatory requirement for YEC to prepare a resource plan, or to update its plan every five years. There is also no regulatory requirement or mandate for the YUB to review or approve YEC's capital projects or its resource plans. YEC's resource plans can be used in YUB proceedings to support the justification for major new generation and transmission capital projects. The 2006 Resource Plan was filed with the YUB as a standalone proceeding. The Board’s recommendations arising from the 2006 Resource Plan review indicated that resource plans be updated every five years (at the latest), and the expectation that stakeholders be consulted in the preparation of the next plan. YEC has subsequently completed updates of its resource plan every five years. An Overview of the 2011 Resource Plan update was filed with the YUB during YEC's 2012-13 General Rate Application proceeding.

Although the YUB does not specifically approve YEC's capital projects or Resource Plans, it has historically reviewed YEC capital projects via two separate mechanisms:

1. **Directions provided from Government under Section 17 or 18 of the Public Utilities Act (PUA)[1]:** This process directs the YUB to provide a report to the Minister of Justice on a specific topic. In prior reviews, terms of reference have been provided by the Minister in order to guide the review process.[2] For resource planning reviews, the terms of reference have focused on system requirements (capacity and energy); the quantum, need and justification for spending commitments, and risks and potential effects on rates (and means to mitigate rate effects).
2. **Part 3 of the *PUA* (Energy Project Certificate & Energy Operation Certificate)**: This process requires issuance of a specific OIC "designating" a specific new generation or transmission project as an "energy project" under the *PUA*. Once a project is designated, the Minister must provide terms of reference for a YUB review and report with recommendations to the Minister. In this instance, the YUB only reviews the specific designated project. It is generally focused on the need and justification for the project, including consideration of risks and rate impacts, how they are mitigated, and alternatives considered. The Minister then refers to the YUB review and report when considering whether to issue the required Energy Project Certificate and Energy Operation Certificate, and any terms and conditions for such Certificates. This YUB review process has been used by the Yukon Government for the Carmacks to Stewart Transmission Project (2007); the Mayo Hydro Enhancement Project (2010); and the Whitehorse Diesel-LNG Conversion Project (2014).

While these YUB review processes do not result in orders approving specific projects or plans, they do provide an opportunity for a public review of the project or plan, and a report to the Minister regarding the plan or project (addressing issues of need, justification, risks and rate impacts, and adequacy of related mitigation measures).

1.4 Yukon Government Orders, Policies, and Objectives

In the Territorial context, YEC is accountable for meeting policy directives as outlined by the Yukon government and its agencies. Key recent policy developments include:

1.4.1 Micro-Generation Policy

This Policy, issued by the Yukon Government in October, 2013, aims to encourage the small-scale generation of electricity by individuals, small businesses and communities to meet their own needs, as alternatives or supplements to traditional centralized grid-connected power. The policy is applicable to micro-generation projects up to 50 kW. The stated objectives of the Policy are to:

- Provide opportunities for Yukoners to produce electricity from renewable technologies for their own consumption;

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[1] This approach was used for the 1991/92 YEC/YECL Cost of Service & Rate Design Review by the YUB; the 1992 YEC/YECL Capital Plan review by the YUB; and the 2005 YEC Resource Plan (as released in 2006) review by the YUB.

[2] Terms of Reference are provided either through correspondence to the YUB or via an OIC.

- Encourage the development and adoption of new individual renewable energy sources to reduce greenhouse gas emissions;
- Support ongoing research and technology to diversify renewable energy sources; and,
- Promote energy conservation and greater energy efficiency.

1.4.2 Independent Power Producer (IPP) Policy

This policy, issued by the Yukon Government in October 2015, aims to provide opportunities for non-utility entities to generate new power that can assist the utilities in meeting the demand for affordable, reliable, flexible and clean electrical energy. The stated objectives of the Policy are to:

- Increase electrical supply to meet future energy needs;
- Strengthen energy security and affordability of Yukon's electrical system;
- Develop local electricity resources, which are renewable and/or cleaner than diesel;
- Encourage new, local economic opportunities;
- Provide Yukon First Nations with opportunities to participate in the Yukon economy, obtain economic benefits, and develop economic self-reliance; and
- Facilitate collaboration between public utilities and independent power producers, in the development of new clean energy supply projects, which best serve the long-term interests of Yukon consumers.

In order to meet these objectives, this policy will establish the following aspirational targets for IPP contribution to Yukon's electrical grids.

- 10% of new electrical demand to be met by Independent Power Production; and
- At least 50% of IPP projects to have a Yukon First Nation ownership component.

YEC and ATCO are actively working with the Government to structure the Standing Offer Program (SOP), which is a key element of the IPP Policy. The SOP is intended to provide a standardized technical and commercial framework for grid connections in small capacity range (30-1,000kW). In order to deliver on the IPP Policy target of 10 percent of new electrical demand being met by the IPP sector, YEC has made an allowance for IPP-sourced energy in its assumptions for future supply options in the 2016 Resource Plan at the minimum of 10 GWh/year starting in 2022.

1.4.3 Yukon Energy Strategy[3]

This strategy**,** released by the Yukon Government in 2009, sets out Territorial energy priorities, strategies and actions and includes the following priority actions to: "update and develop a policy framework for electricity that emphasizes efficiency, conservation and renewable energy" that are relevant to YEC's ongoing planning processes. The Energy Strategy for Yukon focuses on four priorities:

- Conserving energy and using it more efficiently;
- Increasing the supply of energy and using it more efficiently;
- Meeting Yukon's current and future electricity needs; and
- Managing responsible oil and gas development in Yukon.

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[3] Government of Yukon (2009) Energy Strategy for Yukon.

Within these priorities, a number of strategies and related actions for energy conservation and the development of renewable energy resources were identified. There was a specific focus on electricity, and YEC's role in the implementation of electricity-related initiatives.

Energy efficiency and conservation is recognized as the starting point for the Energy Strategy both broadly and as it relates to electricity. The Government of Yukon committed to increasing energy efficiency in Yukon and increasing the renewable energy supply to reduce fossil fuel use and related greenhouse gas emissions.

1.4.4 Yukon Climate Action Plan[4]

The 2009 Yukon Government Climate Change Action Plan builds on the four goals outlined in the Climate Change Strategy and reflects the Yukon government's belief that "climate change is happening, that human behavior is a major contributor, and that a coordinated response is needed", while recognizing that Yukon is a small jurisdiction and the importance on focusing on priority actions that provide the most benefit to Yukon. The priorities of the Climate Action Plan include:

- Enhance knowledge and understanding of climate change;
- Adapt to climate change;
- Reduce greenhouse gas (GHG) emissions; and
- Lead Yukon action in response to climate change.

In December 2015, the Yukon Government issued a progress report[5] on the Climate Action Plan. The report presented a range of new actions to support the climate change goals documented in the original Plan, including specific support for the use of Secondary Sales to reduce the GHG footprint of specific Yukon government buildings.

1.4.5 Biomass Strategy

The Biomass Energy Strategy was issued in February 2016, and identifies the potential for biomass energy as a viable alternative to fossil fuels for space heating, reducing greenhouse gas emissions from the residential and institutional sectors.

1.4.6 Mineral Development Strategy

The Department of Energy, Mines and Resources is currently drafting a Mineral Development Strategy which may influence electrical infrastructure development in the future.

Recent policy decisions by the Yukon government such as the Independent Power Producer policy have necessitated interconnection agreements and tariff structures that will require review and approval by the YUB.

1.5 Joint Federal and Yukon Government Orders, Policies, and Objectives

On December 9, 2016, Yukon Premier Sandy Silver joined Canada's first ministers to finalize the Pan-Canadian Framework on Clean Growth and Climate Change.

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[4] Government of Yukon (2009). Climate Change Action Plan.

[5] http://www.gov.yk.ca/news/15-377.html#.WFDOEYWcGDs

While not all provinces signed onto the framework, this development indicates clear national momentum on climate change. The framework is both a concrete plan with key commitments, and also a launching point for further collaboration across Canada in addressing and adapting to the impacts of climate change and shifting to a clean, renewable economy. It introduces carbon pricing across Canada and includes annexes addressing each jurisdiction's particular needs.

The Pan-Canadian Framework on Clean Growth and Climate Change was based on reports from four working groups in the areas of: mitigation opportunities; adaptation and climate resilience; carbon-pricing mechanisms; and clean technology, innovation and jobs.

Examples of new actions that have been committed to in the Pan-Canadian Framework include:

- Reducing reliance on diesel in Indigenous, remote, and northern communities. Governments are committed to accelerating and intensifying efforts to improve the energy efficiency of diesel generating units, demonstrate and install hybrid or renewable energy systems, and connect communities to electricity grids.
- Building climate resilience in the north - Federal, provincial and territorial governments and Indigenous Peoples will continue working together to develop and implement a Northern Adaptation Strategy to strengthen northern capacity for climate change adaptation.

Yukon's annex commits the Governments of Yukon and Canada to partnering on investments in renewable energy projects, research and pilot projects, and energy efficiency improvements to buildings for the benefit of all Yukon communities.

It also commits that Yukon will retain 100 per cent of the revenues from carbon pricing. The Yukon Government has indicated that it will distribute these revenues back to individual Yukoners and businesses through a rebate. The Yukon Government indicated the need to work with all Yukon First Nations in implementing the Pan-Canadian framework.

The 2016 Federal budget included $5 billion Canada-wide funding for green infrastructure over five years. Of this funding, $518 million over five years is allocated for 'climate change mitigation and adaptation infrastructure projects'. This level of funding, and its intention, predates recent developments with the Pan Canadian Framework summarized previously.

1.6 Comparison of the 2016 Resource Plan to the 2011 Resource Plan

The 2011 Yukon Energy 20-Year Resource Plan: 2011-2030[6] was reviewed prior to developing the 2016 Resource Plan, with the intention of preserving the best elements of the 2011 Resource Plan, while implementing improvements, where possible. The following categories of these changes are documented and discussed:

1. Planning principles and methodologies
    - Planning principles;
    - Load forecast methodology;
    - Fuel price forecast methodology;
    - Public consultation methodology; and

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[6] http://www.yukonenergy.ca/media/site_documents/1204_Resource%20Plan%20-%20full%20document.pdf

    - Portfolio analysis methodology.
2. Key inputs and assumptions
    - Existing unit capabilities;
    - Existing unit retirement assumptions; and
    - New committed resources.
3. Conclusions and recommendations
    - Major findings; and
    - Execution of the action plan.

1.6.1 Planning principles and methodology

1.6.1.1 Planning Principles

In the 2011 YEC Resource Plan, the following four key planning principles were used to evaluate resource options and create action plan:

- Reliability
- Affordability
- Flexibility
- Environmental responsibility

Planning principles to evaluate resource options in the 2016 Resource Plan remained similar to those used in the 2011 Resource Plan. In the 2016 Resource Plan, as presented in Chapter 5, the following four key principles guided YEC in evaluating resource options:

- Reliability
- Affordability
- Environmental responsibility
- Socio-economic responsibility

Reliability refers to the need for reliable capacity and energy to meet customer demands over the short and long-term. This includes the need for reliable capacity to meet winter peak loads, and to minimize the number and duration of power outages.

Affordability refers to the goal of the YEC, as a regulated utility, to minimize costs for power utility customers today and in the long term. The Yukon Utilities Board regulates the costs to be recovered through rates, focusing on the need, justification, and reasonableness of costs incurred, with a clear objective to minimize the costs required to serve customers. YEC also aims to avoid rate shock. Rates need to be equitable, fair, and socially responsible for Yukoners. Accordingly, new resource supply options need to be planned in light of any such ongoing load uncertainties and must provide for resilience given the potential for major customer attrition.

Environmental responsibility refers to the aspirations to minimize local and global impacts on water, air, land, as well as wildlife in water, air and land as addressed in Chapter 5.

Socio-economic responsibility refers to recognition of the importance of social responsibility with regard to First Nation lands, traditional lifestyle, heritage resources, tourism & recreations, and cultural and community wellbeing. Economic responsibility includes the provision for local opportunities for jobs and community development.

The **Flexibility** principle highlighted in the 2011 Resource Plan was also integral to the selection of resources within the Action Plan of the 2016 Resource Plan, as presented in Chapter 9. The need for flexibility was identified in the risk analysis chapter (Chapter 7) of the 2016 Resource Plan, in terms of the need for the Action Plan to be robust in the event of future changes in the planning environment, such as an adjustment to the load forecast, adverse regulatory outcomes, technological progress resulting in a change in electricity use, or government policies. The need for flexibility has been manifested in the selection of smaller, modular resources representing less risk and cost. Smaller, modular resources require less construction time, a lower financial commitment per asset, and generally less environmental and social impact – per site. Although YEC recognizes that larger single generation resources may provide beneficial economies of scale, larger assets inherently involve greater completion risks to the YEC and ratepayer.

1.6.1.2 Load Forecast Methodology

The energy and peak demand forecast developed for the 2016 Resource Plan used a considerably more detailed approach than that used for the resource plans produced by YEC in 2011. Both resource plans developed different scenarios to highlight impacts of different economic developments within the 20-year planning period.

The residential and commercial customer sector energy forecasts in the 2011 Resource Plan were based on historical population trends, available Yukon population forecasts, and static projections of recent electricity use per customer. Brief commentary was provided on recent trends in average electricity use per customer in different Canadian utilities, including impacts of demand side management (DSM), and on the potential effects of climate change. The 2011 Resource Plan forecasts did not account in detail for future demographic trends, impacts of changes to economic activity or the prospect of changing efficiencies in electricity use.

The 2016 non-industrial load forecast used a multi-sector, macro-economic model of Yukon, developed specifically for the 2016 Resource Plan, as discussed in Chapter 4. The model included an internal representation of the linkages and dependencies between different sectors of the Yukon economy. The outputs of the model included demographic and economic metrics such as population, employment, housing starts and GDP.

These forecast drivers were subsequently used to develop residential and commercial customer class statistically adjusted end-use (SAE) models, which incorporated the benefits of both econometric and end-use approaches. The SAE models considered factors such as appliance efficiencies, new uses of electricity, and the adoption rates of appliances within homes and businesses.

A key consequence of the 2016 load forecast approach was that economic inputs into the Yukon economy such as mining developments and federal transfer payments were manifested as spillover effects into residential and commercial sector electricity demands. That is, increased industrial sector activity altered the broader load forecast in terms of employment, and ultimately population growth, and also economic drivers such as GDP. This level of sophistication was not present in the previous forecasts.

The 2011 Resource Plan's industrial load forecast, as well as that of the 2016 Resource Plan, was based on existing and potential future mine development, and informed by the most recently collected intelligence on mining prospects. The scenarios studied in the 2016 Load Forecast covered a wider range of plausible potential mining outcomes.

The 2011 Resource Plan non-industrial peak demand forecast undertook a simple approach by applying load factors to the energy forecast to create the peak demand forecast. As a consequence, the previous peak forecast was based on a historical ratio between energy and peak loads and it was assumed that this ratio would persist into the future. The 2016 non-industrial sector peak demand forecast was undertaken with the same degree of sophistication as the energy forecast, specifically by using the SAE model.

An updated load forecast was created in November 2013, based on the same forecasting principles as those used for the 2011 Resource Plan.

A comparison of the load forecasts for peak demand and energy from the following resource plan updates is presented in Figure 1-1 and Figure 1-2 respectively:

- 2016 Resource Plan (Medium Industrial Activity scenario);
- 2011 Resource Plan (base case scenario), as presented in the Overview of 20-Year Resource Plan: 2011-2030 (released in July 2012); and
- November 2013 updated load forecast (base case scenario).

The forecasts included both industrial and non-industrial customers before DSM is deducted from the forecasts. Figure 1-1 and Figure 1-2 also present the actual historical loads. The peak load forecasts presented in the figures did not consider the single contingency (N-1) criterion.

The increased sophistication of the load forecast methodology in the 2016 Resource Plan identified a potential outcome not anticipated in the 2011 Resource Plan and the 2013 load forecast update, specifically that that non-industrial loads were forecast to flat-line and then decline after about 2030, mainly due to demographic factors. This has significant implications in terms of long-term planning for capital projects, and has been a key consideration in the development of the (flexible) resource recommendations in the Action Plan of the 2016 Resource Plan.

The 2011 Resource Plan load forecast presented an average long-term energy growth of 2.1% per annum and growth in peak demand of 1.9% per annum in the medium growth case over the period from 2013 to 2030.

The November 2013 Load forecast presented an average long-term energy growth of 2.2% per annum and 2.0% per annum growth in peak demand of in the medium growth case over the period from 2013 to 2030.

The 2016 YEC load forecast indicated an annual growth of 0.7% per annum in energy requirements from 2016 to 2035, and 1.7% for peak under the Medium Industrial Activity scenario. Detailed analysis of the 2016 Resource Plan load forecast is presented in Chapter 4.

Figure 1-1: System Peak Demand Forecast Comparison

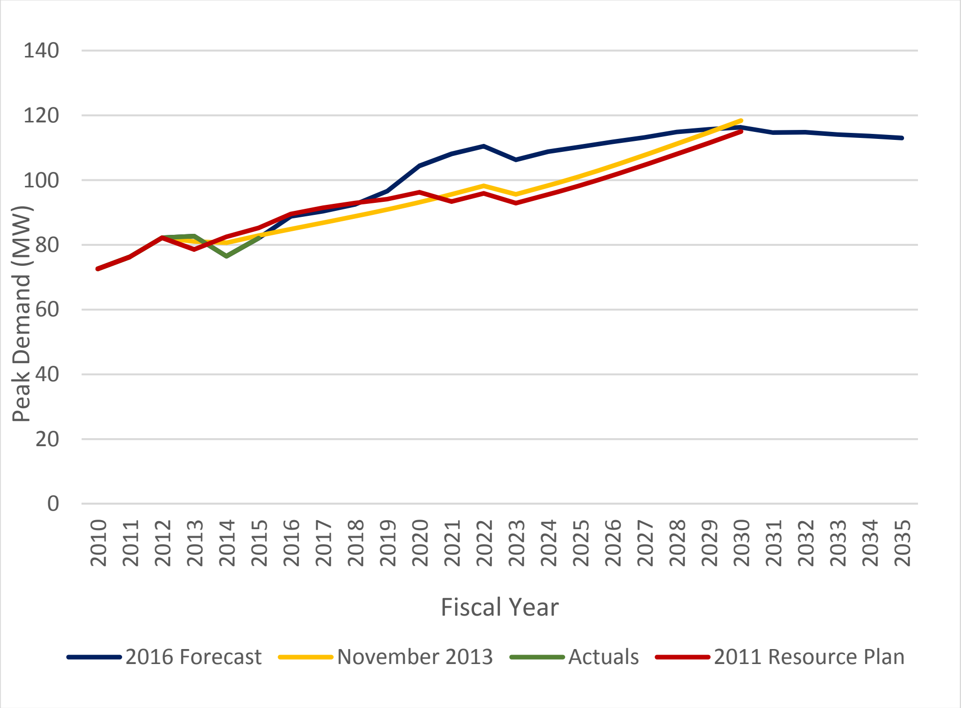
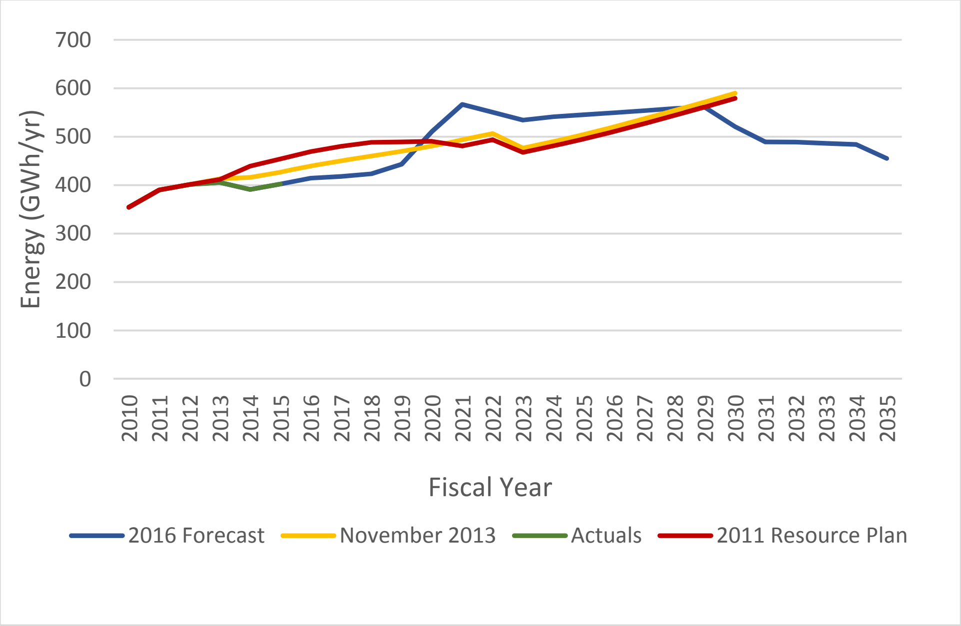


Figure 1-2: System Energy Forecast Comparison



1.6.1.3 Fuel Price Forecast Methodology

There are several ways to create fuel price forecasts. The simplest approach involves a trend analysis, in which recent historical prices are escalated using an inflation-based index. This was the approach used in the 2011 Resource Plan. For example, the forecast of future diesel prices was constructed by anchoring then-current diesel prices, and applying price escalation at inflation.

The 2016 Resource Plan took a more detailed approach, as presented in Chapter 6. The key driving components of diesel and LNG fuel prices were analyzed, and specific escalation factors were applied separately to each of the driving components. For example for diesel, the key components were the fuel cost (crude oil), refining costs (crude oil converted to diesel), marketing, shipping and taxes. The separate cost forecasts for each component were then aggregated to generate the total price forecasts.

Energy prices are among the most uncertain and volatile of all commodities, and are subject to the future events such as technology developments, changes in taxation and energy policies, customer demand, and substitution by other fuels. An additional enhancement in the 2016 Resource Plan was that a scenario-based forecasting approach was used to account for these uncertainties.

1.6.1.4 Public Consultation Methodology

The consultation and stakeholder engagement principles undertaken to inform the 2016 Resource Plan was generally consistent with those undertaken as part of the 2011 Resource Plan.

The 2011 Plan stakeholder engagement approach consisted of the following major components:

- As part of YEC's multi-year public awareness campaign, the corporation completed two public and stakeholder opinion surveys in June 2010 and in early 2011. These were telephone and online surveys targeting the general public and the business community. Over 600 people took part. The surveys were designed to understand what Yukoners and the business community knew about the Corporation.
- The Charrette: To enhance public understanding of resource planning issues, YEC engaged Yukoners (along with recognized energy experts) in a three day Charrette planning process in Whitehorse, where Yukon's energy demand situation and potential opportunities, both near term and long-term, were reviewed. A cross-section of Yukoners representing various interests was invited to participate in the process.
- Public meetings: Prior to the Charrette, community meetings were held in three Yukon communities (Mayo, Dawson City and Haines Junction) to learn about electrical energy concerns at the community level. In addition, stakeholder interviews were carried out involving approximately 50 individuals and representatives from a broad array of organizations, agencies and government departments.

The results of this consultation were discussed in the Preface of the 2011 Resource Plan document titled: 'Yukon Energy 20-Year Resource Plan: 2011-2030'. At a high level, the Charrette resulted in the development and subsequent application of four key planning principles: Reliability, Affordability, Flexibility and Environmental Responsibility.

The public engagement process in the 2016 Resource Plan was more comprehensive than that in the 2011 Resource Plan. The goals of the 2016 Resource Plan engagement with First Nations (FN), stakeholders, and the public during the preparation of the 2016 Resource Plan were:

- To ensure openness and transparency at every stage of the process; and
- To substantively incorporate the ideas, suggestions and values of Yukoners from every part of the territory representing many different viewpoints related to resource planning.

The overall engagement program was completed in four main phases, each related to a key element of the 2016 Resource Plan: Load Forecast, Resource Options, Portfolio Analysis and Action Plan and Draft Plan.

YEC followed three parallel streams throughout each phase: Technical Advisory Committee (TAC), First Nations, and Public.

Considering the complexity of the resource plan, as well as the diverse interests of First Nations and the general public, YEC employed multiple methods in each phase of the resource plan to inform and engage Yukoners. Those methods included:

- Electricity Values Survey;
- Meetings with First Nations, the general public and Technical Advisory Committee;
- Mailers to all Yukon households;
- Information sheets provided at the public meetings as take home material;
- Newspaper infomercials that provided electricity literacy;
- Newspaper and radio ads notifying Yukoners about public meetings;
- Discussion paper used with six classes of F. H. Collins High School students to introduce the idea of resource planning;
- Posters displayed at various public locations in Dawson, Mayo, Haines Junction, Carcross, Faro, and Teslin notifying Yukoners about public meetings;
- E-invite notification to Yukoners, including First Nations, about public meetings;
- Social media (YEC blog, Facebook, LinkedIn);
- Resource planning website: regular updates on resource planning work, notification of public meetings, and two-way conversations with Yukoners sharing information, ideas and opinions;
- Electricity Values Survey to gather Yukoners values related to electricity;
- Maps showing potential energy projects by Yukon First Nations' traditional territories;
- Briefings to political parties and government representatives; and
- Draft Resource Plan, posted on the Resource Plan website, offering the public an additional opportunity to provide feedback before the final resource plan document was made public.

A key stakeholder engagement element in the 2016 Plan was the Electricity Values Survey. A stratified, random sample of more than 4,500 Yukon households was selected to complete the survey. This sample represented approximately one-third of all Yukon households, and is considered statistically to be a very robust sample size. The goal of the survey was to gain information regarding Yukoners' preferences with respect to potential future electricity generation in the territory. The survey also sought to understand Yukoners' preferences and values relating to energy use. The survey results helped YEC in analyzing portfolios and creating the Action Plan.

The Electricity Values Survey showed that the priorities of the Yukoners were ranked in the following order: environmental protection, cost, reliability of energy supply and social responsibility. These planning principles were aligned with the principles adopted in the development of the 2016 Resource Plan.

1.6.1.5 Portfolio Analysis Methodology

Energy planning is an exercise in tradeoffsbetween cost, reliability, environmental, social, and economic considerations. Some of these factors are easier to quantify, such as the strict costs arising from the procurement and ongoing operation of generation assets. Some environmental impacts, such as the cost of GHG emissions can also be quantified. However, many remaining factors cannot be easily quantified.

The portfolio analysis in the 2016 Resource Plan was performed in two sequential steps. In the first step, a quantitative technical and financial evaluation was completed to identify portfolios which meet future energy and capacity needs, while minimizing total capital and operating costs.

The financial analysis applied in the 2016 Plan introduced an enhancement over previous YEC resource plans with the application of optimization modeling. To service future load growth, YEC needed to select among a suite of possible resource options that meet planning criteria. This introduced a nearly infinite number of possible resource combinations. This complexity was further multiplied due to the consideration of multiple load, price and alternative resource scenarios. Given the complexity of the exercise, an industry-standard capacity expansion optimization model, the System Optimizer, was used for the portfolio analysis. For the first time, a rigorous analytical optimization approach has been used, consistent with large-utility best-practices. This analysis enabled evaluation of a large number of combinations (portfolios) and resulted in selection of the optimal portfolio that would have the minimal total resource portfolio costs (the present values of all fixed and variable costs) while meeting energy and capacity planning criteria, as well as taking into account the earliest in-service date for resources.

In the second step, primarily qualitative environmental, social and economic evaluation screening was completed on each portfolio, with the evaluation criteria being informed by the extensive stakeholder consultation undertaken.

The goal of the portfolio analysis, as presented in Chapter 8, was to create portfolios that meet technical, environmental, social and economic requirements, while minimizing total capital and operations & maintenance costs.

The 2011 Resource Plan portfolio analysis methodology was similar to that used in the 2016 Plan, with the objective of minimizing the present value of all the expenditures, while meeting energy and capacity planning criteria. Instead of using an optimization model to financially evaluate a large number of portfolios that met the planning criteria and select the optimal one among them, the analysis in the 2011 Resource Plan was focused on evaluating only a limited number of portfolios satisfying a plausible range of resource combinations. The combinations (portfolios) were developed using professional judgement, with the selection of the generation resources within each portfolio and determination of portfolio costs undertaken manually. The present value of all fixed and variable costs was calculated for each portfolio and the portfolio with the minimal present value was selected as the optimal portfolio. The methodology used in the 2016 Resource Plan provided evaluation of a much larger number of portfolios than that used in the 2011 Resource Plan.

The 2011 Resource Plan did not use a formal methodology for evaluating portfolios against environmental, social and economic attributes, as the 2016 Resource Plan did. The environmental considerations were included into the 2011 Resource Plan portfolio analysis indirectly, through replacing thermal resources.

A significant change to the evaluation of resources in the 2016 Resource Plan portfolio analysis was the application of a Social Cost of Carbon (SCC) to the economics of resources. Recent Federal developments with respect to the application of a carbon tax required that YEC prudently apply the SCC. The SCC was not used in resource evaluation in the 2011 Resource Plan.

1.6.2 Key Inputs and Assumptions

1.6.2.1 Existing Unit Capabilities

A comparison between the dependable capacity values for the existing resources used in the 2016 Resource Plan and those in the 2011 Resource Plan showed minor differences that resulted in a decrease in dependable capacity, from 116 MW in 2011 to 115 MW in 2016. The difference is due to the following updates:

- YEC's internal assessment of the diesel generators has de-rated the dependable capacity of a diesel unit in Dawson (DD4) from 1.2 MW in 2011 to 1.0 MW.
- After an internal review, dependable capacity of two diesel units in Whitehorse (WD3 and WD4) have been uprated from 2.25 MW each in the 2011 Resource Plan to 2.5 MW each.
- In 2011, the Mayo Generating Station dependable capacity was estimated at 11 MW, while in 2016, it was assessed at 9 MW due to reassessments of flow restrictions and ice-management protocols on the lower Mayo River.
- ATCO Electric Yukon (ATCO) reassessed the dependable capacity of their diesel units, reduced the total dependable capacity of their diesel fleet from 7.2 MW in 2011 to 5.4 MW in 2016.
- ATCO's Fish Lake Hydro was excluded in the inventory of existing resources, as its contribution had already been accounted for by YEC in the 2016 load forecast in terms of reduced net load. This removal is only an accounting change, in order to avoid double-counting in YEC's analyses.

The details on the existing resources are presented in Chapter 4 of the 2016 Resource Plan.

1.6.2.2 Existing Unit Retirement Assumptions

Over the planning period, YEC anticipates the retirement of the two remaining Mirrlees diesel engines (FD1 and WD3) in 2021, and potentially some other diesel engines, depending on the extent of future diesel operations, as presented in Chapter 4. The retirement date of two units (FD1 and WD3) is consistent with the 2011 Resource Plan.

Given the low average usage of the YEC thermal fleet, which accounts for less than 2% of YEC's annual energy generation, YEC has been able to extend the life of several thermal-diesel engines, as the life span of these primarily depends on operating hours. If the use of thermal assets were to increase significantly, such as for example during potential prolonged drought in the future, the operating hour limitation may require that these units be retired within the 20-year planning horizon. However, under reasonably foreseeable operating expectations, these units should be available throughout the planning period and beyond.

The end of life for the diesel units, apart from FD1 and WD3, was assessed in the portfolio analysis as a function of their actual use, which depended on the future load and resource mix. This approach is an improvement compared to that in the 2011 Resource Plan where the diesel retirement dates were fixed.

1.6.2.3 New Committed Resources

The requirement for YEC energy procurement under the Standing Offer Program (SOP) arose subsequent to the issuance of the 2011 Resource Plan. YEC and ATCO are actively working with the Government to structure the SOP, which is a key element of the Independent Power Producer (IPP) Policy. The SOP is intended to provide a standardized technical and commercial framework for grid connections of IPP projects in small capacity range (30-1,000kW). YEC has made an allowance for SOP-sourced energy in its assumptions for future supply options in the 2016 Resource Plan at the 10 GWh/year starting in 2022, as presented in Chapter 8.

1.6.3 Conclusions and Recommendations

1.6.3.1 Major Findings

The Action Plan in the 2016 Resource Plan contains the following key conclusions and recommendations, as contrasted with the 2011 Resource Plan:

- YEC currently needs new capacity to meet requirements under the N-1 criterion and without remedial measures the capacity shortfall is expected to increase each year. Given the lead time in constructing new resources, the expected electricity demand under all load cases is expected to exceed YECs generating capacity until the year 2021.
- The 2006 and 2011 Resource Plans each identified a need for new future resources, but neither of these resource plans faced the capacity shortfall immanency as that identified in the 2016 Resource Plan.
- The 2016 Load Forecast identified an expected long-term flat-line in peak demand and decline in energy load after about 2030. This trend was not identified in either the 2006 or 2011 Plans;
- Both the 2016 and 2011 Resource Plans identified industrial (specifically mining) electricity demand as a key uncertainty facing YEC, and that this potentiality was the primary theme of the load sensitivities/scenarios undertaken. One new mining load could increase YEC electricity demand by 25% or more; and
- Both the 2016 and 2011 Resource Plans highlighted the need for flexibility within an uncertain future, particularly due to the continued need to consider potential new mine loads that would not be sustained to the end of the 20-year planning horizon.
- The 2016 Resource Plan recommended both Short and Long Term Action Plans, while the 2011 Resource Plan recommended Near Term and Longer Term resources planning.

1.6.3.2 Execution of the Action Plan

The primary purpose of resource planning is the development of a strategy-level action plan for meeting future electricity demands. While the 2016 Resource Plan considered the practicalities of developing specific resources at a high level, and identified resources of interest, the development of future resources will require subsequent detailed technical, financial, environmental and socio-economic analysis as well as engagement with First Nations and stakeholders, as per the stagegate project development framework. In addition, certain projects and programs will require review by the Yukon Utilities Board.

Practicalities of the execution (engineering, procurement, construction) for projects are highlighted in the 2011 Resource Plan in Figure 7-3 (pg. 197). This level of detail, particularly a consideration of the issues involved in the execution of specific projects, is not within the scope of the 2016 Resource Plan

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2 Introduction: Electricity in the Yukon

2.1 Corporate Background

Yukon Energy Corporation (YEC) is the main generator and transmitter of electrical energy in Yukon. Working with its parent company, the Yukon Development Corporation, YEC's provides Yukoners with a reliable, affordable and sustainable (both economically and environmentally) power. YEC's focus is on renewable sources of power and energy solutions that complement our legacy hydro assets. YEC is incorporated under the Business Corporations Act and regulated by the Public Utilities Act and the Yukon Waters Act. YEC's core business and strategy goal is to minimize the use of nonrenewable sources due to their higher variable costs and environmental impacts.

There are almost 15,000 electricity consumers (accounts) in the territory. YEC directly serves about 2,100 of these, most of whom live in and around Dawson City, Mayo and Faro. Indirectly, YEC provides power to many other Yukon communities (including Whitehorse, Carcross, Carmacks, Haines Junction, Ross River and Teslin) through ATCO Electric Yukon. ATCO Electric Yukon buys wholesale power from YEC and sells it to retail customers in the Yukon.

At present, the electrical system in Yukon shown in Figure 2-1 is comprised of:

- 1 large hydro-based grid called the Yukon Integrated System (YIS);
- 1 medium-sized diesel-based grid serving Watson Lake; and
- Three smaller isolated communities with diesel generation (Old Crow, Beaver Creek and Destruction Bay/Burwash Landing).

Figure 2-1: Yukon Electrical Systems

Yukon's Transmission and Generation Facilities

YEC SYSTEM	(in MW)
Hydro Facilities	
Whitehorse	40.0
Aishihik	37.0
Mayo	15.1
Total	**92.1**
Wind Facilities	
Haeckel Hill	0.65
LNG Facilities	
Whitehorse	8.8
Diesel Facilities	
Whitehorse	15.0
Faro	8.5
Dawson	5.1
Mayo	2.5
Total	**31.1**
TOTAL YEC SYSTEM	132.65

ATCO SYSTEM	(in MW)
Hydro Facilities	
Fish Lake	1.3
Diesel Facilities	
Carmacks	1.5
Haines Junction	1.5
Teslin	1.5
Ross River	1.0
Watson Lake	5.0
Beaver Creek	0.9
Destruction Bay	0.9
Old Crow	0.7
Pelly Crossing	1.2
Stewart Crossing	0.1
Swift River	0.3
Total	**14.6**
TOTAL ATCO SYSTEM	15.9
Other Diesel	
Minto Mine	8.0
Total Yukon Capacity	**155.9**

2.2 Generation and Electricity Demand Considerations

YEC is mandated to provide Yukoners with an adequate supply of electricity every day of the year, every year. YEC must build more power generation than is required on average, to cover extreme events that could include an outage at a hydro plant or a transmission line, or due of extreme cold or drought conditions.

YEC must supply both energy and capacity to meet customer demands. These critical concepts are explained as follows:

- Energy: the amount of electricity used over a period of time. It is usually measured in kilowatt-hours (kWh) for residential usage or gigawatt-hours (GWh) for territorial usage. The average Yukon home uses about 12,000 kilowatt hours per year (or 0.012 GWh/yr). Yukon-wide energy consumption is more than 400 gigawatt-hours per year.
- Capacity: the amount of electricity that is available or required at any given instant. Capacity is measured in watts, kilowatts (one thousand watts), megawatts (one million watts). For reference, a portable residential space heater requires about 1 kilowatt of demand. An industrial mining customer can use over 1 megawatt of electricity.

On December 15, 2016, a cold winter day, YEC reached its highest electricity demand at 88 megawatts (MW). YEC has the maximum capacity to generate about 132 MW. In the summer, up to 92 MW can be produced from hydro and wind combined, with the remainder coming from thermal back-up (diesel and natural gas). During the winter, when electricity demand peaks, YEC hydro facilities have less water available, reducing its hydro generation capability to just over 70 MW.

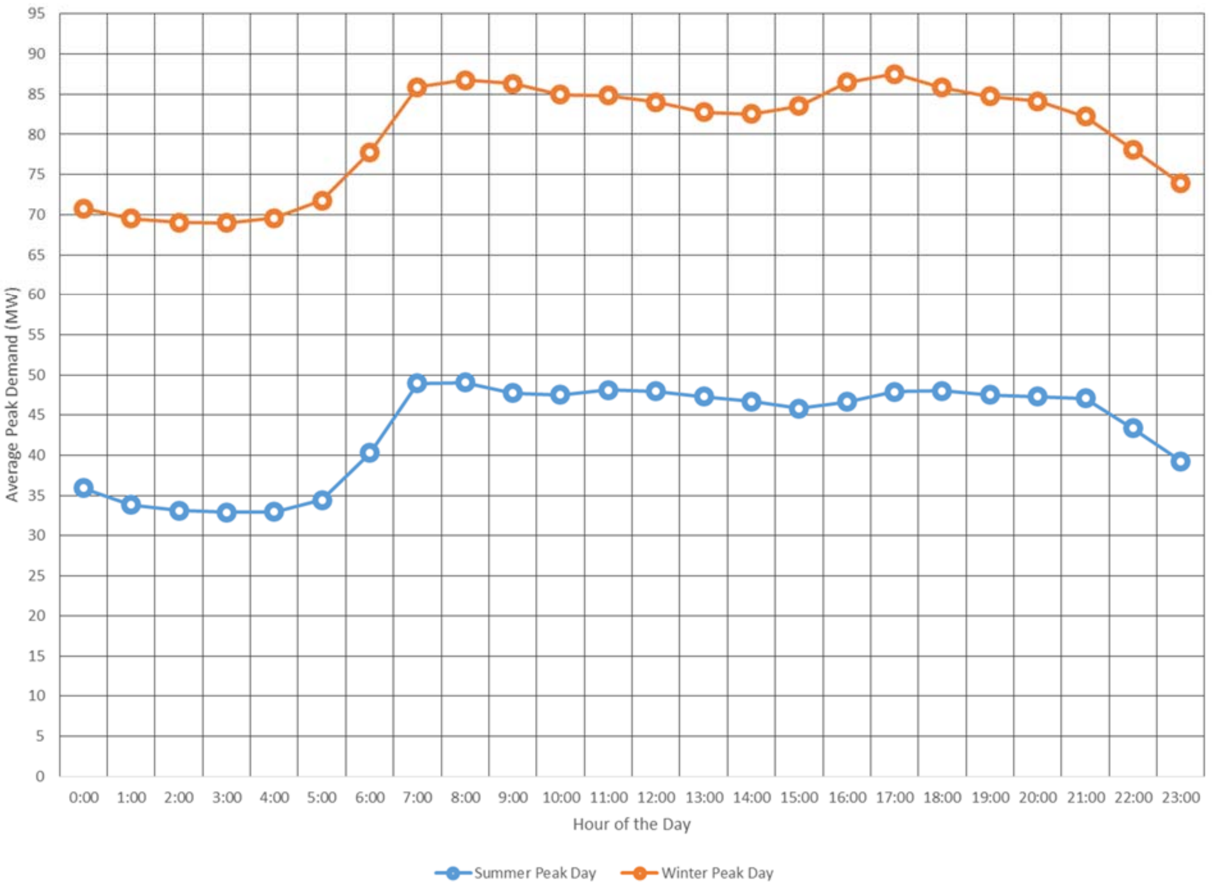
YEC's generating capacity can be broken down as follows: 92 MW are provided by hydro facilities in Whitehorse, Mayo and Aishihik Lake (40 MW at Whitehorse, 37 MW at Aishihik and 15 MW at Mayo), 31 MW by diesel generators (which are currently used only as backup), 9 MW by liquefied natural gas (also backup) and less than 1 MW by a wind turbine located on Haeckel Hill near Whitehorse.

Non-controllable factors, such as water inflows, demand variability, and demand growth have a significant influence on YEC and its planning. These factors influence YEC's strategies, with a key planning objective of the corporation being the minimization of potential negative impacts. Additional uncertainties include market prices for commodities, interest rates and foreign exchange rates. Variability of water inflows is a key consideration in YEC's future plans. YEC's electricity generation can meet current demand almost exclusively with hydro-generated power. However, the short and long-term uncertainty inherent in hydrology presents a fundamental planning risk to YEC.

Another key planning risk is the potential for electricity demand growth, which is driven by population gains and economic expansion. A single new large industrial customer (such as a new mine) could cause a significant increase in YEC demand (10% or more), over a relatively short timeframe. Mineral prices have a major impact on the Yukon mining sector, with exploration, production and development activities all positively or negatively impacted. This industry has a major secondary impact on territorial employment, economic development, government revenues and ultimately population. YEC must consider this uncertainty in this Plan, by analyzing and developing contingencies for a range of possible and plausible scenarios. The area of long-term demand growth uncertainty is covered in extensive detail in the Load Forecast section of Chapter 4.

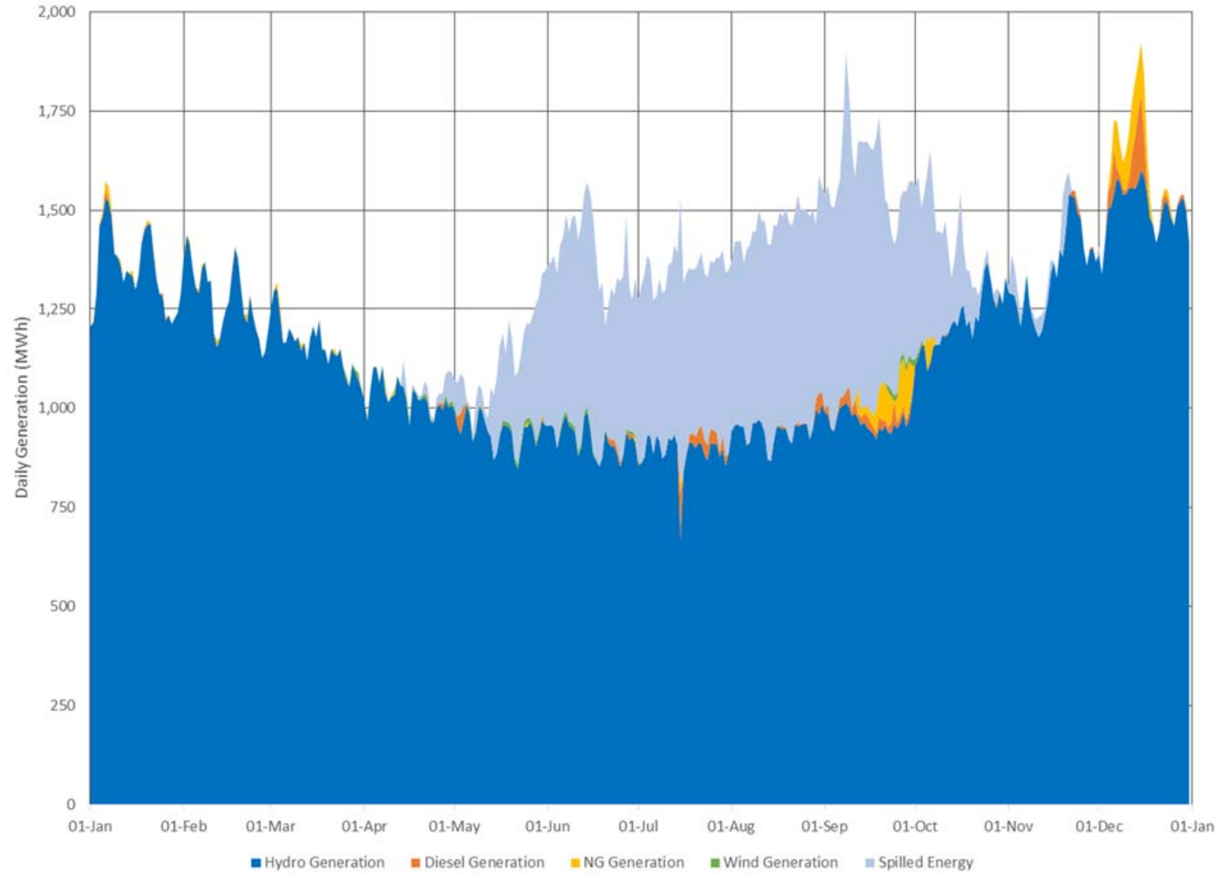
YEC faces challenges from both seasonal and daily fluctuations in electricity demand. Yukon's electricity demand typically peaks during cold winter days, over suppertime, driven by space heating, lighting and cooking demands. During the winter peak periods, YEC must often rely on thermal generation to fill the gap between available hydro-based energy generation and the demand. In the late spring and summer months, particularly during the freshet (snow melt runoff), the demand for power drops to a little more than half of the winter demand, partly due to lower space heating and lighting requirements. Figure 2-2 shows typical winter and summer peak day load.

Figure 2-2: Typical Winter and Summer Peak Day profile



YEC typically has more water available during the summer than is required to meet customer demands. This extra water refills its hydro reservoirs and ultimately leads to spilled water, mainly at Whitehorse. The seasonal mismatch between potential electricity production from hydro generation and the timing of maximum customer demands is a key planning constraint for YEC. Figure 2-3 shows the seasonal load variations and spilled hydro generation.

Figure 2-3: Seasonal Load Variations and Spilled Hydro Generation (2016)



These constraints, and the resulting value of storage to capture spilled unused hydro resources, will be discussed in detail in the Resource Options and Portfolio Analysis chapters, Chapter 5 and Chapter 8, respectively.

In addition to the seasonal mismatch between winter demand and winter supply, electricity demand in the Yukon is highly variable, and changes considerably over the course of a day and the year. Not all sources of electricity generation can respond these demands. Apart from environmental and cost attributes, electricity generation has specific performance attributes, which can be summarized as follows:

- Dispatchability;
- Curtailability; and
- Firmness.

YEC depends on dispatchable generation, or sources of electricity that can be quickly turned on to meet increasing demands. YEC has dispatchability with its large hydro generation, and also with its thermal generation (diesel or natural gas). The degree of dispatchability varies with the type of generation, in general the faster the start-up and ramp-up speed, the more valuable is the generation in terms of meeting variable demands.

YEC also requires curtailability, or the ability to stop or ramp-down supplies in response to dropping demand. This drop could be in response to regular, predictable patterns (such as falling demand in the spring, or at nighttime), or sudden outages in large commercial or industrial sector loads. Again, the faster the response and greater the flexibility, the greater the value of the generation in meeting variable demands.

A critical requirement of electricity generation is firmness. This attribute refers to the ability of the generation to maintain output with a high degree of reliably. The opposite is intermittency, which refers to electricity supply that is not continuously available due to an external factor (e.g., not enough wind velocity or solar radiation). Hydro generation is subject to the variations of water supply. In general the larger the upstream water storage, the more firm the hydro generation output. Small hydro generation is particularly vulnerable to winter freeze-up. Thermal generation (diesel and natural gas) is generally highly firm. No generation is absolutely firm, as all subject to some degree of outages due to planned and unplanned maintenance.

Creating diversity in intermittent generation adds some degree of firmness. That is, adding small hydro to solar and wind generation increases the firmness of the overall generation portfolio. This strategy works best in a large grid with a diverse range of generation types and locations.

2.3 Demand Side Management

Another important way of meeting future electricity demands is through Demand Side Management (DSM). This involves using incentives, rate structures, building and appliance codes and standards to encourage customers to reduce the amount of electricity they use. This could have the benefit of avoiding or delaying the construction of new electricity generation. DSM is often less expensive and has a lower environmental impact than the construction of new electricity supply infrastructure to meet growing load. However, DSM is relatively new to YEC, and the size and breadth of current programs are relatively small. Another limitation of DSM is that capacity savings (to lower the peak) are more challenging to execute than energy savings. That is because capacity DSM savings would have to be dependable at the time of YEC’s peak demand.

YEC and ATCO Electric Yukon jointly operate a DSM program called inCharge[1] that provides rebates and electricity savings kits. More detailed information on YEC’s DSM options and efforts is available in Chapter 5.

2.4 Secondary Sales

As indicated previously, during the summer, YEC has the ability to produce more electricity than is strictly required by its customers. To take advantage of the economic and environmental potential of this surplus hydro power, YEC has developed a Secondary Sales Program.

This program gives eligible Yukon businesses the option of using hydro power to heat their facilities instead of diesel fuel or propane, both of which are more expensive and produce greater GHGs than YECs hydro-based power. A key stipulation is that the businesses existing heating system must be

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[1] www.inchargeyukon.ca

maintained and fully operational so that it can be re-activated if surplus hydro power is no longer available. The secondary electric heating system thereby becomes a dispatchable source of electricity demand for YEC. The Secondary Sales Program helps customers save 10 per cent or more on heating bills.

2.5 Rate Considerations

The adoption of time-of-use (TOU) rates is being studied by YEC and ATCO Electric Yukon. Under typical TOU schemes, customers would be charged more for the power they use during peak times, and less for off-peak times. As such, TOU may help shift the pattern of electricity demand with the intention of shifting electricity demand away from the seasonal and daily peaks. If successful, this would cut down on the amount of non-renewable power YEC needs to generate.

2.6 Transmission Considerations

The Yukon is an ‘Islanded grid’. Most other areas of the North American continent are part of a large electricity system that connects power producers and consumers through a series of transmission and distribution wires, supplied by numerous electricity generation facilities. For example, the Western Electricity Coordination Council (WECC) region covers Alberta and British Columbia, the Western US (largely west of the Rockies), and into Baja Mexico. This grid is electrically synchronized, and power generated in one part of the WECC region can reach another part of the grid at the speed of light. But the Yukon is not a part of the WECC or any other system. It needs to be self-sufficient, which imposes challenges when it comes to maintaining and planning for the electricity needs of the Territory.

The key challenge is that the Yukon must produce all of its own power. Unlike the WECC and the other connected grids on the continent, YEC cannot depend on adjacent jurisdictions to provide backup electricity. The Yukon cannot generate more electricity than is required as there are no neighboring markets into which to sell surplus electricity. This constraint holds true over every timeframe and the supply of electricity in the Yukon must match the demand not just yearly and daily, but on an instantaneous basis. In addition to self-sufficiency, the integration of significant amount of installed capacity of intermittent resources poses a challenge to YEC. The nature of the Yukon grid places a cap on the absolute amount of installed capacity of intermittent resources that can be integrated without incurring additional backup (storage) costs.

Islanding imposes financial costs to YEC ratepayers. The requirement for total self-reliance creates higher costs, relative to connected systems, due to the need for additional backup infrastructure. Islanding also invokes financial risks to Yukon ratepayers. The inability to export excess electricity makes it risky to build/generate electricity in anticipation of increased demand, as this future demand may not materialize in Yukon’s commodity-dependent economy. And, in the event of unexpected demand growth, the Yukon cannot simply import electricity, making growth in local generation capacity crucial to future economic and population growth.

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3 Engagement with Yukoners

This chapter provides details on the following aspects of the stakeholder engagement for the 2016 Resource Plan:

- A description of the engagement goals;
- Details of the engagement timelines and streams;
- Details about and results of the Electricity Values Survey;
- Information about the engagement methods, and the materials used;
- Key learnings of the 2016 Resource Plan as shared with Yukoners; and
- A summary of consultation input received, YEC's response to the inputs, and how these inputs were incorporated into the Plan.

3.1 Goals

The goals of YEC's engagement with First Nations (FN), stakeholders, and the public during the preparation of the 2016 Resource Plan were:

- To ensure openness and transparency at every stage of the process; and
- To substantively incorporate the ideas, suggestions and values of Yukoners from every part of the territory representing many different viewpoints related to resource planning.

The steps by which these goals were achieved are detailed in the following sections.

3.2 Electricity Values Survey

A key element of the stakeholder engagement in the Resource Plan was the completion of an electricity values survey. The goal of the survey was to gain information regarding Yukoners' preferences with respect to potential future electricity generation in the territory. The survey also sought to understand Yukoners' preferences and values relating to energy use. The survey results helped YEC to analyze portfolios and create the Action Plan.

3.2.1 Methodology

YEC worked with the consulting firm ICF International and the Yukon Bureau of Statistics to design the survey during the late winter and spring of 2016. The Bureau of Statistics conducted the survey via telephone during the months of May and June and analyzed the results over the summer of 2016.

A stratified random sample of more than 4,500 Yukon households was selected to complete the survey. This sample represented approximately one-third of all Yukon households, and is considered statistically to be a very robust sample size.

The Bureau used standard statistical practices to ensure representative, unbiased, scientifically measurable data.

Respondents were asked to provide input in four thematic areas related to the development of new sources of electricity:

- Environment protection;
- Cost;
- Reliability; and
- Social responsibility.

These themes aligned with the attributes considered during the portfolio analysis portion of the resource plan work.

The response rate to the survey was 63.2 percent, which, according to the Bureau of Statistics, provides reliable and reprehensive survey results.

The refusal rate was 10.2 percent, which according to the Bureau of Statistics is not an unexpected number given that this survey required a fair amount of thoughtful input.

3.2.2 General Findings

The full values survey report is presented in Appendix 3.1. The general findings were:

- Respondents ranked four major factors in order of importance to YEC's future projects. Environmental Protection was ranked first by 44 percent of respondents, followed by Cost (23 percent), Reliability (21 percent), and Social Responsibility (8 percent).
- Respondents ranked statements on Environmental Protection in order of importance. 'Reduce pollution to land, water, and air, other than greenhouse gas emissions' was ranked first by 30 percent of households, followed by 'Reduce impacts on species' habitats and wildlife populations at risk' (24 percent), and 'Reduce impacts on Earth's atmosphere' (23 percent). 'Minimize the amount of land affected by a new energy project' was ranked last (12 percent).
- While Social Responsibility was ranked fourth of the four major factors, a question asking respondents to rank statements relating to social responsibility revealed that one-third of Yukon households ranked 'Enhancing economic growth and creating jobs' as the most important social responsibility.
- In contrast to the importance allocated to YEC's projects, cost was the most important factor (chosen first by 45 percent of respondents) influencing the selection of respondents' own home heating system. Respondents' selection of home heating system was more influenced by cost than by all four of the other factors (safety, environmental concerns, comfort, and ease of maintenance) combined.
- When asked if they would support specific YEC initiatives even if it meant a potential increase in electricity rates, respondents answered 'Yes' to the following:
    - An effort to reduce impact on species' habitats and wildlife populations at risk (81 percent)
    - An effort to reduce GHG emissions in energy production (78 percent)
    - An effort to create local jobs (73 percent)
    - An effort to maintain access to wilderness recreation (73 percent)
    - An effort to reduce power outages in your area (71 percent)
    - An effort to not compromise traditional pursuits as a way of life (69 percent)
    - An effort to enhance economic growth for Yukon (57 percent)
    - A decision to supply electricity to mines (46 percent)

- In ranking three energy sources in order of preference for Yukon's future, 59 percent of the responding households chose renewable energy as their preferred future energy source, 31 percent preferred energy conservation as a future energy source, while only 5 percent preferred fossil fuels as a future energy source.
- If YEC is required to choose a fossil fuel for future back-up generation, slightly over half of Yukon households (51 percent) would prefer the use of natural gas. Only 14 percent would prefer diesel fuel.

- Fuel oil is the most prevalent primary home heating source used by 47 percent of responding households. Electricity (baseboard, furnace or boiler) is the second most prevalent primary home heating source and is used by 25 percent of responding households. Of those who did not already use electricity as a primary or secondary home heating source, only 18 percent had considered switching to electric heat.
- Forty one percent of responding households do not have a secondary home heating source. Of households that did have secondary home heating sources (59 percent), wood was the most common (36 percent), followed by electricity (31 percent). While fuel oil was the most commonly used primary source of heat, it was not commonly used (13 percent) as a secondary home heating source.
- A little over three-quarters of the respondents (76 percent) said their electricity bills are affordable, while 55 percent thought Yukon's current electricity rates are reasonable. Almost all respondents (97 percent) claimed they make efforts to reduce their energy use. However, a little over three-quarters (77 percent) of respondents said they 'always' or 'frequently' check the energy efficiency rating when purchasing a new appliance or electronic device.
- Eighty five percent of all households experienced at least one power outage in 2015. About two-thirds of the households felt it necessary to have back-up heating and/or a generator in case of power outages.
- Most (61 percent) respondents were confident that YEC is able to plan and develop sustainable energy sources to meet future needs. About a fifth (19 percent) of the respondents said that that they do not have confidence in YEC's abilities in this regard.

3.2.3 Major Survey Conclusions

Based on the survey results, YEC draws the following major conclusions:

- Environmental protection is the most important value to Yukoners, followed by cost, reliability and social responsibility.
- Pollution of land, water, air is of greatest concern to Yukoners. Wildlife protection is close second, closely followed by GHG emissions in third place.
- There is low support among Yukoners for fossil fuels as a generation source, but if thermal is needed for back-up, LNG is preferred to diesel.
- There is high support for and awareness of energy conservation.
- Yukon electricity bills are affordable, although not necessarily reasonable.
- Yukoners would support higher rates to protect the environment; but not necessarily to connect mines.

3.3 Engagement Phases

As part of the process for finalizing the engagement strategy for the 2016 Resource Plan, YEC met with the Chair of the Council of Yukon First Nations and several chiefs in September 2015, to seek their input.

The key message from the First Nation leadership was that YEC should engage with First Nations as governments, and as potential energy partners, and as members of the Yukon public. First Nation leadership advised that YEC should not single out First Nation citizens for separate engagement, but include them with all other members of the Yukon public. This is important context in interpreting the Summary of Engagement results presented in Table 3-4. Most of the comments received from First Nation Yukoners were included in the 'Public' category as opposed to the 'First Nation' category. Input was only included in the ‘First Nation’ category if it came specifically from a First Nation government or development corporation.

The overall engagement program was completed in four main phases, each related to a key element of the 2016 Resource Plan:

- Load forecast (October 2015 – May 2016);
- Resource options (June – November 2016);
- Portfolio analysis and Action Plan (December 2016 – February 2017); and
- Draft plan (March 2017).

3.4 Engagement Streams

YEC worked in three parallel streams throughout the resource planning phases, as this was felt to be the most effective way of engaging with all the Corporation’s key audiences. Those streams are:

1) Technical Advisory Committee (TAC);
2) First Nations; and
3) Public.

3.4.1 Technical Advisory Committee

The TAC was made up of representatives from a broad range of Yukon groups, including business, mining, government, First Nations, non-governmental organisations, and utilities. Specifically, the following groups were represented on the committee:

- The Council of Yukon First Nations;
- Yukon Conservation Society;
- Yukon Chamber of Commerce;
- Yukon Chamber of Mines;
- Yukon Development Corporation;
- Yukon Government’s Energy Branch;
- Yukon Housing Corporation;
- ATCO Electric Yukon (ATCO);
- Yukon Government’s Water Resources Branch;
- A renewable energy advocate; and
- An independent resource planning expert from BC Hydro.

Engagement with the TAC took the form of five face-to-face meetings held from September 2015 to January 2017. Information was also shared via email and an interactive website developed specifically for the resource planning process. The purpose of the meetings was to share progress at regular intervals, and seek advice and feedback on a technical level.

Table 3-1 provides general topics discussed in the TAC meetings. The details related to questions raised at TAC meetings and YEC’s responses are presented in Table 3-4.

Table 3-1: General Topics Related to TAC Meetings

Dates	Focus	Notes
Sep 11, 2015	• Introductions • TAC Terms of Reference • Load Forecasting Framework	• Much of the discussion centered on the forecasting of economic activity that can affect growth of electrical consumption.
Feb 11, 2016	• Economic and load forecast results • Environmental, social and economic attributes methodology • Review of draft values survey	• Discussion points included electric vehicle penetration in Yukon and fuel switching for home heating retrofits from fossil fuels to electricity. • There were a number of suggestions for wording of the Yukon-wide values survey. • The TAC suggested conducting a life cycle analysis of greenhouse gases for all the resource options.
Aug 5, 2016	• Environmental, social and economic attributes methodology (continued from February meeting) • Life cycle analysis of GHGs • Resource options	• There was a discussion related to the results of the electricity values survey and possibility of assigning weights to the environmental, social and economic attributes to help with resource comparison, as well as the results of the life cycle analysis of GHG's.
Sep 28, 2016	• Load Resource Balance	• Discussion pointed out the gap between the future needs for energy and capacity and current capabilities. The capacity gap was presented as an urgent need to be addressed.
Jan 13, 2017	• Portfolio analysis • Action Plan	• The TAC was generally accepting of the Action Plan, but pointed out that YEC may need to revisit its plan in light of potential new Yukon government policies.

3.4.2 First Nations

As mentioned earlier in this chapter, YEC contacted the Grand Chief of the Council of Yukon First Nations during the engagement planning to discuss how First Nations would like to be involved in the 2016 Resource Plan process. YEC met with the Grand Chief and several other First Nation Chiefs in September 2015 to seek their input.

The First Nation leadership advised YEC to engage with First Nations as governments, and as potential energy partners/investors, and as members of the general Yukon public.

Subsequently, engagement by YEC took the form of face-to-face meetings with representatives of Yukon First Nation governments, and/or the sharing of information via email or telephone.

At the beginning of each round of engagement, YEC contacted First Nation governments in those communities where the Corporation planned to hold public meetings. First Nations offices were consulted about public meeting dates that would work for First Nation government schedules, and offers were made to have separate meetings with Chiefs and Councils ahead of the public sessions.

Customized presentations and information materials were prepared to highlight issues of special interest to various Yukon First Nations. For example, during the fall of 2015, when YEC was hiring contractors to carry out various studies related to the Resource Plan, it provided the Request for Proposals (RFP) advertisements to all First Nations on whose traditional territory the research would be conducted. In the fall of 2016, YEC prepared maps of all the potential energy projects considered, by First Nation traditional territory. These maps were posted on YEC's website and were provided to individual First Nations.

First Nation governments received personalized invitations to any public meetings in their traditional territory. Where possible, First Nations were provided with materials prepared for the public in advance.

As potential energy partners, a First Nations representative selected by the Council of Yukon First Nations was invited to be a member of the Technical Advisory Committee. While that representative was not able to attend any of the TAC meetings in person, he was offered a one-on-one briefing on the entire process after the final TAC meeting.

As with members of the Yukon public, First Nations citizens attended and participated in public meetings, where they asked questions and expressed options regarding specific interests. For example, there were questions related to projects on First Nation's territories, and Independent Power Producer opportunities. First Nations, as with the Yukon public, were also engaged through the resource planning interactive website, social media outreach, the Electricity Values Survey, four mailers sent to every Yukon household, emails, and phone calls.

It should be noted that the 2016 Resource Plan does not seek approval of specific future projects, but has a strategic focus that addresses YEC's long-term requirements and lists potential projects to meet those requirements. YEC will engage directly with those First Nations on whose traditional territory specific potential projects exist, as part of future planning work undertaken on those potential projects. Table 3-2 provides details related to FN engagement.

Table 3-2: Details Related to First Nation Engagement

Dates	**Focus**	**Notes**
Sep 2015	Meeting with Grand Chief of the Council of Yukon First Nations and several other FN chiefs to discuss how they wished to be engaged through the 2016 Resource Planning work.	• Yukon First Nations are to be consulted as governments, as potential energy partners/investors, and as members of the Yukon public.
Nov 2015	Keeping First Nations informed.	• Yukon First Nations were provided copies of all YEC's RFP ads that went out seeking contractors to do research on potential energy options.
Nov 2015 – Feb 2017	Keeping First Nations informed.	• Yukon First Nations were provided with all mailers and information pieces prepared to keep Yukoners updated on the resource planning process.
Nov 2015 – Feb 2017	Keeping First Nations informed.	• Yukon First Nations were consulted on public meeting dates and received personalized invitations to the public meetings. • Offers were made to have separate meeting with Chiefs and Councils.

Dates	Focus	Notes
		• In cases where YEC has regular meetings with a First Nation, the 2016 Resource Plan was always on the agenda. • On several occasions, YEC's President and Vice-President met with representatives of the Carcross-Tagish First Nation, Kwanlin Dun First Nation, and Little Salmon/Carmacks First Nation to brief them on the 2016 Resource Plan.
Nov 2016	Keeping First Nations informed.	• Yukon First Nations were provided with maps showing, by traditional territory, all potential projects being considered by YEC.

3.4.3 Public

A key element of YEC's engagement with the Yukon public was through public meetings, to present data and solicit feedback from the public. Three rounds of public meetings were held, with each round taking place in six Yukon communities: Whitehorse, Dawson City, Mayo, Teslin, Carcross and Haines Junction. These communities were chosen based on population, connection to the Yukon grid, and proximity to potential energy projects. A request from the Town of Faro resulted in a public meeting taking place in that community in February 2017.

In addition to these public sessions, in late February 2016 YEC staff gave classroom presentations to six F.H. Collins High School classes, and led a visioning exercise aimed at helping the students understand what is involved in creating a 20-year Resource Plan and how they could be involved in that planning.

Once the draft resource plan was completed in February 2017, YEC invited the public to review the report that was posted on the resource plan website and to provide their comments directly on the interactive website, via email, social media, by phone, or a face-to-face visit.

The public comments were considered in the final version of the Plan.

Throughout each phase, the Yukon public was informed and engaged through the interactive resource planning website, social media, Electricity Values Survey, four mailers sent to every home in the territory, phone calls, and emails. Table 3-3 provides details related to the public meetings.

Table 3-3: Details Related to Public Meetings

Dates	Focus	Notes
<u>Round 1</u> Feb 29 – Mar 17, 2016 Meetings with Yukon public, high school students	• Load Forecast	• Purpose was to help Yukoners understand what is considered when forecasting future electricity demands - under a range of scenarios over a 20-year period.
<u>Round 2</u>	• Energy options • Results of values survey	• Purpose was to share results of the research on 14 supply options and show how YEC evaluated each of them against the other using a consistent set of criteria.

Dates	Focus	Notes
Nov 22 – Dec 1, 2016 Meetings with Yukon public		- YEC demonstrated how it would incorporate the values survey results into its choice of supply options.
Round 3 Jan. 30 – Feb. 16, 2017 Meetings with Yukon public	- Portfolio analysis - Action Plan - Key learnings	- Purpose was to share best combinations of supply options to meet both energy and capacity needs under various scenarios and present the key learnings of the process.

YEC's public presentation for Round 1 was recorded and posted on YouTube for those who could not attend the sessions. https://www.youtube.com/watch?v=f7j4NZaXVlQ

3.5 Engagement Methods

Considering the complexity of the Plan, as well as the diverse interests of First Nations and the general public, YEC employed multiple methods in each phase of the resource plan to inform and engage Yukoners. Those methods included:

- Electricity Values Survey;
- Meetings with First Nations, the general public and Technical Advisory Committee;
- Mailers to all Yukon households;
- Information sheets provided at the public meetings as take home material;
- Newspaper infomercials that provided electricity literacy;
- Newspaper and radio ads notifying Yukoners about public meetings;
- Discussion paper used with six classes of F. H. Collins High School students to introduce the idea of resource planning;
- Posters displayed at various public locations in Dawson, Mayo, Haines Junction, Carcross, Faro, and Teslin notifying Yukoners about public meetings;
- E-invite notification to Yukoners, including First Nations, about public meetings;
- Social media (YEC blog, Facebook, LinkedIn);
- Resource planning website: regular updates on resource planning work, notification of public meetings, and two-way conversations with Yukoners sharing information, ideas and opinions;
- Electricity Values Survey to gather Yukoners values related to electricity;
- Maps showing potential energy projects by Yukon First Nations' traditional territories;
- Briefings to political parties and government representatives; and
- Draft Resource Plan offering the public an additional opportunity to provide feedback before the final resource plan document was made public.

The details on the communication methods and engagement goals associated with each phase of the engagement process are presented in Appendix 3.2.

3.6 Engagement Conclusions

YEC recorded all the input from First Nations, the Technical Advisory Committee, and the public throughout each engagement phase. Table 3-4 summarizes details of the public input, YEC's immediate response, and how the input has been reflected in the 2016 Resource Plan, with a reference to the specific chapter where each issue is addressed. As presented in Table 3-4 while YEC received broad range of comments throughout the resource planning process, the following viewpoints were commonly expressed during the engagement process:

- Members of the public commented that YEC had completed a thorough job in preparing the 2016 Resource Plan and that they appreciated the fact that most of this work was completed in-house as opposed by outside consultants;
- Yukoners said they learned a lot and now feel they have a better understanding of the challenges faced by those doing the resource planning;
- First Nations governments expressed appreciation at having received information at regular intervals about the resource planning work, and appreciated the sensitivity shown by YEC to potential projects within First Nation traditional territories;
- When considering new energy options, environmental protection is most valued by Yukoners, followed by cost, reliability, and social responsibility;
- Pollution of land, water, air is of greatest concern to Yukoners. Wildlife projection is close second, closely followed by GHG emissions in third place;
- There is high support for energy conservation/efficiency measures;
- While the Electricity Values Survey indicated low support for the use of thermal resources, most Yukoners understood why YEC is proposing thermal for back-up (capacity);
- Yukon electricity bills are affordable, although not necessarily reasonable;
- Yukoners would support higher rates to protect the environment; but not necessarily to connect mines;
- Yukoners are pleased that under the Action Plan proposed by YEC, between 92 – 99 percent of the average annual power produced would be renewable;
- Yukoners are supportive of the Social Cost of Carbon being included in the evaluation of resource projects;
- Several smaller energy projects are preferred over one large energy project;
- There is interest in energy self-sufficiency among a number of rural Yukon communities;
- There is broad interest in a variety of energy technologies;
- There appears to be strong support for wind and solar resources;
- It is important to diversify the sources of energy and not just rely on hydro and thermal; and
- YEC should pursue Time of Use Rates and smart meter/grid technology.

Table 3-4: Summary of Yukoner's Input to 2016 Resource Plan: Sep 2015 – Mar 2017

Note: In speaking with Yukon First Nations in the fall of 2015 regarding how they wished to be involved in the resource planning work, YEC was asked to engage with them as governments, potential energy partners, and members of the Yukon public. There was a desire that YEC not single out First Nation citizens for separate engagement, but include them with all other members of the Yukon public. To this end, most of the First Nation comments recorded in this summary are shown in the 'Public' section. Only if it was clear to YEC that the comment/question was coming from a First Nation government or development corporation representative was the input recorded in the 'First Nation' category.

Sept. 2015 - Preliminary Engagement (Discussions with First Nations) Topic: Approach

	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
First Nations	• YEC approached and met with the Chair of the Council of Yukon First Nations, along with several chiefs, to seek input about the engagement process for the 2016 Resource Plan. Key take-away was that First Nations should be engaged at three levels: as governments, potential business partners/investors/IPPs, and as members of the Yukon public.	• We will process with our engagement based on this premise.	• First Nation governments were kept updated throughout the process and their options sought on various issues. • A First Nation representative was chosen by the Council of Yukon First Nations to sit on our Technical Advisory Committee for this project. • First Nation citizens were notified about the public meetings that took place throughout this process. • Maps were prepared and shared with First Nations and the public that showed all potential projects, sorted by traditional territory.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Climate Change

	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• Yukon will need to change as a result of the Paris conference and the new federal government's priorities regarding climate change. Will YEC run scenarios that consider policies that do not current exist but will likely be created as a result of the Paris conference?	• We will certainly consider this.	• YEC considered energy portfolios with and without the social cost of carbon, as presented in Chapter 8.
	• Has YEC considered the cost of carbon when doing the load forecast?	• We are looking at this as part of the portfolio analysis.	• YEC considered energy portfolios with and without the social cost of carbon, as presented in Chapter 8.
	• Does the load forecast take into account environmental refugees from global warming?	• The model does not consider climate change refugees within the population forecast. The model uses migration to fill the gap that can't be met by the local labour force .	• At this moment in time, the issue of environmental refugees could not be forecast with sufficient accuracy. If it becomes more imminent it will be reflected in the updated load forecast and future resource plans.
First Nations			
Technical Advisory Committee	• YEC should take into account that people may move here as environmental refugees.	• The model does not consider climate change refugees within the population forecast. The model uses migration to fill the gap that can't be met by the local labour force.	• At this moment in time, the issue of environmental refugees could not be forecast with sufficient accuracy. If it becomes more imminent it will be reflected in the updated load forecast and future resource plans.
	• Did YEC consider a carbon tax in its calculations?	• YEC is looking at including a social cost of carbon as part of the portfolio analysis.	• The social cost of carbon was considered in the portfolio analysis, as presented in Chapter 8.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Government Policy

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• Could you run a scenario where you have been instructed by government to reduce your fossil fuel use by 20 percent: what would that look like? • Could YEC create portfolios that assume different policy i.e. COP GHG reduction commitments? • Who sets direction – YEC or Yukon government?	• We can see if this is possible. • YEC will analyze the impact of the social cost of carbon as part of the portfolio analysis • YEC must follow government's framework (i.e. Energy Strategy, etc.) but government does not tell us on a day to day basis what to do.	• YEC presented both mixed portfolio that consisted of renewable and thermal resources, and one with no new thermal resources in the future, as presented in Chapter 8. • The social cost of carbon was considered in the portfolio analysis, as presented in Chapter 8. • The 2016 Resource Plan was prepared without specific direction from the Yukon government, although YEC abided by direction set out in the Energy Strategy and existing government energy policies, as presented in Chapter 1.
First Nations			
Technical Advisory Committee	• How much is the load forecast/resource plan trying to predict future government policy? • It is important for government policy to address bringing forward a plan that is best for Yukon and not necessarily the cheapest possible option.	• Only those policies that have been announced for the near term, such as the Independent Power Production (IPP) Policy will be addressed. It is very difficult to predict future policies. Energy allocation will be made for the IPP Standing Offer Program. In addition, some of the future resource options might be developed by IPP. • This plan looks at not just financial, but also technical, environmental, socio-economic, plus will incorporate what we learn through the values survey.	• The portfolio analysis included the Standing Offer Program as a part of the Yukon Government's Independent Power Producer Policy as presented in Chapter 4. • The resource plan did not consider just the costs. The objective of the plan was to provide cost effective solutions that are environmentally friendly and socially acceptable.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Mining

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• You should consider planning for a longer period of time (60 years) to better capture fluctuations in the mining industry. • How are mining rates set? Who sets rates? • Mines suck up all the available power. Could they not be forced to generate their own power? I don't want to subsidize the mines	• The mandate of our resource plan is to consider the loads over the next 20 years. The load forecast accuracy is reduced for longer forecast periods. The resource plan is not a static document. It gets updated every five years to reflect changing conditions/loads. • Mining rates are set based on the cost of service. Two utilities present Yukon Utilities Board with a proposal and the YUB sets/approves rates. • It is always a balancing act: we have an obligation to serve, but that can't mean substantial increases for other ratepayers.	• The 2016 Resource Plan considered a 20-year planning period, which is a typical planning horizon considered in the industry. • Setting up electricity rates is outside the scope of the resource plan • The 2016 Resource Plan considered connecting some mines to the grid, as presented in Chapter 4. The objective of this resource plan is to provide cost effective resources for all our customers, including industrial ones.
First Nations			
	• It is important to service mining loads with renewably produced electricity to reduce GHG emissions.	• The portfolio analysis will provide answers about how much energy will be needed at what point in time to meet potential mining loads. Considering the competitive price of renewable energy, it is expected	• The portfolio analysis answered the questions about how much energy will be needed at what point in time to meet potential mining

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Mining

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Technical Advisory Committee		that the mining load will be met in large part at least by renewable resources.	loads. The portfolios are strongly weighted towards the use of renewable resources, as presented in Chapter 8. .
	• Consider a boom and bust cycle in mining activity as part of the load scenarios.	• We will do that.	• The resource plan considered this industrial activity scenario, and the associated load was presented in Chapter 4.
	• Use the medium mining scenario for base case.	• We will do that.	• The medium mining scenario was used for the base case in the resource plan, as presented in Chapter 8.
	• Would YEC proactively build infrastructure to serve a mine?	• YEC would not build new generating assets with an expectation that a mine may or may not come online.	• The resource plan does not advocate building any new generating assets assuming a mine may come online.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Fuel Switching (home heating)

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• YEC should include wood heat when looking at home heating. Many homes might switch from furnace oil or propane to a renewable source.	• YEC's mandate is to provide electricity. Space heating is not part of our mandate.	• The resource plan focused on providing electricity. It did not consider options for space heating. YEC did analyze the fuel switching for space heating from oil/propane/biomass to electricity and concluded that there was not business case for the switch, as presented in Chapter 4.
	• You should include a question on your survey about what people are currently using to heat their homes and if they would be willing to switch to electric.	• We will consider this.	• This question was included in the Electricity Values Survey.
	• If I switch to electric heat to try to get off fossil fuel, I am penalized by having to pay Tier 2 and 3 rates. Not fair.	• Thank you for your comment. Rate design is not something we can address in our resource plan.	• The issue of rate design is out of scope for the resource plan
	• There don't seem to be very many incentives to build SuperGreen or energy efficient housing.	• The Yukon government can provide details about their programs.	• This resource plan addressed energy conservation and efficiencies through Demand Side Management, as discussed in Chapter 5.
First Nations			
Technical Advisory Committee	• There seems to be a trend to switch to propane from oil, but not a lot to electric.	• YEC conducted a study to estimate fuel switching in space heat. Electricity was more expensive than the fossil fuels even when the social cost of carbon was considered. Electricity was more expensive than the fossil fuels even when the social cost of carbon was considered. A sensitivity analysis showed that the impact on load forecast would not be significant even if 10 percent of existing homes would switch from fossil fuels to electricity for space heating.	• As part of the work on the resource plan, YEC conducted a study to estimate fuel switching in space heating. Results showed there would be very little impact on load over the next 20 years, since there was no business case for switching, as presented in Chapter 4.
	• Overall the group can accept a sensitivity scenario of 10 percent of older homes switching to electric.	• Thank you for the feedback	• The load forecast reflected the fact that there would likely be only a small percentage of Yukoners in older homes switching to electric heat as presented in Chapter 4.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Attributes and Values Survey			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• Will the survey ask about technical and financial attributes?	• The survey will focus more on environmental and social attributes, although there will be some questions about affordability of power.	• The Electricity Values Survey and its results are included as an appendix to the resource plan as a part of Chapter 3.
	• You should consider an attribute that talks about whether a project would have a direct or indirect impact on settlement lands (later clarified to say an attribute not necessary but this is something that should be considered when choosing energy options).	• We will do that.	• First Nation land was one of the attributes considered in evaluating energy options as presented in Chapter 5.
First Nations	• I am concerned the survey was developed without input from First Nations and communities.	• The Bureau of Statistics will use a stratified random sample that represents one-third of total eligible Yukon household, both in Whitehorse and the communities, and both First Nation and non-First Nation.	• The Electricity Values Survey included as a part of the resource plan used standard practices to ensure representative and unbiased data. It targeted one-third of Yukon households, as presented in Chapter 3.
	• I am concerned the phone survey will only allow people with phones to give their views. What about people without phones?	• Bureau of Statistics says there is a very low number of people who don't have phones, but we will talk to the Bureau about how they handle this when they do other surveys	• The Bureau of Statistics assured YEC that it was able to contact enough people who had phones to ensure representative and unbiased data.
Technical Advisory Committee	• You should consider upstream GHG emissions from fuel sources in your attributes.	• We can do that, at least for fossil fuels.	• YEC conducted a full life cycle analysis for GHG emissions for all resource options, as presented in Chapter 5.
	• Consider instream flow requirements of a particular river.	• We agree this would be a good idea.	• Before any resources suggested in the resource plan are further developed, more analysis would need to be completed to confirm resource attributes.
	• Be aware and cautious of the fact we have more information on some areas or technologies than others.	• Yes, we are aware of this.	• Before any resources suggested in the resource plan are further developed, more analysis would need to be completed to confirm resource attributes.
	• How do you measure public perception as compared to reality? The public may perceive one project to be very unsafe and not perceive another project to have any safety concerns, while both projects are assessed to be equally as safe.	• This has been addressed in the environmental, social and economic attribute evaluation of the resource options.	• This was addressed in the environmental, social and economic attribute evaluation of resource options as presented in Chapter 5.
	• I would appreciate reviewing the questions to determine if the community stewards are recognized and valued. **Note that this question came after the survey was completed.*	• The Electricity Values Survey was completed earlier this year after input from Yukon stakeholders.	• The Electricity Values Survey used standard survey practices to ensure representative and unbiased data.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Specific Energy Options			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• Micro-hydro and small resource options best. They are less expensive, and might have a better chance of being permitted.	• YEC did a broad inventory of all resource options.	• For this resource plan, YEC did a broad inventory of all resource options as presented in Chapter 5.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Specific Energy Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	• You should consider what each community might be able to generate (small projects instead of one big project).	• A number of the possible resource options are in or near rural Yukon communities.	• Many of the considered resource options are located in communities. This resource plan considered economies of scale to provide affordable and reliable power, while meeting social and environmental requirements.
	• Did you consider connecting to the grid in either Alaska or B.C.?	• Yes, part of our research included the cost of connecting to other grids.	• The transmission options were considered and evaluated as presented in Chapter 5.
	• Did you consider extending the transmission line to Destruction Bay?	• Yes, we looked at that.	• This transmission option was considered and evaluated as presented in Chapter 5.
	• I agree with small scale nuclear, and small and medium scale hydro. As well, the hydro storage capacity of the Southern Lakes should be optimized.	• We looked at small hydro and storage projects. We did not look at nuclear because there are no nuclear options available on the current market that would meet our needs.	• This resource plan considers only commercially available resource that meet technical requirements in terms of energy and capacity. At this point in time there are no small commercially available nuclear options available to meet YEC's requirements.
	• Priorities should include a large scale hydro project, exploring small scale nuclear options, a connection to the (North American) grid i.e. a line south where we can both sell electricity and have redundancy when our systems fail. Possibly a line to Skagway/Juneau to sell electricity as well.	• We looked at small hydro and grid connections. We did not look at nuclear because there are no viable nuclear options available that would meet our needs.	• This resource plan considered only commercially available resource that meet technical requirements in terms of energy and capacity. Large hydro was considered at by the Yukon Development Corporation through its Next Generation Hydro project.
	• If people want solar and wind they should have to install it themselves and cover their costs, without government subsidies. Don't make the rest of us pay for it.	• Thank you for your comment.	• Wind and solar were both considered as resource options as presented in Chapter 5.
First Nations	• Wind! We have a lot of wind here in Yukon.	• We considered wind in our research.	• Wind was considered for this plan as presented in Chapter 5.
Technical Advisory Committee			

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Time of Use/Smart Meters

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• How do we get time of use rates and who sets the price?	• Utilities would go to the Yukon Utilities Board (YUB) with proposal, and YUB would set/approve rates. A time of use rate and smart meter study is planned with ATCO in 2017.	• The resource plan does not address time of use rates.
	• YEC should be planning for smart meters.	• We plan to work with ATCO in 2017 on a time of use rate and smart meter study.	• The resource plan does not address time of use rates.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Time of Use/Smart Meters

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	- We don't want smart meters.	- Thank you for your comment.	- The resource plan does not address time of use rates.
	- We need a smart grid so we can shave peaks.	- A time of use rate and smart meter study is planned in 2017.	- The resource plan does not address time of use rates.
	- Smart meters are a waste of money for residential customers. It would be far simpler to turn off hot water heaters with simple 'smart-timers' during peak demand periods like many utilities have been doing for decades. Those customers who opted into the program could be exempt from any 'fuel riders' on their bills, or other incentives could be provided.	- Thank you for your comments.	- The resource plan does not address time of use rates or smart meters.

Oct. 2015 to May 2016 - Round 1 Engagement (Load Forecast) Topic: Miscellaneous Comments

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	- The informal interview style of presentation at the public meetings was interesting and informative.	- Thank you for the feedback.	- Chapter 3 of the resource plan outlines engagement methods and timing.
	- Happy to see the resource plan being completed in-house instead of by an outside consultant.	- Thank you.	- As much of the resource plan as possible was prepared in-house.
	- YEC doesn't appear to be aggressively looking for load.	- YEC would like to grow the business, but it is difficult to encourage people to do things that don't have a business case (i.e. switching from furnace oil to electric).	- The purpose of the resource plan was to develop a plan to meet current and future loads, as opposed to looking for load.
First Nations	- There is a working group in Teslin (Teslin Tlingit Council, Municipality, Energy Solutions Centre, etc.) currently working on an Energy Strategy. We should be working together so we don't duplicate the work. Would be nice if YEC were more involved in this initiative.	- YEC is happy to share all the studies we have been completed and provide whatever support we can.	- This resource plan has been shared publicly for all to read and use.
Technical Advisory Committee			

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Climate Change

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public			
First Nations			
	- Regarding the life cycle analysis for GHG emissions for the energy options, why did you not consider downstream effects?	- The contributions were less than one percent so were not considered significant enough to be included for further analysis. Operation emissions were considered however.	- As part of the work for the resource plan, YEC conducted a full Life Cycle Analysis of GHG emissions for all resource options as presented in Chapter 5.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Climate Change			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Technical Advisory Committee	• On the same topic, were fuel extraction activities and fuel source used in the manufacturing of the parts both included in the examination of upstream effects when doing the GHG life cycle analysis?	• Yes on both counts. Also the sensitivity analysis will show the difference in choosing material from different locations such as wind turbine parts manufactured in Germany using renewable power in comparison to China using coal power.	• As part of the work for the resource plan, YEC conducted a full Life Cycle Analysis of GHG emissions for all resource options as presented in Chapter 5.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Individual Energy Options			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	<u>Demand Side Management</u>		
	• When looking at DSM, you should consider smart meters/time of use rates. This will provide additional capacity. You are the utility and you can affect change.	• We did our work on this plan based on the existing rate structure. However we are going to be working with ATCO on a time of use rate and smart meter study in 2017.	• The resource plan does not address time of use rates or smart meters.
	• How far can DSM go when the low hanging fruit is gone?	• There is still a lot we can do that is very cost effective.	• DSM was a key resource as presented in Chapters 5 and 8.
	• DSM is hard to enforce. How do you determine benefit?	• The current inCharge program has an evaluation plan that follows best practices to determine the benefit and cost effectiveness of the programs. Benefits are measured over time, as it takes time to develop a conservation culture.	• The resource plan outlined how DSM benefits grow over time as presented in Chapter 5.
	• Does DSM work to reduce peak?	• DSM does work to reduce peak. Energy DSM measures can have a coincident peak reduction and we are also looking at the feasibility of DSM measures that are specific to peak demand reduction.	• The resource plan showed how DSM can help reduce peaks as presented in Chapter 8.
	• What is the next DSM technology?	• We have not chosen the next technologies yet. The potential considered a large number of possible technologies. The choice will happen in the program design phase if DSM is chosen in the portfolio.	• DSM was a key resource as presented in Chapters 5 and 8.
	• For DSM, did you consider controlling water heaters?	• We have not yet chosen DSM programs or technologies.	• DSM was a key resource as presented in Chapters 5 and 8.
	<u>Pumped Storage</u>		
	• Pumped Storage makes renewables more effective.	• Pumped storage projects are considered in the portfolio analysis.	• Pumped storage projects were considered in this resource plan as presented in Chapter 5.
	• What is the preferred pump storage plant according to your research?	• Possibly Moon Lake, but it's hard to say at this point. The preliminary selection of the pumped storage facility will be completed during the portfolio analysis stage.	• The resource plan addresses pumped storage. It is a relatively expensive energy option compared to the competing options, as presented in Chapter 8.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Individual Energy Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	Small Hydro		
	Are there any small hydro options in Watson Lake/Rancheria area?	No, we have not looked at any hydro in the Watson Lake area. Finlayson River is half way between Ross River and Watson Lake.	There aren't any small hydro options identified in the resource plan that are in the Watson Lake area.
	Biogas		
	Biogas – will different types of compost change the amount of energy produced?	Yes, different combinations can have an effect on the gas production.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Do you have storage options with the gas?	The gas is very voluminous so it would be hard to store for more than 10 hours.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Will creating biogas smell?	It wouldn't create any more of a smell than the current compost system.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Does the community produce enough waste?	No, that is one of the problems with this option.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Would biogas be less effective in winter?	Yes, that's correct.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Would biogas be viable for a small community like Dawson?	No, it is pretty expensive power even in Whitehorse because of the small volume, and would be more expensive in a community the size of Dawson.	Biogas is addressed in the resource plan as presented in Chapter 5.
	What about using raw sewage?	We looked at that but Whitehorse doesn't have a waste treatment plant but rather a sewage lagoon. Also, the location of the sewage lagoon is too far from the dump. So it just wasn't feasible.	Biogas is addressed in the resource plan as presented in Chapter 5.
	Biomass		
	How long could the potential biomass facility run on the source before the need to harvest green standing trees?	A plant larger than one megawatt would need harvested standing trees.	Biomass is addressed in the resource plan as presented in Chapter 5.
	Why didn't you consider standing wood for biomass?	It would not be as economic.	Biomass is addressed in the resource plan as presented in Chapter 5.
	Without the need to produce in the summer season, could you store the biomass until winter?	Theoretically you could for the 2 MW plant, but it would create a greater need for a larger harvest capacity.	Biomass is addressed in the resource plan as presented in Chapter 5.
	The last study suggested this was not economical. Is this still true?	We would need to have a source for the heat before it could come close to being economic.	Biomass is addressed in the resource plan as presented in Chapter 5.
	Have you sourced material around the Watson Lake area?	No, we looked at Haines Junction area. Watson Lake is not on the grid	Biomass is addressed in the resource plan as presented in Chapter 5.
	Have you looked at wood pellet production?	We initially looked at pellets but they are much more expensive than waste wood that has been chipped.	Biomass is addressed in the resource plan as presented in Chapter 5.

June to Nov. 2016 - Round 2 Engagement (Energy Options)   Topic: Individual Energy Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	Waste to Energy		
	• Waste to energy – do we have the population and enough garbage to have a facility?	• Yes, Yukon population is sufficient to provide waste for a small waste-to-energy facility.	• Yukon population is sufficient to provide waste for a small waste-to-energy facility.
	• Can we store the garbage in the summer and burn it in the winter?	• Yes. But the plant is designed to run all year long. It reduces the economics to sit idle.	• Waste to energy was addressed as presented in Chapter 5.
	• Did you take into consideration that the communities have waste and was this part of the original survey?	No, we just looked at what is in Whitehorse. The waste in the communities is a very low volume.	• Waste to energy was addressed as presented in Chapter 5.
	• I am concerned that a Waste to Energy plant would result in us importing garbage, or increasing the amount of garbage that communities produce .	• The plant is designed to intake the amount that Whitehorse produces. It would not create more garbage.	• Waste to energy was addressed as presented in Chapter 5.
	• Waste to energy doesn't appear to be a good fit for Yukon.	• Thank you for your comment.	• Waste to energy is an expensive option.
	Batteries		
	• California is using batteries and we should be looking at that as an option.	• We are considering batteries as a possible supply option.	Batteries were considered as a viable resource option as presented in Chapters 5 and 8.
	• There should be financial rebates for an Electrical Thermal Storage (ETS) program. Same with electric cars, which are like batteries on wheels.	• Thank you for your comment.	• The ETS was not directly addressed in the resource plan. Batteries are used as a proxy for the ETS. In addition the ETS could be considered as part of the time of use rate study that is planned for 2017.
	• I am concerned about how to dispose of the batteries a generation from now.	• We have not yet looked at the total lifecycle of batteries.	• This issue was addressed in the resource plan as presented in Chapter 5.
	• New storage technologies are coming out all the time. Did you look at these new technologies?	• YEC commissioned a study to address all commercially available storage technologies.	• Energy storage was addressed in the resource plan as presented in Chapter 5. Grid-size batteries were proposed in the action plan.
	• Have you looked at incentives for storage at the household level?	• We would need results from the time of use rates study first to assess the feasibility of this idea. We plan to do that study in 2017.	• Household storage was out of scope for the resource plan. Once household level batteries penetration increases to have impact on the load, YEC will update the load forecast to reflect the household battery penetration. Utility scale battery storage is considered as a viable resource option in this resource plan as presented in Chapter 5.
	Thermal		
	I am concerned that by YEC using LNG, it will open up LNG production in the territory.	• Our operations alone would not require enough LNG to make it viable to extract LNG from Yukon. For us, it would cost as much to ship from Eagle Plains as it does to ship from Southern Canada.	• Our operations alone would not require enough LNG to make it viable to extract LNG from Yukon. For us, it would cost as much to ship from Eagle Plains as it does to ship from Southern Canada.
	Why not place any new thermal engines at the current site?	• There is not enough space in our existing Whitehorse diesel plant, and major refurbishments would be needed.	• The resource plan identifies sites for new diesel.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Individual Energy Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	Hydrogen		
	• Did you look at hydrogen?	• We looked at it, but there are some issues with the cost and maturity of the technology.	• Hydrogen was not a supply option considered in this resource plan due to its high price.
	Wind		
	• Wind is always blowing somewhere…you should look at several sites.	• True to a certain extent but even at different sites the generation curve throughout the year is about the same (higher in winter and lower in summer, which is good for us)	• Wind is one of the energy options considered in this resource plan as presented in Chapter 5.
	• Did you look at vertical blades on wind turbines?	• Have heard of those but didn't study them.	• Wind is one of the energy options considered in this resource plan as presented in Chapter 5.
	• If you used wind, would it allow you to make better use of Aishihik as a 'battery'?	• Aishihik is already used as a battery. If we changed how we operate that facility, we would lose some of the ability to use it the way we do now. There would be a cost.	• Uprating our two oldest Aishihik hydro units, and wind, are two separate options considered in this resource plan.
	• Why did you look at 10 MW of wind and not 20 MW?	• Initially, up to 10 MW could be integrated into the system.	• The resources required to meet the High Industrial Activity Scenario load included 20 MW of wind.
	• The benefit of wind is that it is scalable.	• Yes, correct.	• Wind is one of the energy options considered in this resource plan as presented in Chapter 5.
	• You should help pay for the Keno line by adding generation, such as wind, at the end of that line.	• One of the potential locations for a wind farm is at Tehcho near Stewart Crossing.	• Wind is one of the options considered in this resource plan, with one potential location being at Tehcho near Stewart Crossing.
	• Get the Casino mine to build five wind mills and leave them for Yukoners after they shut down.	• Casino is far away from the grid. It is not economic to connect to windmills at Casino.	• Considering the current uncertainties related to development of the Casino mine and its energy supply, the idea of purchasing power from Casino was not considered in the resource plan, which does not preclude considering it once that options becomes more realistic.
	Solar		
	Did you consider rooftop solar and electric cars?	• We accounted for a certain percentage of growth in rooftop solar in our Load Forecast. We also accounted for the growth of electric cars in our load forecast.	• Solar is one of the options considered in this resource plan. The growth of electric cars is reflected in our load forecast as presented in Chapter 4.
	• Did you look at solar for areas just on or near the grid?	• Yes, near existing or potential transmission grids.	• Potential solar sites in this resource plan are located near existing or potential transmission lines as presented in Chapter 5.
	• Why did your consultants choose a solar site in Haines Junction? The mountains provide shade for a significant part of the day.	This was a high level study only. If we were to go ahead with a solar project, there would need to be much more work completed to confirm the best location.	• Solar is one of the options considered in this resource plan as presented in Chapter 5. Before any projects proceed, additional studies need to be completed to confirm the best location.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Individual Energy Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	Southern Lakes Enhanced Storage		
	• This is a good project and you shouldn't let a few opponents stop this from moving forward.	• We are working with the FNs on whose traditional territory this project would take place and we would not move forward with this without their support. They are taking time right now to better understand the potential effects.	• The Southern Lakes Enhancement Project is a viable option considered in this resource plan as presented in Chapter 5.
	Nuclear		
	• Did you consider nuclear?	There is no nuclear option small enough at the moment.	• This resource plan considered only commercially available resources that meet technical requirements in terms of energy and capacity. At this point in time there are no small commercially available nuclear options available to meet YEC's requirements. Potential future advancements in the nuclear technology might be reflected in future resource plans.
	General Comments		
	• We should be diversifying our sources of energy and not just rely on hydro and thermal.	• Yes, this will be considered as part of the portfolio analysis.	• The resource plan considered a wide range of supply options; not just hydro and thermal.
	• Your economic model needs to consider wear and tear on your equipment.	• Yes, we agree.	• Lifespan of resources was considered as presented in Chapter 5.
	• Mayo Enhancement Storage Project – concern about dropping one meter. YTG biologists don't agree with YEC's studies.	• We would need to submit a project proposal to YESAB and have it approved before we could move ahead with this as an energy option.	• The Mayo Enhancement Storage Project is one of the options considered in this resource plan as presented in Chapter 5.
	We need power in the communities and diesel isn't good for the environment. Here in Mayo we need renewable solutions.	• The goal of the resource plan is to provide affordable power that meets environmental and social requirements.	• The resource plan proposes the most cost-effective energy solutions that also meet environment and social requirements as presented in Chapter 8
	• Comment from Mayo: our power bills go up and up, but we don't see any improvements in our service.	• As our assets age, it costs more and more to maintain them.	• The resource plan proposes the most cost-effective energy solutions that also meet environment and social requirements as presented in Chapter 8.
	• In Teslin, we as a First Nation need to produce our own power. We would like to be able to contribute back to the grid.	• The IPP policy exists for that. The Yukon government also has a micro-generation program.	• The resource plan reflects the IPP policy as presented in Chapter 4.
	• Here in Teslin, we are embarking on a biomass project for heat and building a green subdivision in the near future. Has YEC looked at a hybrid model with combined heat and power?	Our regulator the YUB told us not to sell heat. But the government's IPP policy states that 10 percent of the gap has to be met by IPPs, so an IPP could sell both heat and electricity.	• The resource plan reflects the IPP policy as presented in Chapter 4.
	• If you do identify a project in Teslin Tlingit traditional territory, how would you consult with us?	• We would approach you to see how you would like to work with us on a go-forward basis. We would not proceed with any project without your support and ongoing engagement.	• Before making this resource plan public, we engaged with any First Nation on whose traditional territory we have identified a potential project. If we were to advance any of these possible projects, it would be in collaboration with the appropriate First Nation(s).

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Individual Energy Options			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	- The Mayo hydro enhancement option seems like a 'no brainer' and should be strongly considered.	- Thank you for your comment.	- The Mayo Lake Enhancement Storage Project was considered as a supply option in this resource plan as presented in Chapter 5.
	- Get the Casino mine to build five wind mills and leave them for Yukoners after they shut down.	- Casino is far away from the grid. It is not economic to connect to windmills at Casino.	- Considering the current uncertainties related to development of the Casino mine and its energy supply, the idea of purchasing power from Casino was not considered in the resource plan, which does not preclude considering it once that options becomes more realistic.
	- The survey says people are willing to pay more to protect the environment. But when it comes right down to it, will people be able to afford to pay more? For example, in Ontario rates have skyrocketed as they close coal plants.	- The situation in Ontario is unique and was brought on because of a number of things. We aren't seeing that situation in Yukon.	- The Resource Plan tries to balance results from the values survey with considerations of cost, reliability, and environmental, social, and economic considerations as presented in Chapter 8.
	- What did you take away from the survey question about the use of LNG versus diesel for back-up?	- Diesel and natural gas engines have different characteristics and are both valuable. We will still be using diesel for some time to come.	- The resource plan calls for the use of both natural gas and diesel, depending on the scenario/requirements as presented in Chapter 8.
	- Did you ask people what they thought of IPPs providing power as opposed to YEC?	- No, we did not ask that.	- The portfolio analysis included the Standing Offer Program as a part of the Yukon Government's Independent Power Producer Policy as presented in Chapter 4.
	- The question regarding using LNG as future back-up fuel may have been responded to assuming there are no new assets required and just referred to the generators already installed.	- We will ask the Yukon Bureau of Stats to see whether there were any comments recorded for this question that may shed some light on this observation.	- The Bureau of Statistics reported that only one individual sought clarification about the meaning of the question. The Electricity Values Survey report is included as part of this resource plan as presented in Chapter 3.
	- The high refusal rate on the LNG back-up question is very telling that the issue is politically charged and the public doesn't have the information they need to make a decision.	- That is possible.	- The Electricity Values Survey report is presented in Chapter 3.
	- People's willingness to pay a few more cents per kWh as compared to paying thousands of dollars out of pocket for their own investment may not be a contradiction, but a result of the scale and timing of that spending.	- That is possible.	- The Electricity Values Survey report is presented in Chapter 3.
First Nations			
Technical Advisory Committee			

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Capacity

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public			
First Nations			
Technical Advisory Committee	• The information provided by YEC makes it obvious that we should be focusing on building more capacity.	• Yes, that is true.	• This resource plan recommended a plan for addressing both energy and capacity needs to the year 2035.

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Government Policy/Regulations

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• With the new government are you going to try to influence new technologies? • Does the Yukon Utilities Board need direction from the Yukon government to change from looking at just the economics of a project to also taking into account environmental effects? • We need the political will to focus on more than just LNG and diesel.	• We would be happy to work with the new government on new technologies if that is what they wish to do. • That would be a good question to ask the government. • Thank you for your comment.	• This resource plan only addressed currently viable technologies. • This resource plan considered technical, financial, environmental, social and economic attributes of projects. • This resource plan focussed on both renewable and thermal solutions to address various scenarios.
First Nations			
Technical Advisory Committee			

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: First Nations Investment/Involvement

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• Don't overlook that First Nations have access to funds others don't. This should be considered when looking at opportunities for First Nations to invest.	• We agree.	• The resource plan considered IPP opportunities. If any project were to be advanced on the traditional territory of one or more First Nations, it would be advanced in collaboration with Firs Nations.
First Nations			
Technical Advisory Committee			

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Attributes			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• For the almost 50 categories you considered, were there set measurements or were you just making judgement calls?	• There were set measurements and numeric evaluation as much as possible. In other cases, we did qualitative measures of low, medium, and high. If the outcomes are similar for various resources, a judgment call will be made.	• The 2016 Resource Plan presented how the attributes were considered and incorporated into the proposed action plan in Chapter 8.
First Nations			
Technical Advisory Committee			

June to Nov. 2016 - Round 2 Engagement (Energy Options) Topic: Mining customers			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• On the topic of firm versus intermittent energy, residents are firm customers; mines are not. Did you consider this in your gap analysis?	• Yes.	• Yes, as presented in Chapter 4.
First Nations	• You should make the mines cut down on their power at certain times when you don't have enough renewable power. We are the ones who pay for their large energy usage.	• Thank you for your comment.	• This idea was not proposed in this resource plan.
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Diesel vs LNG			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• Why did the model choose diesel over LNG?	• Diesel is less expensive to build than LNG, but LNG is cheaper if it is going to be run for any substantial period of time. This Resource Plan is a story of the need for capacity, meaning we wouldn't be running thermal very much. Given the circumstances, diesel is the more cost effective choice.	• The 2016 Resource Plan recommended diesel in most cases, although it also recommended building the LNG third engine since this facility had already been approved and could be brought online quickly as presented in Chapter 8.
First Nations			

Technical Advisory Committee	• Why did the model choose diesel over LNG?	• Diesel is less expensive to build than LNG, but LNG is cheaper if it is going to be run for any substantial period of time. This Resource Plan is a story of the need for capacity, meaning we wouldn't be running thermal very much. Given the circumstances, diesel is the more cost effective choice.	• The 2016 Resource Plan recommended diesel in most cases, although it also recommended building the LNG third engine since this facility had already been approved and could be brought online quickly as presented in Chapter 8.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Rate increases

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• How would these projects affect rates?	• Determining the rate impacts of any of these potential projects would be one of the next steps in the planning process. We are always conscious of the costs of projects and have to be fiscally prudent.	• The rate impact was not considered in the resource plan. At the same time, the portfolios were selected based on the minimizing costs, as presented in Chapter 8. The rate impact calculation is completed outside the resource plan.
First Nations			
Technical Advisory Committee	• What would the rate increases be if you built all these new projects?	• We don't know yet. We haven't completed those calculations.	• The rate impact was not considered in the resource plan. At the same time, the portfolios were selected based on the minimizing costs, as presented in Chapter 8. The rate impact calculation is completed outside the resource plan.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Capacity Demand Side Management

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public			
First Nations	• Would new energy efficient residential developments help in terms of how much electricity you need?	• Yes, initiatives like the ones in Teslin would help reduce the energy requirements on the grid.	• Increased efficiency of end use of electricity was assumed in the load forecast.
Technical Advisory Committee	• Did you consider having your SCADA system control government buildings, so heating could be turned down or off during peak periods? • You should let the customers help you with capacity shortages, by installing things like ETS. • Can you look at curtailing loads at large institutions to help address the capacity gap?	• No, this is not something we have included in the work for the resource plan but it is a good idea. We hope to work with the Yukon government on DSM projects that would address the peak. • We would like to explore doing a pilot project with the Yukon government that would involve installing ETS units into homes. • Yes, this is something we want to investigate. Collaborating with the Yukon government on DSM options to help reduce peak is something we would like to pursue.	• Considering the small scale, SCADA control heating in government buildings was not considered in the Resource Plan. However, it does not preclude YEC to pursue this option as an operational measure. • While the 2016 Resource Plan recommended the use of grid-scale batteries as a proxy for the ETS units, YEC will be interested in exploring ETS technology further. • While the 2016 Resource Plan did not address this specifically, YEC intends to engage with the Yukon government on DSM programs that could reduce the peak demand.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Government Policies/Direction			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• In Sweden and other European countries, governments have made decisions that allow them to get out of using diesel totally. Why can't we do that?	• We do not set policy. Governments set policy. We also can't do resource planning based on policies we think will be brought in at some point in the future. We can only go on the policies that are in place now.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
	• Why are you not doing more to reduce peaks? Your DSM programs depends on customers to make the right choices, but you aren't doing things like turning people's hot water heaters off at peak times.	• We would like to engage with the Yukon government on finding some money to do a DSM program that works to shave peaks. Keep in mind that we can't always count on DSM. We put six programs in front of the YUB and they only approved three of them.	• The 2016 Resource Plan did include DSM as an option in all industrial activity scenarios. Controlling people's hot water heaters would require government direction/policy.
	• Why not get money from the Federal government to help with things like electrification?	• In doing our resource planning, we can't assume that we will receive government funding.	• The 2016 Resource Plan did not make assumptions about potential federal funding.
	• Have you had discussions with the new Yukon government about space heating?	• It is early days for the government. We have not yet had discussions on this topic.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
	• It is possible to use hydro and wind to meet the space heating market. The problem is we don't have the right government policies.	• YEC does not have the ability to set policy. That is the role of government.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
	• Are you including incentives to curb energy use?	• We cannot anticipate future policies. We use policies that are in place and when policies change we can update the work. There are some DSM programs factored into the portfolios.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
	• Where have you included net metering?	• It is included in the load forecast. The energy produced through net metering is removed from the energy requirements.	• The 2016 Resource Plan does take into account net metering.
	• How is the resource plan aligned with the new government policies with the Liberals now in power?	• As a utility we can't speculate on possible new government policies. The resource plan is not in perfect alignment but it is pretty close in most areas. We will engage with government moving forward. We have a gap that exists today and we must move on it. We have a responsibility to keep the lights on.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
	• We recognize the need for your resource plan to align with new government policies.	• Correct. YEC does not have the ability to set policy. That is the role of government.	• The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.
First Nations	• IPP are for 3rd parties or First Nations. Are you talking about projects on settlement lands?	• Through the Standing Offer Program, we are committing to buying power up to a certain point (about 10 gWh/year). Projects don't have to be on settlement land, just in the traditional territory to be a First Nation IPP.	• Standing offer program, as a part of Yukon Government's Independent Power Producer policy is included in the portfolios selected to meet energy demand as presented in Chapter 4.

Technical Advisory Committee	- This resource plan doesn't seem to take into account the thinking of the new government, which is all about renewables.	- It is true that government policies could change things, but we can only go by what we know now. If new government policies are put in place we will review and act accordingly.	- The 2016 Resource Plan did not make assumptions about Yukon government's future policies. If YEC receives direction that will alter our plan, we proceed with the direction and make the necessary changes.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Electrification (EVs and home heating)

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	- You didn't take into account electrification of electric vehicles and home heating. Your approach is flawed. - It would be a really good PR move for YEC to work with the government and other groups to encourage electrification of transportation and heating.	- We did consider both of those things during the Load Forecast work we did. Studies completed on fuel switching in existing homes indicated there wouldn't be a huge amount of uptake in fuel switching since propane and oil are still cheaper than electric. Hard to sell a more expensive option to Yukoners without some kind of government incentives in place. As for EVs, our study indicated relatively low penetration in Yukon over the next 20 years. However this resource plan is not carved in stone. We will be watching trends, and if there are indications there will be greater uptake of electric vehicles, we can adjust our load forecast. This is the nature of long term planning. - Thank you for your comment.	- Studies for fuel switching and EVs are included as part of the Resource Plan appendices related to Chapter 4. Results of these studies helped develop our load forecast. The 2016 Resource Plan does not make assumptions about possible government incentives/programs that could economically level the playing field regarding home heating. - While not addressed specifically in the 2016 Resource Plan, YEC would like to explore options with the Yukon government and others regarding projects such as this. The 2016 Resource Plan addressed penetration of electric vehicles in the Territory from 2016 to 2015.
First Nations			
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Various Supply Options

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	- How can you say solar is more expensive than diesel? It's not true. - Why did you choose batteries over ETS, when ETS is the cheaper option?	- This is first and foremost a capacity story. We need options to meet the capacity gap that we are seeing even today. We can't rely on solar for capacity, since it is an intermittent energy source. That is one of the reasons why diesel was selected over solar. - For a few reasons. Batteries are more flexible, plus we would need government policies to implement use of ETS (allowing us to control people's heating systems). That being said, we see ETS as a viable option and we would like to explore this further with government.	- The 2016 Resource Plan recommended what YEC considered the best options for meeting both the capacity and the energy gap as presented in Chapters 8 and 9. - The 2016 Resource Plan does not make assumptions about potential government policies.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Various Supply Options			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	• Why are you limited in terms of how many batteries you put on the system?	• We need enough renewable energy at night to charge the system, so it can be used during the peaks in the day time. We don't want to be in a position of using thermal to charge the batteries. For that reason, there is a limit our use of batteries.	• The 2016 Resource Plan considered the limit that would need to be placed on battery use.
	• Could you charge some batteries with hydro and some with solar?	• In the winter, solar cannot be relied on. We simply don't get enough out of solar units.	• The 2016 Resource Plan recognized that intermittent energy such as solar could not be relied on to meet capacity gaps.
	• We should use micro hydro; not big mega hydro projects.	• The hydro projects considered here are not large hydro such as the New Gen Hydro projects. IPPs are included in our plan as a way of meeting load, and this could be provided with a micro hydro project.	• The 2016 Resource Plan did not consider large hydro options.
	• Have you looked at buying power from outside Yukon? If you could buy from down South, what kind of power would you buy?	• We are an islanded grid and not connected to any outside power. Some studies have been conducted to estimate the cost to connect and it the cost they presented were very high. If we could purchase from outside, it would be whatever BC Hydro or other generators are producing.	• Connecting to the North American grid is not an option recommended in the 2016 Resource Plan, largely for cost reasons.
	• Are you considering smart meters?	• Smart meters per se are not a part of the 2016 Resource Plan. However YEC will be working with ATCO in 2017 on a smart meter and Time of Use study.	• Smart meters were not a part of the 2016 Resource Plan. YEC will be working with ATCO in 2017 on a smart meter and Time of Use study.
	• What were the projects that were looked at under the small hydro category?	• We leave them nameless because they are not projects, just options. So it is a general small hydro option.	• The 2016 Resource Plan narrowed down a number of small hydro project to six potential projects that YEC believed should be considered as presented in Chapter 5.
	• Why are we not seeing more green options (referring to the energy slide)	• Most green options are intermittent options, and this slide is for capacity. Intermittent options cannot be counted as capacity.	• The 2016 Resource Plan addressed how to meet both energy and capacity needs.
	• Why did you not look at double batteries?	• We considered having a larger one but there were problems with the charging time.	• The 2016 Resource Plan recommended 4 MW of battery capacity, which would be the optimal capacity considering the charging time and shape of YEC's daily load.
	• Why are you only considering IPPs starting in 2022?	• We assumed it would take that long to have everything in place for these projects. At this point here are no shovel ready projects.	• The 2016 Resource Plan recommended energy from IPPs at what YEC believed would be the earliest possible opportunity.
	• We need backup generation in our (Southern Lakes) communities.	• That would be a discussion for ATCO and the Yukon Utilities Board.	• The 2016 Resource Plan did not address individual back-up generators for communities directly served by ATCO i.e. Carcross and Tagish, since it was out of scope of the resource plan.
	• What is the difference in economic benefit from wind and solar?	• There is a difference in capital between the two projects. Solar is brownfield and wind would be a new construction site. The new site requires more jobs to complete the work than does the solar project.	• The 2016 Resource Plan considered economic benefit for all supply options studied by YEC for this plan as presented in Chapter 8.
	• Why are you not upgrading our assets?	• We are looking at refurbishment in these scenarios but this alone would not meet all of our needs.	• Upratings and refurbishments are both recommended by YEC in the 2016 Resource Plan as viable options for addressing electricity needs over the next 20 years as presented in Chapter 5.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Various Supply Options			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	• Solar can produce cheaper power and batteries are getting better.	• YEC will stay appraised of new technologies. This is one of the reasons the resource plan is updated every five years.	• The 2016 Resource Plan recommends the use of batteries to meet some of the electricity need over the next 20 years. The plan is a living document that will be updated again in five years.
	• Why isn't solar an option in your plan?	• Solar may be an option provided by IPPs (we have set aside 10 GWh per year for IPPS). But this is a story about a need for more capacity, and solar can't provide us with reliable capacity.	• The 2016 Resource Plan sets aside 10 GWh/yr for renewable energy (possibly solar) from IPPs as presented in Chapter 4.
	• Why does the diesel drop off in 2021?	• We have old diesels that need to retire.	• The 2016 Resource Plan reflects the reality that 9 MW of diesel must be retired soon, as presented in Chapter 4. .
	• Is the small hydro option a run of river?	• It could be.	• The 2016 Resource Plan looks at six small hydro options, two of which are run of river as presented in Chapter 5.
	• Is small hydro part of the Next Generation Hydro Project?	• No. The Next Generation Hydro Project looked at options over 40 plus years. The IRP only looks at planning 20 years out.	• The 2016 Resource Plan does not consider the Next Generation Hydro Project.
	• Hydro is great, but it is difficult to get approval for hydro projects. Look what is going on in B.C. with Site C.	• The hydro sites we are proposing are small (20 MW or under) with small footprints, so hopefully approval would be more likely.	• The 2016 Resource Plan suggests small hydro projects with smaller footprints.
	• Why not consider building multiple small hydro sites instead adding more diesel to the system?	• It's a matter of cost. Diesel is the most cost-effective option for addressing the capacity gap.	• The 2016 Resource Plan recommends adding diesel to address the capacity gap, since it is less costly than adding multiple hydro sites as presented in Chapter 8.
	• How likely is it to find geothermal projects in Yukon?	• There has been some early work done. The challenge with geothermal is that finding a viable site is very costly.	• Geothermal resource option was not recommended in the proposed action plan because of the high cost.
First Nations	• At one point we were talking about a biomass plant in Haines Junction. Is that opportunity gone?	• Biomass produces a huge amount of heat and you would need to sell the heat to make the project economic. Our conclusion on the project is that is a good thing for a community to take on. It could be an IPP, First Nation or business that builds it and then sells heat to customers. Biomass was considered too expensive to make it financially viable for YEC to take on as a project.	• Biomass was considered as one option for the 2016 Resource Plan but was found to be relatively expensive as presented in Chapter 5.
	• Which geothermal projects were retailed for your 2016 Resource Plan?	• The consultant hired to do the study on geothermal resource options considered several sites and in the end found Vista Mountain near Whitehorse and MacArthur Springs near Pelly Crossing to be the options with the best potential.	• Geothermal resource option was not recommended in the proposed action plan because of the high cost.
	• What about a grid-connection with Southern Canada?	• We analyzed that option a few years ago and the price of building the line and substations was between $1.5- and 2.5-billion.	• A grid connection to other jurisdictions was not one of the recommended options in the 2016 Resource Plan, because of the prohibitive cost.
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Mining Customers			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• Is YEC obliged to provide power to mines? Can't the mines pay for these new power sources? Why should we have to pay? Shouldn't we just focus on electricity needs for Yukoners instead of for mines?	• We do have an obligation to serve mines in most cases, but they have to pay all system impacts. In terms of who pays, we have a system where the costs are spread among all customers. New assets may serve mines, but they also become legacy assets for customers. Remember that the capacity shortfall we are predicting does not include the load from mines, as they are an interruptible customer in these cases since they have onsite generation.	• YEC's goal was to provide a plan that is of benefit to all Yukoners and not just mines.
	• Would you increase your capacity if we needed to connect a new mine?	• Yes. But under the N-1 scenario, we would disconnect the mine load.	• The 2016 Resource Plan takes into account the fact that during an event where YEC loses its largest asset (Aishihik line or generating plant), the Corporation can interrupt power to the mines, since they have their own on-site back up power.
First Nation	• Should we support connection mines to the grid?	• Supply mines with power is a key question. Some mines such as Casino are located too far from the grid so that the there is no economic justification to build a new transmission line to connect it to the grid. For projects like Victoria Gold, we have to look at what would be the impact on the system/other ratepayers. To address this, we are currently doing a grid impact study.	• Connection of some mines to the grid was considered in the portfolio analysis. Before any mine gets connected to the grid YEC will consider the impact on the grid and rates.
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Social Cost of Carbon/Lifecycle Costs			
	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
Public	• I understand your choices from a Yukon perspective, but from a global perspective I don't. You are not taking into account the negative impacts globally of your choices.	• The analysis for all the energy options included a social cost of carbon. As well, a lifecycle analysis was completed regarding the GHG impacts of each option.	• The analysis completed for the 2016 Resource Plan included the application of a social cost of carbon, and considered the life cycle of GHG emissions to each energy option as presented in Chapters 5 and 8.
	• Did you calculate the fugitive emissions from wellhead to stack with regard to LNG?	• Yes, we did.	• The 2016 Resource Plan considered lifecycle costs of GHG for LNG, as presented in Chapter 5.
	• I am glad to see the social of carbon being considered in this plan. What difference did it make?	• Yes.	• The social cost of carbon was considered for all the energy options, as presented in Chapter 5.
	• Did you look at upstream emissions for the LCA?	• When we did a sensitivity analysis on the portfolios by removing the carbon tax, it did not make a difference in the low and medium scenarios and it only made a slight difference in the high case. That's because there is not a lot of fossil fuel being burned.	• The social cost of carbon was considered for all the energy options, as presented in Chapter 5.

First Nation			
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Thermal versus Renewables

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• Did you take into account the falling cost of renewables and the rising cost of thermal? • By forecasting a load drop off at the end of the planning period as you have, it will artificially force the selection of options that are cheap to buy but expensive to operate, such as thermal.	• In order to do our research, we needed to look at the situation at one point in time (2016). However the Resource Plan is a living document and as the situation changes, the document will change. That is why it is updated every five years. • This is a 20-year plan. We are not able to look out years beyond that, since forecasting becomes extremely difficult and inaccurate.	• The 2016 Resource Plan reflects a specific point in time (2016) and can be revised/updated as necessary. • The 2016 Resource Plan forecast over 20 years, from 2016 to 2035. The load forecast is typically updated every two years to reflect potential changes in the load.
First Nation			
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Project Impacts

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• What will you do for people who would be affected by these projects? • We need to help the salmon get above Wareham dam. We need to build a ladder. • If you do the enhancements in Mayo then YEC should be hatching and releasing salmon eggs into the local river and lake. • How will climate change affect the hydro facilities?	• There would be an effects assessment and monitoring programs for any project built. We would work collaboratively with those affected by projects. • This issues has been looked at extensively with a number of parties including DFO, the local First Nation, and YEC. There is a lot of healthy habitat for salmon below the plant and it was felt there was not a critical need for salmon to access more habitat above the dam. We have considered capturing the fish and trucking them above the dam, but it was felt that it was not required at this time. • DFO has considered this and if the decision is made to go ahead with the Mayo Lake Enhancement Project, YEC would work collaboratively with the partners involved. • We are doing studies on this. The study results so far predict there will be more water overall, but the extreme events such as flooding or drought could be more pronounced.	• Effects assessments and monitoring programs were not part of the 2016 Resource Plan. They would be part of the work to be completed should the projects identified in the plan move ahead. • The 2016 Resource Plan did not consider the issue of salmon at the Wareham Day. It is considered an operational as opposed to planning issue. • The 2016 Resource Plan did not address specifics such as releasing salmon eggs in Mayo. It is considered an operational as opposed to planning issue. • The impacts of climate change on projects was considered as part of our consideration of environmental, social and economic attributes for each supply option as presented in Chapter 5.
First Nation			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Project Impacts

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Engagement and Consultation

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• How will you consult on these projects? Is this the consultation?	• This is engagement on a proposed 20-year resource plan. This plan is not set in stone but is a living document that is updated regularly. When a project is chosen for further investigation there will of course be engagement on that particular project.	• The 2016 Resource Plan did not consider consultation and engagement for specific projects. Once more detailed studies point out what project should be pursued, related consultation will be undertaken.
	• You've done a thorough job with your research and you have explained things clearly. Thank you.	• Thank you for your comment.	• A key component of the work completed for the 2016 Resource Plan was to ensure Yukoners were informed regularly, transparently, and in a way that was both detailed and easy to understand.
	• I have learned a lot!	• Thank you for your comment.	• A key component of the work completed for the 2016 Resource Plan was to ensure Yukoners were informed regularly, transparently, and in a way that was both thorough but easy to understand.
	• I would have liked to have seen more advertising about the public meeting in my community. There were posters, but not many, and I don't use social media.	• Thank you for the feedback. We will work harder next time to get the word out.	• Public meetings were advertised in the newspapers, on radio, through community posters, group emails, and on YEC's website and social media sites. For the meeting in Faro, YEC was not able to advertise it much since the meeting came together on short notice. In Faro, the meeting was advertised through posters in the community, email, and social media/website.
First Nation	• We appreciate receiving regular information about the resource plan.	• Thank you for your comment.	• A key component of the work completed for the 2016 Resource Plan was to ensure that First Nations needs for information and engagement were addressed.
Technical Advisory Committee			

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Miscellaneous Comments

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	• Given the global surfeit of investment capital looking for assets to buy, we should take extra care to keep Yukoners as owners of our electrical utility. First Nations s can be good investment partners.	• Thank you for your comment.	• The 2016 Resource Plan did not address this issue directly, since it was out of scope of the resource plan.

Dec. 2016 – Feb. 2017 – Round 3 Engagement (Portfolio Analysis) Topic: Miscellaneous Comments

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
	What was the period of time that YEC considered for the resource plan?	The study period was 20 years.	The 2016 Resource Plan considered the electricity needs to the year 2035.
	For the new 20MW diesel capacity, that includes 9MW of retired Mirrlees engines, so the 20MW is not all new capacity, correct?	Yes, that's correct.	The 2016 Resource Plan reflected the fact that of the new diesel recommended, 9 MW of that would be replacing old diesels that have reached end of life, as presented in Chapter 4.
	Why is YEC not taking a position on smart meters?	There are technological, infrastructure and rate requirements for smart meters. There is a white paper on smart meters completed by ATCO.	Smart meters were not considered directly as part of the 2016 Resource Plan. YEC and ATCO plan to conduct a study on smart meters and time of use rates in 2017.
	Has there been any research in terms of social competitiveness? For example keeping up with the Joneses in terms of energy efficiency?	YEC has not. A smart meter would allow people to compare their energy savings.	Smart meters were not considered directly as part of the 2016 Resource Plan. YEC and ATCO plan to conduct a study on smart meters and time of use rates in 2017.
	We appreciate the fact that you considered electrification, and understand that additional capacity is needed as insurance against the loss of Aishihik. We are glad YEC is doing a study on smart meter and time-of-use rates.	Thank you for your comments.	Smart meters were not considered directly as part of the 2016 Resource Plan. YEC and ATCO plan to conduct a study on smart meters and time of use rates in 2017.
First Nation	Did you consider the Aishihik plant to be run in the same way as it is today? There is currently a re-licensing project for this plant and First Nations have indicated there are some impacts around how this plant is run.	Yes we considered Aishihik to be run in the same way as it is now for the model. The re-licensing project could change the parameters of how it is run, but we don't know the outcome of that project yet.	The 2016 Resource Plan assumed that the future water license would change the current capabilities of the Aishihik Generating Station..
Technical Advisory Committee			

March 2017 –Draft Plan: General Feedback

	Question/Comment	Response	How this is reflected in the 2016 Resource Plan
Public	It looks like the plan you've chosen to go forward with was the most cost effective plan, with some mix of renewable and other energy sources. I think that is the best way forward. The one plan that I didn't agree with was going 100% renewable, as the cost would be crazy, and people would be surprised by the high cost of electricity, such as Ontario is feeling right now. I like that you've chosen solid projects, with proven technology (hydro) and LNG.	Thank you for your comments.	The member of the public agreed with YEC's approach in developing the Action Plan. No action needed.
	A lot of good work has gone into the public engagement process!	Thank you for your comments.	The member of the public positively commented on the public engagement process. No action needed.

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	- I am glad that this plan is just a draft and as Mr. Hall said in a media interview, “a living document” because in essence YEC is finally realizing that the world of energy is evolving rapidly right now. With the advancement of electrified transportation and space heating, home energy storage and smart grid as a service industry, the grid of tomorrow will be that of distributed storage and supply. Ratepayers will become providers and warehouses of energy. YEC needs to be ahead of this in its planning.	- Thanks for your comments.	- Considering the facts that the YEC grid is isolated and self-sustaining (there is no opportunity to import power from another jurisdiction in the time of shortage, or export power to another jurisdiction in the time of surplus) and the cyclical nature of the load caused by short term mine life which drives the industrial load, the long term planning in Yukon is more complex than that in larger jurisdictions with more diversified economy. As a consequence, YEC is aware that the resource plan needs to be revised and adjust to changing conditions on a regular basis and/or every time YEC foresees changing conditions, which is emphasised in the 2016 Resource Plan.
	- I am very impressed by the growing energy literacy amongst Yukon people and it is great to see the insightful comments on your website.	- Thanks for your comments.	- The member of the public positively commented on YEC’s approach in developing 2016 Resource Plan. No action needed.
	- What is the “winter load schedule” at Eagle Gold that “reduces the winter peak contribution from this project”	- Thanks for your comments.	- The peak demand at the Eagle Gold project does not coincide with YEC’s winter peak demand. The Eagle Gold project has a peak load in the summer. If the Eagle Gold Project peak were in the winter, YEC’s peak demand would be greater than it is.
	- InterGroup, authors of former YEC resource plans, tasked with environmental and socio-economic attributes for this resource plan, included the Gladstone Diversion in Chapter 8. Is this project still on the table? Or was InterGroup not aware that YEC has committed to a respectful relationship with Champagne and Aishihik First Nations, and that CAFN signed a motion against Gladstone diversion?	- Thanks for your comments.	- At the time the projects were evaluated against environmental, social and economic attributes, the decision on the Gladstone diversion project had not been made. Since then we have decided not to proceed with the Gladstone Project. As a consequence, the project was not discussed in the final version of the 2016 Resource Plan.
	- Why isn’t the report on the Whitehorse Rapids hydroelectric uprates in the public domain? The Aishihik uprate report is online. The Whitehorse Rapids dam is decades older than the Aishihik dam, so why would YEC conclude that a 4% increase in efficiency be estimated for both? Replacing or refurbishing turbines at the Whitehorse Dam has long been discussed by the public. What did Hatch, who did the study on Whitehorse uprates, conclude?	- Thanks for your comments.	- At the time of the 2016 Resource Plan development, YEC did not have the study on the Whitehorse uprates completed by external consultants. Considering uprate similarities between Aishihik and Whitehorse Generation Stations, an internal analysis, fashioned after the Aishihik uprate study, was used to provide Whitehorse Generation Station uprate attributes, as presented in Chapter 5. YEC will make the Whitehorse uprate study public once the study is completed in the future.
	- Were the water management constraints at Mayo Hydro and Mayo B understood prior to the proposal and construction of Mayo B? It seems that the net loss of installed capacity for Mayo Hydro would be 2.7 MW rather than 0.2 MW. Mayo B’s net gain to the system has been consistently overstated if this is the case.	- Thanks for your comments.	- The water management constraints were considered in determining dependable capacity of a refurbished Mayo Generation Station. The appearance of the capacity loss comes from the fact that the total dependable capacity of Mayo and Mayo B Generating Stations is not the sum of the individual dependable capacities. It is less that than because of operational constraints. Both stations cannot be run at their full capacity at the same time.

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	• What is the reason for the cost for the third LNG engine to be $5.8million when it was originally quoted at $4.4million?	• Thanks for your comments.	• The financial attributes presented for all the considered resources in Chapter 5 are based on the latest updates in the resource costs. The cost of resources is not static and it depends on multiple external factors.
	• Why in the system optimizer model did YEC only model two portfolios – one being "renewables only". It is confusing not to anticipate policy about electric car or heat incentives influencing load forecasting, but then explicitly state on 8-10 to choose the renewables portfolio, "to account for potential future government policy mandating the development of only renewable future resource options."	• Thanks for your comments.	• One of the prudent planning principles is not to anticipate possible future government policies that could affect the future load or development of future resource technologies. Any new policy or technology will warrant updates to load forecast and potentially resource plan. The resource plan is a living document that is adjusted to reflect external and internal changes. The electric vehicle load was included in the 2016 Resource Plan based on the best estimates at the time. Consequently, the load from electric vehicles was analyzed in all the portfolios presented in Chapter 8. To demonstrate impact of a potential policy of only renewable resources in the future, a renewable portfolio was analyzed and compared to a mixed portfolio. The analysis demonstrated that the percentage of renewable energy generated increased by 1%, from 98% to 99%, while the cost doubled.
	• Why are portfolio summaries against load scenarios at average water when earlier in the process it was low water?	• Thanks for your comments.	• As discussed in Chapter 8: "These graphs show the energy requirement as a line, existing energy capability under average water conditions as bars in the shades of gray, and future energy of new resources shown in different colored bars. Note that the portfolio analysis considered firm energy production requirements to meet the energy planning criterion as discussed in Section 4.3, while it considered energy under average water conditions to calculate operating costs. The firm energy planning criterion was met for each portfolio. The firm energy graphs were not shown since it was judged that the average energy graphs would be more informative as they show how much each resource would be used under average operational conditions. By doing so, it is possible to check how much thermal generation is used in real operations, as opposed to how much thermal energy is available. The firm energy graphs would not present the expected energy generation, but potential for generation under the worst case conditions. For example, the diesel and LNG firm energy significantly exceeds their expected generation.
	• 8.8% line loss seems significant. What can be done to reduce this?	• Thanks for your comments.	• The transmission and distribution losses depend on the nature of the transmission and distribution grids. To reduce those losses, the existing distribution and transmission grids would have to be significantly upgraded, which would require significant costs that would be greater than the benefits. The losses in the YEC integrated system are within industry expected ranges.
	• In "existing resources" YEC's generating capacity includes ATCO diesels on the YPS. Why did YEC not include YG's?	• Thanks for your comments.	• YEC considered only resources that can be relied on, i.e. resources that can reliably provide power to the grid. At this point in time, no

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
			clear inventory and state of operational readiness is available for YG's backup generators. In addition to that, those generators cannot be readily connected to the grid.
	• In Table 2, Portfolios for Five Major Industrial Scenarios on page 24, for Very Low 2025 it reads: "Aishihik re-runnering". Is that the same as the "Aishihik uprate" that appears in the remaining four scenarios?	• Thank you for your comment.	• Yes. Corrections were made for word consistency in the final version of the 2016 Resource Plan.
	• The Geothermal section has a confusing statement about Selkirk First Nation and its interest in Ddhaw Ghro. "The site is located within the Ddhaw Ghro Habitat Protection area, an area that has significance to the local First Nation and which is designated for mineral exploration development by Selkirk First Nation." (5-55). There is an Order in Council (2011-131) to remove Ddhaw Ghro from staking.	• Thanks for your comment.	• Clarifications were made in the final version of the 2016 Resource Plan.
	• The public utility's prediction of future electrification of space heating and transportation were very conservative because of the absence of any visionary policy goal setting by the previous Yukon government.	• Thanks for your comment.	• Prudent planning practices do not include potential future government policies. Once policies become more certain, they will be reflected in an updated load forecast and Resource Plan. YEC included the electric vehicles into the load forecast based on the best available estimates. Any future changes related to the electric vehicle penetration will be reflected in an updated load forecast and Resource Plan.
	• The Yukon Conservation Society (YCS) hopes that between now and the next public utility load forecasting exercise, Yukon Government will have updated its Energy Strategy and Climate Change Action Plan and directed the utility and/or Independent Power Producers (IPPs) to plan for and develop renewable energy projects to meet needs currently met by fossil fuels. It is important to send a signal that renewable energy projects are in fact needed so let's get on it.	• Thanks for your comment.	• Any future change related to policies will be reflected in an updated load forecast and Resource Plan.
	• There is a problematic conclusion of the evaluation of the technical and financial attributes in this plan – that four of the five load forecast scenarios, "YEC is expected to have sufficient firm energy without introducing new resources, as long as it is acceptable to run YEC's existing thermal resources."	• Thanks for your comment.	• YEC is expected to have sufficient firm energy to meet the medium industrial activity scenario as long as it is acceptable to run existing thermal resources. At the same time, the analysis in Chapter 8 demonstrated that it would not be beneficial to run thermal resources. Firm energy is a planning criterion designed to provide the system with sufficient energy for the worst case scenario, such as drought. The criterion is designed to avoid blackouts. On the average, renewable energy accounts for 98% for the medium industrial activity scenario, as presented in Chapter 8. That percentage is one of the highest on the continent.

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	- If the Yukon must consider such vast investments in backup thermal assets, let YEC also plan to ensure these assets can fulfill a secondary role in increasing the allowances for intermittent renewable integration on the grid. If a limitation for adding renewable energy is that it needs equivalent backup, can a 20 MW diesel plant enable the development of a 20 MW wind project?	- Thanks for the question.	- The intermittent generation penetration is a function of the future Yukon Integrated System configuration and it needs to be determined for each new renewable resource with significant capacity.
	- Demand Side Management appears in the Short Term Action Plan regardless of whatever load scenario materializes. YCS asks again for the utility(ies) to focus on Capacity DSM or Load Management.	- Thanks for the question.	- One of the most effective capacity DSM is load curtailment and the industrial loads are not included under the single contingency (N-1) criterion. For all the practical purposes, it is load curtailment and contributed significantly to reducing the load. YEC intends to focus on residential capacity DSM in the future.
	- Does the Southern Lakes Enhanced Storage Concept include that level of involvement in monitoring and adaptive management planning as well?	- Thanks for the question.	- Yes, it does.
	- It is unfortunate that Yukon Energy did not have direction to undertake planning with the intention of meeting the space heating market in mind. The 10% of households with existing fossil fuel heating that would change to electricity represented 4 MW, so presumably 100% would represent 40 MW (minus reductions from efficiency upgrades and biomass).	- Thanks for the question.	- Prudent planning practices do not include potential future government policies. Once policies become more certain, they will be reflected in an updated load forecast and Resource Plan.
	- YCS hopes that in partnership with Yukon Government, Yukon Energy will commit to grid impact studies to identify ways that will maximize the accommodation of renewable projects to meet our energy needs that include the benefit that distributed storage afforded by EVs can provide .	- Thanks for the question.	- Once potential government policies become more certain, they will be reflected in an updated load forecast and Resource Plan.
	- Is 20 MW an intermittent cap? How was this arrived at? We need to understand the thinking behind this, and influence thinking on how we can increase any limit placed on the allowance of intermittent renewables on the Yukon Power System.	- Thanks for the question.	- The intermittent generation penetration is a function of the Yukon Integrated System configuration and it needs to be determined for each new renewable resource with significant capacity. An internal estimate put the intermittent resource penetration at 20MW, as presented in Chapter 8.
	- Can the planned capacity projects serve double duty as enablers to allow for more wind and solar on a diverse grid?	- Thanks for the question.	- Yes, the projects with dependable capacity could be used to support intermittent resources.
	- When can the Yukon's existing and proposed new capacity resources be counted as backup for intermittent power sources?	- Thanks for the question.	- As presented in the analysis of the high industrial activity scenario in Chapter 8, intermittent generation (wind) was integrated with thermal backup.

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
	If YEC and ATCO Electric Yukon are in fact "actively working with the government to structure the Standing Offer Program (SOP), which is a key element of the IPP (Independent Power Production) Policy," as it says in this plan on page 1-7, why does the SOP's 10GWh/yr only appear in distant 2022?	Thanks for the question.	As presented in Chapter 8, the in-service date for the SOP energy was guided by the lead time for the expected projects, such as wind.
	Without adequate and reasonable remediation for property owners raising the late summer level of the Southern Lakes will be fraught with litigation. YEC representatives have downplayed ramifications and costs.	Thanks for your comment.	YEC commissioned studies to provide solutions for remediation of affected properties and the estimates of the project costs, including the cost of remediation for properties affected by the increased operational range, as presented in Chapter 5.
	The "participate" section of the Resource Planning website is skewed to avoid legitimate disagreement. My property will be adversely affected by the plan to raise water levels in the Southern Lakes but I have been advised that I won't qualify for full remediation. If my assets are protected I would be in full support of this option .	Thanks for your comment.	YEC commissioned consultants to provide the sound engineering solutions for remediation of affected properties and the latest estimates of the project costs, including the cost of remediation for properties affected by the increased operational range were included in the 2016 Resource Plan, as presented in Chapter 5.
	I was interested to see a revised estimated cost of expanding water storage in the Southern Lakes, up from a long standing claim of $4 million to $15.4 million. I assume this is to take into account the amount of remediation needed on people's properties around the Lakes.	Thanks for your comments.	YEC updates the financial attributes of resource options as changes warrant it. The financial attributes related to the Southern Lakes Enhanced Storage Project presented in the 2016 Resource Plan reflect the latest estimate of the project costs, including the cost of remediation and adaptive management, as presented in Chapter 5.
	It is good to see that YEC has a current strong focus on Demand Side Management.	Thanks for your comment.	The member of the public positively commented on YEC's approach in developing 2016 Resource Plan. No action needed.
	YEC should not be in the business of Energy Conservation. This is better handled by the old model of the Energy Solutions Center. When it comes to Demand Side Management YEC needs to focus on building a resilient smart grid which shaves peaks through load shifting and integrates distributed energy storage.	Thanks for your comments.	The 2016 Resource Plan does not focus on who will develop resource options, including DSM. The recommended Action Plan can be executed by YEC, IPPs, government or a combination of those. At this point in time, YEC has a role in developing and implementing DSM programs as the Energy Solution Centre (ESC) does. YEC and ESC have been cooperating in developing and implementing DSM programs for some time and they will continue cooperating in the future. The ultimate common goal is to use DSM instead of building new generation resources.
	Diesel generation should be phased out.	Thanks for your comments.	Considering costs, reliability, environmental and social responsibility, YEC believes that thermal still needs to play a role as capacity backup and energy supply resource for occasions when renewable resources cannot supply sufficient energy to meet the load. The recommended Action Plan consists of resources that provide approximately 98% of renewable energy to meet the load, as presented in Chapter 9, and YEC believes that additional cost of increasing the percentage of

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	Question/Comment	**Response**	**How this is reflected in the 2016 Resource Plan**
			renewable energy is not aligned with public values as presented in Chapter 3.
	- I believe it is premature to plan to expand the LNG plant. Even though you state that it was approved by the YUB, the LNG plant as is has not been brought into the rate base until it goes before the YUB again and proven to be worth its cost. There is a growing awareness amongst your ratepayers and the new government about the deficiencies in our regulatory review process that let YEC get financially strangled by these ill-advised, carbon intensive projects. It is not YEC's fault that the YUB has not done a good job of regulating. I forever hope that YUB regulatory review will be embraced by this new government. - It is unfortunate that YEC continues to turn its back on the potential for a wind farm on Mount Sumanik. The YEC corporate memory of the extensive research and development from the 90s appears to be totally lost. YEC needs to re-engage with those experts who were involved with that research.	- Thanks for your comments. - Thank you for your comments.	- As presented in the 2016 Resource Plan Load Resource Balance Chapter (Chapter 4), YEC faces an immediate capacity shortage that needs to be filled as soon as possible to avoid potential blackouts in the middle of the winter. Considering the fact that the gap needs to be closed as soon as possible and that intermittent resources such as wind and solar are not reliable in providing dependable capacity, the LNG 3rd engine option was selected as the cheapest and fastest way to close the capacity gap. - The methodology followed in the portfolio analysis identified specific projects, for example the Drury Lake small hydro project and the Thulsoo Mountain wind project. However, many projects presented in the portfolio analysis are in an early stage of development, and final decisions on any project development have not been made. Projects with similar technical, financial, environmental, social and economic attributes may be considered before the final project selections are made. YEC will follow the rigorous stagegate process discussed in Chapter 9 to make the final decision on resources that will be built. As a consequence, YEC keeps options open for every resource option class. Even though the Mount Sumanik wind project is not proposed in the 2016 Resource Plan Action Plan, considering the past research, YEC continues the wind monitoring program at Mount Sumanik to keep that option open.
First Nation	N/A		
Technical Advisory Committee	N/A		

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4 Load Resource Balance

The goal of the load resource balance (LRB) is to determine the capacity and energy gaps YEC will have to fill to meet the electricity needs over the next 20 years. The following inputs are required to accomplish this task:

- Load forecast;
- Existing and committed resources; and
- Resource planning and reliability criteria.

The inputs are discussed in the following sections. The load and peak demand forecast from 2016 to 2035 are presented in Section 4.1. Existing and committed resources are presented in Section 4.2, while resource planning and reliability criteria are presented in Section 4.3. Section 4.4 presents the LRB, which identifies the energy and capacity gaps forecast for a set of planning scenarios.

4.1 20-Year Load and Peak Demand Forecast

Considering the importance and complexity of the load and peak demand forecast, a summary of the forecast is presented first followed by detailed description of the analysis undertaken to complete the load and peak demand forecast for the period from 2016 to 2035.

4.1.1 20-Year Load and Peak Demand Forecast Summary

YEC's energy and peak demand forecast is a key input to its 2016 Resource Plan and it is also used as an input for revenue forecasting and setting rates. The forecast covers a 20-year period from 2016-2035 and is not intended for near-term operational planning.

The forecast is a 20-year outlook for energy requirements in the residential, commercial and industrial customer sectors. In addition, the forecast provides projects YEC's future peak demand requirements, which is the highest expected yearly peak demand for each year in the planning period. The peak demand forecast is critical in the planning to meet YEC's highest yearly requirements, which typically occur during cold winter days, driven by lighting and space heating demands.

The forecasting process uses multiple inputs including economic drivers (GDP, population growth etc.) and electricity end-uses, as well as production forecasts with respect to major industrial customers. Most of these are provided by external expert sources and inputs from the Yukon Government.

Population growth is the key driver of residential customer growth. The residential sector is the most stable in terms of historic and expected future growth rates, although weather causes significant short-term variations from the average as a result of space heating demand.

General economic activity is the key driver of commercial sector growth. Economic cycles and weather have an effect on the short-term demand in this sector.

Industrial demand is the most volatile sector in terms of load variability and future forecast uncertainty. In the Yukon, this sector is comprised of mining and, as a consequence is subject to largely external factors such as commodity demand and prices, currency exchange rates and environmental approvals.

Risk is inherent in all forecasting. The key risks in this forecast include economic and demographic trends, the growth in the number of residences and businesses, and the level of industrial activity. The two predominant risks in this forecast are associated with the level of mining activity in the territory and the level of government spending, which is primarily driven by federal transfer payments, and associated employment.

In order to recognize and quantify future demand uncertainty, YEC has developed a range of scenarios to cover potential outcomes such as increased levels of mining activity, or economic outcomes higher or lower than the most likely forecast. These scenarios are intended to represent a wide range of plausible and possible future outcomes.

This forecast does include the effects of already-realized conservation (or demand side management) activities, which are embedded in YEC's current and future demand requirements. This forecast does not include the effects of future YEC conservation activities. The potential for reducing electricity demand through conservation will be included subsequently in the Resource Plan as a supply resource, for comparison with other potential supply options such as, for example, wind or hydropower.

The potential effects of climate change on future electricity demand have been considered in the forecast. Predicted higher future Yukon temperatures would result in a small reduction in electricity demands. Given the small impact, this potential effect is not included in the base YEC demand forecast due to the risks involved in not serving future customer requirements. In addition, the potential effects of electric vehicles and the conversion of space heating to electricity have been considered in this forecast, with the results being this is a relatively small impact on future YEC electricity requirements. Future policy changes could have an effect on these outcomes.

According to this forecast, YEC's demand for energy for the Medium Industrial Activity scenario would grow by 0.7% per annum (p.a.) over the next 20 years and by 3.3% p.a. over the first 10 years. The peak demand would grow by 1.7% p.a. over the next 20 years and by 3.1% p.a. over the first 10 years. The growth rate declines over the latter half of the planning period due to reduced mining activity and slower growth in population due to demographic trends. The higher growth rate of peak demand compared to that of energy load is attributed to the increased mining peak demand, especially the over the first 10 years, and the end use of electricity, primarily caused by high penetration of electric space heating in new home construction.

YEC's approach to load forecasting in the 2016 Resource Plan is consistent with industry best practices. The current forecast uses a more detailed methodology than the simple trending analysis that was used for the Resource Plans in 2006 and 2011. Previous forecasting approaches for the non-industrial sector involved the extension of recent trends. The new forecast approach includes a consideration of long-term population/demographic factors such as an aging population, and improved efficiencies in appliances and lighting.

4.1.2 Introduction

The energy and peak demand forecast presents Yukon Energy Corporation's (YEC) predicted electricity needs over the next 20 years (2016 to 2035), which is referred to as the planning period. This forecast was primarily developed as a key input into the 2016 Resource Plan, but it can also be used for ratemaking, financial planning and system planning purposes.

Energy refers to the amount of electricity that is produced or used over a period of time. Peak demand refers to the maximum customer electricity demand within a defined timeframe, usually the highest demand hour within one year. The ability of YEC to serve peak demand is referred to as capacity. On a utility-scale, energy demands are expressed in the units of gigawatt-hours (GWh) and peak demand (and capacity) is expressed in megawatts (MW).

The energy forecast is presented separately by customer class which include residential, general service (referred to as commercial) and industrial sectors. Street lighting is forecast separately, but is included in the residential sector forecast in this report. These customer classes are defined by the Yukon Utilities Board rate schedules. Commercial customers (approximately 3,100 accounts) include service-oriented entities such as restaurants, schools, government services offices and sales outlets. Industrial customers (currently a single mining account) include large goods-producing customers such as mines. Residential customers (approximately 15,000 accounts) include homes.

YEC's electricity sales per customer class from 2010 to 2015 were as following: 42% residential (including street lighting), 47% commercial and 11% industrial. Short-term residential customer demands are highly correlated to temperature. Industrial customer demands are the most volatile and most challenging to forecast. These customer characteristics are not dissimilar to that found with most other utilities.

This forecast is specific to the Yukon Integrated System (YIS), that is, the part of the Yukon that is interconnected by a high-voltage transmission system. ATCO Electric Yukon (ATCO) serves a number of electrically isolated (off-grid) communities and the demands of those communities are forecast and planned for external to this forecast and Resource Plan.

The potential effects of climate change on electricity needs was modelled and found to have a relatively small impact on expected future demands, slightly lowering peak and energy demand. Given the small impact and the risks involved in planning to meet customer peak demand, the forecast did not assume a reduction due to climate change. The climate change modelling is detailed in Section 4.1.5.5.4.

The forecast was developed in a three stages:

1) In the first stage, an economic forecast was developed for the Yukon, which was a key input for the energy and peak demand forecasts. Economic activity is one of the main drivers of electricity use. A multi-sector, macro-economic model was developed to forecast future economic activity in the territory such as Gross Domestic Product (GDP).
2) In the second stage, the economic indicators from this model were used as inputs to a statistically adjusted end-use (SAE) model. The SAE model was used to forecast energy and peak demand in the residential (including street lighting) and commercial customer classes. In addition to the economic indicators, the SAE model used past electricity sales data, ambient temperatures, end-use saturations and efficiencies, and electricity prices and price elasticity as inputs. The economic spillover from the mining industrial activity to the rest of the economy was forecast using a generalized economic model using forecasts for specific proxy mines.
3) In the third stage, the loads that could not be captured in the first or second stages were added separately to the outputs of the second stage. Those included loads from the mines connected to the grid, incremental load from adoption of electric vehicles, and system losses consisting of transmission and distribution line losses, transformer losses, and station service loads.

To cover a range of potential future economic possibilities, fourteen economic scenarios were developed. Four scenarios were intended to cover the range of future industrial activity. Ten additional sensitivity scenarios layer on government spending and economic activity in other sectors, such as tourism and the potential for natural gas resource development. Economic indicators such as GDP were forecast for all fourteen scenarios using an econometric model, and then energy and peak demand forecasts were produced using these inputs. The range of results allowed YEC to prudently plan to meet future customer electricity needs through an improved understanding of future uncertainties and risks.

4.1.3 Forecast Methodology

4.1.3.1 *Historical Background*

The energy and peak demand forecast developed for the 2016 Resource Plan used a more detailed methodology than what was used for the 20-Year Resource Plans developed in 2006 and 2011. The 2006 and 2011 forecasts were separated into industrial and non-industrial customer classes. Non-industrial included the residential, commercial and street lighting customer classes. The 2016 forecast separates the non-industrial load into residential and commercial, with street lighting included in the residential forecast.

The 2006 and 2011 non-industrial forecasts were based on historical population trends, and static projections of recent electricity use per customer. These forecasts did not account for demographic trends, impacts of changes to economic activity or the prospect of changing efficiencies in electricity use. The 2006 and 2011 peak demand forecast was based on a load factor. The 2011 Resource Plan energy forecast presented an average long-term non-industrial customer growth of 2.26% per annum in the medium growth case. In the 2006 Resource Plan, projected average growth was lower at 1.85% per annum. The medium growth rate in these forecasts was projected based on the Whitehorse population and residential use per customer trends observed over the previous 10 years.

The industrial forecasts for the current 2016 forecast, as well as the 2006 and 2011 forecasts, were based on expected mine development, and informed by the most recent information on mining prospects.

4.1.3.2 *Econometric Model Description*

The econometric model of the territory used to develop the electricity demand forecast is a multi-sector, macro-economic model developed by the Centre for Spatial Economics (C4SE) for the Yukon Government Department of Economic Development. The model included an internal representation of the linkages and dependencies between different sectors of the Yukon economy. When the model was run under different economic scenarios, these linkages ensured consistency in terms of the forecast outcomes. This capability was critical in predicting how the Yukon economy overall will react to specific key changes.

The sections below discuss the model inputs, variables and outputs, as well as the economic scenarios that were developed for the model runs. Details on the econometric model can be found in Appendix 4.2 - Yukon Marcoeconomic Model 2016-2035.

4.1.3.2.1 Econometric Model Inputs and Outputs

The Yukon economy is influenced by a large number of local, federal, and global factors. The econometric model inputs include:

- Historical and forecasted real GDP, inflation and interest rates in the rest of the world;
- Historical government economic policies;
- Historical production capacity by sector and capacity utilization rates;
- Historical real economic output by industry;

- Historical labour productivity;
- Historical employment, wages and other income;
- Historical population;
- Historical population in and out-migration;
- Historical consumption of goods and services by individuals, companies and government(s);
- Historical investment;
- Export-oriented projects;
- Exchange rates;
- Commodity prices; and
- Capital spending, mineral production, employment of projects.

Federal government tax rates and economic policy influence the Yukon economy. Federal transfer payments are a major contributor to the Yukon economy, and have key secondary impacts on employment and population growth. Economic activity drives the electricity demand.

The econometric model projected of a number of economic indicators (outputs). The econometric model outputs included:

- Real GDP;
- Inflation;
- Production capacity by sector and capacity utilization rates;
- Real economic output by industry;
- Labour productivity;
- Employment, wages and other income;
- Population including the effects of in and out-migration; and
- Consumption of goods and services by individuals, companies and government.

The outputs from the econometric model were used to generate six economic indicators that influence electricity use. These six indicators were inputs into the energy and peak demand forecast. The economic inputs to the energy and peak demand forecast included:

- Population;
- Number of households (derived from population);
- Employment;
- Disposable income (derived from wages and other income);
- Real gross domestic product (GDP); and
- GDP from the mining industry (derived from GDP).

In the energy and peak demand forecast model, population, number of households and disposable income were the primary drivers of residential electricity demand. Employment and real GDP were the primary drivers of the commercial electricity forecast. Mining was the main driver of the industrial electricity demand forecast. Territorial GDP was forecast both including and excluding mining exports to highlight the specific economic effect of the mining industry.

The model results for these key indicators are discussed in Section 4.1.4.

4.1.3.2.2 Economic Scenarios and Sensitivity Tests

To cover a reasonable range of future economic activity in the territory, fourteen scenarios were developed, which included four major and ten sensitivity scenarios. The distinction between the major and sensitivity scenarios is described below, including the key assumptions for each scenario. The scenarios were informed by past and present data, which demonstrated that the major drivers of the economy are the mining industry and government spending.

Mining is the largest non-government industry in the Yukon and has a strong influence on the general economy. Mining activity impacts the territory's service and supply industries, such as transportation and construction. Government spending is also a major driver of the Yukon economy, both in terms of wages paid to government employees, as well as spending on projects, which drives service and supply industries in the same way that mining does.

The four scenarios (scenarios 1 to 4 below) primarily consider very low to high levels of mining activity. The additional sensitivity scenarios layer on factors such as 'boom and busts' in mining, advancements or delays in mining starts, changes in government spending and activity in other smaller sectors such as tourism, forestry, and agriculture, as well as the potential development of regional natural gas projects. The Eagle Gold, Coffee Gold, Wellgreen and Casino mining projects were selected to act as proxies for industrial activity. The selection of these projects was based on their progress in the permitting, feasibility assessment and environmental assessment process.

The following list presents the fourteen economic scenarios that were considered.

The third scenario in the list: Medium Industrial Activity was chosen as the basis of YEC's Load Forecast.

1. Very low industrial activity;
2. Low industrial activity;
3. Medium industrial activity;
4. High industrial activity including a new large mine;
5. Low industrial activity with no growth in government spending;
6. Medium industrial activity with no growth in government spending;
7. Medium industrial activity with sensitivity analysis of smaller economic sectors (agriculture, forestry and fishing);
8. Medium industrial activity with sensitivity analysis of natural gas projects;
9. Medium industrial activity with a later start of production for a new large mine;
10. Medium industrial activity with a mining boom and bust cycle;
11. Medium industrial activity with early mine production timing;
12. Low industrial activity with early Minto closure (Minto ending production in 2017);
13. Low industrial activity with Minto Mine ending production in 2017 and sensitivity analysis on no growth in government spending; and
14. Medium industrial activity with sensitivity analysis of the tourism sector.

A detailed discussion on scenarios and rationale for developing them can be found in Appendix 4.2.

Very low industrial activity, low industrial activity, low industrial activity with early Minto closure, medium industrial activity and high industrial activity scenarios (scenarios 1, 2, 12, 3, and 4) were considered the major scenarios due to a higher probability of realization compared to that of the rest of the scenarios. The scenario with Low Industrial Activity with Early Minto Mine Closure was analyzed to provide additional insights into the portfolio that would result from the early closure of the Minto mine. Subsequent to the completion of the Load Forecast in mid-2016, market changes (metals prices) have warranted a shortening in expected Minto mine life, making this scenario increasingly likely.

Regardless of the selection of the major scenarios, load forecasts were generated for all the scenarios.

4.1.3.3 *Energy and Peak Demand Model Description*

The energy and peak demand forecast was completed by Itron using their SAE MetrixND model. MetrixND was designed and developed for the utility industry and is used to generate monthly energy and peak demand forecasts. The model generated results for the residential (including street lighting) and commercial rate classes, while the load forecast for the mines connected to the grid (industrial load) was added separately based on mine load forecasts provided by the mining companies. Details on the energy and peak demand forecast model can be found in Appendix 4.3.

4.1.3.3.1 Statistically Adjusted End-Use Model Description

There are three main approaches used in energy and peak demand forecasting. These are:

1. Trend analysis: This simple approach uses historical trends to forecast future electrical needs as well as other components such as population, use per customer or economic indicators;
2. Econometric modelling: This approach correlates historical electricity needs with economic factors such as GDP, then uses a forecast of economic factors to project future electricity needs. This approach is more complex than the trend approach above, but it is still relatively simple, as it assumes that historic relationships between the economy and electricity demand will persist into the future. This approach does it not capture the impacts of future technology changes. This approach is also referred to as top-down forecasting, in that the forecast is driven by high-level economic trends; and
3. End-use modelling: This approach forecasts individual electricity end-use which are then summed together to forecast electricity needs. Electricity end-uses refer to the actual appliances or devices that use electricity in homes and businesses, such as refrigeration and lighting. Electricity use depends on the number of appliances or devices as well as their efficiency. Full-scale end-use based models are able to capture efficiency changes over time, but are cumbersome and require the population and maintenance of detailed and costly databases to track technology changes.

The residential and commercial customer class models use a statistically adjusted end-use (SAE) structure, which incorporates the benefits of both the econometric and end-use approaches. Due to these benefits, this approach is now industry-standard, and is used by most large North American utilities to forecast most of the electricity demand. Small utilities usually rely on simple trend-based approaches that do not incorporate possible future demographic, economic, or technology trends.

The end-use data required by the model is collected by the US Energy Information Administration, and calibrated by region of the US. In the YEC SAE model, end-use information such as efficiencies was based on the 2015 US West North Central Census Division forecast. This assumes that the types and efficiencies of appliances and devices available to consumers in the Yukon are not significantly different than this region of the US. The saturation levels of end-uses are based on Yukon-specific studies discussed in Appendix 4.3 - Long Term Load and Demand Forecast 2016-2035.

4.1.3.3.2 Energy and Peak Demand Model Inputs and Assumptions

The input variables into the energy and peak demand forecast model include:

- Economic indicators;
- Historical energy sales data by customer class (i.e. residential and commercial);
- Historical temperature data;
- Historical electricity price and revenue data; and
- Electricity end-use saturation and efficiency trends.

The SAE model was calibrated to and verified on 10-years of historical YEC data: from 2006 to 2015. The calibration and verification process demonstrated the model's ability to replicate the historical peak demand data. Once confidence in model's ability to predict future data was established, the model was used to forecast energy and peak demand. Discussion of the robustness of the model can be found in Appendix 4.3.

Air temperature is an important input into the model and the SEA model assumed standard normal temperature. A standard 30-year temperature normal was calculated using Environment Canada historical daily minimum and maximum temperatures in Whitehorse from 1981 to 2010. The Whitehorse temperature trends were used as a proxy for the entire YEC service area. Outside temperature drives the need for heating and cooling in buildings, which in turn drives the demand for electricity. Temperatures were also used for the peak demand forecast.

Historic price and sales data was used to predict how customers' electricity usage would adapt to a change in electricity price. The model predicted this change in behavior through an imposed price elasticity. YEC has assumed an electricity price elasticity of -0.10. This means that a 10% increase in electricity price would cause a 1% reduction in electricity demand. This assumption is in the range of price elasticity used by other utilities.

In the Yukon, electricity is an essential service, particularly during cold days. As such, customers are not expected to be able to greatly reduce their electricity usage in response to prices changes in the short term. Because the timing and scale of electricity price changes are unknown, the model simulation assumed a constant (real dollar) electricity price over the planning period. The model will be updated if and when YEC electricity rate changes are made.

The residential energy forecast included all customers in the residential rate class including street lighting. The street lighting forecast was based on growth in the residential customer forecast, and took into account the trend towards (high efficiency) LED street lighting. Street lighting demands were included in the residential forecast. Based on historic date, an assumption was made that 95% of new residences would be electrically heated over the planning period. Already existing DSM programs were captured in the residential forecast, while future DSM programs were treated as resource options.

The commercial energy forecast included all customers in the general service rate class such as businesses, light industry and governments. Secondary sales, consisting of additional summer sales to major commercial customers, were not included in the forecast as they are interruptible and available only when inflows to reservoirs permit.

Generally, the SAE model generates the industrial energy forecast by including all customers in the industrial rate class. At this time YEC's major customers in this rate class are mines. The economic activity (spillover effect) generated by mines contributes to the electricity use in the residential and commercial customer classes and was captured in the Non-Industrial Energy Forecast presented in Section 4.1.5.2. The SAE model captured the spillover effect by using specific proxy mines assumed to be operating in the Yukon over the planning period. All other smaller industries such as forestry or the natural gas sector were also captured in the non-Industrial forecast. The load of the mines connected to the grid could not be captured by the SAE model due to a limited number of mines in the Yukon, each with very different characteristics. The SAE model is more suited for forecasting mining load in jurisdictions with more mature and diversified mining sector.

Consequently, the industrial load forecast, i.e. load for the mines connected to the grid, was generated outside the SAE model and added to the SAE model forecast as discussed in Section 4.1.3.4.

4.1.3.4 *Additional Load Assumptions*

In the third stage of the load forecast, the loads that could not be captured in the first or second stage were added separately to the outputs of the SAE model. Those included loads from the mines connected to the grid, electric vehicles, and system losses consisting of transmission and distribution line losses, transformer losses, and station service loads.

The energy and peak demand forecast for mines connected to the grid was generated using historical mine loads for currently operating, and, for the potential future mines, information generated by mining companies during feasibility studies for their proposed projects. Details on the load of future mines are presented in Appendix 4.4.

A report on the adoption rates of electric vehicles (EVs) and impact on the YIS was completed by ICF International (ICFI) and can be found in Appendix 4.5. Based on current EV technologies and costs ICF estimated a low, medium and high penetration with 445, 1144 and 1864 EVs respectively in the territory by 2035, representing 1.1%, 3.0% and 4.4% of total vehicles. The report found that at the above adoption rates, EVs are not expected to have a significant impact on the YIS. The high penetration EV load was included in the YIS load forecast.

The energy forecasts also includes transmission and distribution line losses, transformer losses, and station service loads.

4.1.4 Econometric Forecast

This section presents the results of the econometric model for the six economic indicators, discussed in Section 4.1.3.2.1, which were used as inputs to the SAE model. The results are presented for the five major scenarios (scenarios 1, 2, 12, 3, and 4), while the sensitivity scenarios results are presented as a range shaded in gray in each chart to avoid presenting fourteen lines in each chart. The scenarios that are presented within the range and discussed in the following paragraphs are at the bounds of the ranges. The detailed discussion on economic forecast of all fourteen scenarios for the six variables can be found in Appendix 4.2.

All the economic indicators presented in Figure 4-1 to Figure 4-4 are bounded by the High Industrial Activity scenario in the short- to mid-term, from 2016 to 2023.

After 2030, growth in population and households as shown in Figure 4-1 and Figure 4-2, was higher in the scenarios that assumed natural gas development and an increase in the tourism sector (scenarios 8 and 14), than in the High Industrial Activity scenario.

After 2028, employment, shown in Figure 4-3, was continuously higher in the scenario with assumed high growth in the tourism sector (scenario 14) than in the High Industrial Activity scenario. This is due to the high number of employees required in the tourism sector per unit of sector GDP.

The population and household decrease in the later part of the planning period, as shown in Figure 4-1 and Figure 4-2 was attributed to the demographic trends, such as declining birth rate and aging population. This will translate into fewer people of working age. Further impacting employment, the assumption was made that mineral production activities in the Yukon will become more automated, as a competitive measure. This will result in less operational employment opportunities in Yukon mines, as presented in Figure 4-3.

After 2023, per capita disposable income, shown in Figure 4-4, was higher in the scenario that tested the sensitivity to an increase in secondary industries such as agriculture, forestry and fishing (scenario 7) than in the High Industrial Activity scenario. While tourism resulted in a high job growth, average wages in the other secondary industries are forecast to be higher.

Overall, as presented in Figure 4-1 to Figure 4-4, the scenarios with no growth in government spending (scenarios 5, 6 and 13) had the lowest results for all of the economic indicators. This demonstrates the strong influence that government spending has on the economy of the territory.

Territorial GDP was forecast both including and excluding mining exports, shown in Figure 4-5 and Figure 4-6 to highlight the specific economic effect of the mining industry. The Yukon's small economy can be significantly altered by the opening or closing of a single mine, as demonstrated by the GDP forecast in Figure 4-6. When mining exports are included in GDP, their contribution dominates the results in the high mining scenario. Scenarios with no growth in government spending (scenarios 5, 6 and 13) exhibited low GDP growth. An increase in the natural gas sector (scenario 8) also demonstrated high GDP growth.

Figure 4-1: Population Forecast

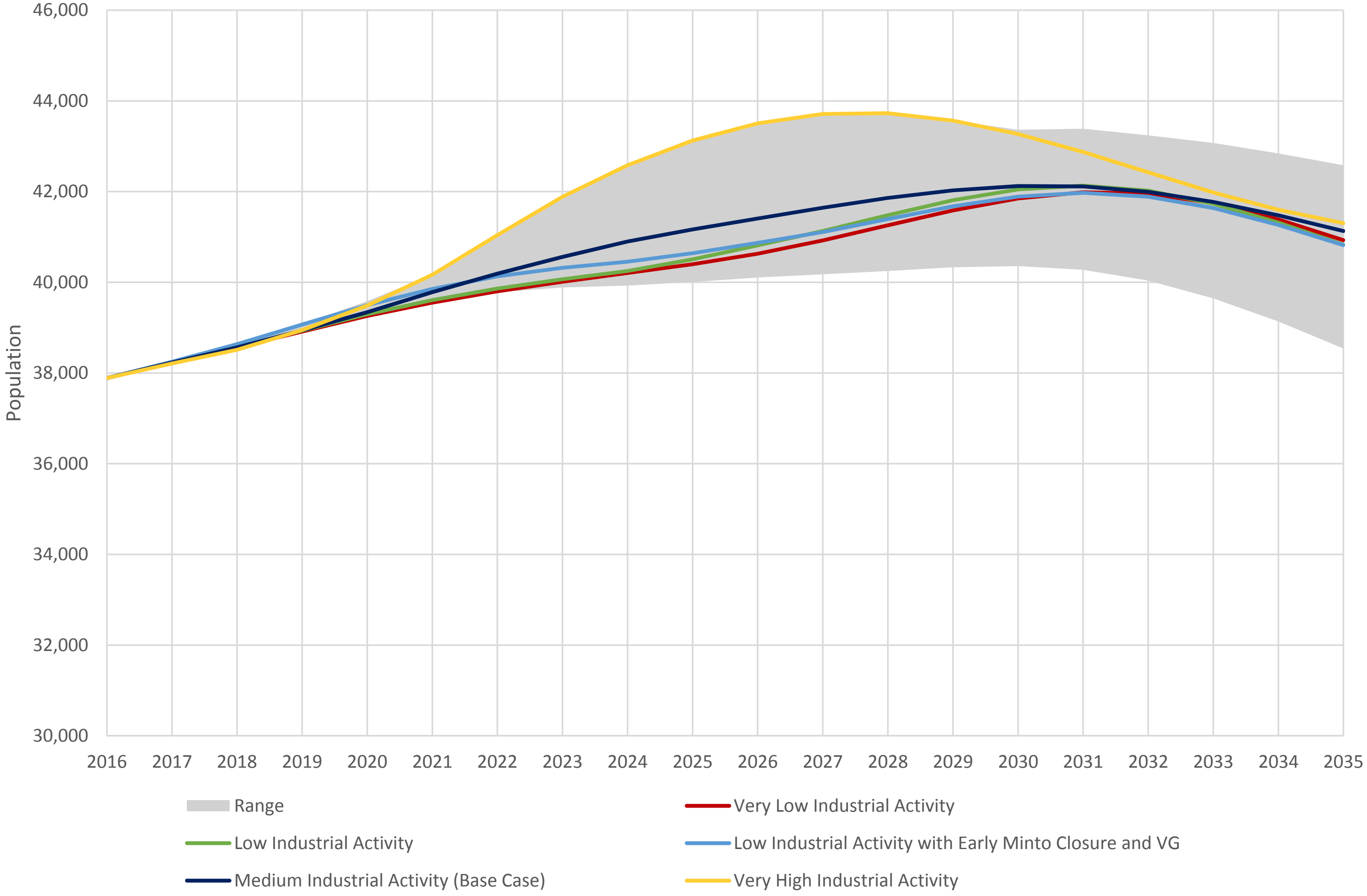


Figure 4-2: Number of Household Forecast

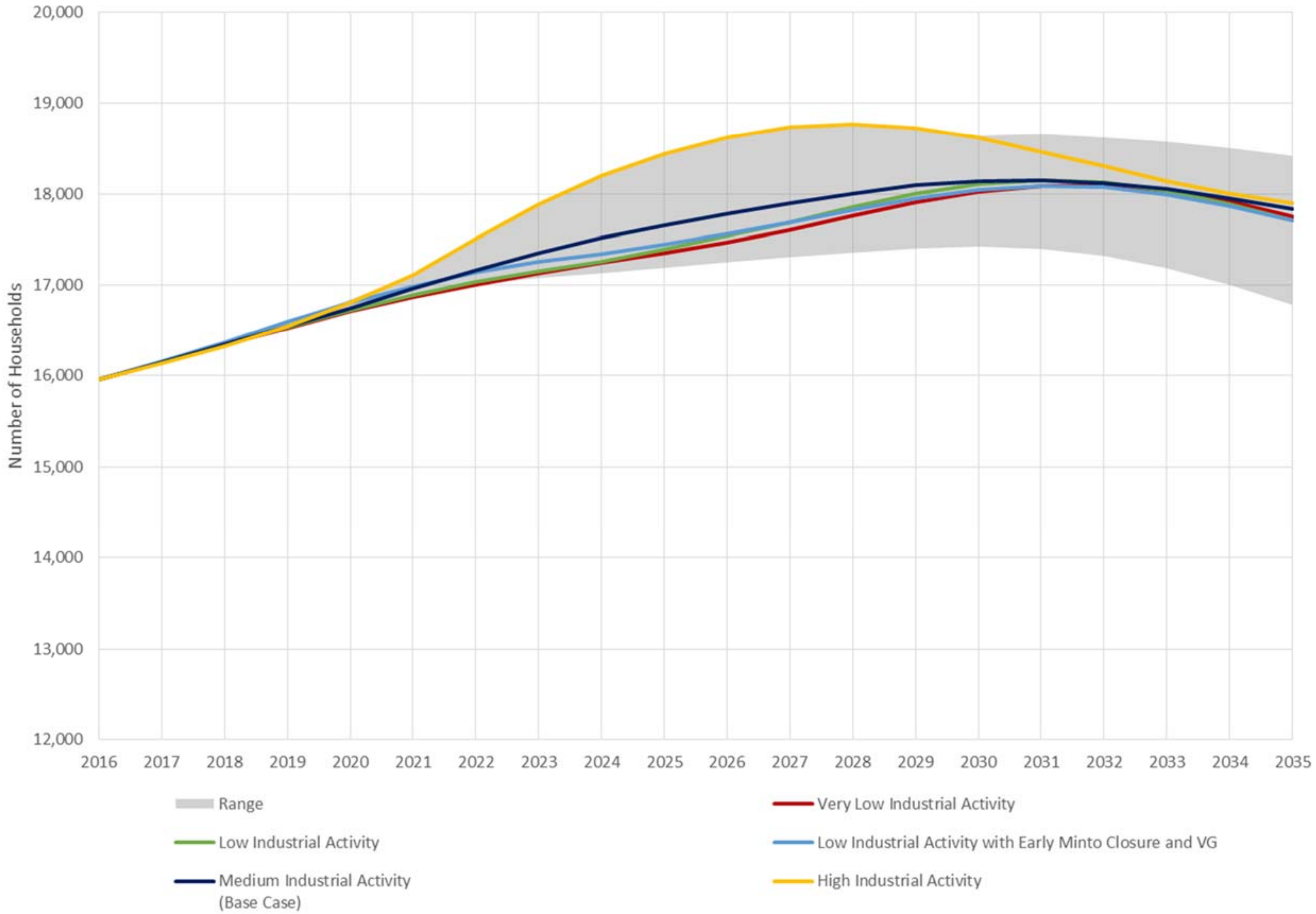


Figure 4-3: Employment Forecast

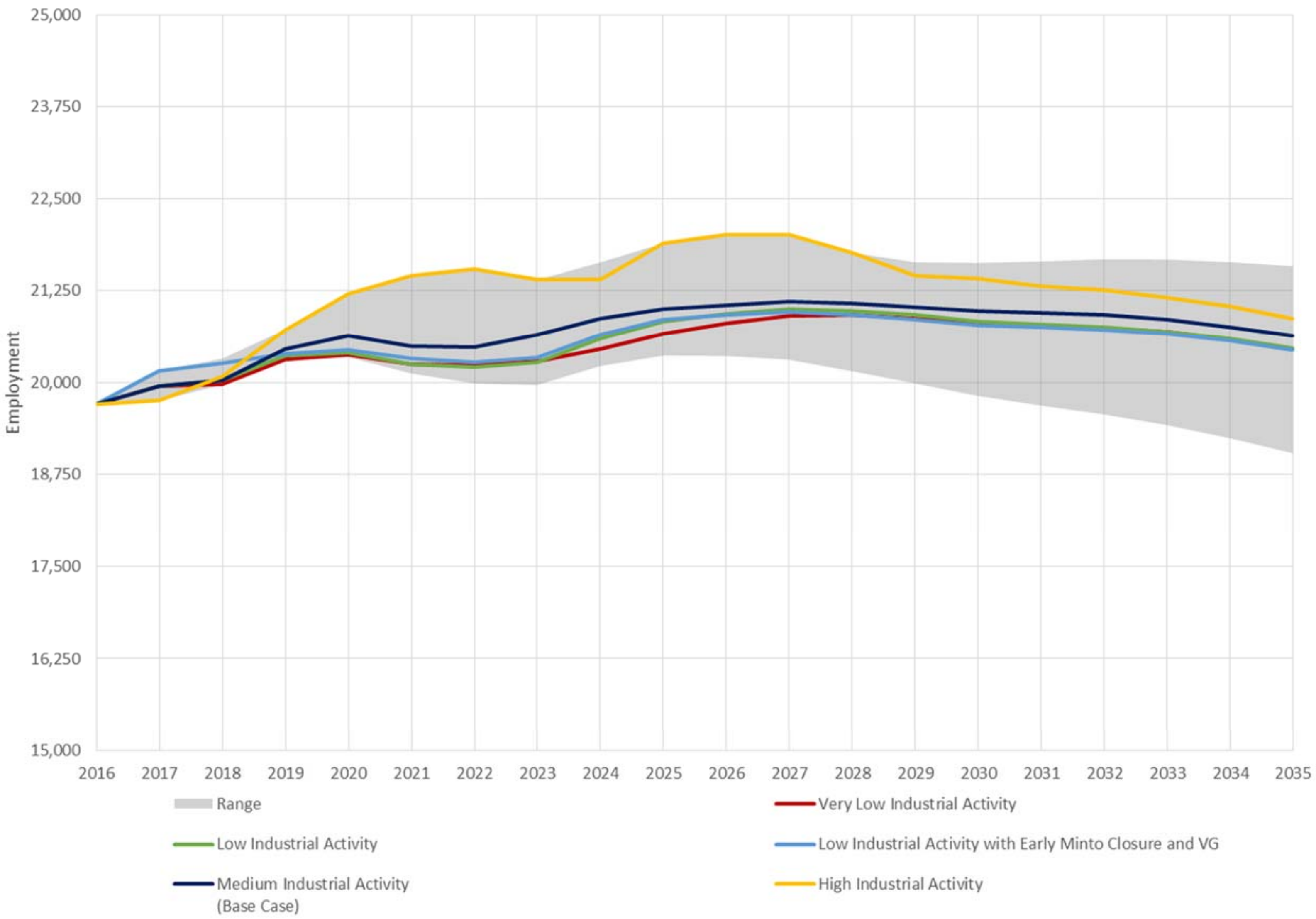
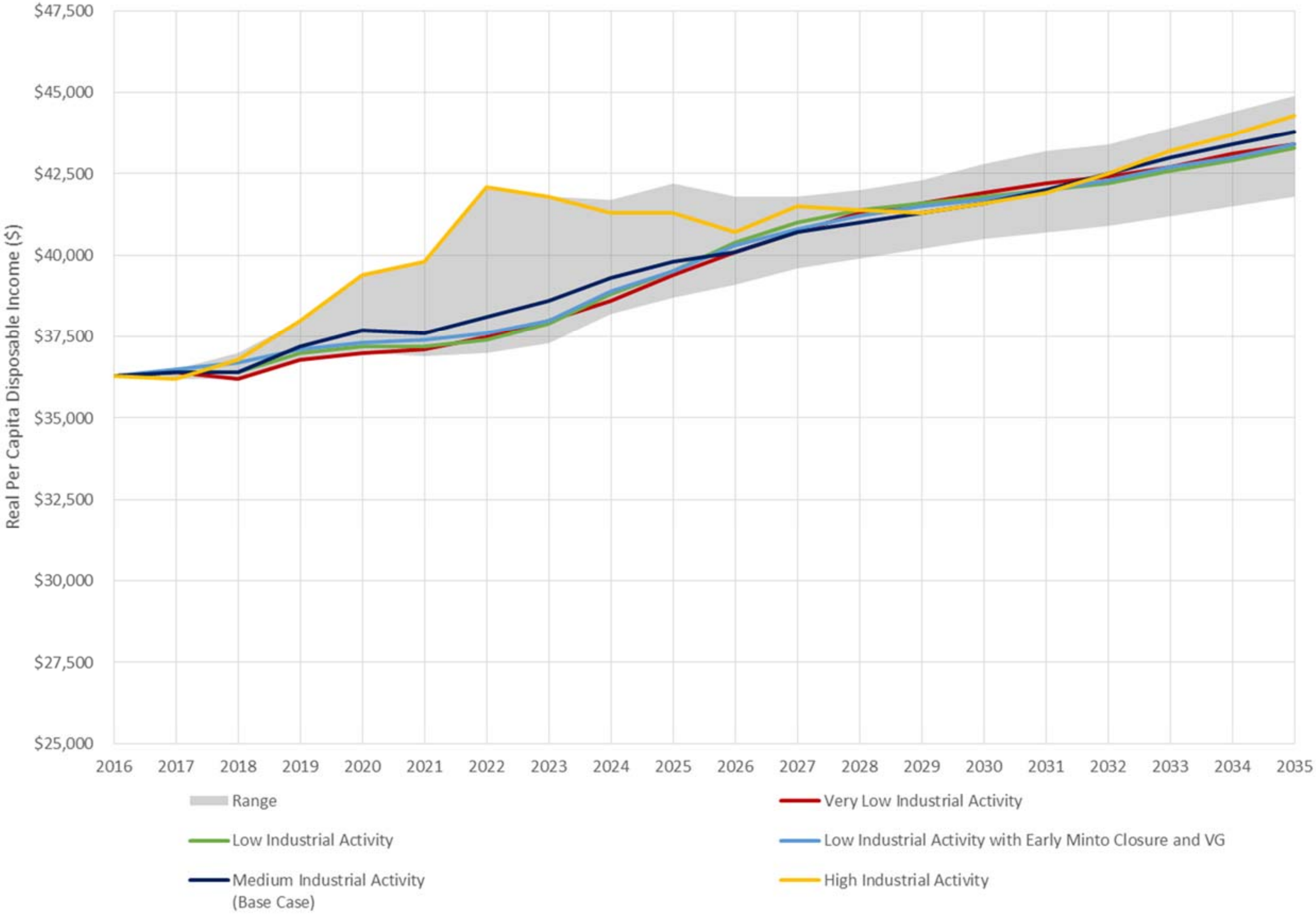
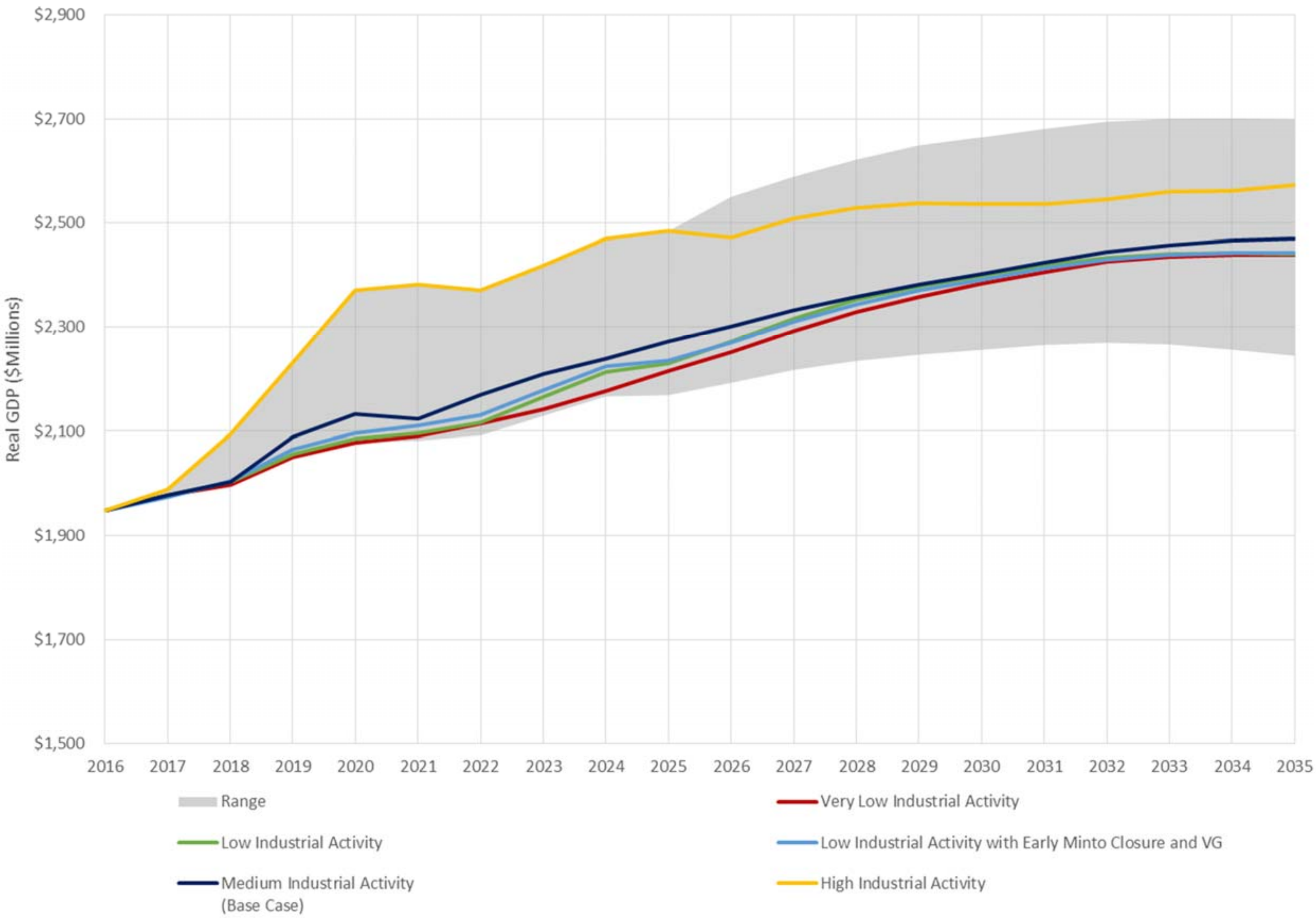


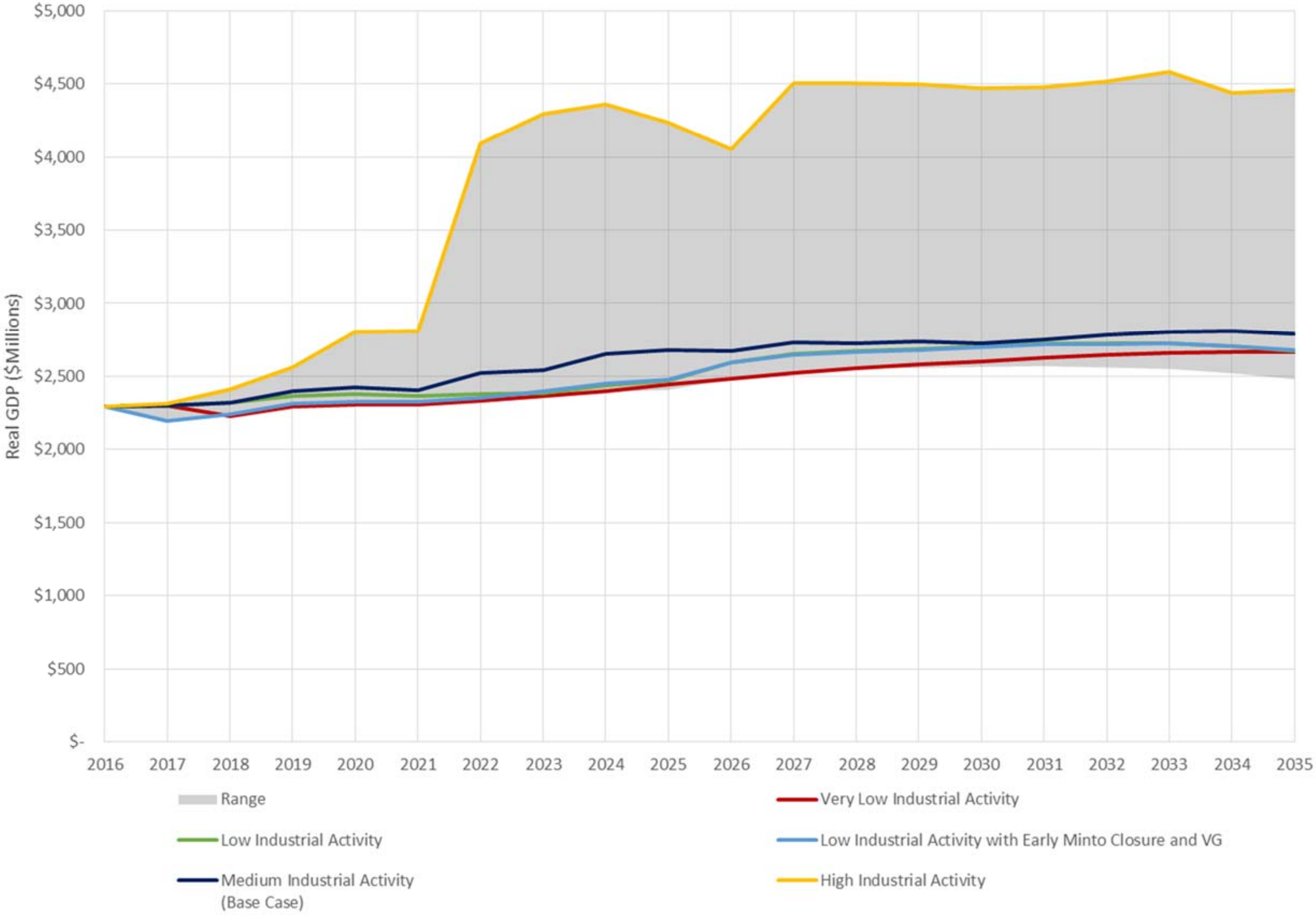
Figure 4-4: Disposable Income Forecast



1 *Figure 4-5: GDP excluding Mining Forecast*



1 *Figure 4-6: GDP including Mining Forecast*



4.1.5 Energy Forecast

This section presents the energy forecast for the main electrical grid in Yukon (YIS). Energy refers to the amount of electricity that can be produced or used over a period of and is expressed in gigawatt-hours (GWh). The energy forecast is presented first without mines connected to the grid, then with mines connected to the grid, followed by a total energy forecast for the YIS. It is important to remember that while all industrial activity will affect the territory's economy, which in turn will increase electricity needs, not all mines will connect to the grid.

The Yukon's small customer base means that the connection of a single mine to the grid has a substantial effect on electricity requirements.

4.1.5.1 *Yukon Integrated System Description*

Yukon Energy Corporation supplies electricity to the YIS. The majority of the electricity demand (approximately 79%) on the YIS is from the City of Whitehorse. There are also a number of small communities that are not connected to the YIS (referred to as off-grid). These communities are served locally with diesel generated electricity provided by ATCO Electric Yukon. The electricity demand forecasts presented here only includes requirements on the YIS, and does not include off-grid demands.

The energy forecasts presented in the following sections includes transmission and distribution line losses, transformer losses, and station service loads. A review of actual sales and generation data indicates overall losses on the YIS for the 2012-2015 period were 8.8%. This represents an increase of 0.1% from the 8.7% reported in the 2012 GRA[1] and LNG Part III application[2].

Figure 4-7 shows the Yukon electrical system including the main grid, generating facilities and off-grid communities.

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[1] Yukon Energy Corporation, 2012. 2012/2013 General Rate Application, application submitted to the Yukon Utilities Board, April 2012.

[2] Yukon Energy Corporation, 2013. *Application for an Energy Project Certificate and an Energy Operation Certificate Regarding the Proposed Whitehorse Diesel-Natural Gas Conversion Project*, application submitted to the Yukon Utilities Board, December 2013.

Figure 4-7: Yukon Power Grid and Load Centers

Yukon's Transmission and Generation Facilities

YEC SYSTEM	(in MW)
Hydro Facilities	
Whitehorse	40.0
Aishihik	37.0
Mayo	15.1
Total	92.1
Wind Facilities	
Haeckel Hill	0.65
LNG Facilities	
Whitehorse	8.8
Diesel Facilities	
Whitehorse	15.0
Faro	8.5
Dawson	5.1
Mayo	2.5
Total	31.1
TOTAL YEC SYSTEM	132.65

ATCO SYSTEM	(in MW)
Hydro Facilities	
Fish Lake	1.3
Diesel Facilities	
Carmacks	1.5
Haines Junction	1.5
Teslin	1.5
Ross River	1.0
Watson Lake	5.0
Beaver Creek	0.9
Destruction Bay	0.9
Old Crow	0.7
Pelly Crossing	1.2
Stewart Crossing	0.1
Swift River	0.3
Total	14.6
TOTAL ATCO SYSTEM	15.9
Other Diesel	
Minto Mine	8.0
Total Yukon Capacity	**155.9**

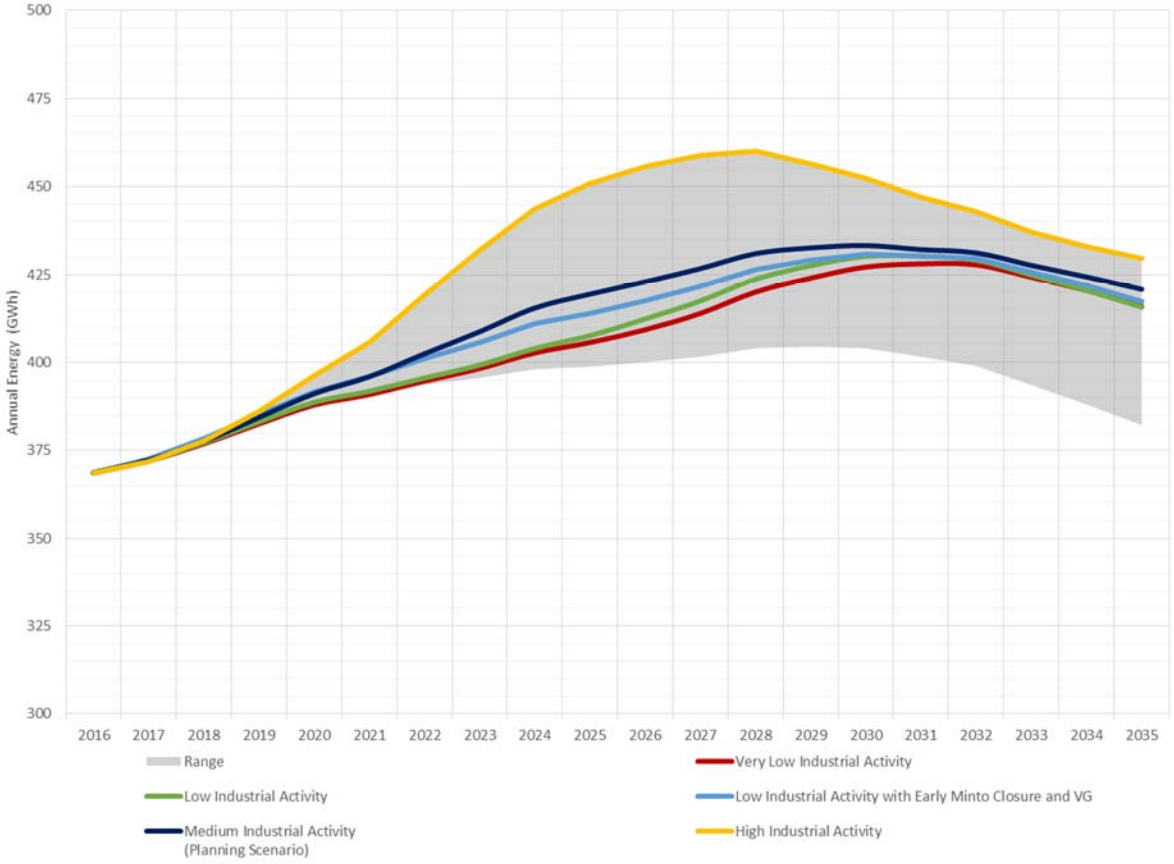
4.1.5.2 *Non-Industrial Energy Forecast*

This section presents the non-industrial energy forecast (residential and commercial combined) and the contribution to the forecast by residential and commercial customers. Street lighting is included in the residential forecast.

Figure 4-8 shows the annual non-industrial energy requirements for the five major scenarios and the nine sensitivity scenarios presented as a range shaded in gray. Note that the vertical axis in Figure 4-8 starts from 300 GWh to better demonstrate the difference among presented scenarios. The numerical data for all the scenarios are presented in Appendix 4.1. The scenarios are outlined in Section 4.1.3.2.2. The energy forecast indicates a relatively narrow range of results between the scenarios, with minimal growth followed by a leveling and then a decrease towards the end of the planning period. This result is consistent with the economic indicators described earlier. All the analyzed scenarios show a load decline towards the end of the planning period that is primarily attributed to reduction in the spillover from mining activity, population, households, employment and increased efficiency of electricity end use.

Details on population, households, and employment forecast as a part of the econometric forecast are presented in Appendix 4.2.

Figure 4-8: Non-Industrial Energy Forecast



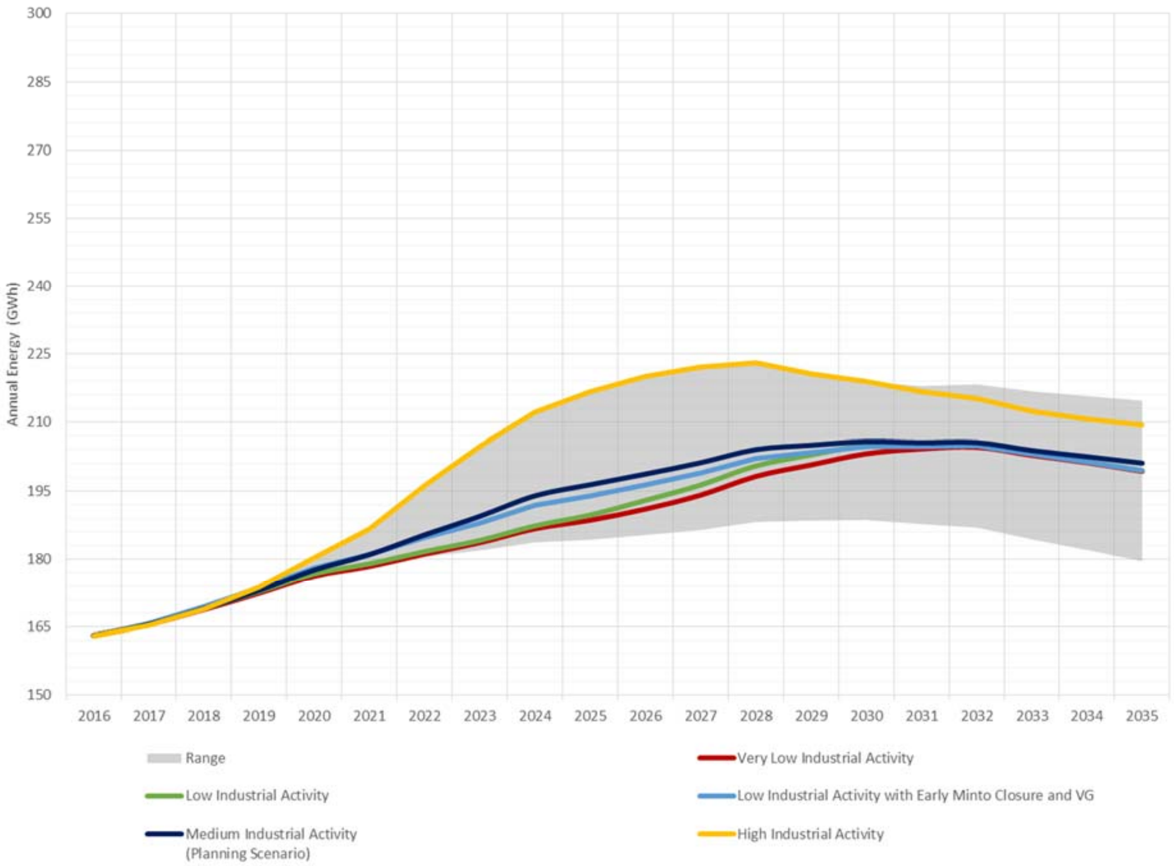
4.1.5.2.1 Residential Energy Forecast

The residential energy forecast includes all customers in the residential rate class including street lighting. Already existing DSM programs are captured in the residential forecast.

As shown in Figure 4-9, the residential energy requirement is expected to grow through most of the planning period before leveling off or dropping slightly in 20 years-time. The rate of growth of the Medium Industrial Activity scenario is an average of 2.2% per annum until 2025. This is mainly due to the forecast increase in population as presented in Figure 4-1 and the assumption of predominantly electric heating in new homes. All the analyzed scenarios show a load decline towards the end of the planning period that is primarily attributed to reduction in population, households and increased efficiency of electricity end use.

Details on the population and households forecast as a part of the econometric forecast is presented in Appendix 4.2.The numerical data for all the scenarios are presented in Appendix 4.1.

Figure 4-9: Residential Energy Forecast



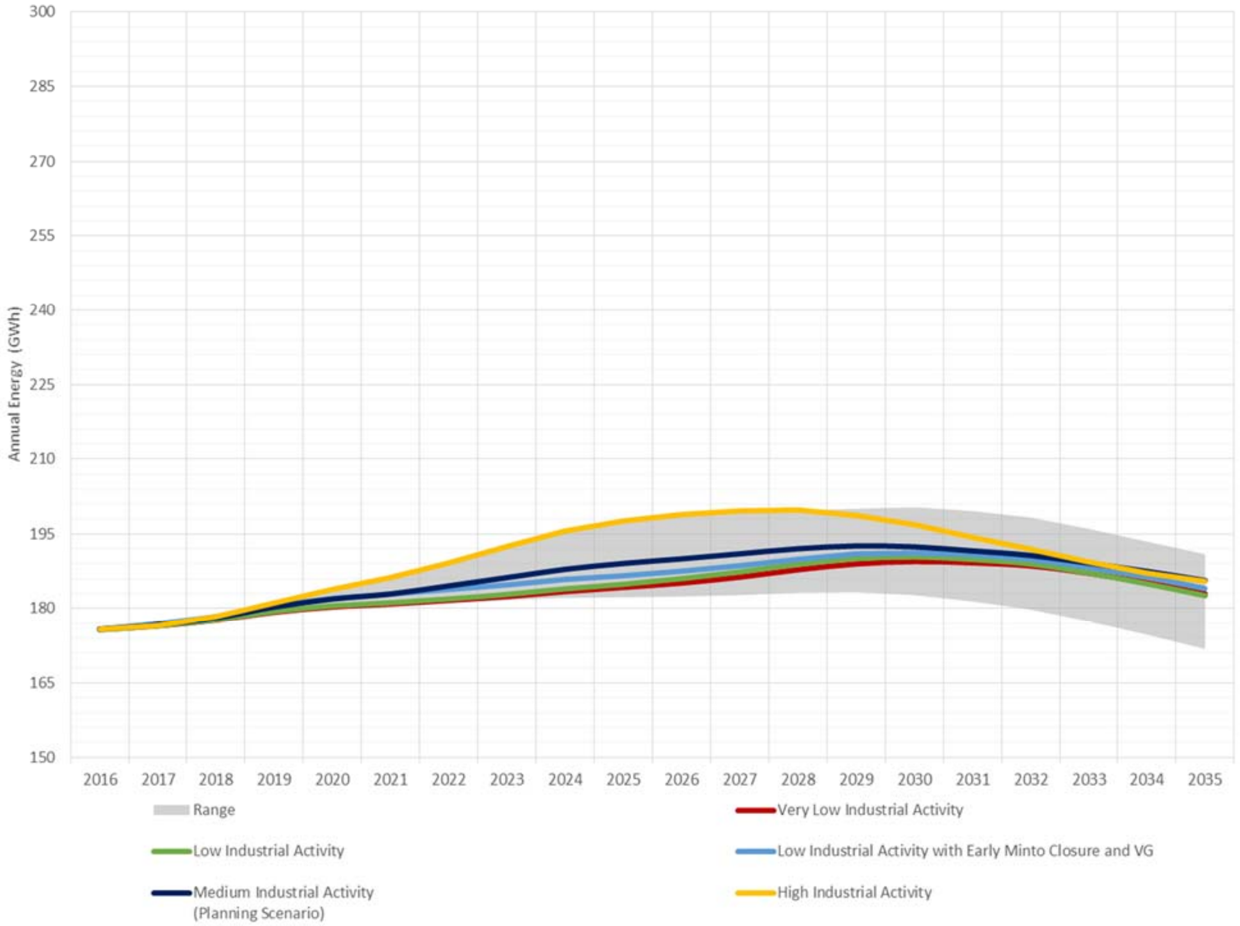
4.1.5.2.2 Commercial Energy Forecast

The commercial energy forecast includes all customers in the general service rate class which includes businesses, light industry and governments. Secondary sales, consisting of additional summer sales to major commercial customers, are not included in the forecast as they are interruptible and available only when inflows to reservoirs permit.

Similar to the residential forecast, as shown in Figure 4-10, the commercial forecast shows growth in the near-term, followed by a flattening out or decline. The average rate of increase for the Medium Industrial Activity scenario is 1.0% per annum until 2025. The commercial forecast is mainly driven by economic activity in the territory as well as some electrification of space heating, although at a lower level as forecast in the residential sector. All the analyzed scenarios show a load decline towards the end of the planning period that is primarily attributed to reduction in spillover from mining activity, population, economic activity and increased efficiency of electricity end use.

The numerical data for all the scenarios are presented in Appendix 4.1 - Energy and Peak Demand Forecast Data 2016-2035.

Figure 4-10: Commercial Energy Forecast



4.1.5.3 *Industrial Energy Forecast*

The industrial energy forecast includes all customers in the industrial rate class. At this time the only customers in this rate class are mines. All other smaller industries such as forestry or the natural gas sector are captured in the commercial forecast (Section 4.1.5.2.2). Details on the industrial energy forecast can be found in Appendix 4.4.

The industrial energy forecast considers the electricity requirements for mines connected to the grid. The economic activity generated by mines contributes to the electricity use in the residential and commercial customer classes and is captured in the Non-Industrial Energy Forecast (Section 4.1.5.2). If feasible, a grid connection offers mines the opportunity to utilize electricity from a predominantly hydro grid at a regulated rate. The alternative is to operate the mine using imported fossil fuels.

The industrial energy forecast uses data from proxy mines to estimate future grid-connected mining needs. The Very Low Industrial Activity and Low Industrial Activity scenarios assume that Minto Mine would remain the only mine connected to the grid with the closure in 2016 and 2020 respectively.

The Low Industrial Activity with early Minto closure scenario assumes closure of the Minto Mine at the end of 2017 and that only one new medium scale mine would be in operation in the Yukon during the planning period. Victoria Gold's Eagle Gold mine was used as a proxy for the mine in this scenario.

The Medium Industrial Activity scenario assumes that Minto would remain connected until closure in 2022 and a medium scale mine would connect to the grid with development beginning in 2019, production in 2020 and mine closure activities starting in 2030. Victoria Gold was used as a proxy mine for this forecast.

Under the High Industrial Activity scenario, Minto Mine remains connected to the grid until closure in at the end of 2021, Bellekeno Mine is assumed to return in 2020 and close in 2026, three medium mine connect in 2017 (Victoria Gold's Eagle Gold as a proxy), 2019 (Copper North's Carmacks Copper and Golden Predator's Brewery Creek as proxies) with mine closures in 2033, 2032 and 2029, respectively.

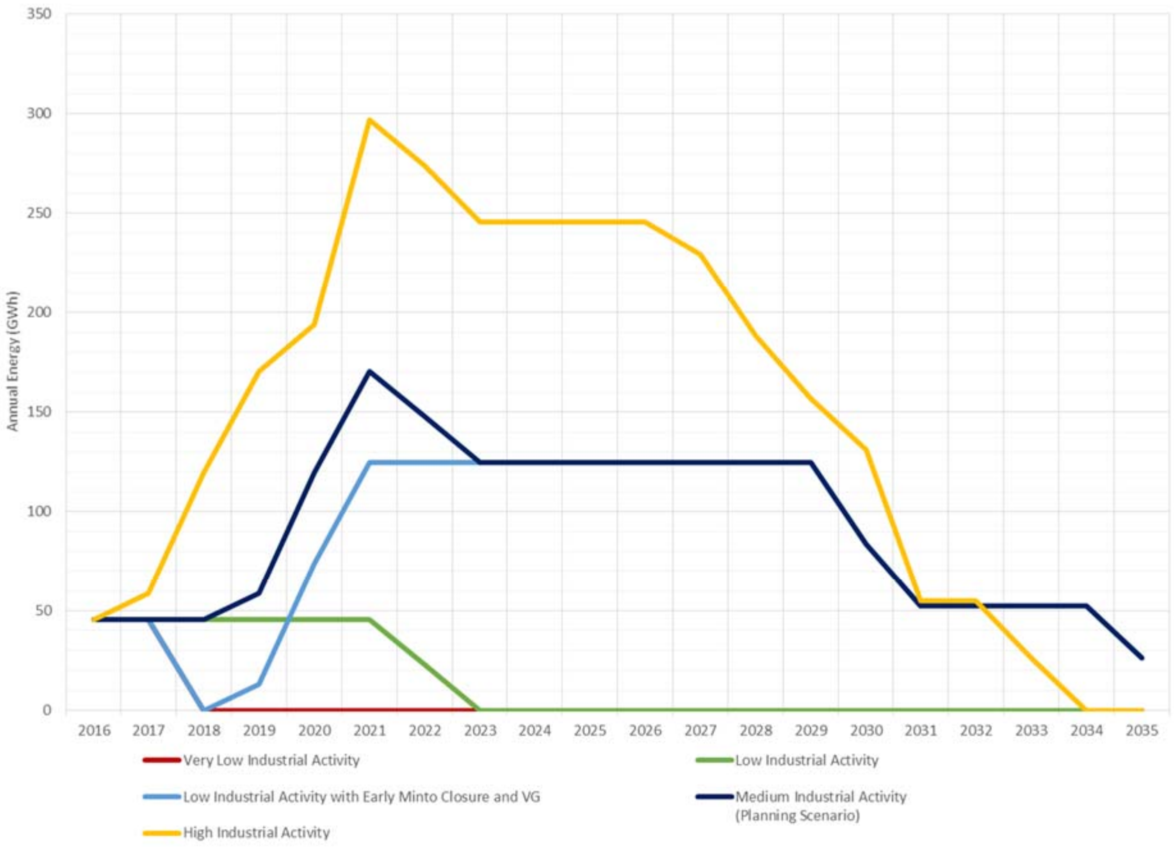
Figure 4-11 shows the forecast industrial energy needs from the mines connected to the grid. The estimated additional electricity needs from new mines connecting to the grid in the Medium Industrial Activity and High Industrial Activity scenarios would be significant. The Very Low Industrial Activity and Low Industrial Activity scenarios show the current energy needs from Minto Mine (46 GWh/year) dropping off, and no other mines connecting to the grid during the planning period.

For the Medium Industrial Activity scenario, energy requirements varies between 171 and 125 GWh/year is estimated between 2021 and 2029. This is in addition to the 364 to 401 GWh/year of non-industrial energy forecast in the same time period.

For the High Industrial Activity scenario, 297 GWh/year is estimated in 2021 falling to 246 GWh/year between 2023 and 2026. This is in addition to the non-industrial energy forecast of 405 GWh/ year in 2021, growing to 459 GWh/year in 2026. The numerical data for all the scenarios are presented in Appendix 4.1.

All the analyzed scenarios show a load decline towards the end of the planning period that is attributed to reduction in mining activity.

Figure 4-11: Industrial Energy Forecast



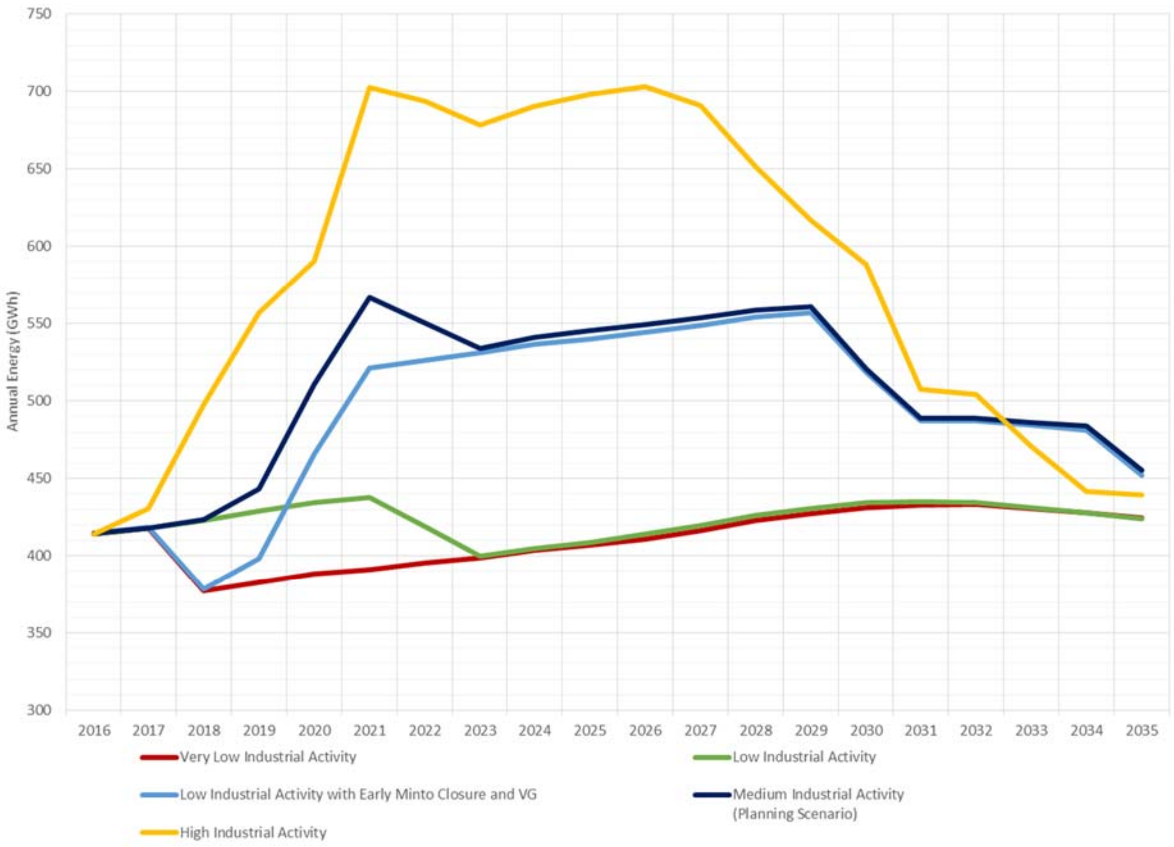
4.1.5.4 *Yukon Integrated System Energy Forecast*

To forecast the energy needs for the entire YIS, the industrial, non-industrial (residential and commercial), electric vehicle energy forecasts, as well as system losses are combined and shown in Figure 4-12; for clarity, only five major scenarios are shown. The forecast energy needs under the four industrial activity cases show a wide range of results with the lowest energy needs of 414 GWh/year in 2016 for the Very Low Industrial Activity scenario and highs of about 703 GWh/year in 2021 and 2026 for the High Industrial Activity scenario. This range is largely driven by assumptions in the industrial sector forecast.

YIS's demand for energy would grow by 0.3% to 0.7% per annum over the range of the major scenarios over the next 20 years and by 0.2% to 5.9% per annum over the range of the major scenarios over the first 10 years. The growth rate declines over the latter half of the planning period is due to a decreased mining activity and slower growth in population due to immigration and demographic trends. For comparison purposes, the recorded load growth from 2011 to 2015 was 1.9% per annum.

The numerical data for all the scenarios are presented in Appendix 4.1 - Energy and Peak Demand Forecast Data 2016-2035.

Figure 4-12: Yukon Integrated System Energy Forecast



4.1.5.5 *Energy Forecast Risks and Uncertainties*

Any forecast inherently includes risks and uncertainties and this section summarizes the potential risks in forecasting Yukon Energy's long-term electricity needs.

4.1.5.5.1 Residential Energy Forecast Risks and Uncertainties

Uncertainty in the residential sales forecast is primarily caused by the following factors: number of accounts, weather and the forecast of use per customer.

- Number of accounts: In the near term, an error in the forecast of account growth would not result in a significant error in the forecast for the total number of accounts, due to the large stock of existing housing, relative to the small yearly growth in housing as presented in Figure 4-1. In the long term, there is increased risk of forecasting error in the number of accounts, due to the cumulative effect of errors in the forecast for account growth. Increased economic activity, such as mining, would have employment effects that would ultimately increase residential electricity demand.
- Weather: In the near term, weather is highly variable, and has a strong effect on residential energy and peak demand, and to a lesser extent commercial demand. Therefore, on a cold day in any one year, there is a risk that weather may have a significant impact on sales and peak

demand. The YEC peak demand forecast is presented for an average peak winter day, which is defined as the peak one-hour demand during the average coldest day in a future year. The risks inherent in actual demands being higher than what is expected during an average peak day is covered in YEC's planning criteria, where YEC applies reserve margin to meet extreme peak events as discussed in Section 4.3.2.

- Use per customer: Most of the risk in the residential forecast resides in the forecast of use per customer. Unlike the forecast of account growth, an error of 1% in the forecast for use per customer in any year would contribute to a direct error of 1% to the forecast for residential sales for that year.

  Some of the factors that would increase use per customer are:

  Increases in home sizes;

  - Increases in electric space heating share;
  - Increases in real disposable income;
  - Increased saturation of appliances; and
  - New sources of electricity uses such as for example electric vehicles.

  Some of the factors that would decrease use per customer are:

  - Increases in heating system efficiencies;
  - Naturally-occurring efficiency improvements in end uses;
  - YEC or government-sponsored conservation programs or technologies that encourage behavior change in electricity consumption;
  - Conservation programs or technologies that encourage behavioral change in electricity consumption;
  - Fuel oil or propane prices decreasing faster than electricity;
  - New dwellings being built with higher insulation standards;
  - Heat emissions from additional appliances reducing electric space heating load;
  - Increased use of programmable or smart thermostats; and
  - Decreases in household sizes (people per household).

Two studies were completed to address specific risks in the demand forecast: the potential adoption of EVs and the potential conversion of residential home heating systems from hydrocarbon fuels to electricity.

A report on the adoption rates of EVs and impact on the YIS was completed by ICF International (ICFI) and can be found in Appendix 4.5. Based on current EV technologies ICFI estimated a low, medium and high penetration with 445, 1144 and 1864 EVs respectively in the territory by 2035, representing 1.1%, 3.0% and 4.4% of total vehicles. The report found that at the above adoption rates, EVs are not expected to have a significant impact on the YIS. The high penetration EV load was included in the YIS load forecast. If a significant breakthrough in EV technology occurs with respect to the cold weather performance of batteries, or the driving range of EVs, or the price of EVs drops to a point that they are within reach of the average customer, the adoption rates could be significantly higher. Consequently, the load forecast will be updated.

Electric heating systems are being installed in the majority of new homes being built in the territory and this trend is already being captured in the residential forecast. The majority of older homes in the territory are heated with furnace oil or propane. An economic analysis of the costs of electricity for heat in comparison to the furnace oil and propane was completed and is included as Appendix 4.6. This study indicates that electricity is a more expensive heating fuel, even when significant carbon tax adders are applied to the cost of hydrocarbon fuels. Thus, YEC decided not to include the potential load caused by retrofits in home heating from fossil fuels to electricity to the load forecast. In addition, discussions with building inspectors, and observations by ATCO do not indicate that a large number of the existing oil or propane heated homes are being retrofit to electric heat. If a large number of home owners start to retrofit their existing homes with electric heat, or if the trend towards installation electric heat in new homes declines, it would have an impact on the residential energy forecast, and these developments would be incorporated into the next YEC demand forecast.

4.1.5.5.2 Commercial Energy Forecast Risks and Uncertainties

Uncertainty in the commercial sales forecast is primarily caused by changes in economic and demographic growth. There are factors that would increase or decrease commercial sales that were recognized in the forecast and there is uncertainty inherent in all of these factors.

Some of the factors that would reduce forecast commercial sales:

- A change in the economic conditions as commercial electricity demand tends to follow the major indicators of the economy (such as GDP);
- Reduced mining activity in the territory, due to reduction in the secondary (spill over) effects of local mining employment and expenditures;
- Naturally-occurring efficiency improvements in end uses;
- YEC or government-sponsored conservation programs or technologies that encourage behavioral change in electricity consumption; and
- An aging provincial population will suppress future employment growth.

Some of the factors that would increase forecast commercial sales:

- A robust economic recovery and increased mining and tourism activity that would create additional local demands for commercial services; and
- Low interest rates encourage consumer spending.

Similar to the residential sector, the choice of heating fuel and building practices in the commercial sector would influence the electricity demand for heating. The data gathered for heating systems in new homes was not collected for commercial buildings, making the estimate of trends in heating fuel selection more challenging in this sector. An assumption was made that the commercial sector will opt for more cost-effective heating fuel, which is not electricity at this point in time. YEC will follow the heating fuel trends and adjust the load forecast in the future if needed.

The commercial electricity demand forecast is dependent on the activity in various private sectors as well as in the local, territorial and federal governments. Therefore, the scenarios chosen for the development of commercial demand forecasts tested a range of economic activity, influenced by levels of industrial activity, activity in other sectors, and government spending levels. The range of commercial activity forecast for the different scenarios is discussed in detail in Appendix 4.2 - Yukon Macroeconomic Model 2016-2035 and the effects that the various economic inputs have on the energy forecast is discussed in detail in Appendix 4.3.

4.1.5.5.3 Industrial Energy Forecast Risks and Uncertainties

Uncertainty in the industrial sales forecast is primarily caused by changes in mining activity, considering that mining is a major driver of economic growth in the territory and that historically, mines have been Yukon Energy's sole industrial customers.

The connection of a mine to the grid has a large impact on energy demand, as seen in Figure 4-11. Unlike the residential or commercial sectors, where there are many diverse customers each using a small amount of electricity, the industrial sector has a small number of customers, each requiring a large amount of electricity. For example, Minto Mine accounted for approximately 9% of total YEC energy demand in 2015.

To account for potential future development of other industries in the territory, Yukon Energy developed a sensitivity scenario for economic activity resulting from development in the natural gas sector (scenario 8). However it is not expected that these projects would connect to the grid, as they tend to be remote, and for energy requirements, this industry tends to self-supply. If YEC has reason to believe that there is another large industrial grid-connected customer developing in the territory, the industrial energy forecast will be updated.

Because of the makeup of the industrial sector in the territory, demand forecast risks faced by YEC tend to be aligned to the following mining sector uncertainties:

- Global metals prices (copper, gold and molybdenum) driven by global economic activity, influencing opening or closing mines;
- The cost of capital and risk perception among investors and banks;
- The industry perception of the resource friendliness of the Yukon government policies and government's present and anticipated tax regimes;
- Level of supporting infrastructure (ports, roads, power and proximity to communities) and the potential for future development;
- Future provincial and federal government actions that increase or decrease clarity of regulatory policy, conflict resolution measures, and tax efficiencies;
- Outcome of future environmental assessment applications; and

The level of mining activity in Yukon is strongly influenced by the commodity markets, and is therefore to a large extent is subject to global forces outside of the control of YEC or the territory. The fourteen economic scenarios cover a wide potential range of mining activity. These scenarios were developed to help understand the range of demand impacts from mining activity in the territory. The economic influences outside of the mineral export value are captured in the residential and commercial forecasts due to the economic spillover effects of mining activity to other sectors.

4.1.5.5.4 Yukon Integrated System Energy Forecast Risks and Uncertainties

The factors that could change the energy forecast across all customer classes include government spending, global commodity prices and climate change. Mining activity and government spending are the two main factors influencing the economy of the Yukon.

Climate change affects temperatures, which drive customer heating requirements and electricity use. To quantify the impact of climate change on peak demand and energy requirements over the planning period, a sensitivity scenario to the Medium Industrial activity was completed using data provided from a study published by Yukon College[3]. A new climate normal caused by climate change was calculated from the climate change temperature projections over the planning period and was integrated into the SAE model to generate an energy and peak demand forecast. This new climate normal saw an average increase of 0.08°C per annum in comparison to the current normal.

Figure 4-13 and Figure 4-14 show the YEC Medium Industrial Activity scenario energy and YEC Medium Industrial Activity scenario non-industrial peak demand forecasts respectively with and without the climate change-related temperature increases. The predicted increase in the future Yukon temperatures of 1.3°C over the planning period of 20 years would result in a small reduction in electricity demand. Given the small impact, this potential effect is not included in the base YEC demand forecast due to the risks involved in not serving future customer requirements.

YEC did not study potential secondary demand effects of climate change, such as possible changes to industrial production, agriculture, or population. YEC is not aware of any utility that includes such adjustments to its demand forecasts or resource plans.

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[3] Northern Climate Exchange, Yukon Research Centre, Yukon College: Yukon Climate Change Indicators and Key Findings 2015,

Figure 4-13: Effect of Climate Change on Medium Industrial activity scenario Non-Industrial Energy Forecast

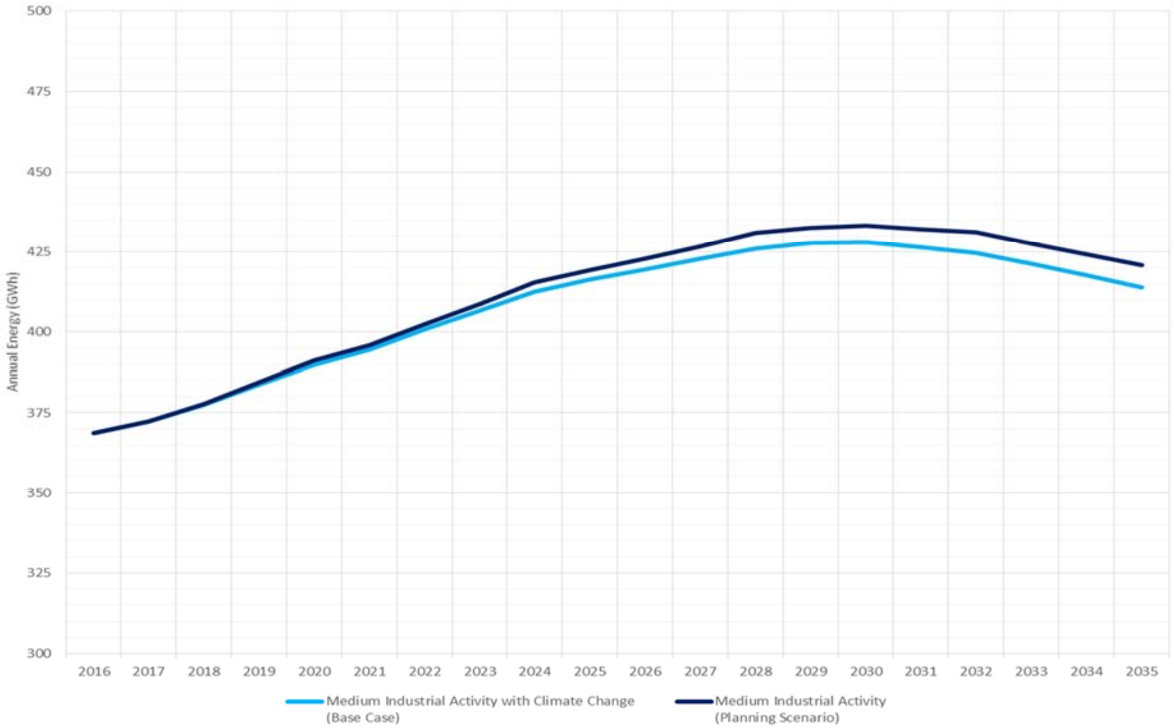
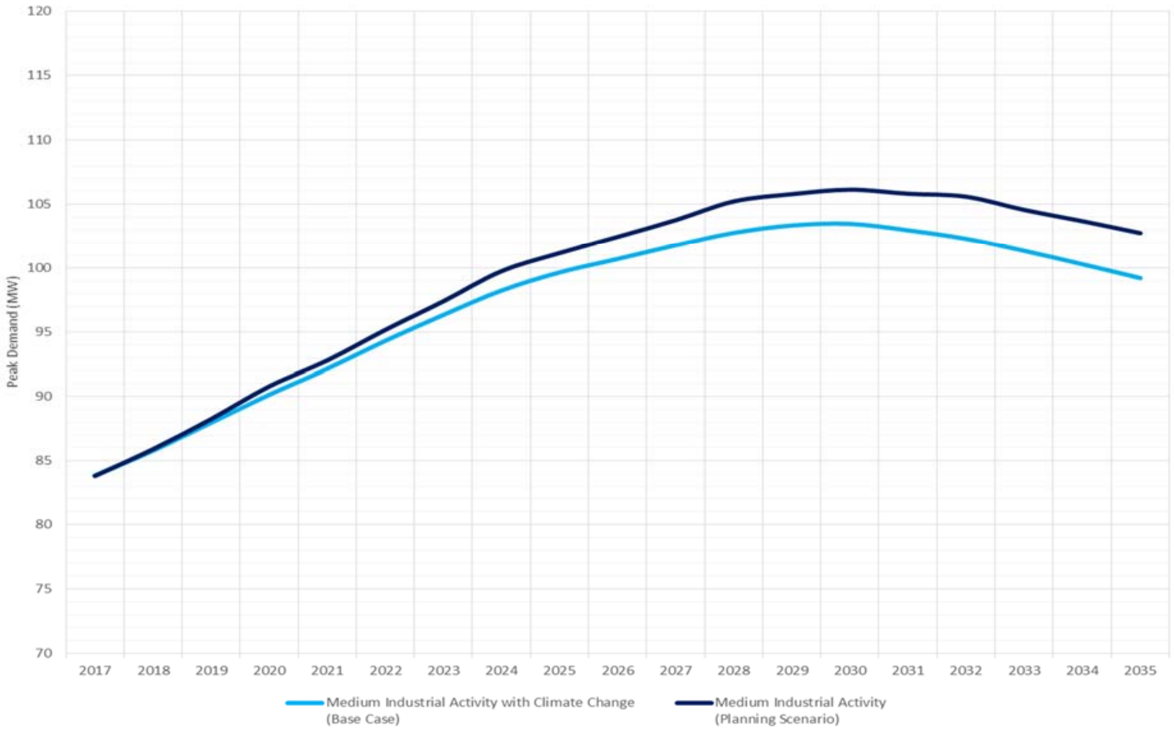


Figure 4-14: Effect of Climate Change on Medium Industrial activity scenario Non-Industrial Peak Demand Forecast



4.1.6 Peak Demand Forecast

This section presents the peak demand forecast for the YIS. Peak demand is the maximum amount of electricity that customers demand and YEC must supply at any point in time expressed in units of megawatts (MW). The peak demand forecast is presented first without mines connected to the grid, then the peak demand forecast for connected mines, and finally the total peak demand for the YIS.

4.1.6.1 *Peak Period Description*

YEC's electricity demand generally peaks in December or January due to cold temperatures which drive the need for heating, and fewer daylight hours, which drives increased lighting. Over the course of a day, there are two demand peaks, the first of which occurs between 7:00 and 10:00 am, and the second higher peak between 5:00 and 8:00 pm. These peaks are driven by increases in morning thermostat settings, morning and evening lighting, and the use of appliances, particularly for cooking during the evening peak.

4.1.6.2 *Non-Industrial Peak Demand Forecast*

This section presents the non-industrial peak demand forecast. The non-industrial forecast includes the residential (including street lighting) and commercial customer classes. The residential and commercial customer classes share the same distribution infrastructure, so that historical demands in these sectors cannot be broken down further. Details on the non-industrial peak demand forecast can be found in Appendix 4.3. The SAE model was used to forecast the non-industrial peak demand.

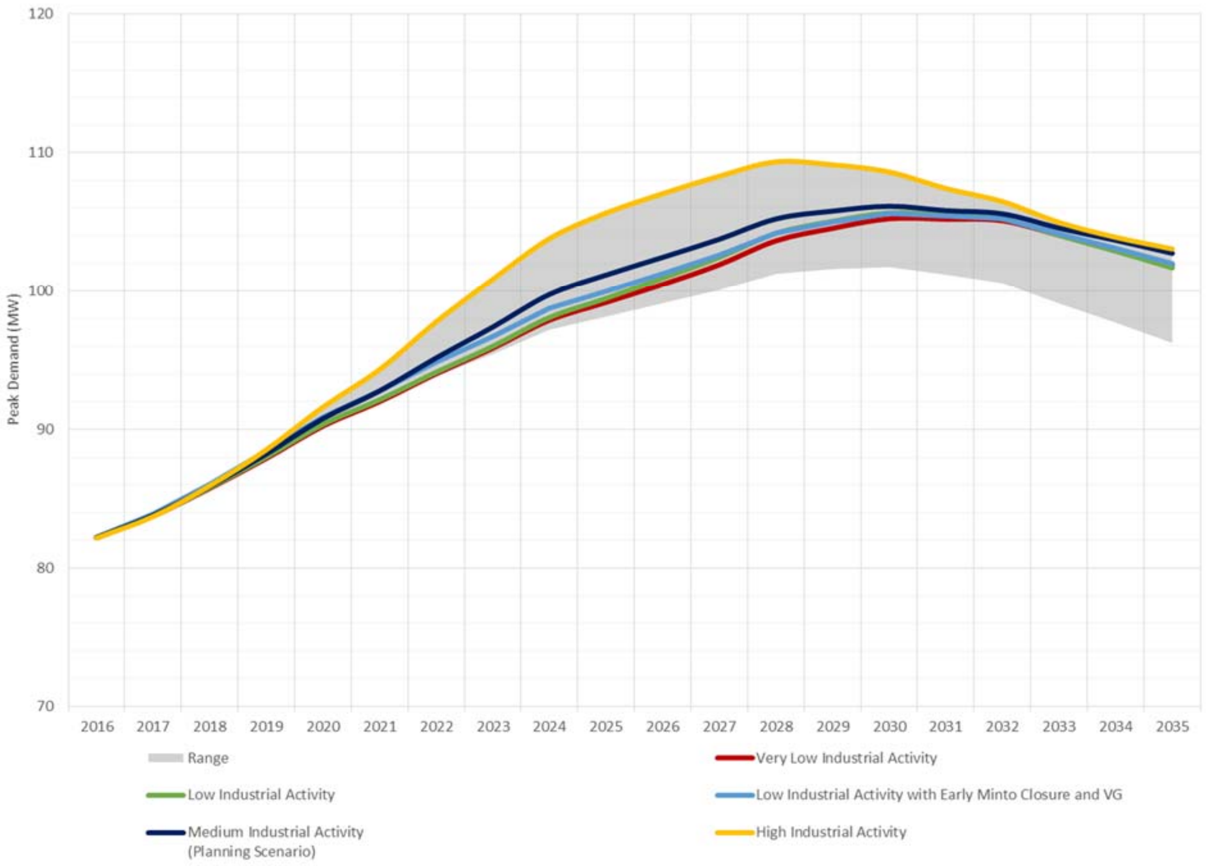
Figure 4-15 shows the annual non-industrial peak demand forecast for the five major scenarios with the nine sensitivity scenarios presented as a range.

The peak demand forecast shows a steady increase at the beginning of the period up to 2030 for all the scenarios. The increase is driven by the increased penetration of electrical space heating in both residential and commercial buildings. With all scenarios, there is a flattening or decrease of peak requirements towards the end of the planning period, largely driven by the reduced population and employment in the territory, as well as increased efficiency of end use. The details on the population and employment forecast as a part of the econometric forecast are presented in Appendix 4.2. The highest peak demand forecasts is 109 MW for the High Industrial Activity scenario in in 2029, while the peak demand for the Medium Industrial Activity scenario is 106 MW in 2030. The scenarios with no growth in government spending exhibit the largest drop in peak demand at the end of the planning period. Note that the vertical axis in Figure 4-15 starts at 70 MW instead of at 0 MW to better demonstrate the differences among the presented scenarios. The numerical data for all the scenarios are presented in Appendix 4.1 - Energy and Peak Demand Forecast Data 2016-2035.

All the analyzed scenarios show a peak demand decline towards the end of the planning period that is primarily attributed to reduction in the spillover effect from mining, a reduction in the population and number of households, and increased efficiency of electricity end use.

The numerical data for all the scenarios are presented in Appendix 4.1 - Energy and Peak Demand Forecast Data 2016-2035.

Figure 4-15: Non-Industrial Peak Demand Forecast



4.1.6.3 *Industrial Peak Demand Forecast*

The industrial peak demand forecast includes all customers in the industrial rate class. At this time the only customers included in this category are mines. All other smaller industries, such as forestry, are captured in the non-industrial peak demand forecast (Section 4.1.6.2). The industrial peak demand forecast applied the same proxy mine and timing assumptions as the industrial energy forecast, described in Section 4.1.5.3.

Similar to the industrial energy forecast, the industrial peak demand forecast in the Very Low Industrial Activity and Low Industrial Activity scenarios exhibits a demand drop with the closing of Minto Mine.

The industrial peak demand forecasts for five major scenarios are shown in Figure 4-16. As shown in Figure 4-16, the forecast for the Medium Industrial Activity and High Industrial Activity scenarios show a sharp increase of 26 MW and 36 MW, respectively as the connected mines begin production. The peak demand is forecast to level off at 9 MW for the rest of the planning period in the Medium Industrial Activity scenario.

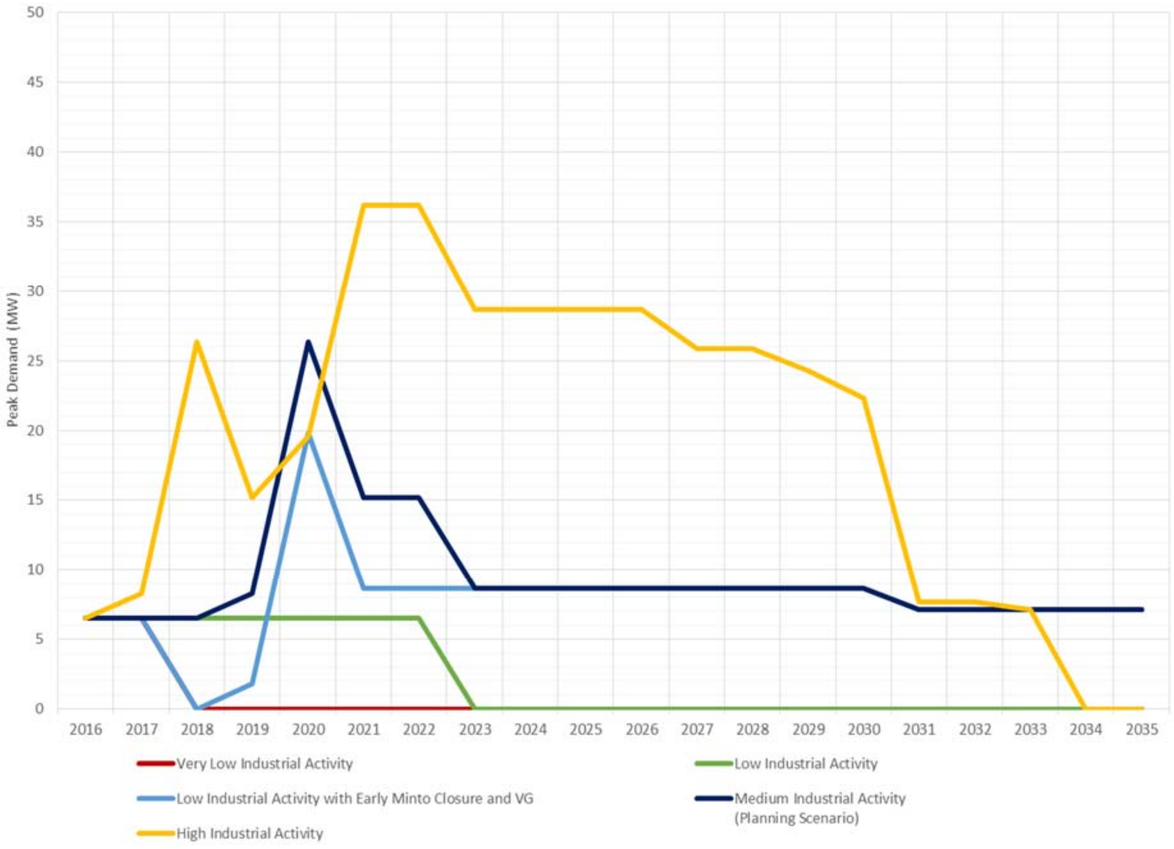
For the High Industrial Activity scenario, the peak demand is forecast to level off at 29 MW during the middle of the planning period, dropping to 8 MW towards the end of the planning period and finally dropping to zero in 2034.

Under the High Industrial Activity scenario, the peak demand increases significantly between 2017 and 2018 due to the transition from construction to production at Victoria Gold's Eagle Gold project. The first full year of production at the mine is scheduled to occur in 2019. At that point, the winter schedule will be in effect, thus reducing the contribution of the industrial demand to the system peak demand. This translates in the decrease from 2018 to 2019 as presented in Figure 4-16. The relatively low contribution to the system peak demand for the Medium Industrial Activity scenario is a direct consequence of the seasonal load schedule at the Eagle Gold mine whereby the project's peak demand occurs during the summer months (March to November), which is not coincidental with the non-industrial peak demand.

The additional peak demand early in the forecast under the Medium Industrial Activity and High Industrial Activity scenarios represents a substantial demand increase when added to the 91 MW of the non-industrial peak demand forecast for the same period (Section 4.1.6.2).

Consistent with the high degree of industrial sector risk, there is a wide range in results in the peak demand forecasts for the four industrial activity scenarios.All the analyzed scenarios show a peak demand decline towards the end of the planning period that is attributed to reduction in mining activity. The numerical data for all the scenarios are presented in Appendix 4.1 - Energy and Peak Demand Forecast Data 2016-2035.

Figure 4-16: Industrial Peak Demand Forecast



4.1.6.4 *Yukon Integrated System Peak Demand Forecast*

To forecast the peak demand for the entire YIS, the industrial, non-industrial (residential and commercial), electric vehicle energy forecasts, as well as system losses are combined and shown in

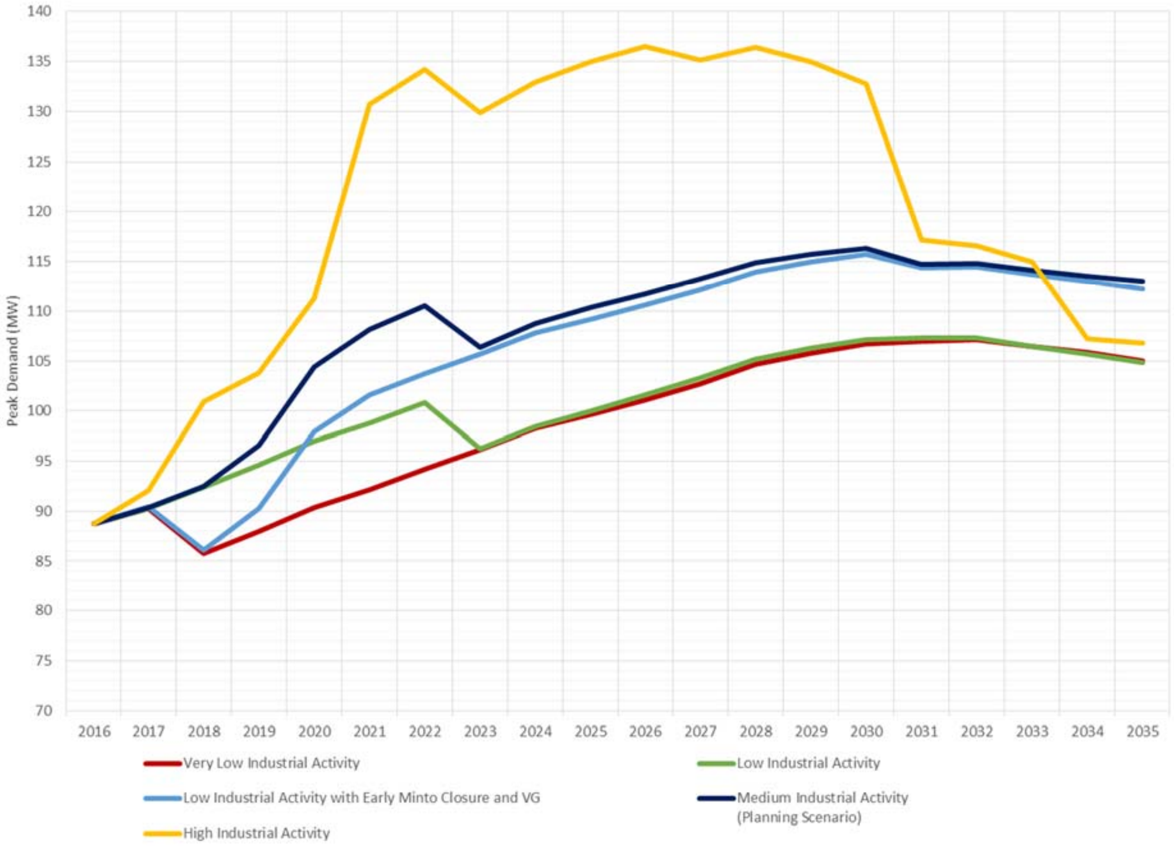
Figure 4-17. For clarity purposes, only five major scenarios are shown in Figure 4-17. The forecast for the five industrial activity levels shows the lowest peak demand of 89 MW in 2016 for the Very Low Industrial Activity scenario and highs of 129 MW in 2020 and 141 MW in 2028 for the High Industrial Activity scenario. This is driven by the wide range of results of the industrial forecast.

YIS's peak demand would grow by 1.3% to 1.7% per annum over the range of the major scenarios over the next 20 years and by 2.0% to 5.2% per annum over the range of the major scenarios over the first 10 years. The growth rate declines over the latter half of the planning period is due to a decreased mining activity and slower growth in population due to immigration and demographic trends. For comparison purposes, the recorded load growth from 2011 to 2015 was 2.6% per annum.

The higher growth rate of peak demand compared to that of energy load, 1.3-1.7% vs. 0.3-0.7% over the next 20 years respectively, is attributed to the end use of electricity, primarily caused by high penetration of electric space heating in new housing.

The numerical data for all the scenarios are presented in Appendix 4.1.

Figure 4-17: Yukon Integrated System Peak Demand Forecast



4.1.6.5 *Peak Demand Forecast Risks and Uncertainties*

Uncertainties affecting the peak forecast are generally consistent with those affecting the energy forecast, such as electric vehicle or/and electric heating penetration discussed previously.

The adoption of EVs will influence peak demand. Apart from uncertainties in the adoption rate, risks to the peak forecast include the time of the day in which charging occurs, and the penetration of quick charge stations. In terms of moderating EV peak demand requirements, off-peak charging periods are preferred; this could be encouraged by YEC through rates or incentives.

Similar to the effect on the energy forecast, a single industrial customer can have a substantial effect on YEC peak demand. For example, Minto Mine accounted for 6% of YECs peak demand in 2015. The scenarios tested by YEC, and presented previously, show a wide but plausible range of mining outcomes, and quantify how these could affect the forecast.

4.2 Existing and Committed Resources

The second key input required to construct the LRB for the YEC Power System is the capability of the existing connected generation resources and committed resources. Committed resources are resources that secured regulatory approvals and are in the process of planning. Both the existing and committed resources were used as inputs to the portfolio analysis.

4.2.1 Existing Resources

The existing resources include YEC's legacy hydroelectric, wind and thermal (diesel-fired and natural gas-fired) resources. The thermal diesel-fired resources owned and operated by ATCO in the communities connected to the Yukon Integrated System also fall within this category. These units are included in the ledger of existing resources.

ATCO's generation resources are assumed to contribute to dependable capacity of the system, with the underlying expectation that ATCO will provide backup power if needed. Due to the absence of reliable information on whether these assets can be operated over an extended period of time or not, it is assumed that they cannot provide firm energy to meet firm annual energy requirements, but can provide energy for operational purposes, as they do in reality. ATCO's thermal contribution to non-firm energy is limited at a 10% capacity factor. This constraint is driven by the absence of information pertaining to the condition, capabilities and planned retirement year of the assets. YEC is thereby prudently limiting its reliance on external assets.

4.2.1.1 *Technical attributes of existing resources*

The technical attributes used to evaluate the existing resources are following:

- Average energy (annual, monthly);
- Firm energy (annual, monthly);
- Installed capacity;
- Dependable capacity;
- Retirement year; and
- Resource dispatchability.

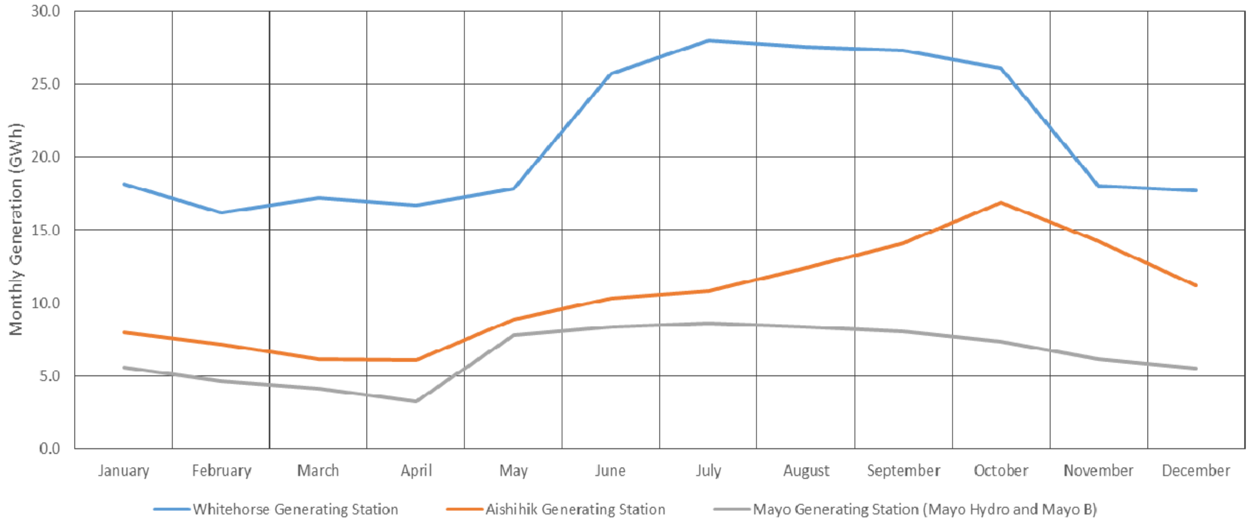
These technical attributes are presented as numerical values, except for dispatchability, which is presented as yes/no. To make Table 4.2 presenting the technical attributes more readable, the average and firm energy data were summed and presented as annual values. The monthly energy data related to those attributes were used in the portfolio analysis.

The technical attributes are defined as follows:

Average Energy, expressed as GWh/year, is the total amount of energy that the resource option can potentially produce in an average year. An average year defined as having historically average fuel availability, such as water or wind. The fuel supply for a thermal generation station (diesel or natural gas) can be available with a high degree of certainty, since these fuels can be stored.

Figure 4-18 shows the combined average monthly energy profiles excluding spilled water for the Whitehorse, Mayo and Aishihik Hydro Generating Stations.

Figure 4-18: Combined average monthly energy profile for Whitehorse, Mayo and Aishihik Hydro Generation Stations.



Firm energy, expressed GWh/year, is the total amount of energy that the resource option can reliably generate in a timeframe, typically reported as annual and monthly. Resource firm energy depends on a number of factors, primarily the reliability of the fuel specific to the resource. For example, the fuel supply for a thermal generation station (diesel or natural gas) can be available with a high degree of certainty, since these fuels can be stored. On the other hand, the intermittent fuel supply for resources such as wind depends on wind speeds, which are inherently uncertain and cannot be controlled by the project operator. Despite this intermittency, it can be expected that certain amount of energy from those resources will be available on a longer timeframe, such as yearly. Hydro generation systems are subjected to variations in water availability on a year-to-year basis, which affect generation capability. Low water years are critical because these constrain YEC's generation capability. Historically, low water conditions in the Yukon have occurred over multiple successive years. Based on the YEC system-wide hydrologic record, the last major drought period occurred in the late 1990s.

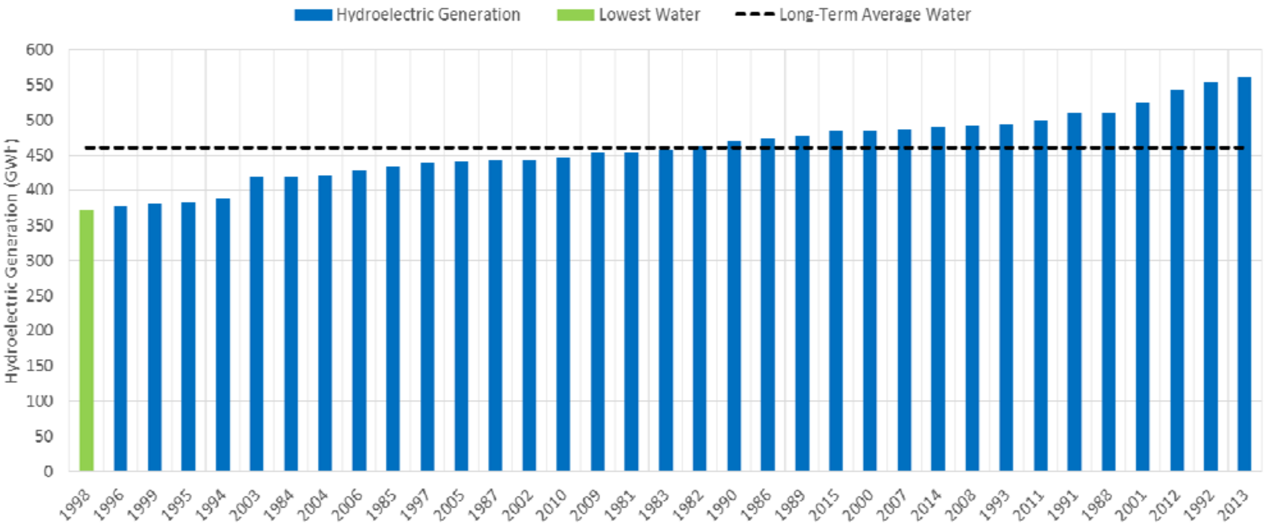
Being an isolated grid, YEC deemed it to be prudent to estimate firm energy assuming the historic lowest water inflows on record. The goal of this approach is to provide reliability under stringent conditions, given that the YEC grid is self-sufficient and isolated with no ability to import energy if its own resources are not able to meet load. The practice of estimating firm energy by assuming low water inflows is followed by other Canadian utilities as indicated in the review of the practices presented in Table 4.1. In hydro generation dominated utilities such as BC Hydro, Hydro-Quebec, Manitoba Hydro and YEC, water could be a limiting factor.

Table 4.1. Energy Planning Criterion for various utilities in Canada

Utility	**Energy Criterion**	**Reference**
BC Hydro	Prior to the implementation of the Clean Energy Act (CEA) self-sufficiency requirement, BC Hydro's generation energy planning criterion "was to meet its energy requirements with "firm" energy plus some degree of reliance on non-firm hydro energy backed up by market purchases. Firm energy is defined as the ability to meet load requirements under the most adverse sequence of stream flows as experienced by BC Hydro's Heritage hydroelectric assets within the 60-year period between October 1940 and September 2000" (i.e. critical water). The CEA self-sufficiency requirement used in BC Hydro's 2013 Integrated Resource Plan establishes two additional requirements: (1) the reliance upon the Heritage assets under *average water condition* and (2) that all other resources must be located within the Province of B.C.	BC Hydro, Integrated Resource Plan, Chapter 1 – Introduction and Context, August 2013
Hydro-Québec	Maintain energy reserves sufficient to alleviate water shortages, with a probability of occurrence of 2%, amounting to 64 TWh over two consecutive years and 98 TWh over four consecutive years.	Decision D-2008-133, File R-3648-2007
Manitoba Hydro	"[…] requires the corporation plan to have adequate energy resources to supply the firm energy demand in the event that the lowest recorded coincident water supply conditions are repeated; the energy supply under these conditions is referred to as dependable energy".	Manitoba Hydro 2015/16 & 2016/17 General Rate Application, Tab 9, January 23, 2015

Under drought conditions, the lowest water on the record, firm energy generation from YEC's hydro stations is 372 GWh/year, a significant (24%) decrease from the 461 GWh/year under average long-term conditions. A comparison of hydroelectric generation for all stations under lowest and long-term average water conditions is presented in Figure 4-19. The figure presents the hydro generation for the 1981 to 2015 period as bars with the black line depicting the long-term average generation. The difference between wettest and driest years on record is about 190 GWh/year.

Figure 4-19. Comparison of Hydro Generation for all Generating Stations under Lowest and Long-Term Average Water



The YECSIM model was used to estimate firm energy of current hydro resources presented in Table 4.2. The YECSIM model was developed by KGS Consulting Group for YEC and has been used by YEC in the past for estimating power generation. It is a planning model that is designed to simulate YEC system energy generation under a variety of hydrological and load conditions.

The major model inputs are:

- The load (energy) forecast and its distribution throughout the year; and
- Resource technical attributes (installed capacity, unit efficiencies, reservoir storages vs. elevation curves, non-power water release rating curves, transmission losses).

The major model operational criteria are:

- Water use license requirements;
- Minimum and maximum flows;
- Minimum and maximum reservoir elevations; and
- Priority or water releases between power generation and environmental releases.

The major model output is expected energy generated by each resource.

Given that the existing wind penetration to the YEC system is small, it is assumed that firm energy for wind is equal to average annual energy.

For YEC's existing thermal resources, a consideration in the determination of firm energy is the frequency and severity of equipment maintenance and failures, which is expressed as a capacity factor. Based on the historic data on scheduled maintenance, a capacity factor of 90% was assumed for the LNG and diesel engines, which means that the LNG and diesel engines are available to run at full load 90% of time.

Installed capacity, expressed in Megawatts (MW), is the maximum amount generating capacity that the equipment for a specific resource option is capable of providing. This metric assumes that the resource asset is unconstrained by its fuel supply, and it is in full operational condition.

Dependable capacity, expressed in MW, is the maximum generation output that a resource can reliably provide in a specific timeframe, typically during the period of greatest demand. YEC defines dependable capacity as the maximum output that a resource can reliably provide over two consecutive weeks during the four winter months (November to February) based on the inflows in the five driest inflow years in history. The YECSIM model was used to estimate dependable of current hydro resources presented in Table 4.2. For thermal resources, dependable capacity was assumed to be equal to the installed capacity, since fossil fuels can be stored. For wind resources, dependable capacity is considered zero, as there is no guarantee that there will be the required wind speeds for the two consecutive weeks within the winter period.

Retirement year, is the year a resource is expected to be retired. For hydro and wind resources the retirement year is defined by the designed project life, while the retirement of thermal resources depends on the wear and tear typically defined by operating hours and/or obsolescence typically defined by the availability of spare parts.

Dispatchability, refers to a feature of a resource that allows it to be turned on or off. Dispatchable resources are able to adjust their power output supplied to the electrical grid on demand. Resource options such as thermal power plants and hydro power plants with reservoirs are dispatchable and they can meet changing electricity loads. In contrast, intermittent resources, such as wind are non-dispatchable because they can only generate electricity while their energy source is available

The inventory of the existing YEC and ATCO resources and their technical attributes are presented in Table 4.2. For comparison purposes, the table also provides the dependable capacity assumed in the 2011 Resource Plan.

A comparison between the dependable capacity values used in the 2016 Resource Plan and those in the 2011 Resource Plan showed minor differences that resulted in a decrease in dependable capacity, from 116 MW in 2011 to 115 MW in 2016. The difference is due to the following updates:

- YEC's internal assessment of the diesel generators has de-rated the dependable capacity of a Dawson diesel unit (DD4) from 1.2 MW in 2011 to 1.0 MW.
- After an internal review, the dependable capacity of two diesel units in Whitehorse (WD3 and WD4) have been uprated from 2.25 MW each in the 2011 Resource Plan to 2.5 MW each.
- In 2011, the dependable capacity of the Mayo Generating Station was estimated at 11 MW, while in 2016, it was assessed at 9 MW due to reassessments of flow restrictions and ice-management protocols.
- ATCO reassessed the dependable capacity of their diesel units, reduced the total dependable capacity of their diesel fleet from 7.2 MW in 2011 to 5.4 MW in 2016.
- ATCO's Fish Lake Hydro was excluded in the inventory of existing resources, as its contribution had already been accounted for by YEC in the 2016 load forecast in terms of reduced net load. This removal is only an accounting change, in order to avoid double-counting in YEC's analyses.

4.2.1.2 *Unit retirements*

Over the planning period, YEC anticipates the retirement of the two remaining Mirrlees diesel engines (FD1 and WD3) in 2021, potentially some other diesel engines, depending on the extent of future diesel operations, and the wind turbine (WW2) located on Haeckel Hill in 2026.

YEC considered the following two factors to determine the retirement of the remaining diesel engines:

1. Original equipment manufacturer and aftermarket manufacturer support, and
2. Remaining operating hours of the engines.

Due to the age of the two Mirrlees engines (FD1 and WD3) brought into service in 1968, YEC must rely on the used parts market or request custom-made parts to maintain these engines, as original manufacturer spare parts are not available. YEC's assessment concluded that these two units must be retired in 2021, which would reduce the dependable capacity of the system by 9 MW. The retirement date of these units is consistent with the 2011 Resource Plan. The engine assessment report is provided in Appendix 4.7.

Given the low average usage of the thermal fleet, which accounts for less than 2% of YEC's annual energy generation, YEC has been able to extend the life of several thermal-diesel engines, as the life span of diesel engines primarily depends on operating hours.

YEC assumes that an engine is at the end of life once it reaches 100,000 hours of operations. Although the current use of the thermal assets is low, depending on the future load and resource mix YEC could potentially significantly increase its reliance on thermal resources. If the use of thermal assets were to increase significantly, the operating hour limitation may require that these units be retired within the 20-year planning horizon. However, under reasonably foreseeable operating expectations, these units should be available throughout the planning period and beyond. The end of life for the diesel units (apart from FD1 and WD3) was assessed in the portfolio analysis as a function of their actual use, which depended on the future load and resource mix. This approach was an improvement compared to the approach in the 2011 Resource Plan where the diesel retirement dates ware assumed based on a fixed generation over the planning period.

The other unit to be retired is the last remaining wind turbine (WW2) located on Haeckel Hill. Unit WW1 was retired in 2015. This WW2 unit is one of the oldest in Canada, and maintenance of this asset has proven challenging and costly as it is not supported by the original manufacturer. YEC's assessment is that WW2 will need to be retired once it reaches the end of life in 2026.

4.2.1.3 *Financial attributes of existing resources*

When considering the financial attributes of the existing resources, the capital costs were considered sunk and as such, they did not change across the portfolios discussed in Chapter 8. Since these capital costs were identical in each analyzed portfolio, they were removed from the portfolio analysis.

The Operations & Maintenance (O&M) costs of the existing resources were included in the portfolio analysis. The O&M costs of $0.05/kWh were assumed for existing hydro generation, while the O&M costs of existing thermal generation depended on the future fuel forecast and actual generation. The O&M costs for the thermal generation were calculated by the optimization model using the long term fuel price forecast presented in Chapter 6, and actual generation predicted by the optimization model. The O&M costs for wind were assumed zero, as a consequence of the marginal amount of wind generation and low maintenance cost.

Table 4.2. Yukon Integrated System Generation Inventory

Location	Retirement Year	Unit #	Original Unit #	Prime Mover Type	Dispatchable	2016 Resource Plan				2011 Resource Plan Capacity Table 2-3
						Average Energy [GWh]	Firm Energy [GWh]	Installed Capacity [kW]	Dependable Capacity [kW]	[kW]
Aishihik										
Hydro	2040	AH1	AH1	Hydro	Yes	126.2	58.6	15,000	15,000	15,000
	2040	AH2	AH2	Hydro	Yes			15,000	15,000	15,000
	2040	AH3	AH3	Hydro	Yes			7,000	7,000	7,000
					Subtotal	**126.2**	**58.6**	**37,000**	**37,000**	**37,000**
Faro										
Diesel	2021	FD1	FD1	Diesel	Yes	31.5	31.5	4,000	4,000	4,000
	2040	FD7	FD7	Diesel	Yes	22.1	22.1	2,800	2,800	2,800
					Subtotal	**53.6**	**53.6**	**6,800**	**6,800**	**6,800**
Dawson										
Diesel	2040	DD1	DD1	Diesel	Yes	5.7	5.7	720	720	720
	2040	DD2	DD2	Diesel	Yes	7.3	7.3	920	920	920
	2040	DD3	DD3	Diesel	Yes	7.3	7.3	920	920	920
	2040	DD4	FD5	Diesel	Yes	7.9	7.9	1,000	1,000	1,200
	2040	DD5	DD5	Diesel	Yes	11.0	11.0	1,400	1,400	1,400
	2040	YM1	FD6	Diesel	Yes	7.9	7.9	1,000	1,000	0
					Subtotal	**47.0**	**47.0**	**5,960**	**5,960**	**5,160**
Mayo										
Diesel	2040	MD1	FD2	Diesel	Yes	6.7	6.7	850	850	850
	2040	MD2	FD4	Diesel	Yes	6.7	6.7	850	850	850
	2040	MD3	FD3	Diesel	Yes	6.7	6.7	850	850	850
					Subtotal	**20.1**	**20.1**	**2,550**	**2,550**	**2,550**
Hydro	2021	MH1	MH1	Hydro	Yes	77.8	60.1	2,550	1,400	4,200
	2021	MH2	MH2	Hydro	Yes			2,550		
	2040	MBH1	MBH1	Hydro	Yes			5,000	3,800	3,400
	2040	MBH2	MBH2	Hydro	Yes			5,000	3,800	3,400
					Subtotal	**77.8**	**60.1**	**15,100**	**9,000**	**11,000**
					Total	**97.9**	**80.2**	**17,650**	**11,550**	**13,550**
Whitehorse										
Hydro	2040	WH1	WH1	Hydro	Yes	256.6	253.1	5,800	6,000	3,400
	2040	WH2	WH2	Hydro	Yes			5,800		3,400
	2040	WH3	WH3	Hydro	Yes			8,400		
	2040	WH4	WH4	Hydro	Yes			20,000	18,500	17,200
					Subtotal	**256.6**	**253.1**	**40,000**	**24,500**	**24,000**
Diesel	2015	WD1	WD1	Diesel	Yes	N/A	N/A	N/A	N/A	3,500
	2015	WD2	WD2	Diesel	Yes	N/A	N/A	N/A	N/A	4,500
	2021	WD3	WD3	Diesel	Yes	35.5	35.5	4,500	4,500	4,500
	2040	WD4	WD4	Diesel	Yes	19.7	19.7	2,500	2,500	2,250
	2040	WD5	WD5	Diesel	Yes	19.7	19.7	2,500	2,500	2,250
	2040	WD6	WD6	Diesel	Yes	19.7	19.7	2,500	2,500	2,500
	2040	WD7	WD7	Diesel	Yes	23.7	23.7	3,300	3,000	3,000
					Subtotal	**118.3**	**118.3**	**15,300**	**15,000**	**22,500**
Natural Gas	2055	WG1	WG1	Natural Gas	Yes	34.7	34.7	4,400	4,400	N/A
	2055	WG2	WG2	Natural Gas	Yes	34.7	34.7	4,400	4,400	N/A
					Subtotal	**69.4**	**69.4**	**8,800**	**8,800**	**0**
					Total	**444.3**	**440.7**	**64,100**	**48,300**	**46,500**
Haeckel Hill										
Wind	2015	WW1	WW1	Wind	No	N/A	N/A	N/A	N/A	0
	2026	WW2	WW2	Wind	No	0.5	0.5	660	0	0
					Subtotal	**0.5**	**0.5**	**660**	**0**	**0**
Mobile Diesels										
Diesel	2040	YM2	YM2	Diesel	Yes	N/A	N/A	150	0	0
	2040	YM3	YM3	Diesel	Yes	N/A	N/A	125	0	0
	2040	YM4	YM4	Diesel	Yes	N/A	N/A	35	0	0
	2040	YM5	YM5	Diesel	Yes	N/A	N/A	125	0	0
					Subtotal	**0.0**	**0.0**	**435**	**0**	**0**
YECL										
Diesel	N/A	CD1	CD1	Diesel	Yes	N/A	N/A	1,280	1,206	1,600
	N/A	TD1	TD1	Diesel	Yes	N/A	N/A	1,200	1,130	1,500
	N/A	RD1	RD1	Diesel	Yes	N/A	N/A	800	750	1,000
	N/A	HD1	HD1	Diesel	Yes	N/A	N/A	1,400	1,320	1,750
	N/A	Pelly G1	Pelly G1	Diesel	Yes	N/A	N/A	220	199	230
	N/A	Pelly G2	Pelly G2	Diesel	Yes	N/A	N/A	480	446	500
	N/A	Pelly G3	Pelly G3	Diesel	Yes	N/A	N/A	240	218	250
	N/A	Stewart G1	Stewart G1	Diesel	Yes	N/A	N/A	120	104	400
					Subtotal	**0.0**	**0.0**	**5,740**	**5,373**	**7,230**
Minto Mine										
Diesel	2040	MMD1	MMD1	Diesel	Yes	N/A	N/A	2,000	0	0
	2040	MMD2	MMD2	Diesel	Yes	N/A	N/A	2,000	0	0
	2040	MMD3	MMD3	Diesel	Yes	N/A	N/A	2,000	0	0
	2040	MMD3	MMD3	Diesel	Yes	N/A	N/A	2,000	0	0
					Subtotal	**0.0**	**0.0**	**8,000**	**0**	**0**
				YEC	**Hydro**	460.7	371.8	92,100	70,500	72,000
					Diesel	239.0	239.0	31,045	30,310	37,010
					Natural Gas	69.4	69.4	8,800	8,800	
					Wind	0.5	0.5	660	0	0
					Total	**769.5**	**680.6**	**132,605**	**109,610**	**109,010**
				ATCO	**Diesel**	N/A	N/A	5,740	5,373	7,230
				Minto	**Diesel**	N/A	N/A	8,000	0	0
					Total	**0**	**0**	**13,740**	**5,373**	**7,230**
				Yukon Power	**Hydro**	460.7	371.8	92,100	70,500	72,000
				System	**Diesel**	239.0	239.0	44,785	35,683	44,240
					Natural Gas	69.4	69.4	8,800	8,800	0
					Wind	0.5	0.5	660	0	0
					Total	**769.5**	**680.6**	**146,345**	**114,983**	**116,240**
					Hydro	N/A	N/A	N/A	33,500	35,000
				Single Contingency (N-1) Dependable Capacity	**Diesel**	N/A	N/A	N/A	34,363	42,490
					Natural Gas	N/A	N/A	N/A	8,800	0
					Wind	N/A	N/A	N/A	0	0
					Total	**0.0**	**0.0**	**0.0**	**76,663**	**77,490**

Notes:

- Single Contingency (N-1) scenario dependable capacity excludes the dependable capacity for ATCO's Haines Junction diesel generator as the community would be isolated by the loss of the transmission line between the Aishihik Generating Station and the Takhini substation. Under this scenario, peak demand in Haines Junction is assumed to be equal to the depenble capacity of the ATCO thermal generation (1.32 MW).

- No firm energy assumed for ATCO diesel generators, Minto Mine diesel generators and YEC mobile generators with the exception of unit YM1

- No dependable capacity assumed for Minto Mine diesel generators and YEC wind turbines and mobile generators with the exception of unit YM1

- Firm energy for diesel and natural gas engines assumes a 90% capacity factor

- Excludes ATCO Fish Lake Hydro. The contribution of the ATCO Fish Lake Hydro plant was not included in the inventory of the existing resources as its contribution was deducted from the load forecast modelling.

4.2.2 Committed Resources

Committed resources include resources that have secured regulatory approvals and for which YEC is in the process of planning. YEC considers the following as committed resources:

1) The Stewart-Keno Transmission Line. As the existing Stewart-Keno Transmission line is considered near the end of life, YEC competed detailed design and secured regulatory approval of the replacement line to make it construction ready. Considering the importance of the project for the existing customers and potential future industrial customers, YEC is currently investigating options for financing the line replacement.
2) The Standing Offer Program (SOP). The SOP is outlined in the Independent Power Production (IPP) Policy of the Yukon Territorial Government issued in 2015. The SOP included in the resource plan analysis envisions 10 GWh/year of firm energy provided by Independent Power Producers (IPP) starting in 2022. As it is assumed that the SOP projects will most likely be intermittent renewable resources such as wind and solar, no dependable capacity credit is assigned to them. The assessment of the SOP in-service date of 2022 was based on analysis of lead time data for renewable resources presented in the resource option studies discussed in Chapter 5. As a proxy, the typical wind resource option lead time of 5 years was assumed.

Even though the committed resources were considered in the portfolio analysis, those resources are not without a risk. It is not certain that the energy assumed under the SOP program will be fully supplied and that funding will be available for the Stewart-Keno Transmission Line to proceed to construction. The uncertainties and risks related to those two resources are discussed in Chapter 7, Section 7.2.1. Resource Uncertainties and Risks: Project feasibility uncertainty and IPP supply uncertainty.

4.3 Resource Planning and Reliability Criteria

Generation resources exist to supply electricity, and transmission resources exist to move electricity to customers. Reliability means that electricity is available when customers need it. Customers experience power outages in terms of frequency (number of times) and duration (hours). The outages in the electricity system can be caused by: a) the insufficient resources to meet the load (insufficient dependable capacity, firm energy, transmission capability) or b) the failure of system elements.

The focus of the 2016 Resource Plan is the development of an Action Plan that documents YEC's recommended development of future generation and transmission assets to serve the Yukon Integrated System. An underlying assumption was made that the third element of the electricity system, distribution network, will have sufficient capacity to deliver power to the customers, and this element of the power system was not further considered.

The extreme climate of the Yukon requires a relatively stringent degree of reliability. Reliability criteria guide utilities in determining the appropriate amount of installed generating capacity and transmission connections to reliably and economically serve the instantaneous demand on the system and achieve the ultimate goal of "keeping the lights on". Generation reliability has two aspects: capacity and energy. Being an islanded system, YEC must ensure there is an adequate supply of both at all time and in the event of unforeseeable events. The isolation of the YIS makes impossible for YEC to rely on additional capacity and energy in neighboring jurisdictions. In order to serve the load in a reliable and cost-effective manner, YEC developed multiple planning criteria that are discussed in the following sections.

To address the reliability requirements, the following criteria were introduced into resource planning process:

- Energy planning criterion - ensures sufficient energy generation to meet energy load; and
- Capacity planning criterion - ensures sufficient capacity to meet peak demand during forced outages.

These criteria are designed to be conservative allowing YEC to provide sufficient energy and capacity to ‘keep the lights on’ under a specified set of extreme conditions.

YEC applies reliability criteria to ensure that the load is met and impose a level of redundant capability to ensure loads can be served even when generation and/or transmission assets fail. Absolute reliability is impossible due to the multitude of unpredictable technical and environmental effects that could cause outages. Levels of increasingly stringent reliability criteria lead to additional redundant capability or reserve margins, and add to system costs. These costs can grow exponentially for increasingly marginal improvements in reliability.

Also, because load is uncertain and varies throughout the year, meeting reliability criteria means that a utility typically maintains more capability than its forecast load in the form of a reserve margin. The reserve margin can be included both into energy and capacity planning criteria.

4.3.1 Energy planning criterion

The energy planning criterion ensures that the system has always sufficient energy to meet energy load under pre-defined stringent conditions. The energy planning criterion is defined as the following: firm energy is equal to or greater than forecast future energy loads.

4.3.2 Capacity Planning Criterion

The capacity planning criterion ensures that the system has sufficient capacity to meet peak demand (peak capacity) under pre-defined stringent conditions. The capacity planning criterion is defined as the following: the difference between dependable capacity and reserve margin is equal to or greater than forecast future peak demand.

Therefore, the dependable capacity of the current and future YEC resource portfolio must exceed expected future peak demand requirements discussed in Section 4.1, including the need for a reserve margin, to allow for contingencies.

4.3.2.1 *Reserve Margin*

Reserve margin can be determined either by using single contingency (N-1) criterion or Effective Load Carrying Capability (ELCC). The ELCC stems from a generation adequacy criterion Loss of Load Expectation (LOLE) that is discussed in the following paragraphs.

For the 2016 Resource Plan, the reserve margin is defined as the greater (more conservative) of the values determined by the N-1 criterion and ELCC, which is consistent with the previous YEC Resource Plans.

YEC’s use of the N-1 criterion in parallel with ELCC is unique because the N-1 criterion is used not only to assess weaknesses in the transmission system but also the adequacy of YEC’s generation sources. The YIS is also unique in the sense that its major generating sources and load are connected via single transmission lines over long distances. Furthermore, there are no interconnections with neighboring power systems to provide back-up in case of failure of elements of the YIS. Thus, Yukon Utilities Board recommended the use of the LOLE and N-1 planning criteria in the letter to the YTG Minister of Justice dated January 15, 2007.

4.3.2.1.1 Single Contingency (N-1) Criterion

The N-1 criterion is based on the assumption that the system should be able to carry the forecast peak demand under the largest single contingency event, i.e. the loss of the largest single element which could be either a transmission line or a generating station, or any other element that can causes the worst possible situation on the power system.

In determining the load requirements, the ability to interrupt customers must be considered. Currently, under the N-1 criterion, YEC can curtail large (i.e., with demand greater than 1 MW) industrial customers it serves to meet peak demand as recommended by the YUB to the YTG Minister of Justice in the letter dated January 15, 2007. Consequently, YEC's obligation under the N-1 criterion is to meet the non-industrial peak winter demand. It should be noted that historically, large industrial customers have installed back-up generation on-site to meet critical loads in the event of an outage.

YEC's N-1 criterion states that each part of the YEC transmission grid should be able to carry the forecast non-industrial peak winter demand, excluding major industrial demand, under the largest single contingency. This is defined as the loss of the system's single largest generating or transmission-related resource.

Normally, utilities throughout North America use contingency analysis such as the N-1 criterion, which consists of removing elements from a power system, to identify weaknesses in the transmission system. This is typically simulated by removing a transmission element at the worst possible time, which is usually during the annual peak, and conducting a load-flow analysis to identify system components that would experience voltage or power transfer limit issues.

The above-mentioned load-flow analysis, which is necessary in power systems that have redundant transmission lines (i.e. with more than one path for the energy to flow between two points) is not necessary for the YIS. The YIS is a radial system, meaning generation and load centers are connected through a single transmission line. A drawback of this configuration is the absence of line redundancy. Consequently, a contingency situation for the YIS, such as the loss of a transmission line, could immediately translate into a power outage situation. Therefore, the appropriate application of the N-1 criterion on the YIS is for YEC to be able to meet the non-industrial peak demand under the largest single contingency.

For the Yukon Integrated System, the largest single contingency is the temporary loss of the transmission line (L171) between the Aishihik Generating Station and the Takhini Substation. The loss of the line would prevent YEC from relying on 38.3 MW of dependable capacity, consisting of 37 MW for the Aishihik Generating Station and 1.3 MW for ATCO thermal-diesel facility, to meet the non-industrial peak winter demand. This scenario also assumes the Haines Junction demand is either met by the ATCO thermal facility or the Aishihik Generating Station. Consequently, the non-industrial peak demand to be served under the N-1 criterion excludes the Haines Junction demand, which is assumed to be equal to 1.3 MW. As such, the net dependable capacity reserve under the N-1 criterion is 37 MW. The loss of the Aishihik Generating Station would result in the same net dependable capacity reserve under the N-1 criterion considering that the dependable capacity of the Aishihik Generating Station is 37 MW.

4.3.2.1.2 Effective Load Carrying Capability

The electricity industry uses a number of metrics (indices) to determine expected reliability and measure resource adequacy, and consequently the Effective Load Carrying Capability (ELCC). One of the most common metrics is the Loss of Load Expectation (LOLE), which represents either the expected number of days in ten years, or hours in a year when all of the generating resource combined are insufficient to meet peak demand. Hourly resolution is useful when there are intermittent renewable resources like wind or solar in the resource mix, and electricity demand can fluctuate significantly from hour to hour. The ELCC is the output of the LOLE modelling. The modelling exercise results in the maximum system capacity, i.e. ELCC that the system can serve. Reserve margin is calculated as the difference between the dependable capacity and ELCC.

As in the 2011 Resource Plan, for the 2016 Resource Plan, hourly resolution was adopted to determine the LOLE. Also consistent the 2011 Resource Plan, an LOLE of 2 hours per year was adopted as the criterion, which is consistent with similar LOLE values used by other utilities in Canada.

YEC's adopted industry practices were developed decades ago and endorsed by North American regional reliability organizations such as North American Electric Reliability Corporation (NERC) and Western Electricity Coordinating Council (WECC). These organizations were formed by electrical utilities to provide a forum for the development and acceptance of minimum reliability standards. This was in recognition that operations on an interconnected grid means that one utility's behavior and planning can impact another utility's reliability. Although the Yukon is not connected to any other of the North American grids, these industry criteria offer aspirational benchmarks for YEC with respect to prudent utility best practices.

While these regional reliability organizations have developed minimum capacity (peak day) criteria for generation and for transmission, no minimum criteria exist for resource adequacy related to energy. This is because utilities worldwide are mostly capacity constrained, and must primarily build generation assets to meet peak day requirements. Once this capacity generation is built, responding to increased annual energy requirements simply involves increasing the plant's utilization, which also applies to YEC. The end result is that there is no consensus with respect to energy acquisition criteria. As discussed in Section 4.3.1, YEC selected the low historical water conditions as the energy planning criterion for hydro resources, 90% utilization rate for the thermal resources and average annual generation for wind resources.

YEC indicated that new generating capacity would not be planned or added to the system for the purpose of ensuring reliable supply to major industrial loads. This has been properly captured in the definition of the N-1 criterion, as the definition explicitly indicates "excluding major industrial loads". However, as recommended by the YUB, YEC included the major industrial loads in the calculations of LOLE.

For the 2016 Resource Plan, YEC updated its estimate of the ELCC that would ensure a LOLE of 2 hours per year. The updated indicates that the YIS can effectively and reliably carry load of 82.9 MW to Whitehorse while meeting the LOLE threshold criteria of 2 hours per year. Considering the system dependable capacity of 115 MW, if the ELCC criterion were selected for determining the reserve margin, the reserve margin would therefore be 32.1 MW. The work on determining the LOLE was completed by Dr. Karkhi of the University of Saskatchewan and is presented in Appendix 4.8.

4.3.2.1.3 Reserve Margin Conclusion

Comparing the reserve margin determined using the N-1 criterion to that determined by the ELCC, the greater, more conservative, value resulted from the N-1 criterion, which is 37 MW. Therefore, this value was adopted as the planning reserve margin for the further analysis in the 2016 Resource Plan. Consequently, for the portfolio analysis, the total dependable capacity of the YIS was reduced by 37 MW to account for the reserve margin.

4.4 Load Resource Balance

The objective of the load resource balance (LRB) is to determine the capacity and energy gaps YEC will have to fill to meet the electricity needs over the next 20 years. The gap is presented as the difference between future loads and existing resources capability, both in terms of energy and peak demand.

Results of the LRB are presented for firm energy, dependable capacity and dependable capacity under the reliability constraint. The LRB for dependable capacity is presented for illustrative purposes. It was not used in the portfolio analysis, because the LRB under reliability constraint was required for the capacity planning criterion.

For the purposes of determining LRB surplus or deficit, only firm energy and dependable capacity of existing and committed resources were used. Being an intermittent resource, wind contributed firm energy but no dependable capacity.

ATCO thermal assets were also included in the LRB. As stated in Section 4.2.1, it was assumed these units could be relied upon to meet system peak demand under normal conditions, and under an N-1 event if required. ATCO's contribution to firm energy was not considered as discussed in Section 4.2.1. This constraint was driven by the absence of information pertaining to the condition, capabilities and planned retirement year of the assets. YEC thereby prudently limited its reliance on external assets.

The fourteen load scenarios presented in Section 4.1.3.2.2 were compared for similarities in order to eliminate redundant/similar scenarios, thereby minimizing the number of analyzed cases. The following five industrial activity scenarios were selected for the LRB analysis, and, consequently, for the portfolio analysis:

- Very Low Industrial Activity;
- Low Industrial Activity;
- Low with Early Minto Closure;
- Medium Industrial Activity; and
- High Industrial Activity.

The discarded scenarios were judged redundant, and not needed to provide additional information that would further inform the portfolio analysis and the Action Plan. The scenario with Low Industrial Activity with Early Minto Mine Closure was analyzed to provide additional insights into the portfolio that would result from the early closure of the Minto mine. Subsequent to the completion of the Load Forecast in mid-2016, market changes (metals prices) have warranted a shortening in expected Minto mine life, making this scenario increasingly likely.

4.4.1 Energy Load-Resource Balance

Firm energy from YEC's existing hydroelectric resources was estimated at 372 GWh/year for the 2016-2020 period. From 2021 until the end of the planning period, the firm energy will decrease to 360 GWh/year, due to the de-commissioning of Mayo Hydro (Mayo B Hydro is not scheduled for decommissioning).

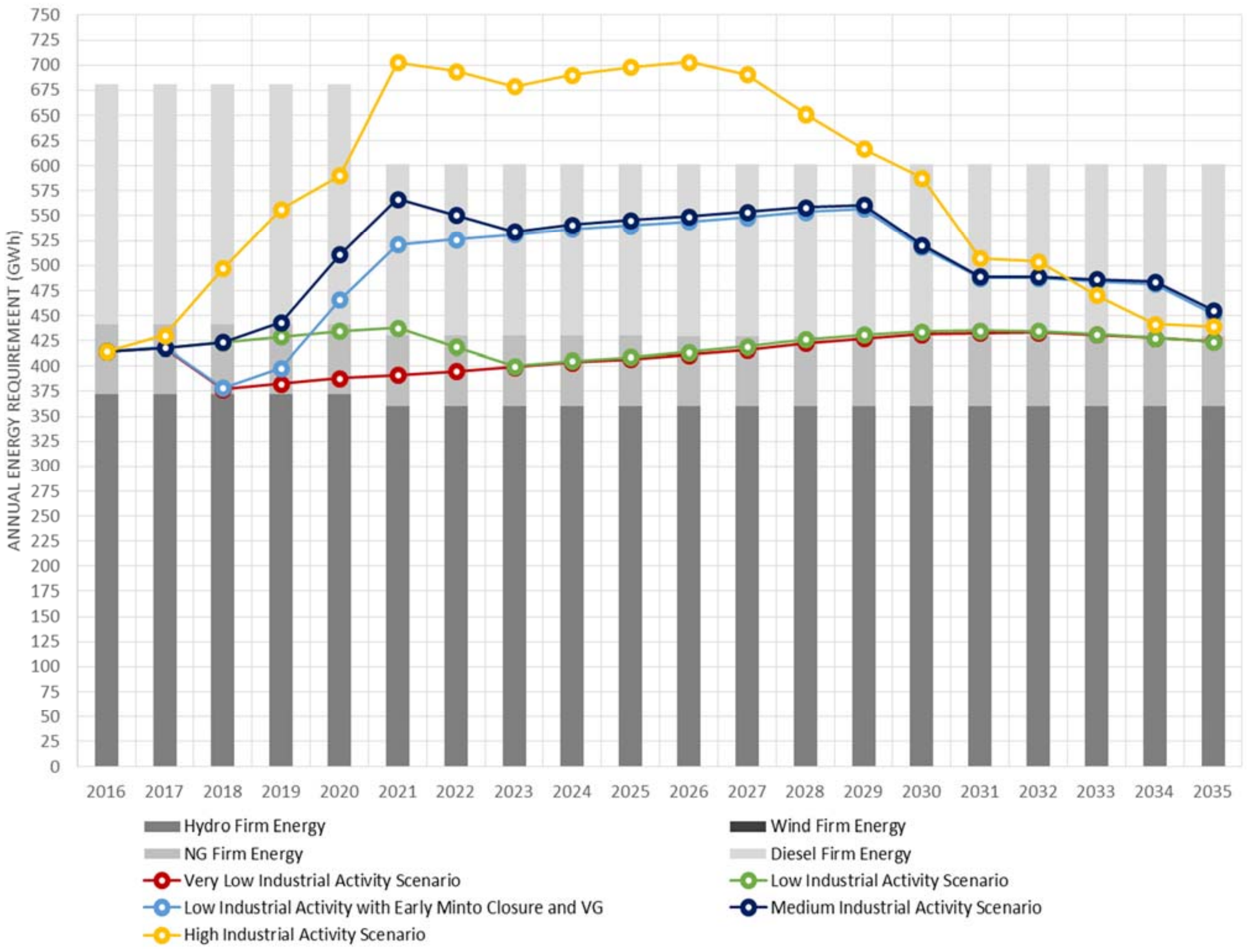
Firm energy for the wind turbine on Haeckel Hill was determined based on historical generation data and was estimated at 0.5 GWh/year for the 2016-2025 period. The unit is scheduled to be de-commissioned in 2026.

Firm energy from YECs existing natural gas was estimated at 69 GWh/year over the entire planning period (Figure 4-20), assuming a 90% capacity factor. The lifespan of the natural gas units was forecast to extend beyond the planning period.

YEC's existing diesel thermal assets account for 239 GWh/year of firm energy for the first five years of the planning period (2016-2020). In 2021, the remaining two Mirrlees units (FD1 and WD3) located in Faro and Whitehorse respectively, are assumed to be retired. Firm energy from 2021 until the end of the planning period was estimated at 172 GWh/year.

Combining the firm energy for YEC's existing assets yielded a total system firm energy of 681 GWh/year for the 2016-2020 period. After 2020, the system firm energy will stay relatively constant at 602 GWh/year. Forecast energy requirements over the planning period are shown overlain on the system firm energy in Figure 4-20.

Figure 4-20. Comparison of Energy Forecast for All Major Industrial Activity Scenarios and Existing System Firm Energy



The results presented in Figure 4-20 indicates that there will be sufficient firm energy to meet future requirements for the Very Low Industrial Activity, Low Industrial Activity, Low Industrial Activity with Early Minto Closure, and Medium Industrial Activity scenarios. Only the High Industrial Activity scenario shows a gap between 2021 and 2029, of 97 GWh in 2021, reaching a maximum of just over 97 GWh in 2026, and then decreasing to 11 GWh in 2029, as presented in Table 4.3.

Although the results do not show firm energy deficits over the entire planning period for the Very Low Industrial Activity, Low Industrial Activity, Low Industrial Activity with Early Minto Closure and Medium Industrial Activity scenarios, they do indicate YEC would have to rely on existing thermal assets, both natural gas and diesel, to meet the forecasted energy requirements. This would in turn lead YEC to incur material fuel costs and would not be aligned with Yukoner's values related to electricity as documented in Chapter 3.

Table 4.3. Firm Energy Surplus/Deficit for Major Industrial Scenarios

Year	Very Low Industrial Activity Firm Energy Surplus/(Deficit) [GWh]	Low Industrial Activity Firm Energy Surplus/(Deficit) [GWh]	Low Industrial Activity with Early Minto Closure Firm Energy Surplus/(Deficit) [GWh]	Medium Industrial Activity Firm Energy Surplus/(Deficit) [GWh]	High Industrial Activity Firm Energy Surplus/(Deficit) [GWh]
2016	271	271	271	271	271
2017	268	267	267	267	255
2018	308	262	307	262	188
2019	303	256	287	242	129
2020	297	251	220	174	95
2021	215	169	85	40	(97)
2022	211	188	80	56	(87)
2023	208	207	75	72	(72)
2024	203	202	70	65	(84)
2025	200	198	66	61	(92)
2026	195	192	62	57	(97)
2027	190	186	57	52	(85)
2028	183	180	52	47	(45)
2029	179	175	49	45	(11)
2030	175	172	88	85	18
2031	173	171	119	117	99
2032	173	171	119	117	102

2033	175	175	122	120	135
2034	178	178	125	122	165
2035	182	182	154	151	167

4.4.2 Capacity Load-Resource Balance

Dependable capacity from existing hydroelectric resources was estimated at 70.5 MW for 2016-2020 period. From 2021 until the end of the planning period, the dependable capacity will decrease to 69.1 MW due to the de-commissioning of Mayo Hydro (Mayo B Hydro is not scheduled for decommissioning).

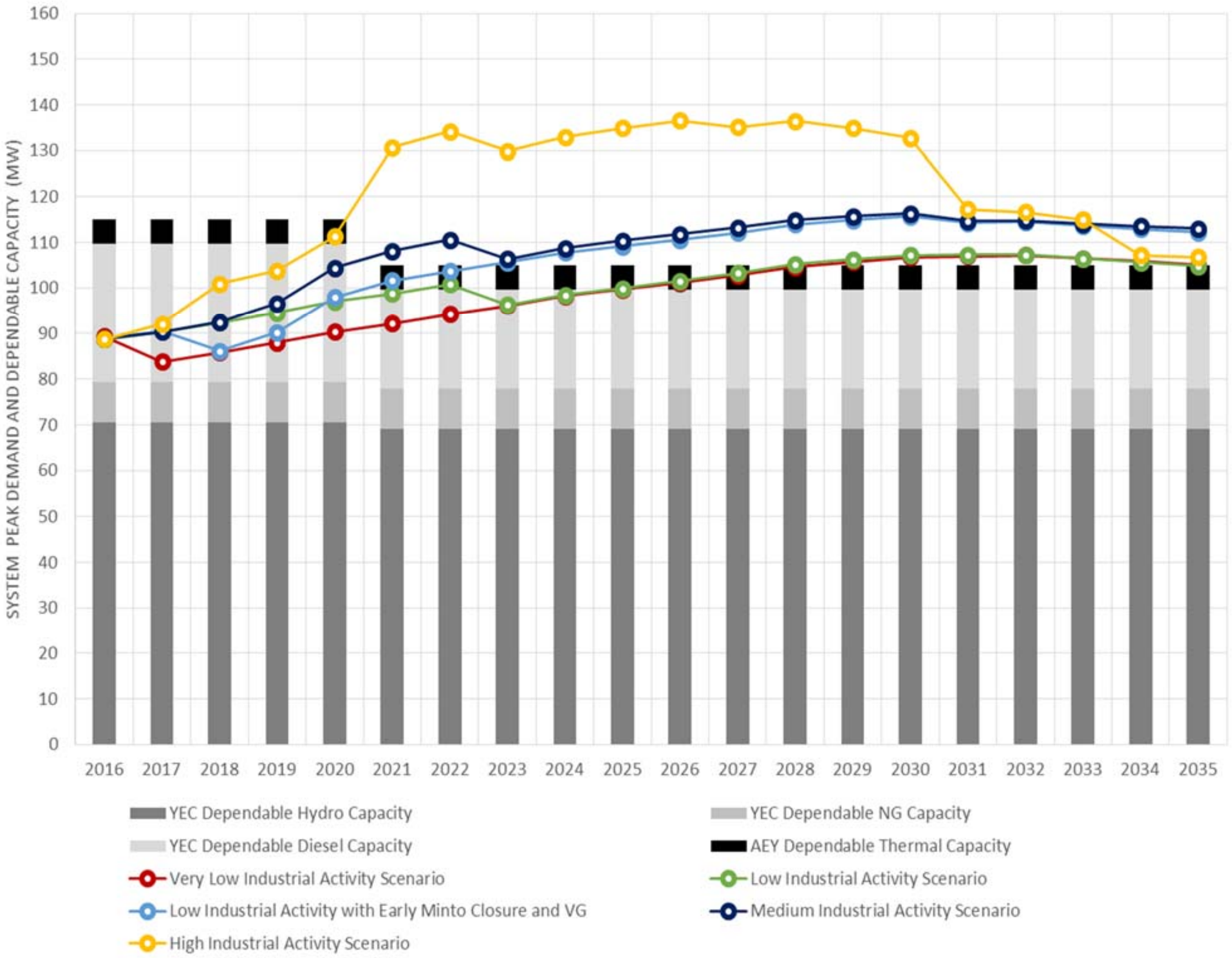
Dependable capacity for intermittent resources such as the wind turbine on Haeckel Hill was set as 0 MW for the entire planning period as there would be no guarantee of sufficient wind for two consecutive weeks.

As for the existing natural gas thermal assets, dependable capacity was estimated at 8.8 MW over the entire planning period. The life of the natural gas units was forecasted to extend beyond the planning period.

YEC's existing diesel thermal assets will account for 30.3 MW of dependable capacity over the first five years of the planning period (2016-2020). As discussed in the previous section, the retirement of the remaining two Mirrlees units (FD1 and WD3) located in Faro and Whitehorse respectively in 2021 will decrease the dependable capacity to 21.8 MW over the remaining years of the planning period (2021-2035).

Summing the dependable capacity for all existing resources yielded a total system dependable capacity of 115 MW from 2016 to 2020. Starting in 2021, the system dependable capacity will decrease to 105 MW and remain constant until the end of the planning period. As stated above, the decrease is related to the de-commissioning of Mayo Hydro (1.4 MW) and the retirement of the remaining Mirrlees units (8.5 MW). Figure 4-21 compares the system forecasted peak demand over the planning period and the system firm energy. Dependable capacity surplus or deficit values for each year are presented in Table 4.4 for each major industrial activity scenarios.

Figure 4-21. Comparison of Peak Demand Forecast for All Major Industrial Activity Scenarios and System Dependable Capacity



Under the Very Low Industrial Scenario, YEC has a surplus of dependable capacity until 2029. The closure of the Minto Mine in 2018 in this scenario results in a near-term decrease in system peak demand. After 2025, dependable capacity and peak demand track closely and YEC would need to rely on ATCO thermal-diesel assets to meet peak demand. Between 2029 and 2034, a capacity deficit is anticipated, reaching a maximum value of 2 MW. After 2035, the continued decrease in system peak demand that started in 2030 suggests that YEC would have an ongoing capacity surplus.

The Low Industrial Activity Scenario, tracks the Very Low Scenario closely, the key difference being the delay in the Minto closure until 2020. Otherwise the capacity gaps are on the same order of magnitude as with the previous case. In this scenario, dependable capacity and peak demand are close for the remainder of the forecast horizon.

The Low Industrial Activity with Early Minto Closure Scenario assumes the Minto Mine closing at the end of 2017 and Eagle Gold project starting construction in 2019 with a ramp-up to production in 2020. YEC is able to maintain a dependable capacity surplus with reliance on ATCO thermal units until load growth exceeds dependable capacity starting in 2023.

The Medium Industrial Activity Scenario assumes Minto Mine remains in operation until the end of 2020 and the grid-connected Eagle Gold project begins to ramp up to production during the same year.

Despite the two overlapping industrial projects, and the retirement of about 10 MW of dependable capacity in 2021, YEC will be able to maintain a dependable capacity surplus with a reliance on ATCO thermal-diesel assets until load growth exceeds dependable capacity starting in 2023, as shown in Table 4.4.

Table 4.4: Dependable Capacity Surplus/Deficit for Major Industrial Activity Scenarios

Year	Very Low Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	Low Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	Low Industrial Activity with Early Minto Closure Dependable [MW]	Medium Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	High Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]
2016	26	26	26	26	26
2017	31	25	25	25	23
2018	29	23	29	23	14
2019	27	20	25	18	11
2020	25	18	17	11	4
2021	13	6	3	(3)	(26)
2022	11	4	1	(5)	(29)
2023	9	9	(1)	(1)	(25)
2024	7	7	(3)	(4)	(28)
2025	5	5	(4)	(5)	(30)
2026	4	4	(6)	(7)	(31)
2027	2	2	(7)	(8)	(30)
2028	0	(0)	(9)	(10)	(31)
2029	(1)	(1)	(10)	(11)	(30)
2030	(2)	(2)	(11)	(11)	(28)
2031	(2)	(2)	(9)	(10)	(12)
2032	(2)	(2)	(9)	(10)	(12)
2033	(1)	(1)	(9)	(9)	(10)
2034	(1)	(1)	(8)	(8)	(2)
2035	0	0	(7)	(8)	(2)

Under the High Industrial Activity scenario, key load growth drivers are four mines. The initial increase is attributed to the assumed earlier start of the Eagle Gold project, which adds directly to system peak demand. This leads to a dependable capacity gap of 9 MW in 2019. The high growth in economic activity results in the deficit increasing until 2028 when it reaches its maximum value of 36 MW. The transition to closure activities at Minto decreases the dependable capacity gap in 2029 to 14 MW. For the last two years of the planning period, the capacity gap is estimated at 2 MW.

4.4.3 Capacity Load-Resource Balance under the Single Contingency (N-1) Criterion

As discussed in Section 4.3.2.1.1, YEC's N-1 criterion assesses whether YEC can reliably meet the non-industrial peak demand after the temporary loss of the transmission line between the Aishihik Generating Station and the Takhini substation.

Aishihik Generating Station being temporarily unavailble would result in a loss of 38.3 MW of dependable capacity (37 MW from the Aishihik Generating Station and 1.3 MW provided by ATCO's Haines Junction thermal-diesel asset). As stated in Section 4.3.2.1.1, the LRB under the N-1 criterion excludes the Haines Junction demand, assumed to be equal to 1.3 MW. As such, the overall system dependable capacity under the N-1 criterion is 76.6 MW for the first five years of the planning period (2016-2020). From 2021 until 2035, the system dependable capacity decreases to 66.7 MW due to diesel assets retirement and de-commissioning of the Mayo Hydro Generating Station.

The overlay of the forecast non-industrial demand on the system dependable capacity under the N-1 criterion indicates YEC is already in deficit of dependable capacity to meet its non-industrial peak demand, as shown in Figure 4-22. As this deficit represents a significant operations risk, new assets will be needed to be constructed to eliminate the deficit, as discussed in details in Chapters 8 and 9.

The existing capacity deficit of 4 MW, forecast to increase to 8 MW in 2018, is present in all the scenarios and can be found in Table 4.5. The dependable capacity starts to diverge between scenarios in 2020 due to different load assumptions. During that year, the capacity gap increases to 12 MW for the Very Low and Low Industrial Activity Scenarios, 13 MW for the Low Industrial Activity with Early Minto Closure and Medium Industrial Activity Scenarios, and 14 MW for the High Industrial Activity Scenario. In 2021, the retirement of the remaining two Mirrlees diesel units and of Mayo Hydro adds just over 10 MW to the dependable capacity gap, increasing the magnitude of the gap to 24 MW for the Very Low and Low Industrial Activity Scenarios, 25 MW for the Low Industrial Activity with Early Minto Closure and the Medium Industrial Activity Scenarios and 26 MW for the High Industrial Activity Scenarios. The maximum dependable capacity gap varies between 39 MW under the Very Low Industrial Activity scenario and 43 MW under the High Industrial Activity scenario. After 2029, the dependable capacity gap is anticipated to decrease and is attributed to a decrease in non-industrial peak demand forecast, as previously discussed.

Figure 4-22. Comparison of Non-Industrial Peak Demand Forecast for All Major Industrial Activity Scenarios and System Dependable Capacity under Single Contingency (N-1) Criterion

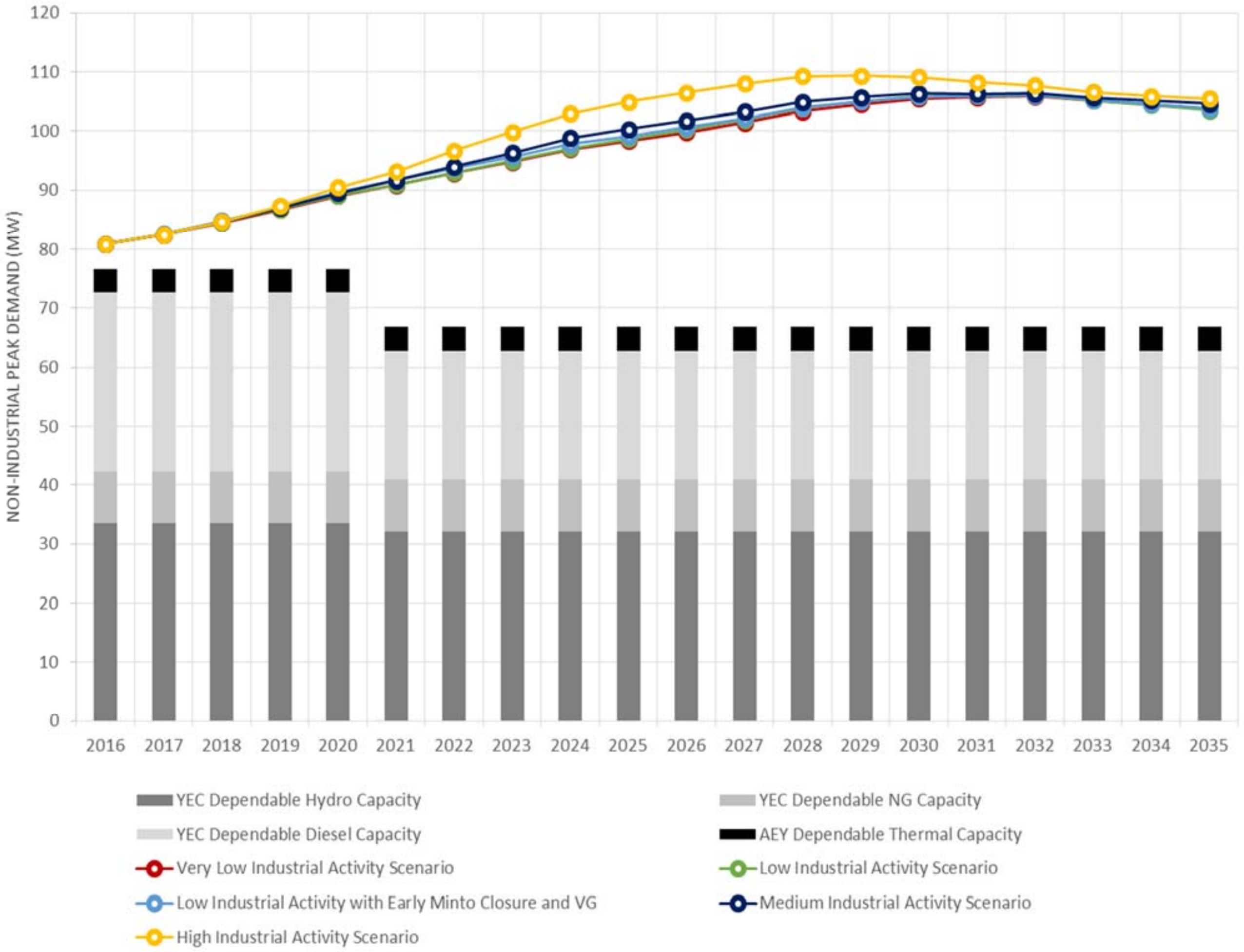


Table 4.5: Dependable Capacity Surplus/Deficit for Major Industrial Activity Scenarios under the Single Contingency (N-1) Criterion

Year	Very Low Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	Low Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	Low Industrial Activity with Early Minto Closure Dependable Capacity Surplus/(Deficit) [MW]	Medium Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]	High Industrial Activity Dependable Capacity Surplus/(Deficit) [MW]
2016	(4)	(4)	(4)	(4)	(4)
2017	(6)	(6)	(6)	(6)	(6)
2018	(8)	(8)	(8)	(8)	(8)
2019	(10)	(10)	(10)	(10)	(11)
2020	(12)	(12)	(13)	(13)	(14)
2021	(24)	(24)	(25)	(25)	(26)
2022	(26)	(26)	(27)	(27)	(30)
2023	(28)	(28)	(29)	(30)	(33)
2024	(30)	(30)	(31)	(32)	(36)
2025	(32)	(32)	(32)	(34)	(38)
2026	(33)	(33)	(34)	(35)	(40)
2027	(35)	(35)	(35)	(36)	(41)
2028	(37)	(37)	(37)	(38)	(42)
2029	(38)	(38)	(38)	(39)	(43)
2030	(39)	(39)	(39)	(40)	(42)
2031	(39)	(39)	(39)	(40)	(41)
2032	(39)	(39)	(39)	(40)	(41)
2033	(38)	(38)	(38)	(39)	(40)
2034	(38)	(38)	(38)	(38)	(39)
2035	(37)	(37)	(37)	(38)	(39)

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5 Resource Options

This chapter presents an assessment of the potential resource options available to meet the needs of YEC's customers over the next 20 years. Both demand-side (energy efficiency and conservation) and supply-side (generation, storage and transmission) resource options were considered and are presented. The resource options studied include:

- Hydro storage enhancement;
- Hydro uprate and refurbishment;
- Small hydro;
- Wind;
- Geothermal;
- Solar;
- Biomass;
- Biogas;
- Waste to energy;
- Natural gas;
- Diesel;
- Pumped storage;
- Energy storage;
- Demand side management; and
- Transmission.

Consistent with the 2006 and 2011 Resource Plans, this planning level assessment is based on current information regarding on-grid electricity demand requirements and alternatives for future electricity supply and conservation. This Plan does not seek approval of specific resource options or projects.

Considering that the assessment of resource options was performed at the prefeasibility level, which did not address all the project specific risks and uncertainties, several planning stages are required following the 2016 Resource Plan prior to any YEC decision to proceed with construction for any preferred project[1].

At a high-level, four key planning objectives are used to guide YECs electricity resource planning. These are Reliability, Affordability, Environmental Responsibility, and Socio- Economic Responsibility. They are further explained as follows:

- Reliability – this refers to the need for reliable capacity and energy to meet customer demands over the short and long-term. This includes the need for reliable capacity to meet winter peak loads, and to minimize the number and duration of power outages. When assessing new resource options, reliability also includes the ability to develop new resource options in a timely manner, in order to meet customer requirements, and to support the economy of the Yukon. The security of resource fuel supplies must

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[1] Subsequent planning stages include: the final feasibility assessment, costing, design and contract arrangements (and related tendering to obtain final estimated costs); consultation with First Nations and others; all required external reviews, approvals and agreements (includes where relevant YESAB, DFO, YWB and other regulatory authorities as required).

also be considered, such as the supply of imported fossil fuels for thermal plants, or wood waste for biomass generation facilities. Ideally, there should be diversity in the generation mix. Reliability also refers to the need for flexibility to deal with major and sudden changes in grid loads, or a boom and bust cycle in the resource-driven Yukon economy. Resource planning must be attentive to the fact that load growth in a jurisdiction such as the Yukon may not be continuous but may rather be intermittent as large mining load connect and then disconnect from the grid over time. Therefore, the Plan needs to explore solutions that are incremental (scalable).

- Affordability – this refers to the goal of the YEC, as a regulated utility, to minimize costs for power utility customers today and in the long term. The Yukon Utilities Board regulates the costs to be recovered through rates, focusing on the need, justification, and reasonableness of costs incurred, with a clear objective to minimize the costs required to serve customers. YEC aims to avoid rate shock. Rates need to be equitable, fair, and socially responsible for Yukoners. Because Yukon is not interconnected with grids in other provinces/jurisdictions, surplus renewable energy in Yukon cannot be exported and new demand cannot be met through energy imports. Sudden loss of mine loads can result in rate increases for the remaining customers in Yukon, to the extent that ongoing fixed generation or transmission costs remain to be funded. Accordingly, new resource supply options need to be planned in light of any such ongoing load uncertainties and must provide for resilience given the potential for attrition.
- Environmental Responsibility – this refers to the importance of minimizing both local and global impacts on water, air, land, as well as wildlife in the water, air and land. This principle goes beyond responsible planning for new resource projects as required by various regulatory authorities before these projects are permitted. YEC is committed to planning for energy solutions that reduce greenhouse gas (GHG) emissions and meeting the goals of climate change action plans in Yukon as well as nationally.
- Socio-Economic Responsibility – this refers to importance of social responsibility with regard to First Nation lands, traditional lifestyle, heritage resources, tourism & recreations, and cultural & community wellbeing. Economic principles include the provision for local opportunities for jobs and community development. Where feasible, there is a preference to use resources that are locally available.

Those four principles were applied in the evaluation of the resource options through the analysis of technical, financial, environmental, social and economic attributes. In this initial resource option analysis, all principles were assigned equal weighting or importance. In the later portfolio analysis stage of the planning process, the key principles were balanced using the key learnings of the Electricity Values Survey (discussed in Chapter 3), to place more weighting or importance on those attributes which are more highly valued by the Yukon public.

Legally Barred and Unviable Resource Options:

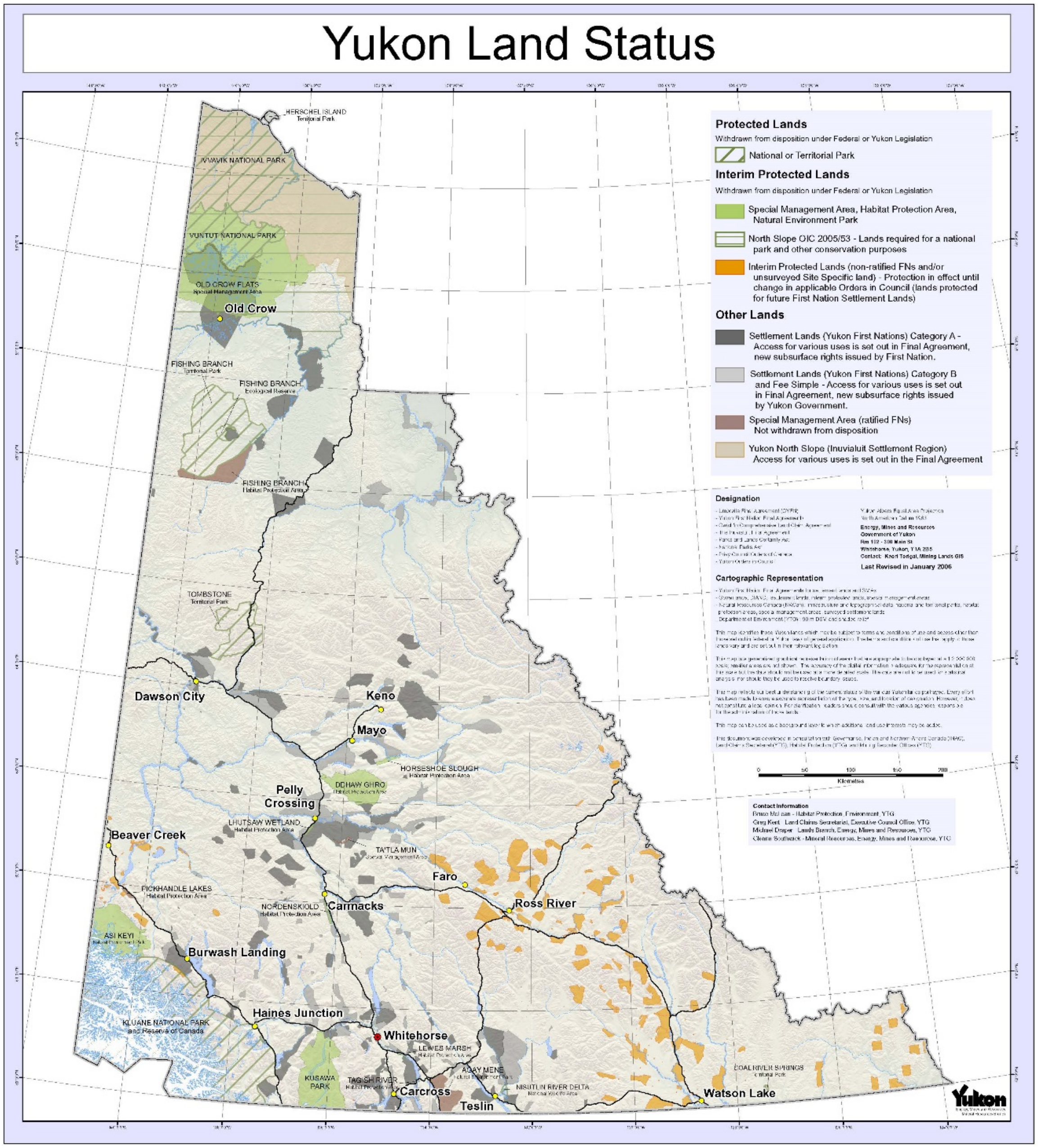
The following resource options and alternatives were excluded from consideration in this Plan:

- Resource options based on unproven or pre-commercial technologies. ‘Commercial’ technologies were defined as technologies already in operation at a commercial scale somewhere in the world. Demonstration of nascent technologies is not common for a regulated utility such as YEC;
- Generation or transmission options that are located in protected areas or interim protected areas, such as inside a National Park, or inundate land within a National Park. The map of Yukon’s protected lands is shown in Figure 5-1;
- Hydroelectric projects that inundates titled property or a private residence, except for the hydro storage enhancement of existing YEC facilities;

- Projects in remote locations, far from the Yukon transmission grid. The servicing of remote communities is not the focus of this Resource Plan, but is covered in specific community planning processes;
- Nuclear technologies;
- Generation options with a capacity above 50 MW of installed capacity. Given the reasonably foreseeable future demand requirements of YEC, and the isolated nature of the Yukon grid, a project beyond this size would exceed domestic requirements, with no ability to sell the surplus; and
- Generation options that deliver below 0.2 MW of installed capacity or 0.4 GWh/year of firm energy in aggregate. This Resource Plan focuses on system-level solutions to long-term electricity requirements, and must consider a reasonable cut-off size for consideration. Resources that provide aggregate benefits at many locations (such as conservation) are considered.

The 2016 Resource Plan assumes that Demand Side Management (DSM) and hydro enhancement projects will be implemented concurrent with the development of any new resource supply. The individual attributes of the preferred resources will be reviewed and reported on, together with the attributes of the recommended portfolio of resource options. A review of the attributes of the resources in the proposed action plan is presented in Chapter 8 to account for the possibility that a unique combination of resources results in an unfavorable environmental, social or economic outcome.

Figure 5-1: Yukon protected lands map



From: http://www.emr.gov.yk.ca/agriculture/pdf/landstatusmap.pdf Accessed February 2017

5.1 Resource Options Attributes

To describe and evaluate the resource options, a series of attributes was established. These attributes are grouped into five categories: technical, financial, environmental, social and economic. The attributes are used as inputs to the 2016 Resource Plan portfolio analysis where the costs and impacts of new resource additions are assessed on a system-wide basis over the planning horizon. The resource assessment used Yukon-specific data wherever possible, such as performance and cost information. Where not possible, the closest proxy was used, such as data from British Columbia.

5.1.1 Technical Attributes

The technical attributes associated with electricity generation can be categorized as follows:

- Monthly average energy;
- Monthly firm energy;
- Installed capacity;
- Dependable capacity;
- Project life (useable lifespan);
- In-service lead time associated with the resource development; and
- Resource dispatchability.

These technical attributes are presented as numerical values, except for dispatchability, which is presented as yes/no. A summary of the seven technical attributes that were analyzed for each resource option is presented in Table 5-1. To make the tables with technical attributes more readable, the monthly and firm energy data were summed for and presented as annual values in the attribute tables. Average monthly energy values are also presented for each resource option in a separate figure. The monthly energy data related to those attributes was used in the portfolio analysis.

Table 5-1: Technical Attributes

Annual Energy	Firm Energy	Installed Capacity	Dependable Capacity	Project Life	Lead Time	Dispatchable
GWh/yr	GWh/yr	MW	MW	Years	Years	Yes/No

The technical attributes are defined as follows:

Annual Energy, expressed as GWh/year, is the total amount of energy that the resource option can potentially produce in an average year. An average year defined as having historically average fuel availability, such as wind or water. For the purpose of YEC's portfolio analysis, energy inputs are available on finer timeframes, such as monthly, depending on the resource option and the analysis undertaken.

Firm energy, expressed GWh/year, is the total amount of energy that the resource option can reliably generate in a timeframe, typically reported as annual and monthly. Resource firm energy depends on a number of factors, primarily the reliability of the fuel specific to the resource. For example, the fuel supply for a thermal generation station (diesel or natural gas) can be available with a high degree of certainty, since these fuels can be stored. On the other hand, the intermittent fuel supply for resources such as hydro, solar and wind depends on water inflows, solar radiation and wind speeds respectively, which are inherently uncertain and cannot be controlled by the project operator.

Despite this intermittency, it can be expected that certain amount of energy from those resources will be available on a longer timeframe, such as yearly. For hydro generation, firm energy is estimated assuming the historic lowest water inflows on record. Given the fact that the YEC grid is self-sufficient and isolated, it has no opportunity to import energy if its resources are not able to meet the load. The practice of estimating firm energy by assuming low water inflows is followed by other Canadian utilities such as Hydro Quebec and Manitoba Hydro. BC Hydro also followed the practice in the past, when one of its planning criteria was self-sufficiency.

Considering that wind and solar penetration to the YEC system is not expected to reach significant levels for the foreseeable future, it is assumed that firm energy for these resources is equal to annual energy.

Another consideration in the determination of firm energy is the frequency and severity of equipment maintenance and failures. For each resource option studied, expected outage rates (planned and unplanned) have been considered in YEC's analysis.

Installed capacity, expressed in megawatts (MW), is the maximum amount generating capacity that the equipment for a specific resource option is capable of providing. This metric assumes that the resource asset is unconstrained by its fuel supply, and it is in full operational condition. The choice of installed capacity was based either on fuel availability or a range of feasible options for each resource. Resources with capacity constrained by fuel availability include biomass, biogas, waste-to-energy, run-of-river hydro, geothermal and DSM. The selection of installed capacity of the other resource options was based on investigating a range of installed capacities to find economies of scale, appropriately sizing projects for the jurisdiction and ensuring that there was an appropriate range of capacity options available for selection in the portfolio analysis.

Dependable capacity, expressed in MW, is the maximum generation output that a resource can reliably provide in a specific timeframe, typically during the period of greatest demand. YEC defines dependable capacity as the maximum output that a resource can reliably provide over two consecutive weeks during the four winter months (November to February). Dependable capacity is determined for each resource individually. For example, the dependable capacity of thermal resources is equal to the installed capacity (barring planned outages that would reduce it), as these fuels can be stored. For hydro resources with storage, dependable capacity is based on the inflows in the 5 driest inflow years in history. For intermittent resources such as wind and solar, dependable capacity is considered zero, as there is no guarantee that there will be the required wind speeds or solar radiation to generate electricity for the two consecutive weeks within the winter period. Eventually, if the YEC system integrates more intermittent resources such as wind and solar at different locations, the production diversity of these resources might provide some degree of dependable capacity.

Project life, expressed in years, is the length of time that the resource option asset will be in service. This takes into account the technical useful life of the resource type, due to wear and tear, and assumptions with respect to obsolescence.

Lead time, expressed in years, is the length of time required to bring a resource into operation. This includes the requirements for planning, consultation, engineering, permitting, construction and commissioning.

Dispatchability, refers to a feature of a resource that allows it to be turned on or off. Dispatchable resource are able to adjust their power output supplied to the electrical grid on demand. Resource options such as diesel or natural gas power plants and hydro power plants with reservoirs are dispatchable in order to meet the always changing electricity loads. In contrast, some renewable resources, such as wind and solar, are intermittent and non-dispatchable, because they can only generate electricity while their energy source is available.

5.1.2 Financial Attributes

The financial attributes describe the expected cost of the energy and capacity for each of the resource options considered. These attributes are presented as numerical values. Table 5-2 shows the two financial attributes that have been determined for each resource option. The financial attributes represent the estimated overall cost of the resource at the point of interconnection with the existing or future transmission grid. They are based on the sum of three cost components: within the plant site, road costs, and transmission interconnection costs.

Table 5-2 Financial Attributes

Levelized Cost of Energy (LCOE)	Levelized Cost of Capacity (LCOC)
$/kWh	$/kW·yr

The levelized cost of energy (LCOE) is the per unit cost of energy produced by a generation asset over its lifetime. This cost takes into account the plant capital investment, plant operating and maintenance costs, road costs and transmission costs to the point of interconnection with the grid. The LCOE is calculated as the Net Present Value (NPV) of the asset expressed in terms of annualized costs divided by annual energy generation.

LCOE indicates, on a consistent and comparable basis, each option's overall costs per unit of energy in current dollars ($2016). The LCOE metric presented throughout the 2016 Resource Plan is a Full Utilization Cost of Energy, which assumes that there are no constraints on energy production from a resource due to inadequate customer demand, such as surplus system energy production during freshet.

LCOE is expressed in $/kWh and is used as one of the criteria to compare the cost of energy from various resource options in the portfolio analysis. This cost is subject to ongoing annual inflation for each subsequent year of operation in order to assess costs over the option's economic life. This cost does not mean that YEC or ratepayers would face this specific cost per kWh during each year of operation. While LCOE may reflect annual costs for fuel intensive options, the costs per kWh of capital intensive options will be higher than the LCOE in the early years following asset construction, but will decline over time to be less than the LCOE.

For the projects that potentially could be developed by YEC, the Resource Plan assumes the cost of capital (discount rate) of 5.45% nominal (3.38% real with inflation of 2%). The presented discount rate is blended, consisting of 60% debt at 8.25% and 40% equity at 1.9%, as per YEC's General Revenue Application (GRA) filing to the YUB in 2012/2013. For the Independent Power Producers (IPP) projects the Resource Plan assumes 6.7% nominal (4.61% real) discount rate. The only project that is an IPP project from the onset is the Atlin/Pine Creek small hydro project

The levelized cost of capacity (LCOC) is per unit cost of capacity produced by a generation asset over its lifetime. The LCOC takes into account the plant capital investment, plant maintenance costs, road costs and transmission costs to the point of interconnection with the grid. As opposed to the LOCE, the LCOC does not take into account the plant operating costs, since this metric is not related to energy generated, but capacity. The LCOC is calculated as the net present value (NPV) of the asset expressed in terms of annualized costs divided by the dependable capacity of the asset.

LCOC indicates on a consistent and comparable basis each option's overall costs per unit of dependable capacity in current dollars ($2016).

LCOC is expressed in $/kW·yr and is used as one of the criteria to compare the cost of dependable capacity from various resource options in the portfolio analysis. This cost is subject to ongoing annual inflation for each subsequent year of operation in order to assess costs over the option's economic life. The discount rate used for LCOC calculations is the same as that used for LCOE calculations.

The calculation of the LCOE and LCOC for most resource options can be found in the technical reports in appendices 5.3 to 5.19. LCOE and LCOC information for waste-to-energy, biomass, biogas, uprates, Mayo refurbishment, hydro storage enhancements, diesel and LNG can be found in the summaries below.

5.1.3 Environmental Attributes

The environmental attributes describe the potential effects that each resource option will have on the environment, including the aquatic environment, terrestrial environment and air. The attributes used to describe the effects on air include greenhouse gas emissions as well as other pollutants such as NO_x, SO_x and particulates. Table 5-3 to Table 5-5 show the environmental attributes with the associated indicators and metrics.

Table 5-3: Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	**Species at Risk & Habitat (En1-2)**	**Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)**	**Consumptive Water Use (En2-1)**	**Relative Scale of New Impoundment/ Flooding (En2-2)**	**Flow Changes (En2-3)**
Presence or absence (Y/N) & Relative Impact (+/-)	Presence or absence (Y/N) & Relative Impact (+/-)	Presence or absence (Y/N) & Relative Impact (+/-)	Water Use Intensity (m^3/day)	Presence or absence (Y/N) & Relative Scale (L/MH)	Presence or absence (Y/N) & Relative Scale (L/MH)

Table 5-4: Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	**Protected & Conservation Areas (En3-2)**	**Wildlife Key Areas (En3-3)**	**Caribou Ranges (En3-4)**	**Footprint Terrestrial Area (En4-1)**	**Linear Dev for Roads/ Transmission (En4-2)**	**Permafrost (En4-3)**	**Wetlands (En4-4)**
Presence or absence (Y/N) & Relative Impact (+/-)	Proximity to Protected & Conservation Area (L/M/H)	Proximity to WKAs (L/M/H)	Proximity to Caribou Ranges (L/M/H)	Area of Terrestrial Footprint (km^2)	Total Length of Linear Features (km)	Presence or absence (Y/N) & Relative Scale (L/MH)	Presence or absence (Y/N) & Relative Scale (L/MH)

Table 5-5: Environmental Attributes - Air

Air Quality (En5)		
GHG Emissions (En5-1)		**Other Air Pollutants (En5-2)**
with Biogenic CO2---intensity per kWh	without Biogenic CO2 - intensity per kW.h	intensity per kWh

The evaluation of the resource options against the environmental attributes highlights the key differences between resource options. Each indicator for the environmental attributes was assigned a low (red), medium (yellow) or high (green) preference ranking for each resource option.

Resource options given a high environmental preference:

- Minimize negative environmental effects, such as reducing greenhouse gas emissions.
- Have no connection between the indicator and the resource option. For example, a resource that has no effect on fish habitat because it is far from any water would receive a high (green) preference rating for the Fish & Fish Habitat attributes.

The evaluation assumes that well understood mitigation measures or best management practices will be adopted to manage potential effects. To provide a common evaluation approach for all resource options, customized mitigations options developed for a specific resource is not considered.

A lifecycle analysis (LCA) of the greenhouse gas (GHG) emissions of resource options was completed for the 2016 Resource Plan by ArcticCan to inform the Air Quality environmental attribute and is presented Appendix 5.1. Given the eventual application of carbon pricing across Canada, YEC chose to assess the impact of a social cost of carbon within the 2016 Resource Plan, specifically on the economics of the resource options studied and in the portfolio analysis. The results of the LCA were used with the social cost of carbon to inform the portfolio analysis of the impact of the GHG emissions costs of every resource option. GHG emissions of resources expressed in tonnes of CO_2equivalent were multiplied by the social cost of carbon expressed in $ per tonne of CO_2equvalent to calculate the costs of the GHG emissions and, consequently, their impact on the economics of the portfolio analysis.

An evaluation of the environmental, social and economic attributes for each resource option was completed for the 2016 Resource Plan by InterGroup with sub-consultants EDI, Ecofor and CNC and can be found in Appendix 5.2.

5.1.4 Social Attributes

The social attributes describe the social effects of each resource option. Table 5-6 to Table 5-8 show the social attributes with the associated indicators and metrics.

Table 5-6: Social Attributes – First Nation Lands and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)

Table 5-7: Social Attributes - Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)

Table 5-8: Social Attributes - Tourism, Recreation & Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)

The evaluation of the resource options against the social attributes highlights the key differences between resource options. Each indicator for the social attributes was assigned a low (red), medium (yellow) or high (green) preference ranking for each resource option.

Resource options given a high social preference:

- Minimize negative effects, such as the impact on traditional lifestyle.
- Maximize positive effects, such as increasing cultural and community wellbeing.

- Have no linkage between the indicator and the resource option. For example, a resource option would receive a high (green) preference rating for Tourism Values if the resource is located far from the areas related to tourism.

The evaluation assumes the adoption of well understood mitigation measures or best management practices to manage potential effects. To provide a common evaluation approach to all options, customized mitigations options developed for a specific resource option was not considered. An evaluation of the environmental, social and economic attributes for each resource option was completed for the 2016 Resource Plan by InterGroup with sub-consultants EDI, Ecofor and CNC and can be found in Appendix 5.2.

5.1.5 Economic Attributes

The economic attributes describe the effects of each resource option on the Yukon economy.

Table 5-9: Economic Attributes - Local Economic Effects

Local Economic Impacts (Ec1) (Positive Effects)		
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects

Table 5-10: Economic Attributes - Climate Change Risk affecting Resource Financial Attributes

Climate Change Risk affecting Resource Financial Attributes (Ec2)				
Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)

The evaluation of the resource options against the economic attributes highlights the key differences between resource options. Each indicator for the social attributes was assigned a low (red), medium (yellow) or high (green) preference ranking for each resource option.

Resource options given a high economic preference:

- Minimize negative effects, such as being adaptable to climate change;
- Maximizing positive effects, such as increasing local employment opportunities; and
- Have no linkage between the indicator and the resource option. For example a resource option that is not susceptible to climate change would receive a high (green) preference rating for the Climate change risk attributes.

An evaluation of the environmental, social and economic attributes for each resource option was completed for the 2016 Resource Plan by InterGroup with sub-consultants EDI, Ecofor and CNC and can be found in Appendix 5.2.

5.2 Resource Options

5.2.1 Hydro Enhancements

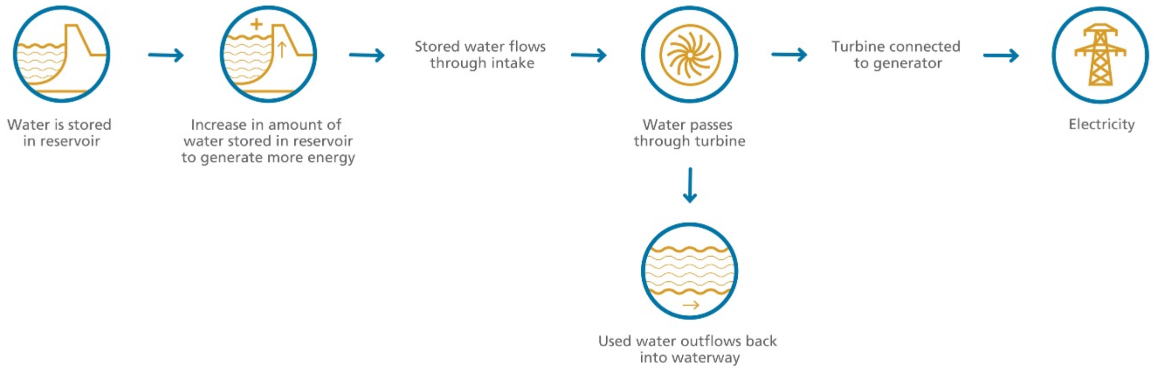
Technology description

Hydro storage enhancements increase the amount of water storage in an existing reservoir for use in the hydro generating facility as shown in Figure 5-2. This can be done by increasing the operational range, i.e. by increasing the upper allowable water level, decreasing the lowest allowable water level, or both. The hydro storage enhancement projects provide additional firm energy, but they do not contribute to dependable capacity.

Two storage enhancement projects were identified in the resource plan, the Southern Lakes Enhanced Storage Concept and the Mayo Lake Enhanced Storage Project. The Southern Lakes Enhanced Storage Concept would expand the storage range on the Southern Lakes system, which provides water storage for the Whitehorse generating station, by decreasing the licenced low supply level by up to 10 cm and increase the licenced upper allowable limit up to 30 cm. The Mayo Lake Enhanced Storage Project would seek to decrease the licenced low supply level by an initial 0.5 m and up to 1.0 m.

Hydro enhancement projects provide dispatchable energy. As existing generators are used, no additional dependable capacity is added. The energy provided by the hydro enhancements is aligned with the load profile as shown in Figure 5-3.

Figure 5-2: Hydro Storage Enhancements



Studies

Over the past six years many studies on the Southern Lakes Enhanced Storage Concept have been completed including baseline environmental and socio-economic studies, preliminary effects assessments and conceptual mitigation design.

Studies on the Mayo Lake Enhanced Storage Project began in 2008 with the Mayo B Project and the environmental monitoring, socio-economic studies and consultation was completed in 2015. A project proposal was submitted to the YESAA designated office in August of 2015, but withdrawn while more information on the maintenance requirements (i.e., dredging) of the outlet channel is gathered.

Information on these projects can be found in Appendices 5.3 and 5.4.

Fuel description

Hydro storage enhancement projects provide more water to existing hydro generation stations, which in the projects considered by YEC, mainly occurs during the winter.

Summary of studies to date and key findings

The findings of the studies on the Southern Lakes Enhanced Storage Concept show that the likely effects are subtle and consist of adding to pre-existing seasonal erosion and groundwater effects in low-lying properties. Mitigation measures to address the erosion and groundwater effects have been designed in consultation with affected property owners. No significant effects are predicted for aquatic and terrestrial habitats or species.

Studies on the Mayo Lake Enhanced Storage Project found the potential for significant effects to fish and fish habitat in the absence of measures to mitigate the effects. Specific mitigation measures were identified that could avoid, minimize, or otherwise manage these effects to an acceptable level. The Project also includes a detailed monitoring and adaptive management plan that was co-developed, and would be implemented, with the First Nation of Na-Cho Nyak Dun.

The studies on Mayo Lake also found sedimentation in the Mayo Lake outlet channel that has been accumulating since the early 1950’s. The sedimentation has resulted in flow restrictions in the outlet channel. Economic modelling of the hydro enhancement project found that it would not deliver an economic benefit with the current restricted flows at the outlet, due to the sedimentation. This issue would need to be resolved before the Mayo Enhanced Storage Project can proceed. The costs of dredging the outlet channel have been included in the Project costs.

Operational challenges related to icing and flooding on the lower Mayo River were historically identified for all Mayo Hydro operations, including feasibility influences on the Enhanced Storage Project. In recent years a new protocol has been developed for ice formation on the lower Mayo River, and operating experience with the new protocol over the winters of 2014-15 and 2015-16 indicate that there are no material impacts on operation of the Mayo hydro facility. As such, this historic issue no longer represents challenge to the Enhanced Storage Project.

The following Table 5-11 describes the technical and financial attributes and Table 5-12 to Table 5-18 describe the environmental, social and economic attributes of the two hydro storage enhancement options. The average monthly energy profile is shown in Figure 5-3. Energy production was estimated under the High Industrial Activity scenario. The location of the hydro storage enhancement projects can be found in Figure 5-4 below.

Table 5-11: Average Hydro Storage Enhancement Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW.yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Southern Lakes Enhanced Storage Project								
9.9	9.9	0	0	0.09	-	34	3	Y
Mayo Lake Enhanced Storage Project								
7.5	7.5	0	0	0.11	-	45	4	Y

Figure 5-3: Average Energy Profile for Hydro Storage Enhancement Resource Option

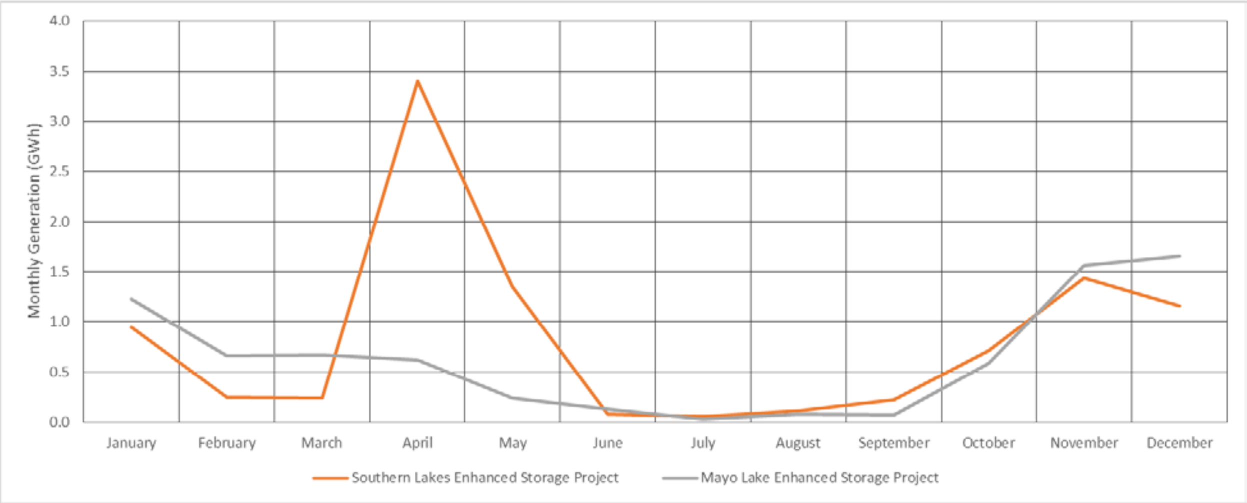


Table 5-12: Hydro Storage Enhancement Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Southern Lakes Storage					
🟨	🟩	🟥	🟩	🟩	🟥
Mayo Lake Storage					
🟩	🟩	🟥	🟩	🟩	🟥
Mayo Lake Dredging					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-13: Hydro Storage Enhancement Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Southern Lakes Storage							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟥
Mayo Lake Storage							
🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Mayo Lake Dredging							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-14: Hydro Storage Enhancement Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Southern Lakes Storage		
🟩		🟩
Mayo Lake Storage		
🟩		🟩
Mayo Lake Dredging		
🟩		🟩

Table 5-15: Hydro Storage Enhancement Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Southern Lakes Storage					
🟥	🟥	🟩	🟨	🟥	🟩
Mayo Lake Storage					
🟩	🟥	🟩	🟩	🟩	🟩
Mayo Lake Dredging					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-16: Hydro Storage Enhancement Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Southern Lakes Storage				
🟥	🟨	🟩	🟩	🟥
Mayo Lake Storage				
🟩	🟩	🟩	🟩	🟥
Mayo Lake Dredging				
🟩	🟩	🟩	🟩	🟥

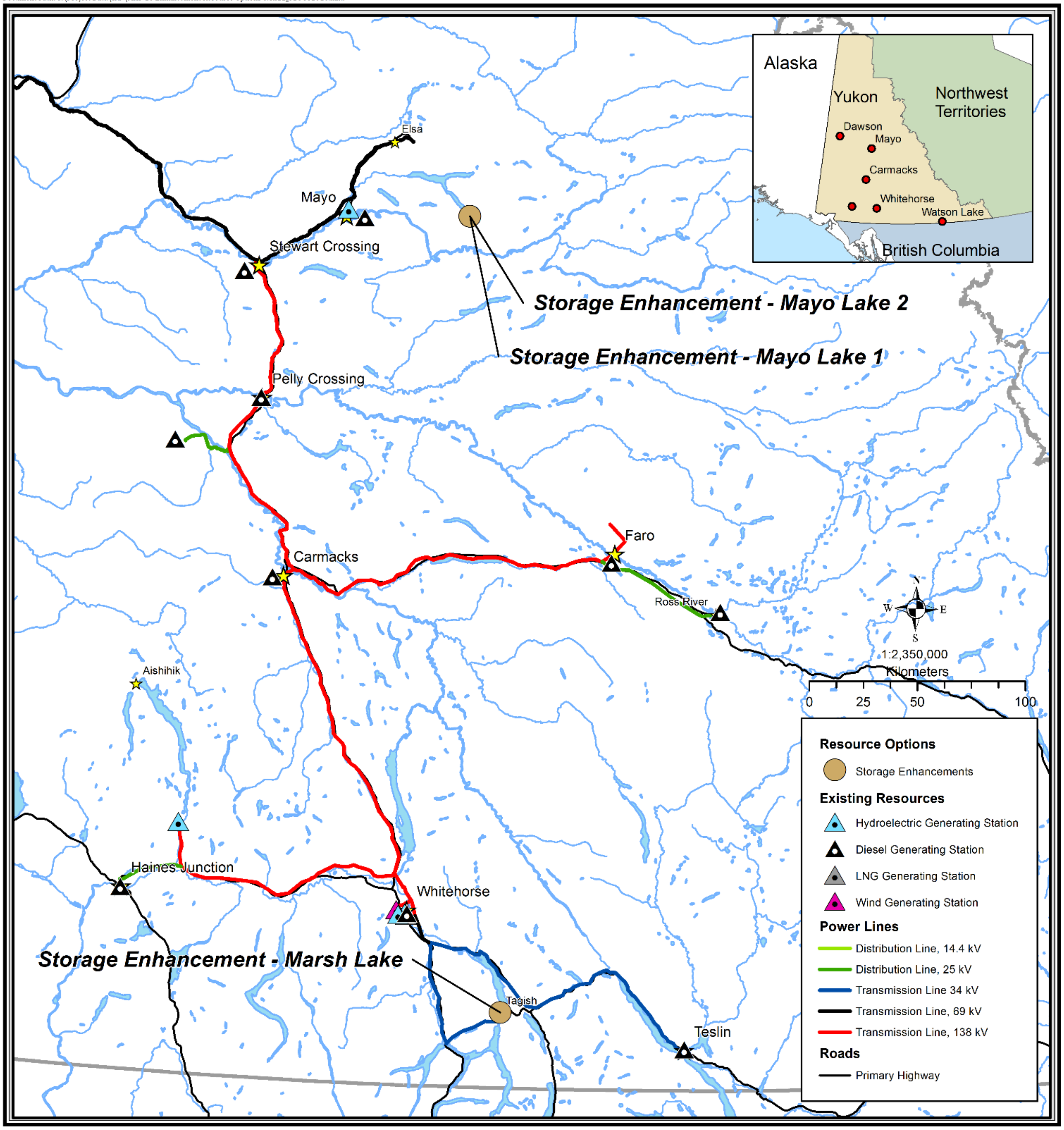
Table 5-17: Hydro Storage Enhancement Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Southern Lakes Storage					
🟩	🟩	🟩	🟩	🟩	🟩
Mayo Lake Storage					
🟩	🟩	🟩	🟩	🟩	🟩
Mayo Lake Dredging					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-18: Hydro Storage Enhancement Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/ Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Southern Lakes Storage							
🟥	🟥	🟥	🟨	🟩	🟩	🟩	🟩
Mayo Lake Storage							
🟥	🟥	🟥	🟨	🟩	🟩	🟩	🟩
Mayo Lake Dredging							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

Figure 5-4: Hydro Storage Enhancement Resource Options Locations



5.2.2 Hydro Uprate and Refurbishment

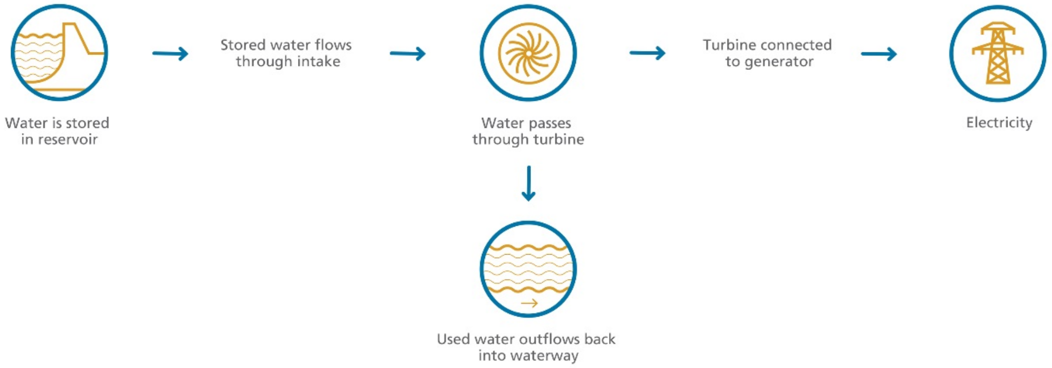
Technology description

Hydro uprate projects, also referred to as re-runnering, increases the efficiency of existing hydro turbines by replacing components of older hydro power plant equipment with more efficient components, shown in Figure 5-5. This results in more generated electricity with the same amount of water throughput. Uprate projects have been identified at the Whitehorse and Aishihik Hydro generating stations. The Whitehorse uprate project provides both additional firm energy and dependable capacity. The Aishihik uprate project that provides only firm energy, because it is affected by the N-1 planning criteria by being connected to the Aishihik transmission line

Refurbishment is a major overhaul or replacement at an existing facility where many pieces of equipment are reaching end of life. A refurbishment project has been identified at the Mayo Hydro generating station.

Hydro uprates and refurbishments provide dispatchable energy and dependable capacity. These projects will provide winter energy which is when the load on the systems is highest. Those projects also provide more energy in the summer months when the energy requirement is lower.

Figure 5-5: Hydro Uprate and Refurbishment



Studies

Three studies were commissioned to assess hydro uprate and refurbishment projects at YECs existing hydro stations. An Uprate Study for the Aishihik Turbines was conducted by the KGS Group in 2016 which considered options for uprating both Aishihik Hydro unit 1 (AH1) and Aishihik Hydro unit 2 (AH2) or uprating just AH2, since uprating AH2 offers a greater benefit. This study included an engineering review of the turbine components, requests for information from vendors and a compiled cost estimate. A similar uprate study is being completed for the Whitehorse Hydro units by Hatch and is expected to be completed in early 2017. For the 2016 Resource Option Report, YEC used the efficiency gain outlined in the KGS study to estimate costs and benefits of the Whitehorse unit uprates.

A study of four options for the future of the Mayo Hydro (MH0, also referred to as Mayo A) facility was completed by KGS in 2016. Mayo Hydro was constructed in 1951 and is YEC's oldest hydro plant and many components are coming to end of life. A conceptual design, high level cost estimate and economic analysis was prepared for each option. The four options considered were:

- Replacement of the Mayo Hydro Station;
- Refurbishment of the Mayo Hydro Station;
- Removal of the Mayo Hydro facility and return the site to near greenfield condition; and
- Safe decommissioning of the Mayo hydro facility and abandon in-situ.

The Aishihik Turbine Uprate Study is presented in Appendix 5.5 and Mayo Hydro Future Facility options Conceptual Design Report can be found in Appendix 5.6.

Fuel description

The goal of hydro uprate and refurbishment projects is to use water that is already being run through a hydro generating plant more efficiently. Storage hydro generation is dispatchable by YEC, within some environmental constraints, and can provide winter generation and capacity.

Summary of studies to date and key findings

The Aishihik study found that by uprating both AH1 and AH2, the plant efficiency could increase from 87.8% to 91.6%, adding 1.3 MW of capacity to the plant. The major components to be uprated included the runner, the generator air coolers, the excitation system and cables. The stators on both units were previously re-wound in 2003 and 2006. From the findings of the Aishihik study, it is estimated that uprating the WH1-4 could result in an additional 1.9MW of capacity.

The evaluation of the future options for the Mayo Hydro Plant found that the optimal solution in terms of the cost and energy generation would be to replace the existing two units with a single one new unit. The choice to construct only one new hydro unit at Mayo Hydro was influenced by constraints in both the downstream flow in the lower Mayo River (a condition of the current water license) and a flow constraint in the intake shared by Mayo Hydro and Mayo B. Consequently, while the current installed capacity of Mayo Hydro is 5 MW, only a single unit at Mayo Hydro, each with an installed capacity of 2.5 MW, can be operated at any one time when Mayo B is in operation. The single rebuilt Mayo Hydro unit would have an installed capacity of 2.3 MW, resulting in a net loss of 0.2 MW of installed capacity for Mayo Hydro Plant. The rebuilt Mayo Hydro Plant would result in more efficient use of water at the Mayo Hydro and Mayo B plants, given the water use constraints discussed above. Overall this results in greater dependable capacity and firm energy for the Mayo Hydro and Mayo B plants combined.

The following Table 5-19 describes the technical and financial attributes and Table 5-20 to Table 5-26 describe the environmental, social and economic attributes of the seven hydro uprate and refurbishment resource options. The average monthly energy profile is shown in Figure 5-6. The location of the uprate and refurbishment projects can be found in Figure 5-7 below.

Table 5-19: Hydro Uprate and Refurbishment Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Aishihik Hydro 2 Uprate								
2.3	2.3	0.7	0.7	0.06	182	40	3	Y
Aishihik Hydro 1 and Aishihik Hydro 2 Uprate								
2.7	2.7	1.3	1.3	0.09	178	40	3	Y
Mayo Hydro Refurbishment								
15.8	15.8	2.3	2.3	0.08	481	65	5	Y
Whitehorse Hydro 1 Uprate								
1.3	1.3	0.3	0.3	0.04	361	40	3	Y
Whitehorse Hydro 2 Uprate								
1.4	1.4	0.3	0.3	0.04	361	40	3	Y
Whitehorse Hydro 3 Uprate								
1.6	1.6	0.4	0.4	0.05	366	40	3	Y
Whitehorse Hydro 4 Uprate								
6.9	6.9	0.9	0.9	0.03	349	40	3	Y

Figure 5-6: Average Energy Profile for Hydro Uprate and Refurbishment Resource Option

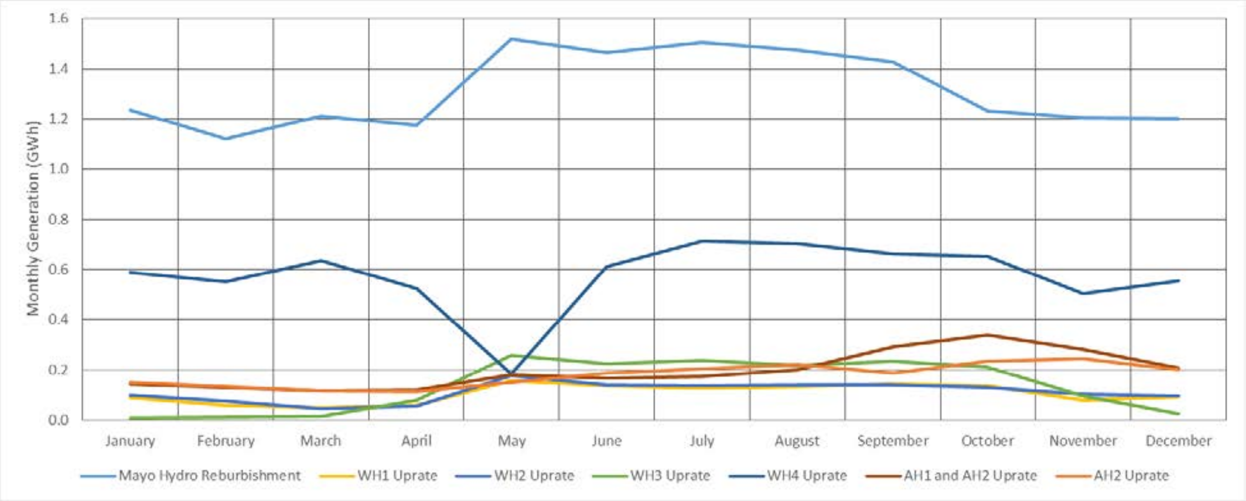


Table 5-20: Hydro Uprate and Refurbishment Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Aishihik Hydro Uprate					
🟩	🟩	🟩	🟩	🟩	🟩
Mayo Hydro Refurbishment					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-21: Hydro Uprate and Refurbishment Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Aishihik Hydro Uprate							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Mayo Hydro Refurbishment							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-22: Hydro Uprate and Refurbishment Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Aishihik Hydro Uprate		
🟩		🟩
Mayo Hydro Refurbishment		
🟩		🟩

Table 5-23: Hydro Uprate and Refurbishment Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Aishihik Hydro Uprate					
🟩	🟩	🟩	🟩	🟩	🟩
Mayo Hydro Refurbishment					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-24: Hydro Uprate and Refurbishmente Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Aishihik Hydro Uprate				
🟩	🟩	🟩	🟩	🟥
Mayo Hydro Refurbishment				
🟩	🟩	🟩	🟩	🟥

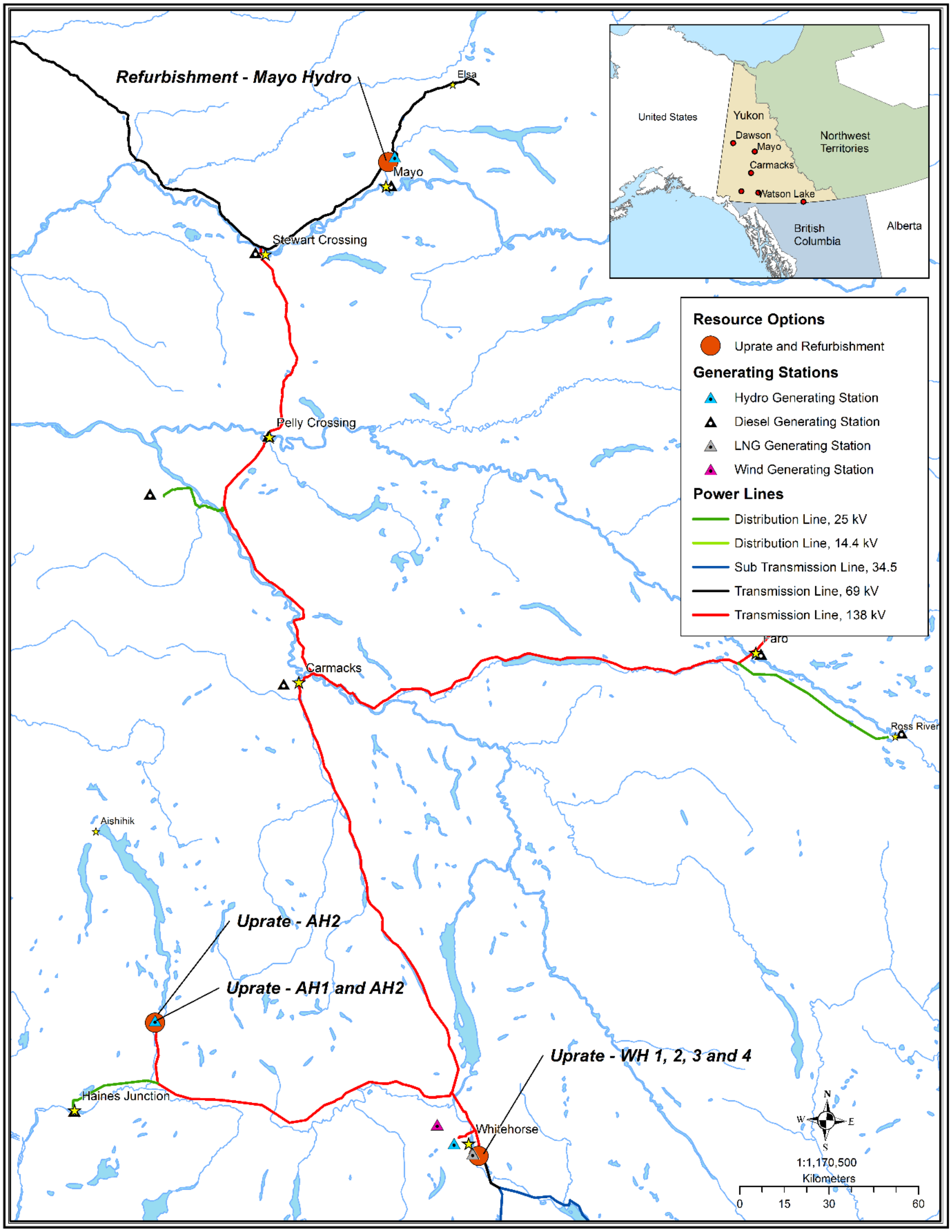
Table 5-25: Hydro Uprate and Refurbishment Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Aishihik Hydro Uprate					
🟩	🟩	🟩	🟩	🟩	🟩
Mayo Hydro Refurbishment					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-26: Hydro Uprating and Refurbishments Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Aishihik Hydro Uprate							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩
Mayo Hydro Refurbishment							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

1 *Figure 5-7: Hydro Uprate and Refurbishment Resource Option Locations*



5.2.3 Small Hydro

Technology description

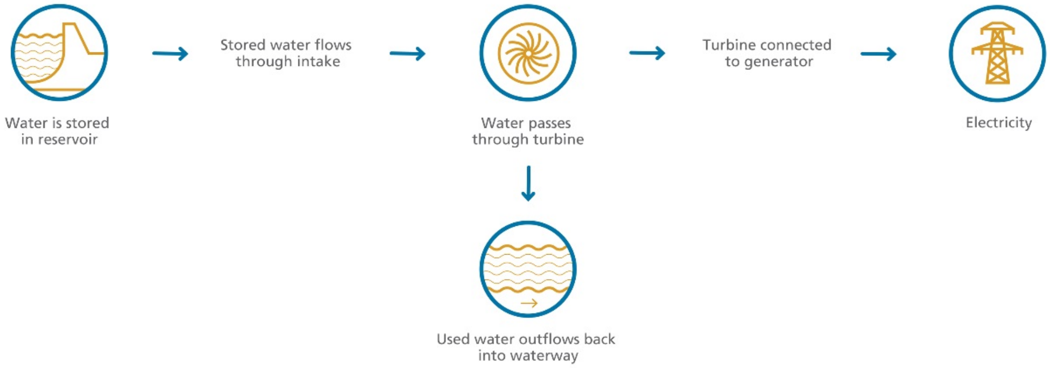
Hydroelectricity generation uses the force of falling or fast moving water to drive a turbine, which in turn drives a generator to produce electricity, as shown in Figure 5-8. Small scale hydro in Yukon could either be a conventional plant with a dam and reservoir to store water or a run-of-river plant.

Conventional hydroelectric plants with storage use an upstream reservoir to store water and control water flows to the powerhouse based on the electrical demand. This type of resource is considered dispatchable as it allows the utility to generate electricity when it is needed.

Run-of-river hydro generation has no or minimal upstream water storage, and uses the natural flow in a river at any given time to generate electricity. Water is typically diverted by a weir into a piping system that brings the water through a powerhouse and then back into the river downstream. The electricity generated varies seasonally with the flow of the river. For this reason, run-of-river hydro plants have limited dispatchability. Run of river hydropower resources typically have a seasonal generation output that depends on the runoff timing. Many rivers in Yukon have peak flows in the late summer when the snowpack melt is at its highest, and the lowest flows during the winter.

Conventional hydro provides dispatchable energy and dependable capacity while run-of-river hydro only provides small amount of dependable capacity. In addition, run-of-river hydro has limited to no dispatchability. The small hydro projects are able to provide energy in the winter, when demand for energy is highest. Some of the projects shown in Figure 5-8 would provide the same or more energy in the summer when demand for energy is lower.

Figure 5-8: Conventional Small Hydro



Studies

A screening assessment of potential small hydro sites in Yukon and northern British Columbia was completed for the 2016 Resource Plan by Knight Piesold. A pre-feasibility study completed by Morrison Hershfield for the Atlin Hydro Expansion was also included and added to the list of retained sites generated by Knight Piesold.

The first phase of this assessment involved a review of prior reports prepared on small hydro by YEC, Yukon Electrical Company, Yukon Development Corporation and other companies over the last 50 years. The

Knight Piesold screening assessment is presented in Appendix 5.7 and contains a list of the reports that were reviewed. The pre-feasibility report by Morrison Hershfield can be found in Appendix 5.8.

The screening assessment report started with 49 potential hydroelectric sites, characterized as both storage and run-of-river. These sites were first screened for redundancy and for those located in restricted areas, such as parks. The next screening was of sites that were more than 25 km away from existing or proposed transmission lines, as it was determined that connecting these sites to the grid would be cost prohibitive. These screenings left 22 sites remaining for further study. The next phase of the assessment was to review the hydrology of the sites, model energy output, review project layouts, estimate cost and finally complete a cost benefit analysis. From this analysis, a shortlist of five sites was chosen for more detailed review. The Atlin Hydro Expansion at Pine Creek in BC was also added to the list, with data coming from the Morrison Hershfield report.

Summary of studies to date and key findings

The six sites shortlisted in the reports are:

- Anvil Creek
- Drury Lake
- Finlayson River
- Tutshi Lake – Windy Arm
- Wolf River
- Pine Creek

The Wolf River and Anvil Creek projects would be considered run-of-river plants and the remaining four would have storage.

It was also noted that the Tutshi Lake – Windy Arm site could have potential synergies with the downstream Whitehorse Generating Station and potential pumped storage hydro sites between Moon Lake and Tutshi Lake that could add more winter generation.

The following Table 5-27 describes the technical and financial attributes and Table 5-28 to Table 5-33 describe the environmental, social and economic attributes of the six small hydro resource options. The average monthly energy profile is shown in Figure 5-9. The location of the small hydro projects are shown in Figure 5-10.

Table 5-27. Small Hydro Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Drury Lake								
31.7	31.7	8.1	8.1	0.19	700	65	6	Y
Tutshi Windy Arm								
56.6	56.3	7.2	7.2	0.14	1100	65	6	Y
Wolf River								
95.6	86.9	20	2.8	0.14	700	65	6	Y
Finlayson River								
138.9	138.9	17.6	17.6	0.12	1000	65	6	Y
Atlin/Pine Creek								
36.1	22.3	8	5.5	0.13	806	30	6	Y
Anvil Creek								
41.3	31	9.8	2.5	0.17	700	65	6	Y

Figure 5-9: Average Energy Profile for Small Hydro Resource Option

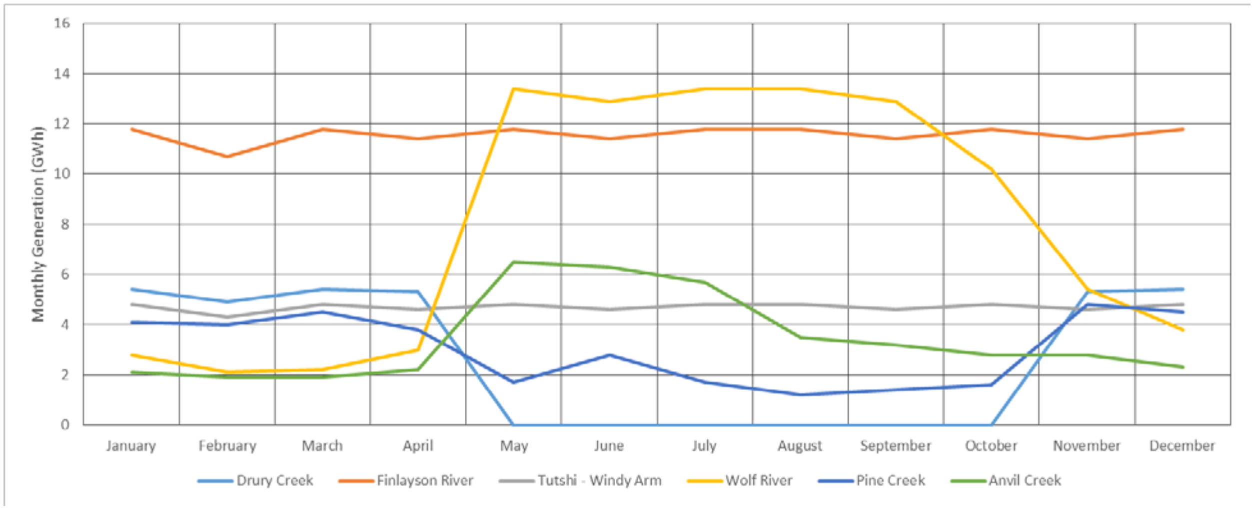


Table 5-28: Small Hydro Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Drury Lake					
🟨	🟩	🟥	🟩	🟨	🟨
Tutshi - Windy Arm					
🟩	🟩	🟥	🟩	🟨	🟨
Wolf River					
🟨	🟩	🟨	🟩	🟩	🟨
Finlayson River					
🟩	🟨	🟥	🟩	🟥	🟨
Atlin/ Pine Creek					
🟩	🟩	🟨	🟩	🟩	🟨
Anvil Creek					
🟨	🟩	🟥	🟩	🟥	🟨

Table 5-29: Small Hydro Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Drury Lake							
🟨	🟩	🟩	🟩	🟥	🟨	🟩	🟩
Tutshi - Windy Arm							
🟨	🟩	🟨	🟨	🟥	🟨	🟩	🟩
Wolf River							
🟨	🟨	🟨	🟩	🟥	🟨	🟩	🟨
Finlayson River							
🟨	🟩	🟨	🟨	🟥	🟨	🟨	🟩
Atlin/ Pine Creek							
🟨	🟩	🟩	🟩	🟥	🟨	🟩	🟩
Anvil Creek							
🟨	🟩	🟩	🟨	🟥	🟨	🟩	🟩

Table 5-30: Small Hydro Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Drury Lake		
🟩		🟩
Tutshi - Windy Arm		
🟩		🟩
Wolf River		
🟩		🟩
Finlayson River		
🟩		🟩
Atlin/ Pine Creek		
🟩		🟩
Anvil Creek		
🟩		🟩

Table 5-31: Small Hydro Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Drury Lake					
🟨	🟥	🟩	🟩	🟩	🟩
Tutshi - Windy Arm					
🟩	🟨	🟩	🟩	🟩	🟩
Wolf River					
🟥	🟥	🟩	🟩	🟩	🟩
Finlayson River					
🟥	🟥	🟨	🟨	🟩	🟨
Atlin/ Pine Creek					
🟨	🟥	🟩	🟩	🟩	🟩
Anvil Creek					
🟥	🟥	🟩	🟩	🟩	🟩

Table 5-32: Small Hydro Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Drury Lake				
🟩	🟩	🟥	🟥	🟨
Tutshi - Windy Arm				
🟨	🟩	🟥	🟥	🟩
Wolf River				
🟩	🟩	🟥	🟥	🟩
Finlayson River				
🟨	🟨	🟥	🟥	🟩
Atlin/ Pine Creek				
🟨	🟩	🟥	🟥	🟩
Anvil Creek				
🟨	🟨	🟥	🟥	🟨

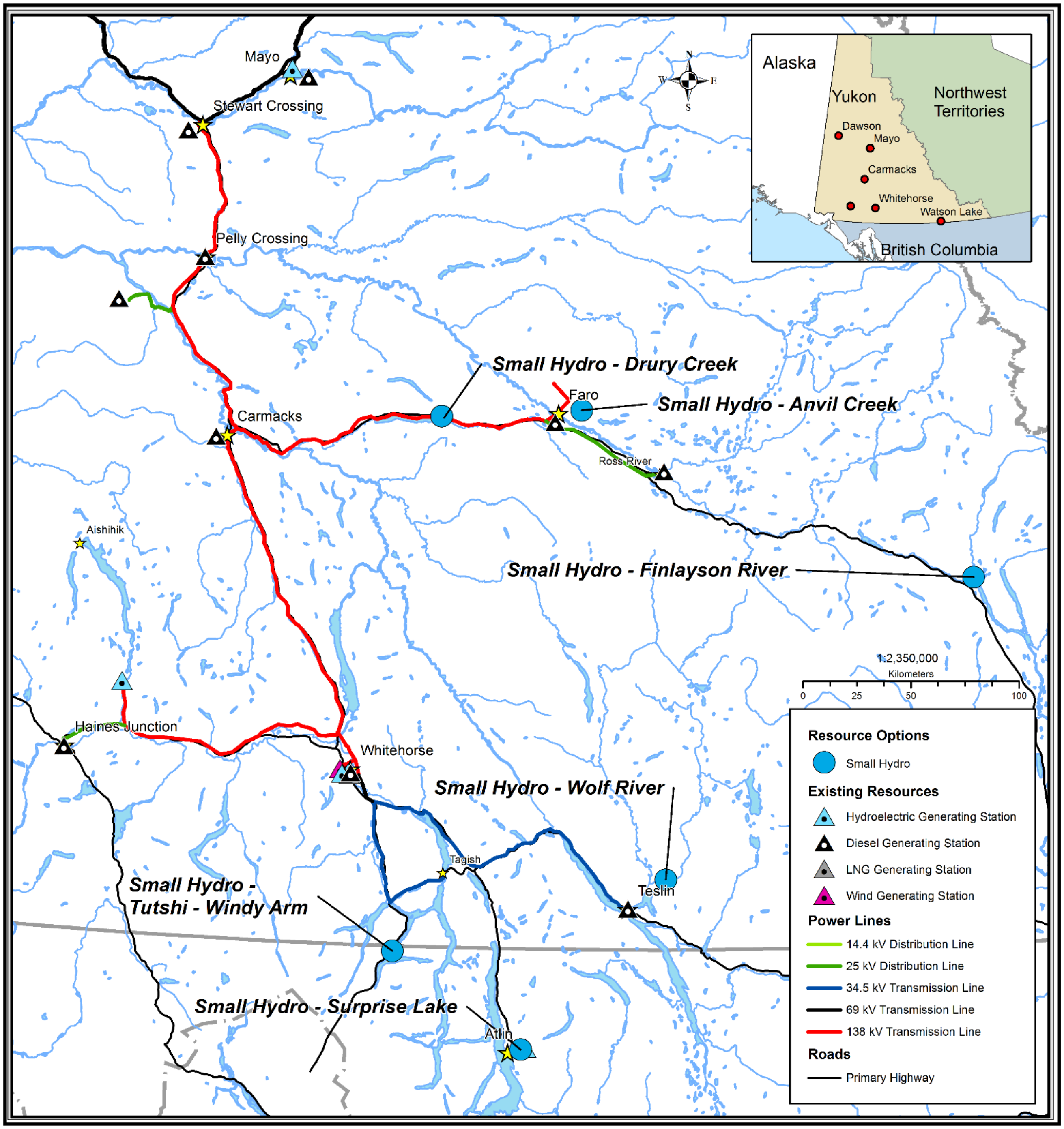
Table 5-33: Small Hydro Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	**Tourism Values (S4-2)**	**Aesthetics (S4-3)**	**Non-renewable Resources (S4-4)**	**Other Renewable Resources (S4-5)**	**Land Use & Renewable Resources Plans (S4-6)**
Drury Lake					
🟥	🟥	🟩	🟩	🟩	🟨
Tutshi - Windy Arm					
🟥	🟩	🟨	🟩	🟩	🟨
Wolf River					
🟨	🟨	🟩	🟩	🟩	🟨
Finlayson River					
🟥	🟥	🟩	🟨	🟩	🟨
Atlin/ Pine Creek					
🟥	🟥	🟥	🟥	🟩	🟩
Anvil Creek					
🟥	🟨	🟨	🟨	🟩	🟨

Table 5-34: Small Hydro Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Drury Lake							
🟥	🟩	🟨	🟥	🟩	🟩	🟩	🟥
Tutshi - Windy Arm							
🟨	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Wolf River							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Finlayson River							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Atlin/ Pine Creek							
🟨	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Anvil Creek							
🟨	🟩	🟨	🟥	🟩	🟩	🟩	🟨

1 *Figure 5-10: Small Hydro Resource Option Locations*



5.2.4 Wind

Technology description

Wind power uses the energy of wind to move turbine blades which drives a generator to produce electricity, as shown in Figure 5-11. Wind turbine generators range in size from very small 50 W turbines that are used in application such as charging batteries on a boat to the largest wind turbine currently produced at 6 MW. Most utility scale wind farms have wind turbine generators that range between 1 and 3 MW. These wind turbines are mounted on steel towers ranging 60 to 100 meters tall with three blades each 20 to 50 meters long. Larger wind generating stations in the Yukon may incorporate batteries to offset substantial fluctuations in generation

Wind is a variable resource and the timing of wind generation cannot be controlled by the operator. There will be times when the turbines do not produce electricity such as when wind speeds exceed the stress specifications of the turbines or towers or when wind speeds are below the start-up speed of the turbine. Because this resource is subject to the variabilities of the wind, it is not dispatchable or firm, and therefore it provides no dependable capacity.

The wind regime in the Yukon provides more energy in the winter which matches the greater demand for winter energy on the grid.

Figure 5-11: Wind

Studies

An inventory of wind energy sites was completed for the 2016 Resource Plan by CBER with sub consultants V3 Energy, LLC and Envint. A number of previous studies were reviewed for this inventory and are discussed in the report which is presented in Appendix 5.9. These studies focused on defining the wind resources on a regional level, as well as at specific known sites: Aishihik, Tehcho (Ferry Hill), Whitehorse and Mount Sumanik. The inventory completed for the 2016 Resource Plan expanded on the mesoscale (large scale) wind mapping work previously completed and identified potential wind energy sites across the Yukon. Considerations of distance to the nearest road as well as existing and planned transmission infrastructure were made when screening for the best sites. Environmental factors and land usage was also considered in the study. Seven sites were selected for conceptual design and economic analysis.

Fuel description

A wind power site requires relatively high wind speeds, which generally occur at higher elevations. Wind turbines at higher elevation sites are more susceptible to rime icing issues.

Summary of studies to date and key findings

Out of a long list of 26 sites, 7 sites were selected based on wind speed, distance to transmission infrastructure, road access and land ownership for an in-depth review and conceptual design. The sites selected include:

- Miller's Ridge (near Carmacks)
- Kluane Lake (near Destruction Bay)
- Cyprus Mine (brownfield site, near Faro Mine)
- Thulsoo Mountain (near the Aishihik Generating Station)
- Sugarloaf Mountain (near Carcross)
- Tehcho (near Stewart Crossing, formerly Ferry Hill)
- Mount Sumanik (near Whitehorse)

Yukon's northern climate means that icing can occur at high elevations during winter, making operating a wind turbine challenging. Of the seven site selected, only one site at Kluane Lake is at a low elevation. Despite energy losses due to winter icing, all seven sites show an average of three-quarters of the expected electricity production occurring in the winter months between October and April. This generation profile is complementary to the Yukon's energy needs, which are higher in the winter due to increase requirements for space heating and lighting.

The following Table 5-35 describes the technical and financial attributes and Table 5-36 to Table 5-41 describe the environmental, social and economic attributes of the seven wind resource options. The average monthly energy profile is shown in Figure 5-12. The location of the wind projects can be found in Figure 5-13.

Table 5-35. Wind Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Cyprus Mine 1								
16.1	16.1	6	---	0.18	---	25	5	N
Cyprus Mine 2								
26.0	26.0	10	---	0.14	---	25	5	N

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Cyprus Mine 3								
49.6	49.6	20	---	0.12	---	25	5	N
Kluane Lake 1								
15.0	15.0	6	---	0.15	---	25	9	N
Kluane Lake 2								
24.4	24.4	10	---	0.13	---	25	9	N
Kluane Lake 3								
47.8	47.8	20	---	0.11	---	25	9	N
Miller's Ridge 1								
18.1	18.1	6	---	0.18	---	25	5	N
Miller's Ridge 2								
29.5	29.5	10	---	0.13	---	25	5	N
Miller's Ridge 3								
57.3	57.3	20	---	0.11	---	25	5	N
Mt Sumanik 1								
14.2	14.2	6	---	0.18	---	25	5	N
Mt Sumanik 2								
21.1	21.1	10	---	0.15	---	25	5	N
Mt Sumanik 3								
41.5	41.5	20	---	0.12	---	25	5	N

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Sugarloaf Mtn 1								
9.9	9.9	6	---	0.23	---	25	5	N
Sugarloaf Mtn 2								
15.9	15.9	10	---	0.19	---	25	5	N
Sugarloaf Mtn 3								
32.3	32.3	20	---	0.15	---	25	5	N
Tehcho 1								
10.3	10.3	6	---	0.22	---	25	5	N
Tehcho 2								
18.3	18.3	10	---	0.17	---	25	5	N
Tehcho 3								
33.4	33.4	20	---	0.15	---	25	5	N
Thulsoo Mtn 1								
17.3	17.3	6	---	0.17	---	25	5	N
Thulsoo Mtn 2								
27.5	27.5	10	---	0.14	---	25	5	N
Thulsoo Mtn 3								
54.4	54.4	20	---	0.11	---	25	5	N

Figure 5-12: Average Energy Profile for Wind (20 MW) Resource Option

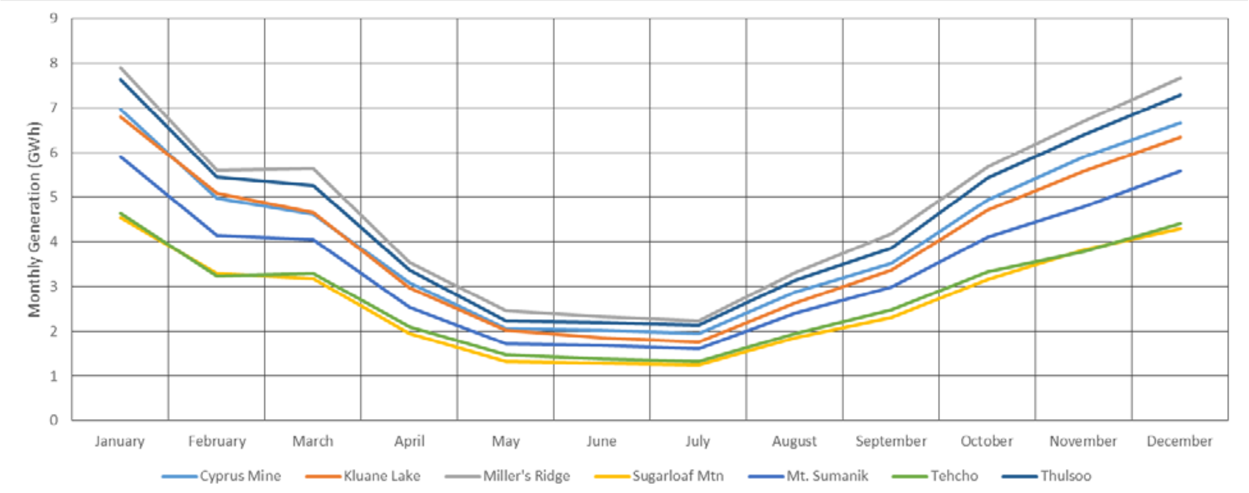


Table 5-36: Wind Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Cyprus Mine Hill, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Kluane Lake, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Millers Ridge, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Mt. Sumanik , 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Sugarloaf Mountain, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Tehcho (Ferry Hill), 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Thulsoo Mountain, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-37: Wind Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				Terrestrial Footprint & Land Use (En4)			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Cyprus Mine Hill, 20 MW							
🟨	🟩	🟩	🟨	🟥	🟨	🟩	🟩
Kluane Lake, 20 MW							
🟨	🟨	🟥	🟩	🟥	🟨	🟩	🟩
Millers Ridge, 20 MW							
🟨	🟩	🟨	🟨	🟥	🟨	🟩	🟩
Mt. Sumanik , 20 MW							
🟨	🟩	🟥	🟩	🟥	🟨	🟩	🟩
Sugarloaf Mountain, 20 MW							
🟨	🟩	🟥	🟨	🟥	🟨	🟩	🟩
Tehcho (Ferry Hill), 20 MW							
🟩	🟩	🟨	🟩	🟥	🟨	🟩	🟩
Thulsoo Mountain, 20 MW							
🟨	🟩	🟨	🟩	🟥	🟨	🟩	🟩

Table 5-38: Wind Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Cyprus Mine Hill, 20 MW		
🟩		🟩
Kluane Lake, 20 MW		
🟩		🟩
Millers Ridge, 20 MW		
🟩		🟩
Mt. Sumanik , 20 MW		
🟩		🟩
Sugarloaf Mountain, 20 MW		
🟩		🟩
Tehcho (Ferry Hill), 20 MW		
🟩		🟩
Thulsoo Mountain, 20 MW		
🟩		🟩

Table 5-39: Wind Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Cyprus Mine Hill, 20 MW					
🟩	🟥	🟩	🟩	🟩	🟩
Kluane Lake, 20 MW					
🟥	🟨	🟩	🟩	🟩	🟩
Millers Ridge, 20 MW					
🟨	🟥	🟩	🟩	🟩	🟩
Mt. Sumanik , 20 MW					
🟩	🟥	🟩	🟩	🟩	🟩
Sugarloaf Mountain, 20 MW					
🟥	🟥	🟩	🟩	🟩	🟩
Tehcho (Ferry Hill), 20 MW					
🟩	🟥	🟩	🟩	🟩	🟩
Thulsoo Mountain, 20 MW					
🟩	🟥	🟩	🟩	🟩	🟩

Table 5-40: Wind Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Cyprus Mine Hill, 20 MW				
🟩	🟩	🟨	🟨	🟨
Kluane Lake, 20 MW				
🟩	🟩	🟨	🟨	🟩
Millers Ridge, 20 MW				
🟩	🟨	🟨	🟨	🟨
Mt. Sumanik , 20 MW				
🟩	🟨	🟩	🟩	🟥
Sugarloaf Mountain, 20 MW				
🟩	🟨	🟨	🟨	🟩
Tehcho (Ferry Hill), 20 MW				
🟩	🟨	🟨	🟨	🟨
Thulsoo Mountain, 20 MW				
🟩	🟨	🟨	🟨	🟨

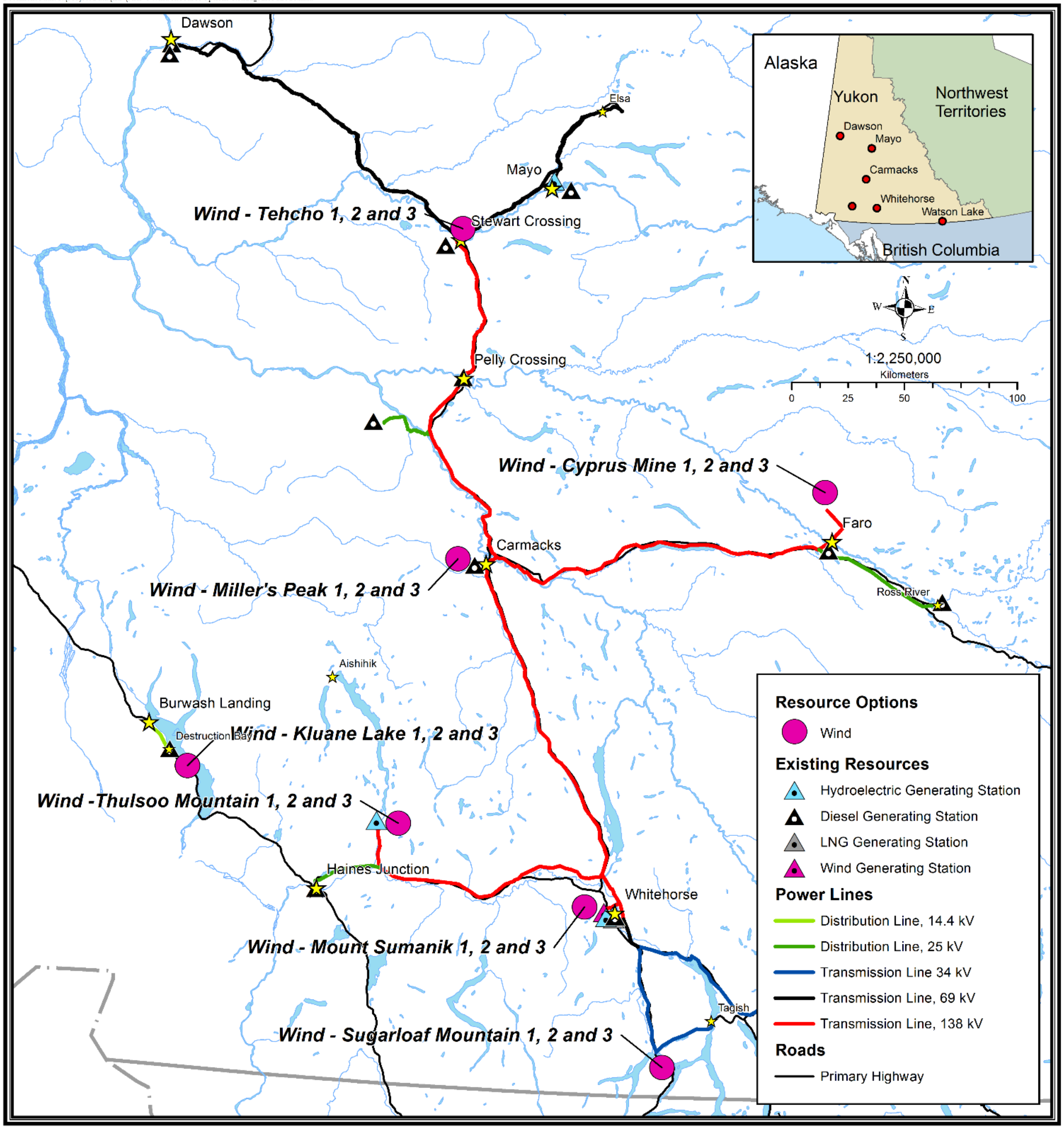
Table 5-41: Wind Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Cyprus Mine Hill, 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Kluane Lake, 20 MW					
🟨	🟨	🟨	🟩	🟩	🟩
Millers Ridge, 20 MW					
🟨	🟨	🟨	🟩	🟩	🟨
Mt. Sumanik , 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Sugarloaf Mountain, 20 MW					
🟩	🟩	🟨	🟩	🟩	🟨
Tehcho (Ferry Hill), 20 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Thulsoo Mountain, 20 MW					
🟨	🟩	🟨	🟨	🟩	🟨

Table 5-42: Small Hydro Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			Climate Change Risk affecting Resource Financial Attributes (Ec2)				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Cyprus Mine Hill, 20 MW							
🟥	🟨	🟨	🟩	🟩	🟨	🟥	🟩
Kluane Lake, 20 MW							
🟨	🟩	🟩	🟩	🟩	🟨	🟩	🟥
Millers Ridge, 20 MW							
🟥	🟨	🟨	🟩	🟩	🟨	🟥	🟩
Mt. Sumanik , 20 MW							
🟥	🟨	🟥	🟩	🟩	🟨	🟥	🟩
Sugarloaf Mountain, 20 MW							
🟥	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Tehcho (Ferry Hill), 20 MW							
🟥	🟨	🟨	🟩	🟩	🟨	🟥	🟩
Thulsoo Mountain, 20 MW							
🟥	🟨	🟨	🟩	🟩	🟨	🟥	🟩

1 *Figure 5-13: Wind Resource Option Locations*



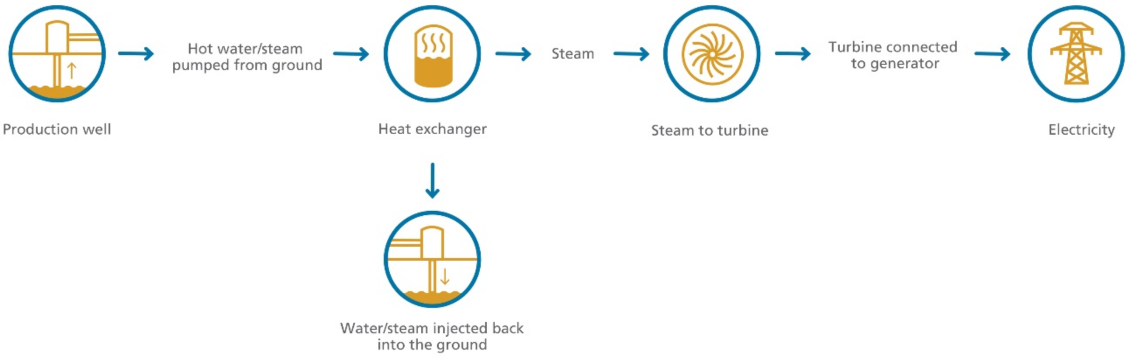
5.2.5 Geothermal

Technology description

Geothermal electricity generation uses the heat from groundwater to power a turbine and a generator, as shown in Figure 5-14. Based on survey work completed to date, geothermal resources in the Yukon provide low to medium temperature water and would require an Organic Rankine Cycle (ORC) power plant. An ORC plant uses steam and hot water from production wells to heat a binary fluid (usually a hydrocarbon) through a heat exchanger. The binary fluid has a low boiling point, and when heated, is vaporized at high pressure and then powers a turbine and a generator to produce electricity. After the vapor is used in the turbine, it is cooled, condensed to a liquid and recirculated through the system. The cooler groundwater is then reinjected back into the reservoir.

Geothermal provides dependable capacity but is not fully dispatchable. The energy provided is slightly higher in winter than summer, which complements the energy demand on the grid.

Figure 5-14: Geothermal



Studies

A review and site inventory of geothermal resources in the Yukon was completed for the 2016 Resource Plan by KGS Group, with sub consultants Mannvit hf and Intergroup. The report reviewed 26 prior studies and memos, dating back to the mid-1970s, with many completed between 2009 and 2012. These reports provided data on the basic geological setting and structure, surface spring temperature, water quality, calculations of geothermal source temperatures, isotope signatures, geothermal gradients, typical ground temperatures and climate normal data. The amount of information varies between reports. Generally the information is very high-level and additional work would be required to confirm the estimates in the report. A full bibliography of prior reports can be found in the technical report, Appendix 5.10.

Fuel description

All of the sites reviewed for this report have low to medium temperature resources, with groundwater temperatures below 150^{o}C. Over the lifetime of a geothermal plant, it is assumed that generation output would decline by 2% per year as geothermal resource extraction slowly cools the water source at depth.

Summary of studies to date and key findings

The study reviewed both the geothermal resource and the proximity to transmission lines. Sites were ranked based on these criteria and the two highest ranking sites were selected for conceptual design development. Those two sites were Vista Mountain near Whitehorse and McArthur Spring near Stewart Crossing.

The site at Vista Mountain is close to existing transmission infrastructure and the main load centre of Whitehorse. It is located in Crown land and has a relatively high inferred resource temperature compared to other sites in the Whitehorse region. Many of the sites had a similar temperatures to the Vista Mountain site. Vista Mountain was chosen due to its location.

McArthur Springs is located in a rugged, remote area far from existing transmission infrastructure and site access would be challenging. The traditional name of McArthur Springs is Chu Tthaw Hot Springs and the site is located within the Ddhaw Ghro Habitat Protection Area on the traditional land of the Selkirk First Nation. The geothermal resource at McArthur Springs has significantly higher temperatures than the other geothermal resources studied to date, and therefore was retained as a candidate site for further analysis.

A technical and economic analysis was completed of the conceptual designs of two sizes of geothermal plants at Vista Mountain and McArthur Springs.

The following Table 5-43 describes the technical and financial attributes and Table 5-44 to Table 5-50 describe the environmental, social and economic attributes of the four geothermal options. The average monthly energy profile is shown in Figure 5-15. The location of the geothermal projects can be found in Figure 5-16.

Table 5-43. Geothermal Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
MacArthur Springs 1								
14.1	14.1	3.1	2.4	0.47	3,220	30	4	Y
MacArthur Springs 2								
36.5	36.5	7.7	6.2	0.23	1,388	30	4	Y
Vista Mountain 1								
6.2	6.2	1.4	1.1	0.37	2,330	30	4	Y
Vista Mountain 2								
15.9	15.9	3.6	2.8	0.19	1,094	30	4	Y

Figure 5-15: Average Energy Profile (Year 1) for Geothermal Resource Option

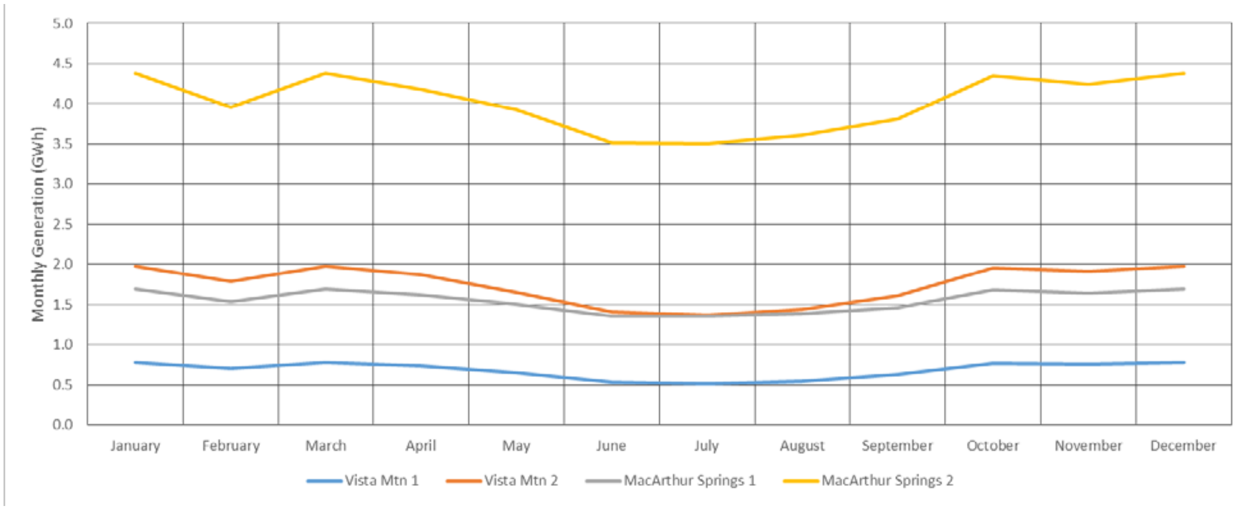


Table 5-44: Geothermal Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
McArthur Springs (3.8 MW Av.)					
🟩	🟩	🟩	🟩	🟩	🟩
Vista Mountain (1.6 MW Av.)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-45: Geothermal Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
McArthur Springs (3.8 MW Av.)							
🟩	🟥	🟨	🟨	🟥	🟨	🟩	🟩
Vista Mountain (1.6 MW Av.)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-46: Geothermal Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
McArthur Springs (3.8 MW Av.)		
🟩	🟩	🟩
Vista Mountain (1.6 MW Av.)		
🟩	🟩	🟩

Table 5-47: Geothermal Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
McArthur Springs (3.8 MW Av.)					
🟨	🟥	🟩	🟩	🟩	🟩
Vista Mountain (1.6 MW Av.)					
🟨	🟨	🟩	🟩	🟩	🟩

Table 5-48: Geothermal Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
McArthur Springs (3.8 MW Av.)				
🟩	🟨	🟨	🟨	🟨
Vista Mountain (1.6 MW Av.)				
🟩	🟩	🟩	🟩	🟥

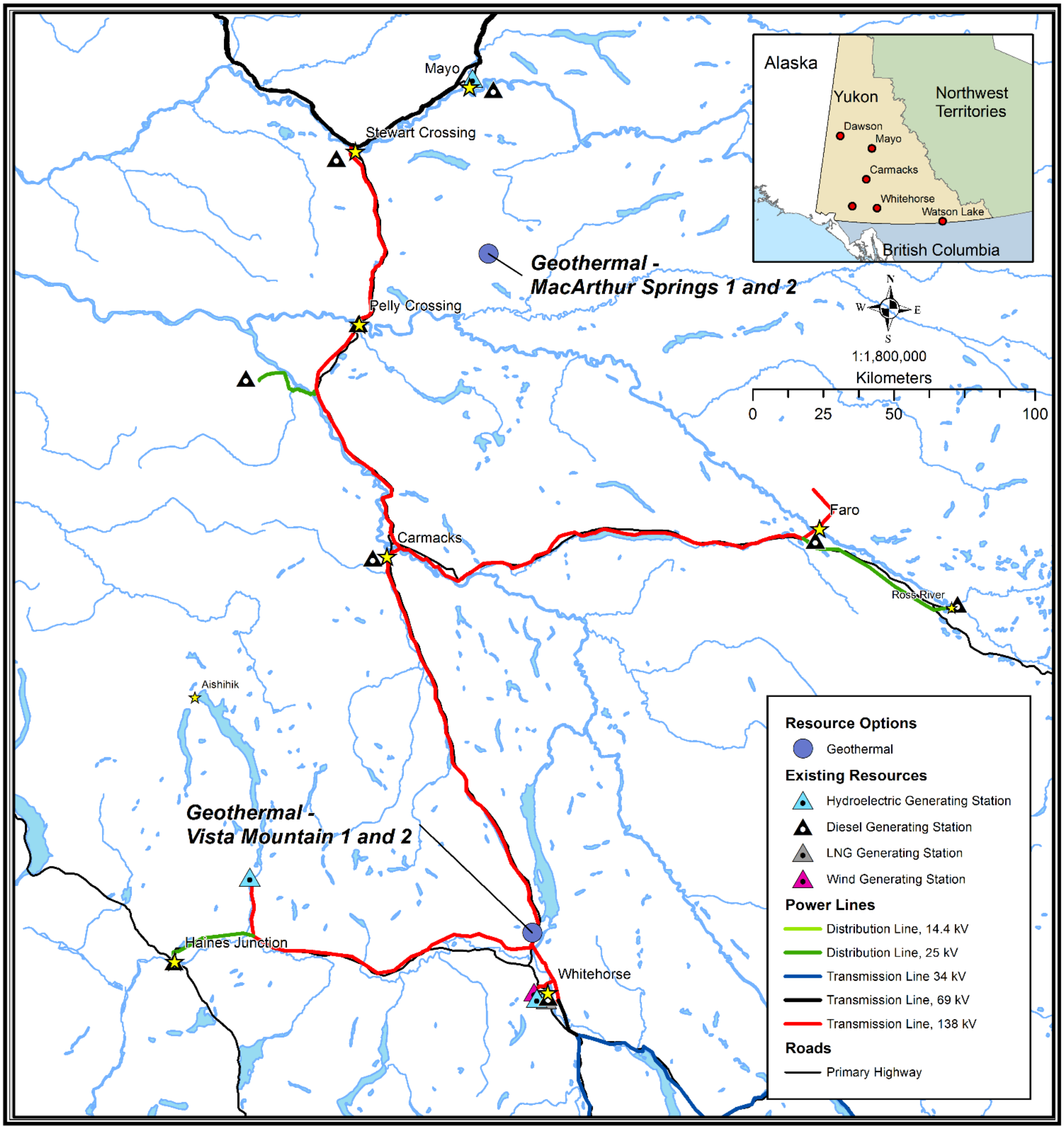
Table 5-49: Geothermal Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
McArthur Springs (3.8 MW Av.)					
🟨	🟨	🟥	🟨	🟨	🟥
Vista Mountain (1.6 MW Av.)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-50: Geothermal Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
McArthur Springs (3.8 MW Av.)							
🟨	🟨	🟨	🟩	🟩	🟩	🟩	🟨
Vista Mountain (1.6 MW Av.)							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

1 *Figure 5-16: Geothermal Resource Option Locations*



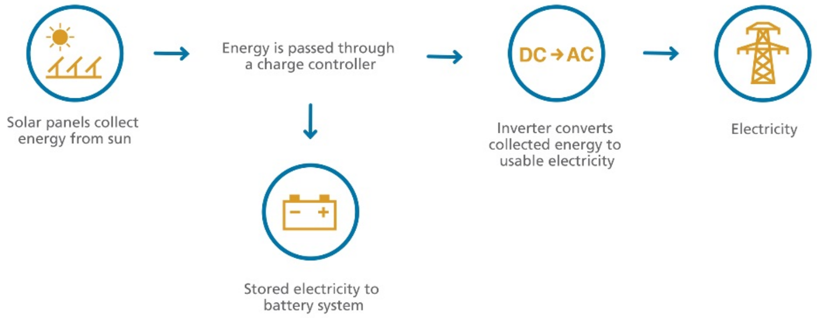
5.2.6 Solar

Technology description

Solar energy produced by photovoltaics (PV) converts sunlight to electricity using semiconductor panels. Solar PV generating sites consist of an array of solar panels mounted on a racking system and connected to inverters, as shown in Figure 5-17. A larger solar generating station may incorporate batteries to offset substantial fluctuations in generation.

Solar is an intermittent resource that is not dispatchable and does not provide dependable capacity. The majority of the energy is produced during the summer, which is opposite of the energy demand profile. Significant production occurs in April and May which is when hydro reservoirs are at the lowest levels after winter. This generation would be beneficial.

Figure 5-17: Solar



Studies

An inventory of potential solar sites was completed for the 2016 Resource Plan by Solvest, and can be found in Appendix 5.11. These sites were evaluated based on solar irradiance profiles, proximity to existing transmission infrastructure, proximity to communities, topography, land ownership and openness of land. The study also evaluated different solar panel, inverter and racking technologies.

Fuel description

The solar resource is quite consistent across the municipalities connected to the Yukon Power System, with the communities showing only a 6% annual variance relative to Whitehorse. The solar resource in Yukon is lower compared with other parts of Canada, but comparable to some countries that have implemented grid-scale solar such as Germany and Japan. A key finding is that solar irradiance in the Yukon is quite high in the late winter and spring months, when hydro generation is at its lowest.

Summary of studies to date and key findings

From an initial review of solar irradiance in the Yukon, four potential sites were identified: Haines Junction, Whitehorse Copper Mine site, Takhini and Canyon. After conducting site visits and a review of topography, it was found that the sites at Whitehorse Cooper Mine and Haines Junction the best sites overall.

The Whitehorse Cooper Mine site is located on the old tailings pile of the Whitehorse Cooper Mine. This site is 120 acres of flat, cleared land with established road access and is close to the ATCO Electric substation at Mount Sima. The location is within Whitehorse city limits, close to the main load, which minimizes transmission losses. It is also close to the main source of construction materials and labour in the Yukon. The Haines Junction site is 1 km from the town's landfill on 65 acres of flat, semi open land close to the highway, and 3.4 km from a substation.

The price of solar panels and their related systems have dropped significantly in the recent years. There are many emerging solar panel technologies being developed that address the deficiencies in current PV technology including low efficiency, high manufacturing costs and power density. The review of PV panels recommended the Heliene Poly and Prism Bi-Facial for both sites.

Solar panels can either be mounted on a fixed racking system, which means the panels will not move, or the panels can be mounted on a racking system that can pivot so that the panels can move to track the sun. These tracking systems can pivot in one direction (single axis) or multiple directions (multi axis). For the Haines Junction location, the use of single axis trackers over fixed racking was recommended as the additional solar energy gains out-weigh the additional costs to install and maintain the single axis tracking system.

The following Table 5-51 describes the technical and financial attributes and Table 5-52 to Table 5-58 describe the environmental, social and economic attributes for three solar resource options. The average monthly energy profile is shown in Figure 5-18. The location of the solar projects can be found in Figure 5-19.

Table 5-51. Solar Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Whitehorse Heliene Poly								
1.1	1.1	1	0	0.21	-	30	2	N
Whitehorse Prism Bi-Facial								
1.2	1.2	1	0	0.23	-	30	2	N
Whitehorse Heliene Poly								
5.6	5.6	5	0	0.16	-	30	2	N
Whitehorse Prism Bi-Facial								
5.6	5.6	5	0	0.17	-	30	2	N
Whitehorse Heliene Poly								
11.5	11.5	10	0	0.15	-	30	2	N

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Whitehorse Prism Bi-Facial								
11.5	11.5	10	0	0.16	-	30	2	N
Haines Junction Heliene Poly								
1.4	1.4	1	0	0.17	-	30	2	N
Haines Junction Prism Bi-Facial								
1.5	1.5	1	0	0.17	-	30	2	N
Haines Junction Heliene Poly								
5.8	5.8	5	0	0.17	-	30	2	N
Haines Junction Prism Bi-Facial								
5.6	5.6	5	0	0.17	-	30	2	N

Figure 5-18: Average Energy Profile for Solar Resource Option

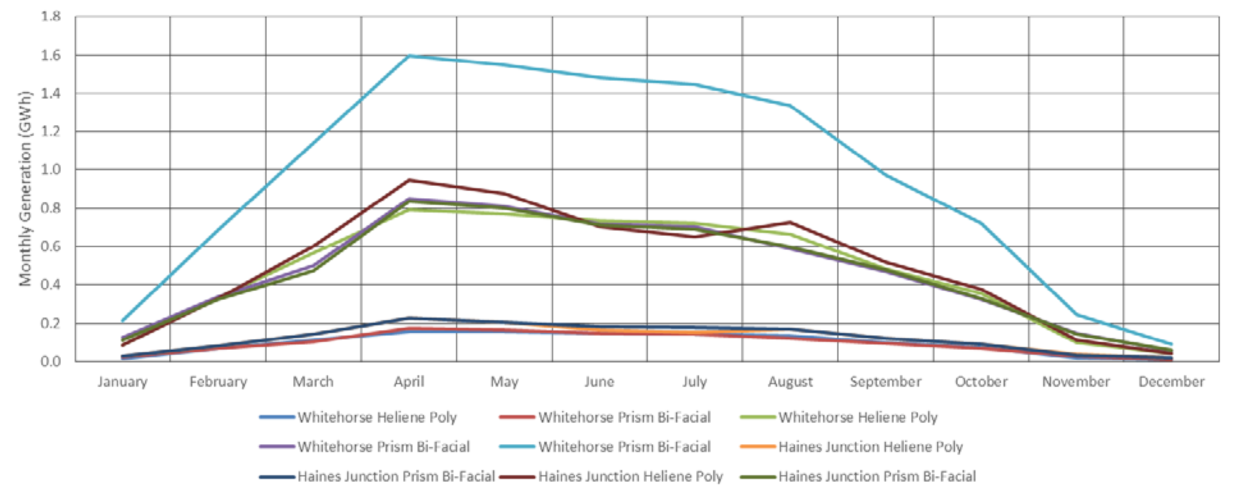


Table 5-52: Solar Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Whitehorse Fixed Tilt: 10 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Haines Junction Fixed Tilt: 5 MW					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-53: Solar Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Whitehorse Fixed Tilt: 10 MW							
🟩	🟩	🟩	🟩	🟨	🟩	🟩	🟩
Haines Junction Fixed Tilt: 5 MW							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-54: Solar Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Whitehorse Fixed Tilt: 10 MW		
🟩		🟩
Haines Junction Fixed Tilt: 5 MW		
🟩		🟩

Table 5-55: Solar Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Whitehorse Fixed Tilt: 10 MW					
🟩	🟨	🟩	🟩	🟩	🟩
Haines Junction Fixed Tilt: 5 MW					
🟩	🟨	🟩	🟩	🟩	🟩

Table 5-56: Solar Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Whitehorse Fixed Tilt: 10 MW				
🟩	🟩	🟩	🟩	🟥
Haines Junction Fixed Tilt: 5 MW				
🟩	🟩	🟩	🟩	🟥

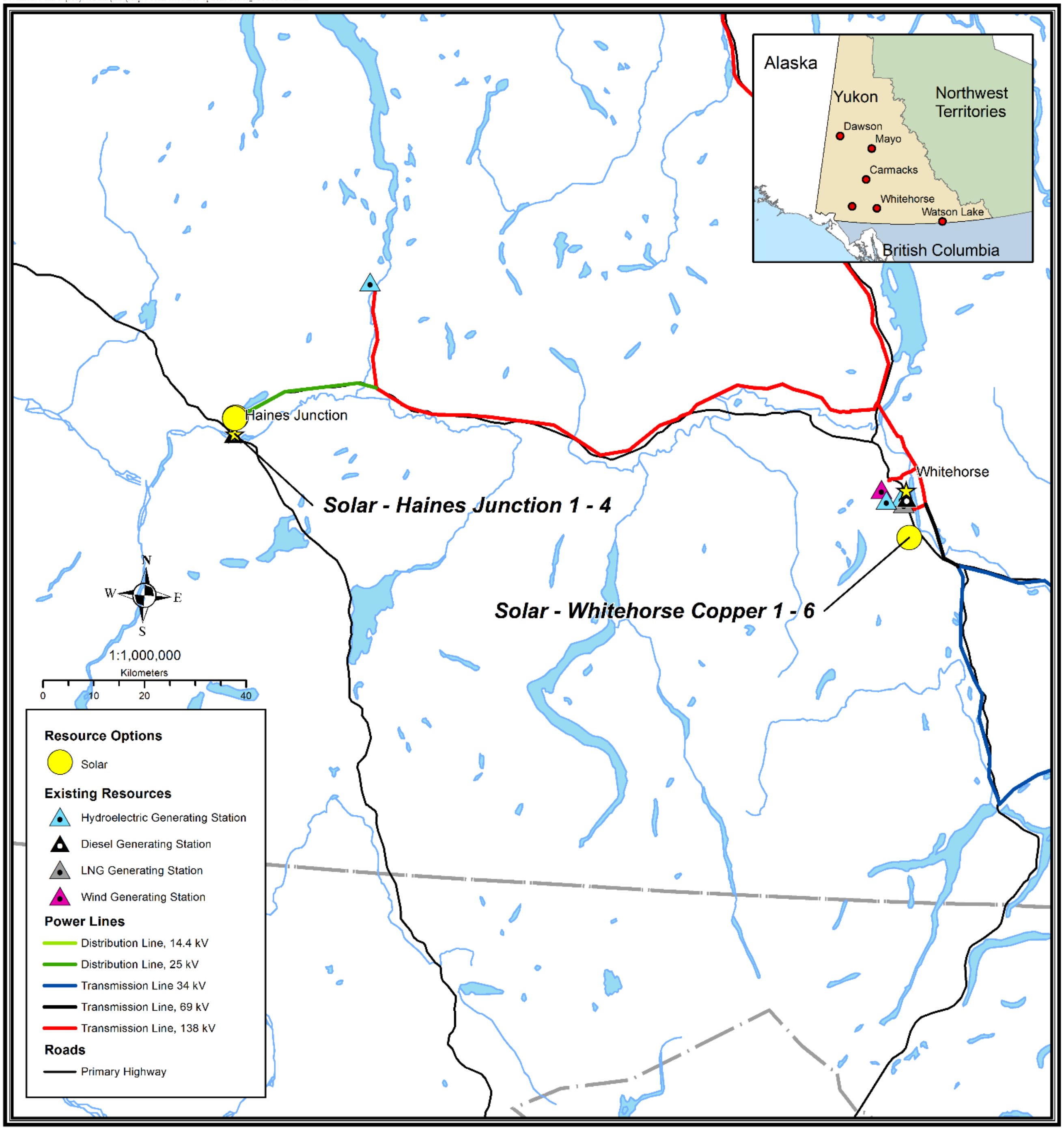
Table 5-57: Solar Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Whitehorse Fixed Tilt: 10 MW					
🟩	🟩	🟩	🟩	🟩	🟩
Haines Junction Fixed Tilt: 5 MW					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-58: Solar Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) **(Positive Effects)**			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Whitehorse Fixed Tilt: 10 MW							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩
Haines Junction Fixed Tilt: 5 MW							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

Figure 5-19: Solar Resource Option Locations



5.2.7 Renewable Thermal Resources

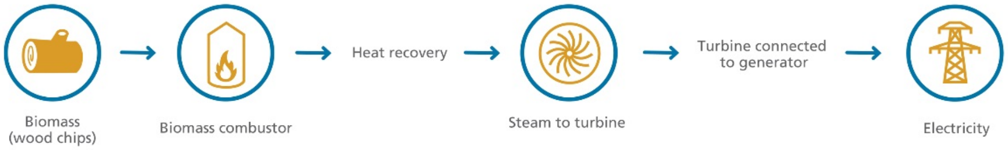
5.2.7.1 Biomass

Technology description

Wood-based biomass fuels are used in conventional, thermal oil (Organic Rankine Cycle or ORC) or gasification units to produce electricity, as shown in Figure 5-20. Conventional and ORC technologies combust biomass to heat a liquid (such as water) into a gas (steam), which is then used to drive a turbine and generator. Gasification systems convert the biomass into a synthetic gas or syngas, which is then combusted in a reciprocating engine to generate power. Conventional boilers, conventional ORC with thermal oil and gasification units were evaluated for this resource option.

Biomass provides dependable capacity and offers some dispatchability depending on fuel availability. Energy production could be matched to the energy demand on the grid.

Figure 5-20: Biomass



Studies

A Front End Engineering Design (FEED) study was completed in 2013 to assess the technical and financial feasibility of biomass electricity generation in Haines Junction. This study was updated for the 2016 Resource plan by Stantec, and presents a screening-level assessment of available technologies in the 0.5 MWe to 2.0 MWe range. This range was based on quotes from equipment vendors and information scaled from the previous FEED study. The updated study looked at three technology types in the categories of conventional biomass power generation/cogeneration and gasification. The study can be found in Appendix 5.12.

Fuel description

The study considered feedstock from sawmill residues and forest harvesting residues at the harvest block landing, including beetle killed wood. The use of beetle kill wood is beneficial because it has a lower moisture content of ~15%, whereas live trees usually have a moisture content in the range of 40-50%.

At the low end of the study range, the 0.5 MW unit would utilize feedstock with no impact to current biomass harvesting operations, and no need to supplement with green timber. There is insufficient sawmill and harvest residue material available to supply the 2.0 MWe unit, and these feedstocks would have to be supplemented by ~68% green timber. This in turn would require new harvesting operations and policies. For this reason, the 0.5 MWe option is considered for this resource plan.

Summary of studies to date and key findings

The 2016 updated report assessed and screened available technologies which would handle 3,000 tonnes per year of biomass wastes, which would be adequate feedstock for the chosen plant size.

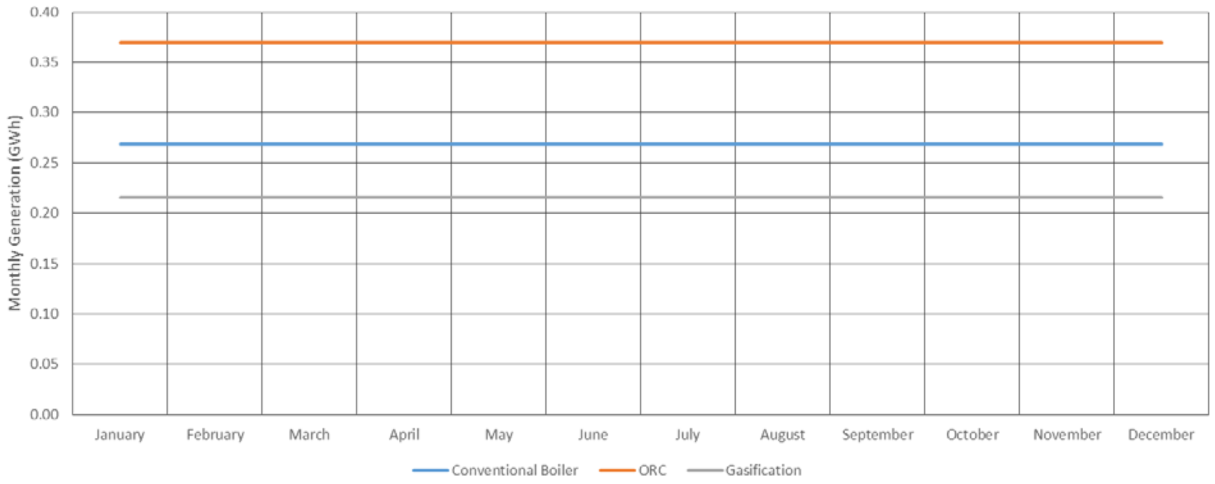
The following Table 5-59 describes the technical and economic attributes and Table 5-60 to Table 5-66 describe the environmental, social and economic attributes of the three biomass resource options. The average monthly energy profile is shown in Figure 5-21. The location of the biomass projects can be found in Figure 5-22.

Technical and financial information presented in the Stantec 2016 updated report (Appendix 5.12) were used in YEC's in-house financial model to obtain estimates of LCOE and LCOC. This approach was taken to standardize the calculation of both technical attributes, thus enabling a direct comparison between resource options.

Table 5-59: Biomass Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** year	**Lead Time** years	**Dispatch-able** Y/N
Conventional Boiler								
3.2	3.2	0.5	0.4	0.44	1,969	20	3	Y
Organic Rankin Cycle								
4.4	4.4	0.6	0.6	0.35	1,715	20	3	Y
Gasification								
2.6	2.6	0.5	0.4	0.43	2,240	20	3	Y

Figure 5-21: Average Energy Profile for Biomass Resource Option



Additional Considerations

Biomass energy generation is seldom economic without the sale of heat. For example, of the energy produced in a biomass gasification plant, only around 22% is converted to electricity. The LCOE shown above does not include heat sales in order to provide consistency with the other resource options in the 2016 Resource Plan.

The economics of Biomass generation system typically rely on sales of heat in addition to energy sales, but the Yukon Utilities Board (YUB) has ruled that YEC cannot sell heat. Potentially, if the project were to be proposed by an independent power producer and if there were a viable heat market, heat produced from biomass in a combined heat and power plant would have to be sold to a nearby customer at $0.185/kWh in order to make it economic. With heat sales included as a revenue, the LCOE for the biomass options would be reduced to:

- $0.359/kWh for Steam Turbine/Boiler;
- $0.298/kWh for ORC; and
- $0.338/kWh for Gasification.

Table 5-60: Biomass Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Biomass 0.5 MW Boiler / Steam Turbine					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-61: Biomass Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Biomass 0.5 MW Boiler / Steam Turbine							
🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩

Table 5-62: Biomass Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Biomass 0.5 MW Boiler / Steam Turbine		
🟥	🟩	🟨

Table 5-63: Biomass Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Biomass 0.5 MW Boiler / Steam Turbine					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-64: Biomass Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Biomass 0.5 MW Boiler / Steam Turbine				
🟩	🟩	🟩	🟩	🟨

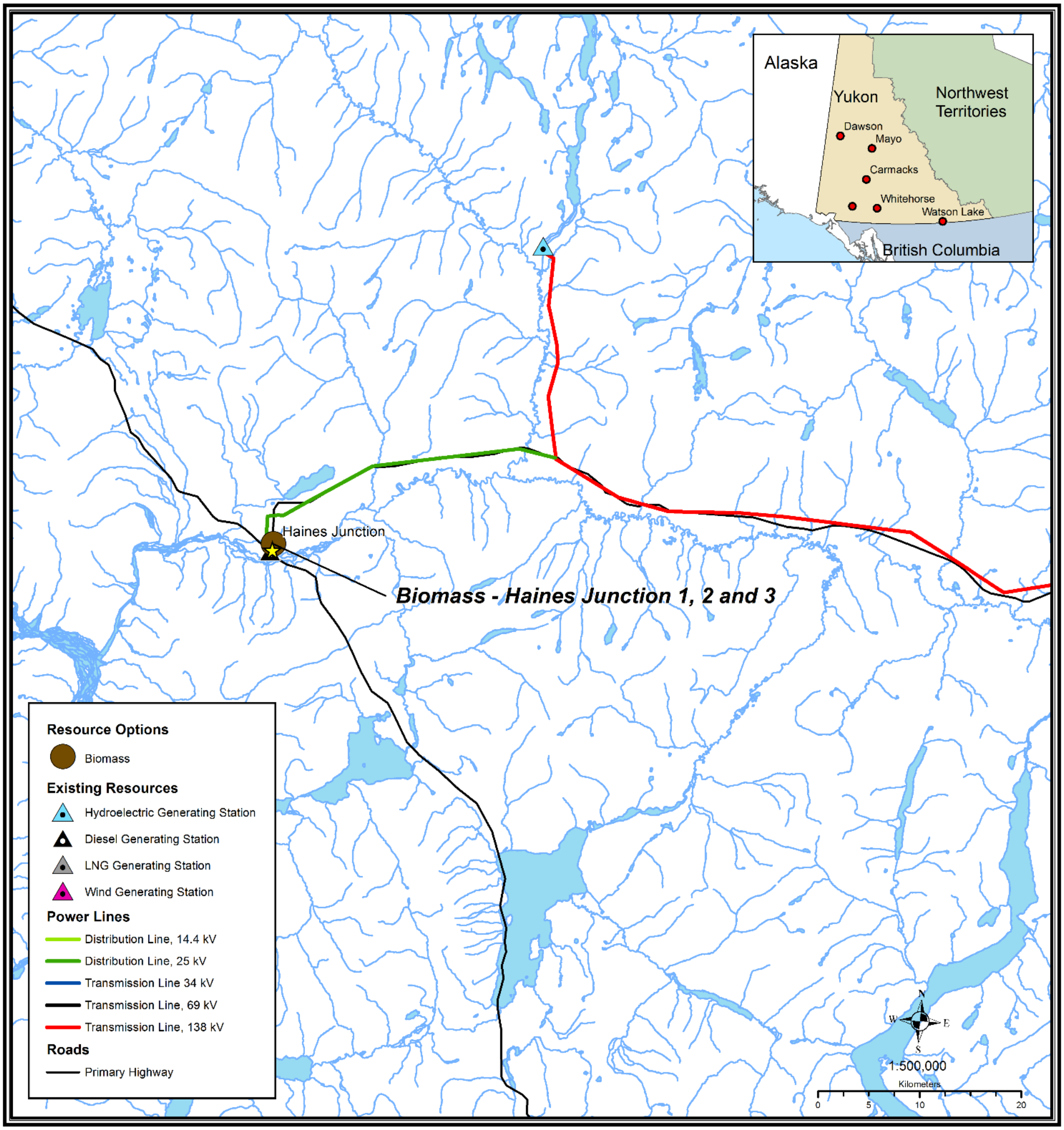
Table 5-65: Biomass Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Biomass 0.5 MW Boiler / Steam Turbine					
🟩	🟩	🟨	🟩	🟩	🟨

Table 5-66: Biomass Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Biomass 0.5 MW Boiler / Steam Turbine							
🟥	🟥	🟨	🟨	🟩	🟩	🟩	🟩

Figure 5-22: Biomass Resource Option Locations



5.2.7.2 Biogas

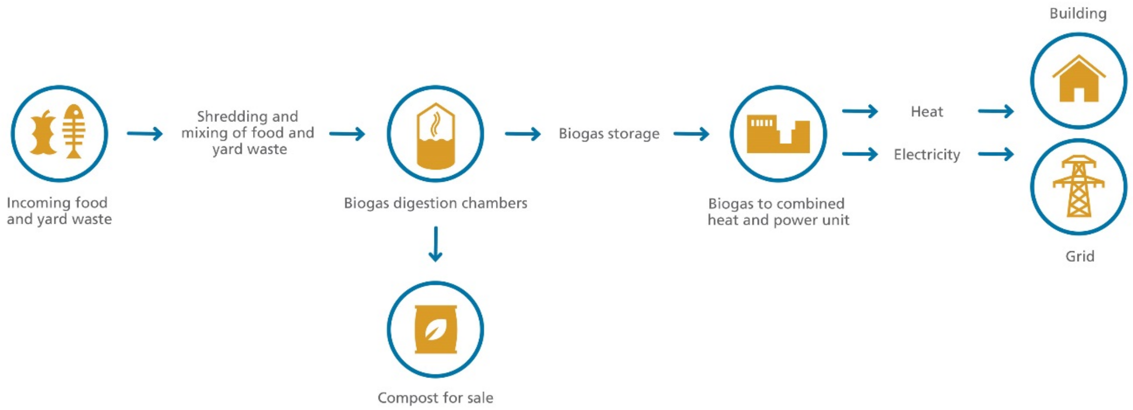
Technology description

Biogas is a methane rich gas derived from the anaerobic digestion of organic material, such as food and forestry industry wastes. The gas is combusted in a reciprocating engine to produce electricity, heat and digestate (compost) as shown in Figure 5-23. Biogas can be cleaned and upgraded to be used in place of, or to augment a natural gas supply. Biogas can be produced in either a wet system using biomass feedstocks containing ~5% solids, or dry system that uses feedstock with 25% solids. These systems can also be heated at different temperatures that encourage different bacteria to break down the organics.

For this study, dry digestion technology was chosen for the biogas system, which is heated to a temperature of about 35 degrees Celsius. This technology was chosen for its tolerance of contaminants, stability, low water requirements and lower input of electricity for heating the substrate. Heating the substrate to a thermophilic bacteria temperature range (55 degrees Celsius) requires much more input energy. The dry digestion technology also produces a high quality compost end product similar to what is currently produced at the Whitehorse compost facility. Therefore there is no loss of usable compost from this process.

Biogas projects could provide dependable capacity. Biogas offers some dispatchability if sufficient fuel is produced and adequate storage is available for handling the fuel. The current project requires the gas to be used when it is produced because of limited storage. Energy generation is higher in the summer than winter months which is the opposite of the energy demands on the grid.

Figure 5-23: Biogas



Studies

In 2015, YEC contracted WSP Canada to conduct a feasibility study for developing a Biogas facility in Whitehorse, at the compost facility at the Son of War Eagle Whitehorse landfill. The City of Whitehorse, Cold Climate Innovation and the Yukon Research Centre were partners on the project. This report can be found in Appendix 5.13. The study considered a 0.1 MW plant, which was sized for the current feedstock availability. A second 0.1 MW unit could be added in 2020 when organic diversion rates from the City of Whitehorse are expected to have increased.

Fuel Description

The study considered the volumes of feedstock available for the biogas facility. The assumed feedstock was based on material currently brought to the compost facility, as well as expected increases from the current green bin organics program run by the City of Whitehorse (Biogas Plant in Whitehorse, WSP 2016). The feedstock includes residential source sorted organics (SSO), industrial SSO, dead garden waste and fresh garden waste. In other biogas plants, sewage sludge from waste water treatment plants is often used in a wet digestion systems to produce biogas. Sewage sludge feedstock was not assessed as part of the study, as the location of the Whitehorse sewage lagoons is far from the compost facility, increasing transportation costs, and given potential concerns regarding the presence of biosolids in the compost end product.

Summary of studies to date and key findings

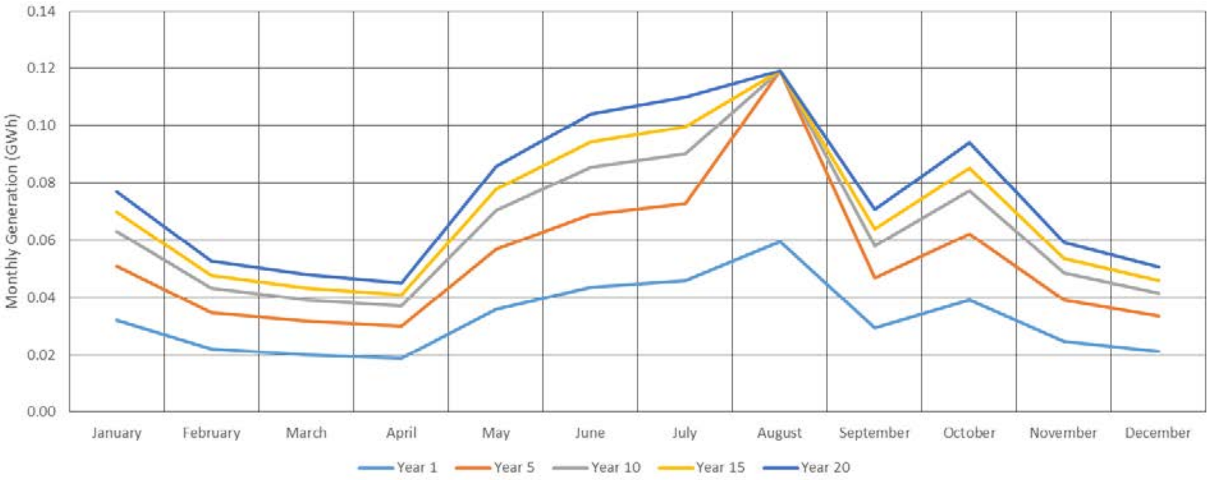
The 2016 report assessed and screened available biogas technologies which would adequately handle 3,000 tonnes per year of organic waste. In order to optimize feedstock availability a 0.1 MW unit would be installed at project start, and another 0.1 MW unit would be installed in 2020 when expected increased diversion would occur according to City of Whitehorse programs and targets.

The following Table 5-67 describes the technical and financial attributes and Table 5-68 to Table 5-74 describe the environmental, social and economic attributes of the biogas resource option. The average monthly energy profile is shown in Figure 5-24. The location of the biogas project can be found in Figure 5-25.

Table 5-67: Biogas Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** year	**Lead Time** years	**Dispatch-able** Y/N
Biogas								
0.44 - 1.03	0.44 – 1.03	0.1 – 0.2	0.1 – 0.2	$0.97	$2,844	20	2	N

Figure 5-24: Average Energy Profile for Biogas Resource Option



Additional considerations

Biogas generation is seldom economic without the sale of heat. Of the energy produced in a biogas plant, only around 35% is converted to electricity. The LCOE shown above does not include heat sales or gate fees in order to provide consistency with the other resource options in the 2016 Resource Plan.

The economics of biogas generation system typically rely on sales of heat in addition to energy sales, but the Yukon Utilities Board (YUB) has ruled that YEC cannot sell heat. Potentially, if the project were to be proposed by an independent power producer and if there were a viable heat market, heat produced from biogas in a combined heat and power plant would have to be sold to a nearby customer in order to make it economic. The Biogas option could produce 750 MWh/year of heat. If the heat were sold heat at $12/GJ ($0.043/kWh) and gate fee revenues were taken into account, a lower LCOE of $0.65/kWh would be achieved.

Table 5-68: Biogas Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Biogas (CHP)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-69: Biogas Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Biogas (CHP)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-70: Biogas Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Biogas (CHP)		
🟥	🟨	🟨

Table 5-71: Biogas Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Biogas (CHP)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-72: Biogas Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Biogas (CHP)				
🟩	🟩	🟩	🟩	🟨

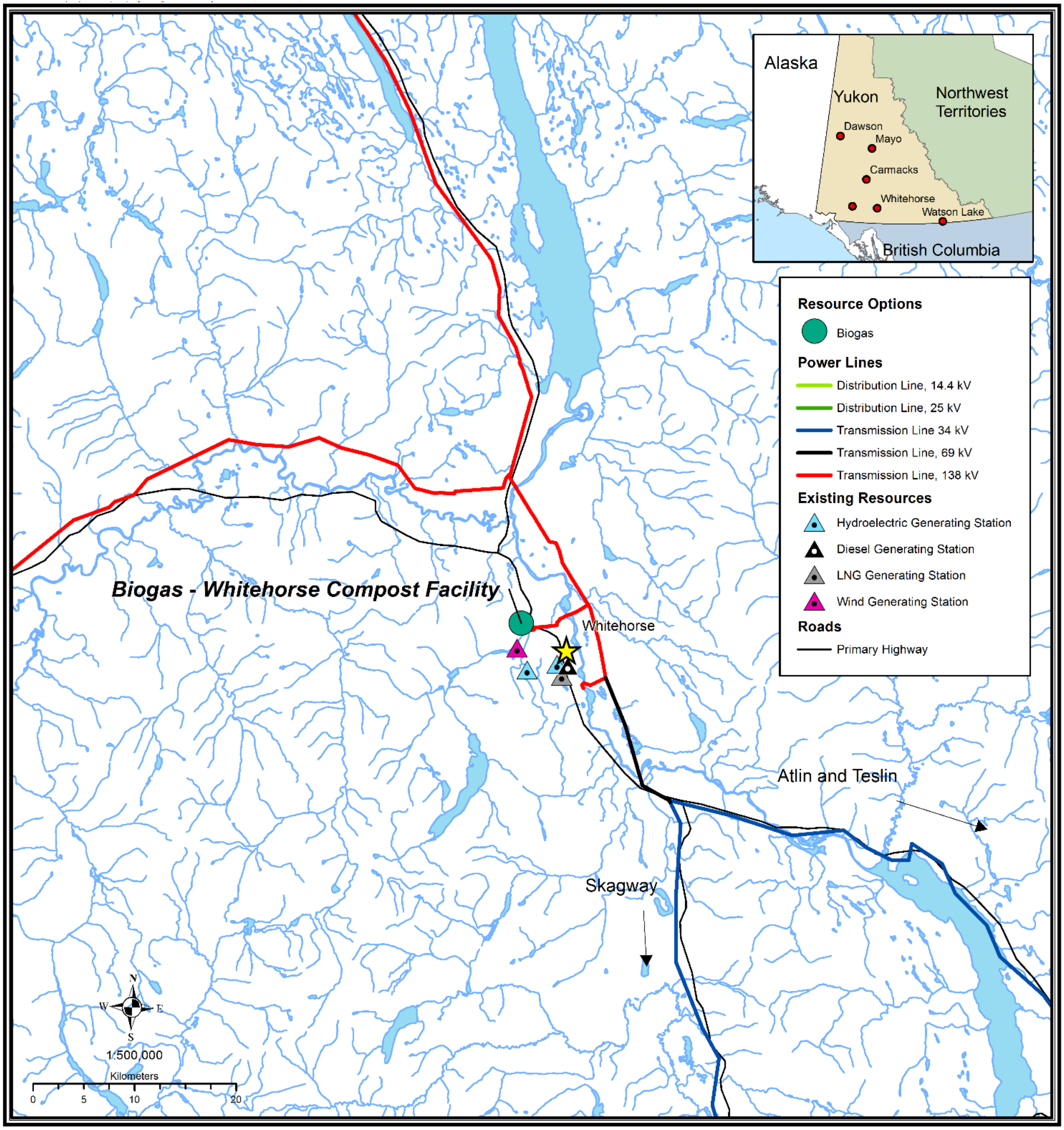
Table 5-73: Biogas Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Biogas (CHP)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-74: Biogas Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Biogas (CHP)							
🟥	🟥	🟨	🟩	🟩	🟩	🟩	🟩

Figure 5-25: Biogas Resource Option Location



5.2.7.3 Waste to Energy

Technology description

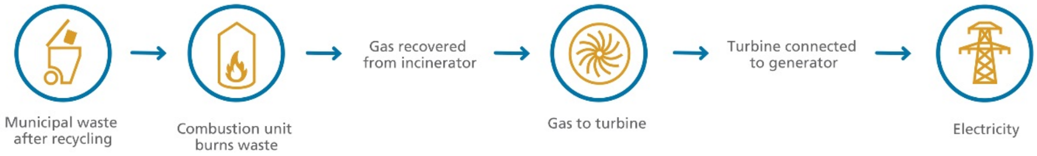
Waste to Energy (WTE) is a process that combusts Municipal Solid Waste (MSW) to produce electricity and heat. WTE technologies are generally categorized under “conventional combustion” or “advanced thermal” technologies.

Conventional combustion technologies include controlled air or small scale mass burn, which combust MSW with excess air to generate a hot flue gas as shown in Figure 5-26. The flue gas runs a conventional boiler to convert water to steam, which is then led through a steam turbine to produce electricity.

Advanced combustion, which includes gasification, pyrolysis and plasma arc gasification, combusts MSW in a reduced oxygen environment at high temperatures which creates a synthetic gas or syngas. Syngas can be combusted in a reciprocating engine which drives a generator to produce electricity. This technology is less developed and less prevalent than the conventional technologies.

Waste-to Energy projects provide dispatchable energy contingent on fuel availability and dependable capacity. Energy production could be matched to the energy demand on the grid.

Figure 5-26: Waste-to-Energy



Studies

In 2012, YEC contracted Morrison Hershfield to complete a design basis and business case analysis for of a WTE facility located in the Marwell Industrial area of Whitehorse. In 2015, Morrison Hershfield provided a letter stating that the findings of the 2012 study could be used as input information for the 2016 Resource Plan. The 2012 report can be found in Appendix 5.14.

The report looked at a 1.6 MW plant which was sized for the current feedstock availability and projected recycling targets. Both conventional combustion and advanced thermal technology were studied for this facility.

Fuel Description

The study considered the volumes of MSW feedstock available for the WTE facility, after the diversion of recycling and food waste. At the time of the report, a 16% recycling rate was being achieved, however the City of Whitehorse had plans to increase recycling rates to 50% by 2015. A financial sensitivity analysis was completed to assess the impact of increased recycling to 50% of total waste volumes by 2015. A 1.6 MW plant was selected, which would utilize 17,300 tonnes per year of MSW assuming that the 50% recycling diversion target is achieved. This quantity of MSW feedstock is insufficient to support full utilization of the 1.6MW plant, and 7,700 tonnes of wood biomass would be initially required to supplement the MSW feedstock for optimal utilization of WTE plant. The use of wood biomass would decrease over time as MSW production is expected to increase with continued population growth in the Whitehorse area. The study assumed a projected 4% increase of MSW per year based of historic trends. Since the Waste to Energy report was completed in 2012, the latest recycling data has been updated from the City of Whitehorse. The data shows actual recycling diversion in 2015 to be 35%, but the City is still working towards the goal of 50%.

Summary of studies to date and key findings

The 2012 report assessed and screened available WTE technologies which would adequately handle 25,000 tonnes per year of MSW and biomass. Two conventional combustion technologies, namely controlled air conventional combustion and small scale mass burn, were selected in the screening study as the only available technologies which met the following criteria:

- Applicability to the MSW feedstock;
- Commercial viability;
- Appropriateness of scale;
- Compatibility to Yukon Feedstocks; and
- Supplemental input requirements.

Air pollution control equipment to treat the emissions from the WTE plan was included in the scope of the plant design. The air emissions analysis found that if energy generated by the WTE facility displaced diesel-generated electricity and furnace oil combustion in space heating, then a net reduction in particulate matter, carbon monoxide and nitrogen oxide emissions would be achieved.

As outlined above, the capacity of 1.6 MW for the facility was chosen based on available feedstock, forecast growth rates and potential recycling rates.

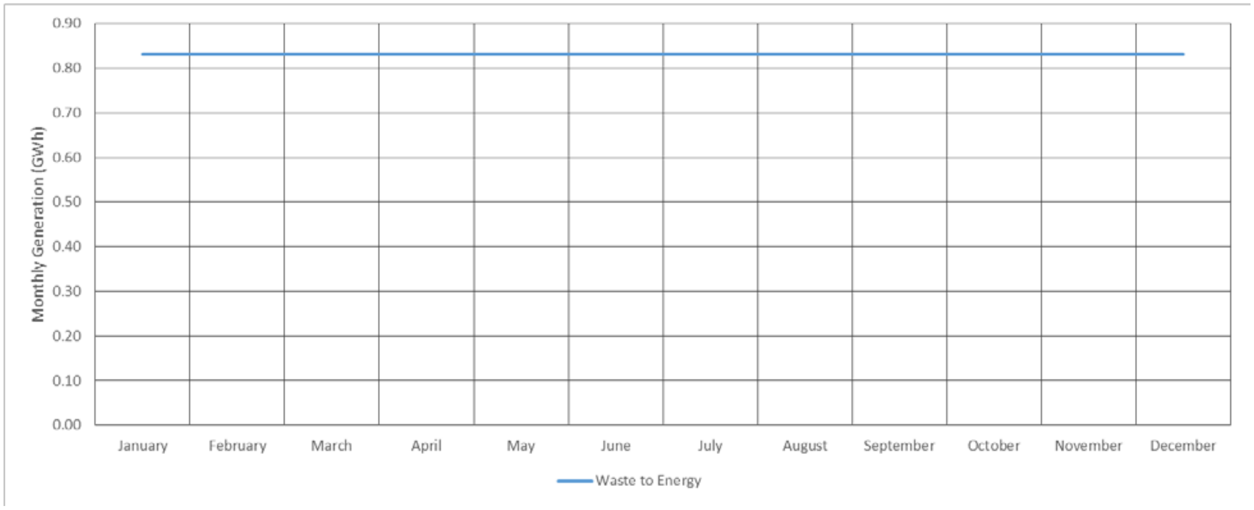
The following Table 5-75 describes the technical and financial attributes and Table 5-76 to Table 5-82 describe the environmental, social and economic attributes of the WTE resource option. The average monthly energy profile is shown in Figure 5-27. The location of the WTE project can be found in Figure 5-28 below.

Technical and financial information presented in the Morrison Hershfield study (Appendix 5.14) were used in YEC’s in-house financial model to obtain estimates of LCOE and LCOC. This approach was taken to standardize the calculation of both technical attributes, thus enabling a direct comparison between resource options.

Table 5-75: Waste-to-Energy Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** year	**Lead Time** years	**Dispatch-able** Y/N
Waste to Energy (1.6 MW)								
10.0	10.0	1.6	1.6	0.45	1,301.68	25	2	Y

Figure 5-27: Average Energy Profile for Waste-to-Energy Resource Option



Additional considerations

WTE generation is seldom economic without the sale of heat (hot water or steam). Of the energy produced in a WTE plant, typically only around 10% is converted to electricity. The LCOE shown above does not include heat sales, since no firm thermal load was identified at the time this report was completed.

The economics of WTE generation typically rely on sales of heat in addition to energy sales, but the Yukon Utilities Board (YUB) has ruled that YEC cannot sell heat. Potentially, if the project were to be proposed by an independent power producer and if there were a viable heat market, heat produced from WTE generation in a combined heat and power plant would have to be sold to a nearby customer in order to make it economic. The WTE option could produce 23,700 MWh/year of heat. If a customer were sold heat at $0.81/kWh into a district energy system, then an LCOE reduction from $0.45/kWh to $0.31/kWh would be achieved.

Table 5-76: Waste-to-Energy Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Waste to Energy					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-77: Waste-to-Energy Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Waste to Energy							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-78: Waste-to-Energy Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Waste to Energy		
🟥	🟨	🟨

Table 5-79: Waste-to-Energy Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Waste to Energy					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-80: Waste-to-Energy Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Waste to Energy				
🟩	🟩	🟩	🟩	🟨

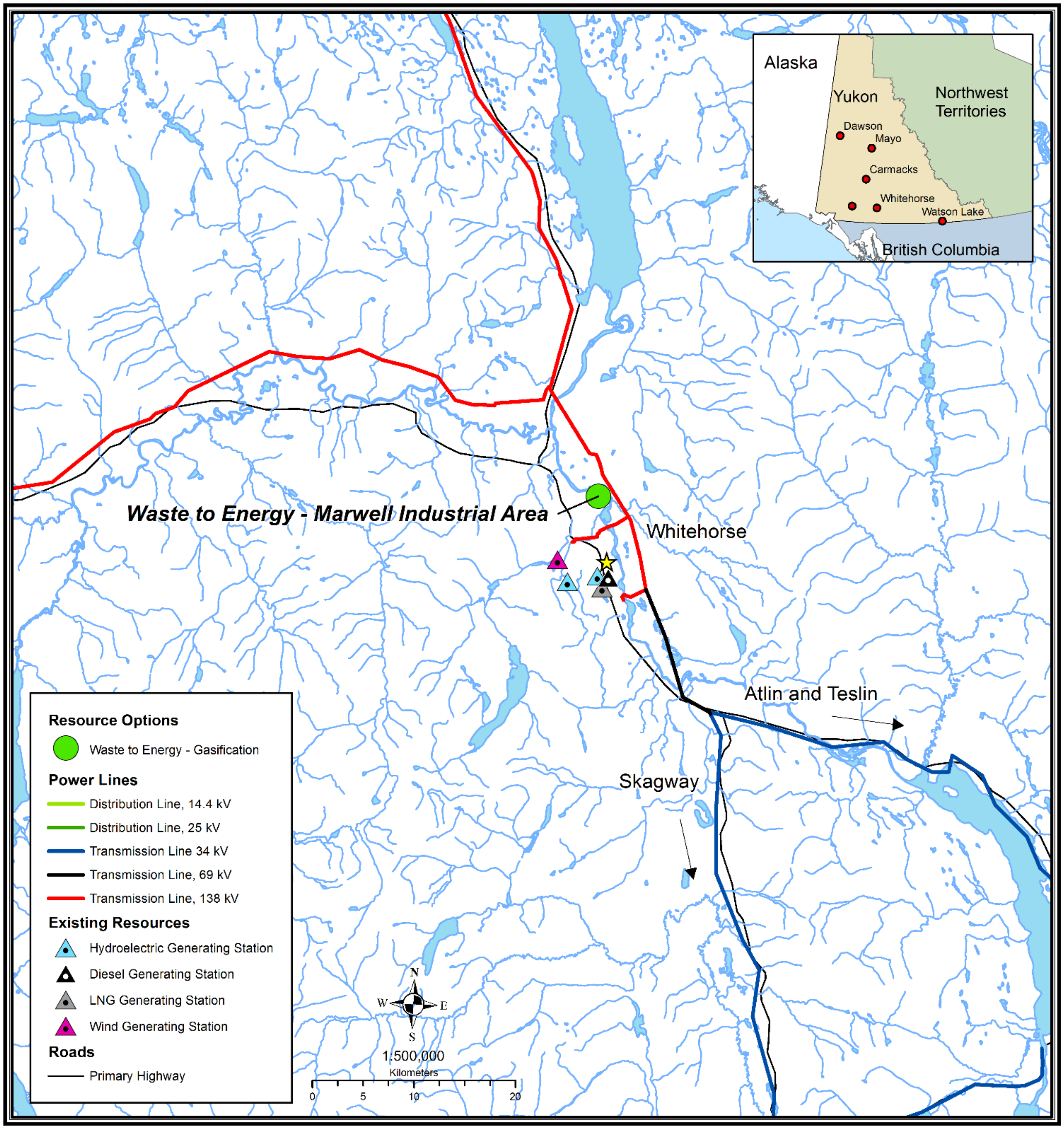
Table 5-81: Waste-to-Energy Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Waste to Energy					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-82: Waste-to-Energy Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Waste to Energy							
🟥	🟩	🟨	🟩	🟩	🟩	🟩	🟩

1 *Figure 5-28: Waste to Energy Resource Option Location*



5.2.8 Non-renewable Thermal Resources

Technology description

Thermal electricity generation refers to the combustion of fossil fuels such as natural gas or diesel in either a reciprocating engine or gas turbine connected to a generator as shown in Figure 5-29. For the 2016 Resource Plan, YEC limited the assessment of the resource options to reciprocating engines.

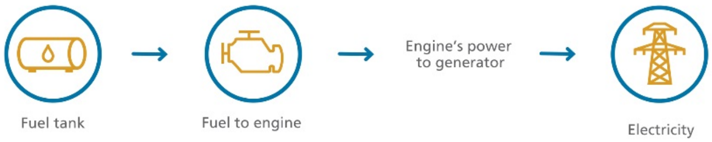
Reciprocating engines are a mature technology with several centuries of history and refinement. They are used throughout the world in a variety of applications including motorcycles, cars, ships, trucks and trains as well as power generation. Reciprocating engines can be designed use a wide variety of fuels, including conventional sources such as diesel, gasoline and natural gas, but also the liquid and gas by-products from municipal solid waste and biomass.

In Yukon, engines and generator are generally located within a building. Alternatively, the engine-generator can also be enclosed in weatherproof housing that can be moved to a different location should it be needed. This can prevent the need for a large, costly building. In addition to the engines and generators, a thermal plant would also include fuel storage, processing equipment such as vaporizers, electrical equipment such as switchgear and transformer, and ancillary systems such as fire suppression equipment, spill containment, heat recovery equipment, etc.

Diesel and natural-gas based generation technologies are the most commonly used in the world. The equipment is standardized and easy to specify and procure. It is also relatively compact, and easy to install, move or sell, if generation requirements change.

Thermal generation provide dependable capacity that can be turned on or off by the utility whenever required. Because if this dispatchability, YEC relies on thermal generation to restore power after an outage, as back-up power if one of the other plants or transmission lines goes offline, and to provide power during peak events such as cold winter evenings. Energy production could be matched to the energy demand on the grid.

Figure 5-29: Fossil Thermal



Studies

A conceptual planning and design study on a natural gas and diesel thermal generating station in the Whitehorse area was completed by Stantec for the 2016 Resource Plan. This study first considered potential sites for the plant. For the two best sites, conceptual layouts for both diesel and natural gas plants at 5, 10 and 20 MW, and a high level cost estimate was produced. This study can be found in Appendix 5.15.

In addition to the green field thermal generation presented in the study by Stantec, YEC considered the installation of a third engine at the existing LNG facility as a separate resource option. Technical and financial attributes for this project were provided by YEC. In the Part III application for the Whitehorse Diesel - Natural Gas Conversion Project (2013), YEC estimated the cost of the third engine at $4.4 million. This number was later reviewed and updated at $5.8 million. Fixed operation and maintenance costs were estimated at $120,000 per year based on actual costs incurred at the existing natural gas plant. For the environmental, social, and economic attributes, YEC used the attributes for the greenfield LNG Whitehorse facility as a conservative approximation for the third LNG engine.

Fuel description

The reciprocating engines considered for the 2016 Resource Plan are fueled by natural gas or diesel. The diesel is purchased in Whitehorse. The natural gas is transported and stored as liquefied natural gas (LNG). YEC currently sources LNG from FortisBC's Tilbury Island plant near Delta British Columbia and from Ferus's Elmworth Alberta plant. In the medium term, YEC also expects that LNG supply points will develop closer to the Yukon in northern British Columbia. Further details on an optimized LNG supply chain and forecasted fuel costs for natural gas and diesel can be found in Section 6.1. Fuel Price Forecast.

Summary of studies to date and key findings

The study identified four sites for consideration, two within the City of Whitehorse and two just north of the city boundary. Two sites were selected for further investigation; one at the City of Whitehorse landfill and one next to the Takhini Substation on the Mayo Road. The zoning at both sites allows for public utilities infrastructure. Furthermore, both sites are directly accessible from a highway and are close to existing transmission infrastructure. The landfill site is a previously developed brownfield, while the Takhini Substation is on undisturbed land.

In addition to the green field thermal resources, YEC considered the installation of a third engine in the existing LNG facility as a resource option. In 2015 YEC constructed and commissioned a natural gas fired facility with 8.8 MW of installed capacity. The generation capability of the facility is provided by two internal combustion engines, each with installed capacity of 4.4 MW. The facility was designed, permitted and constructed for an ultimate capacity of 13.2 MW, allowing for the addition of the third engine with capacity of 4.4 MW. This retrofit would avoid the significant infrastructure associated with a new LNG facility, such as utilities, piping, control systems, foundations and the building structure.

The following Table 5-83 and Table 5-84 describe the technical and financial attributes and Table 5-85 to Table 5-98 describe the environmental, social and economic attributes for natural gas and diesel generation respectively. The average monthly energy profiles are shown in Figure 5-30 and Figure 5-31. The location of the natural gas and diesel projects can be found in Figure 5-32.

Table 5-83: Fossil Thermal (LNG) Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Takhini LNG 1								
41.6	41.6	5	5	$0.26	$812	20	4	Y
Takhini LNG 2								
83.2	83.2	10	10	$0.23	$560	20	4	Y
Takhini LNG 3								
166.4	166.4	20	20	$0.21	$409	20	4	Y
Whitehorse Landfill LNG 1								
41.6	41.6	5	5	$0.26	$814	20	4	Y
Whitehorse Landfill LNG 2								
83.2	83.2	10	10	$0.23	$561	20	4	Y
Whitehorse Landfill LNG 2								
166.4	166.4	20	20	$0.21	$409	20	4	Y
Whitehorse Rapids LNG Third Engine								
36.6	36.6	4.4	4.4	$0.18	$120	20	2	Y

Figure 5-30: Average Energy Profile for Fossil Thermal-(LNG) Resource Option

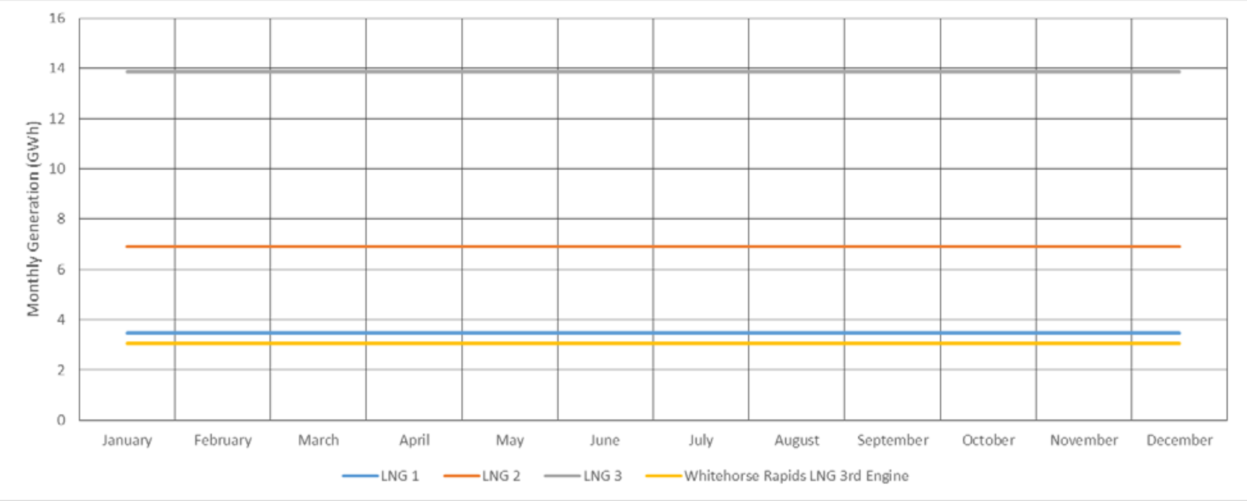


Table 5-84. Fossil Thermal (Diesel) Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Takhini Diesel 1								
41.6	41.6	5	5	0.31	442	20	4	Y
Takhini Diesel 2								
83.2	83.2	10	10	0.29	292	20	4	Y
Takhini Diesel 3								
166.4	166.4	20	20	0.27	217	20	4	Y
Whitehorse Landfill Diesel 1								
41.6	41.6	5	5	0.32	447	20	4	Y
Whitehorse Landfill Diesel 2								
83.2	83.2	10	10	0.29	294	20	4	Y
Whitehorse Landfill Diesel 3								
166.4	166.4	20	20	0.27	218	20	4	Y

Figure 5-31: Average Energy Profile for Fossil Thermal-(Diesel) Resource Option

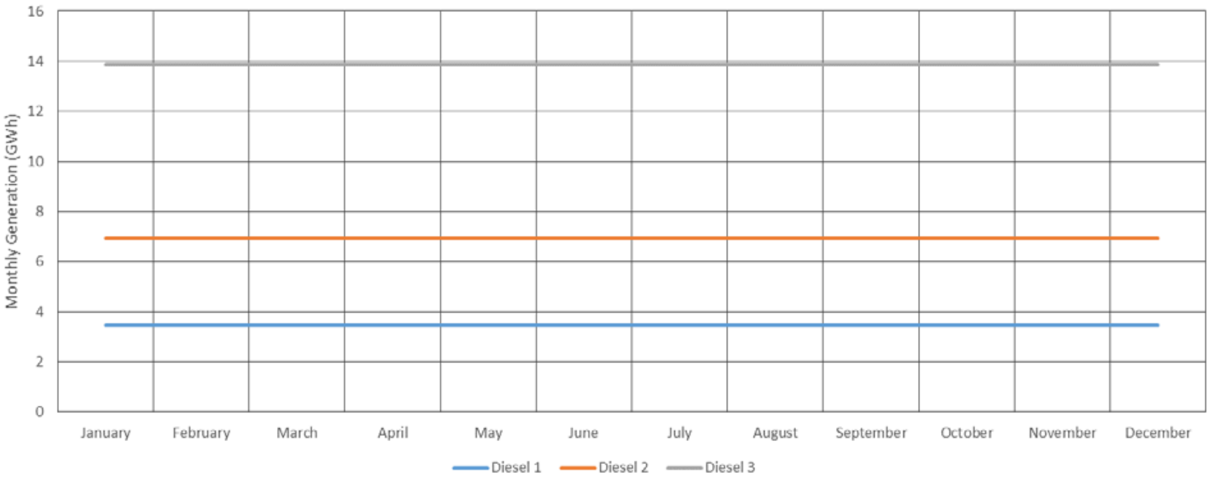


Table 5-85: Fossil Thermal (LNG) Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
LNG Whitehorse (20MW)					
🟩	🟩	🟩	🟩	🟩	🟩
LNG Takhini (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse Rapids LNG Third Engine					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-86: Fossil Thermal (LNG) Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
LNG Whitehorse (20MW)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
LNG Takhini (20 MW)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse Rapids LNG Third Engine							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-87: Fossil Thermal (LNG) Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
LNG Whitehorse (20MW)		
🟥	🟥	🟨
LNG Takhini (20 MW)		
🟥	🟥	🟨
Whitehorse Rapids LNG Third Engine		
🟥	🟥	🟨

Table 5-88: Fossil Thermal (LNG) Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
LNG Whitehorse (20MW)					
🟩	🟩	🟩	🟩	🟩	🟩
LNG Takhini (20 MW)					
🟨	🟩	🟩	🟩	🟩	🟩
Whitehorse Rapids LNG Third Engine					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-89: Fossil Thermal (LNG) Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
LNG Whitehorse (20MW)				
🟩	🟩	🟩	🟩	🟨
LNG Takhini (20 MW)				
🟩	🟩	🟩	🟩	🟨
Whitehorse Rapids LNG Third Engine				
🟩	🟩	🟩	🟩	🟨

Table 5-90: Fossil Thermal (LNG) Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
LNG Whitehorse (20MW)					
🟩	🟩	🟩	🟩	🟩	🟩
LNG Takhini (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse Rapids LNG Third Engine					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-91: Fossil Thermal (LNG) Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			Climate Change Risk affecting Resource Financial Attributes (Ec2)				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
LNG Whitehorse (20MW)							
🟥	🟥	🟨	🟩	🟩	🟩	🟩	🟩
LNG Takhini (20 MW)							
🟥	🟥	🟨	🟩	🟩	🟩	🟩	🟩
Whitehorse Rapids LNG Third Engine							
🟥	🟥	🟨	🟩	🟩	🟩	🟩	🟩

Table 5-92: Fossil Thermal (Diesel) Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Diesel Whitehorse (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩
Diesel Takhini (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-93: Fossil Thermal (Diesel) Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Diesel Whitehorse (20 MW)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Diesel Takhini (20 MW)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-94: Fossil Thermal (Diesel) Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Diesel Whitehorse (20 MW)		
🟥	🟥	🟨
Diesel Takhini (20 MW)		
🟥	🟥	🟨

Table 5-95: Fossil Thermal (Diesel) Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Diesel Whitehorse (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩
Diesel Takhini (20 MW)					
🟨	🟩	🟩	🟩	🟩	🟩

Table 5-96: Fossil Thermal (Diesel) Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Diesel Whitehorse (20 MW)				
🟩	🟨	🟨	🟨	🟨
Diesel Takhini (20 MW)				
🟩	🟩	🟩	🟩	🟥

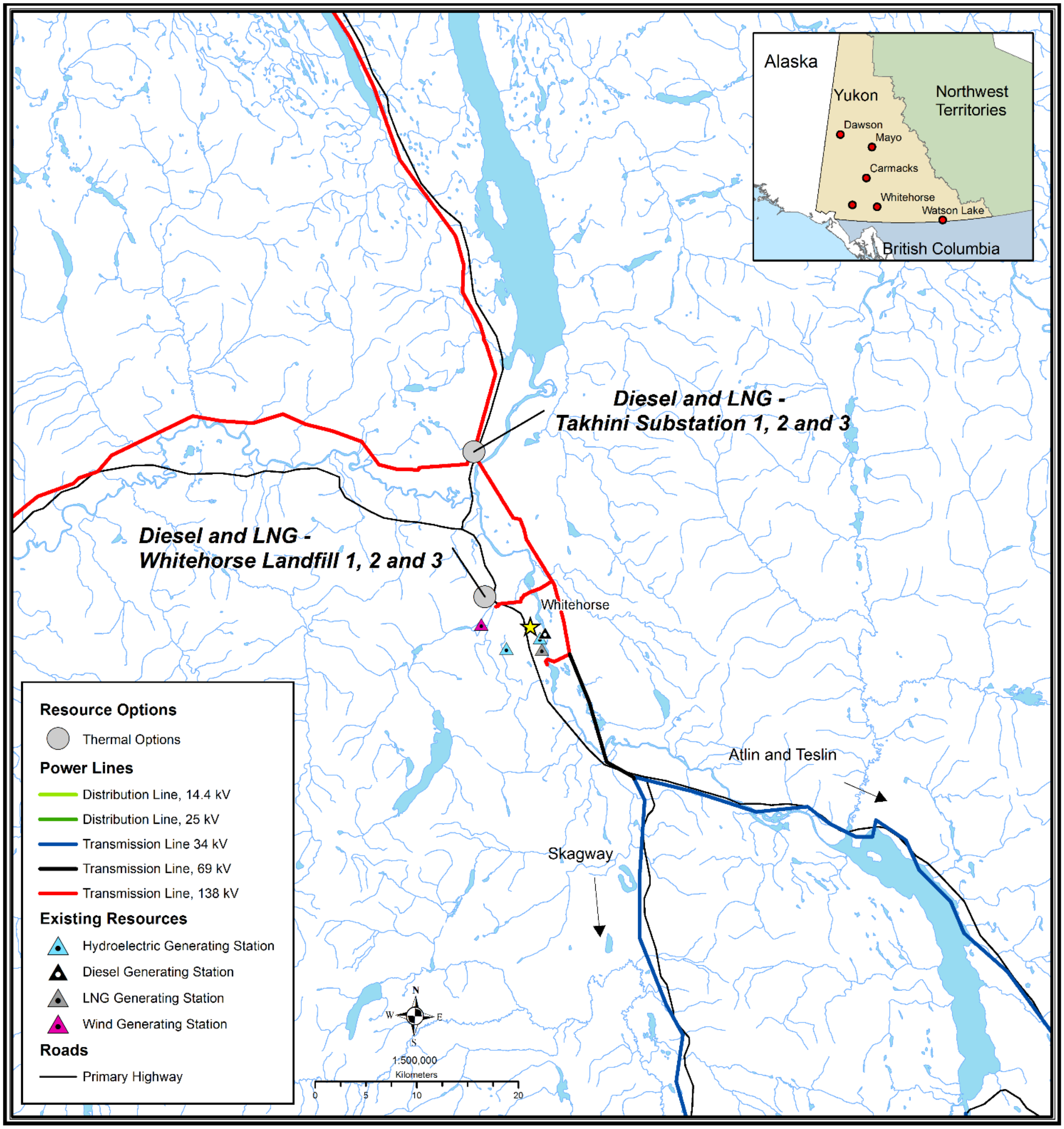
Table 5-97: Fossil Thermal (Diesel) Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Diesel Whitehorse (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩
Diesel Takhini (20 MW)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-98: Fossil Thermal (Diesel) Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Diesel Whitehorse (20 MW)							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩
Diesel Takhini (20 MW)							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

Figure 5-32 Fossil Thermal Resource Option Locations



5.2.9 Pumped Storage

Technology description

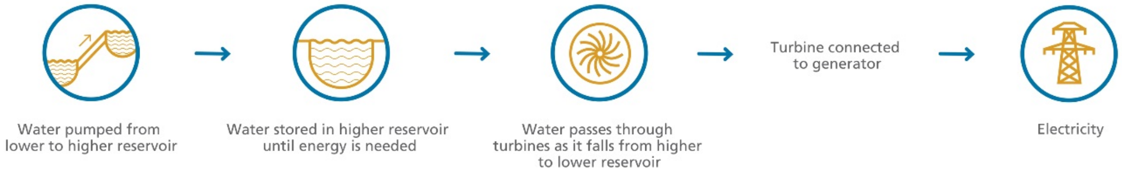
Pumped storage is a form of energy storage that uses energy to pump water from a lower reservoir into a higher reservoir as shown in Figure 5-33. When required, this water is then released back into the lower reservoir through hydro turbines that generate electricity. This allows the operator to shift excess electricity generation to a period when there is an energy shortage. Reversible pump-turbines coupled with a generator is the most common technology used, however some facilities have separated pumps and turbines. Overall round trip efficiency is around 70% to 80%. Meaning there are 20-30% energy losses in pumping the water uphill before running down through the turbines to generate electricity.

Typical pumped storage facilities provide energy storage for durations on the order of hours or days. The study completed for the 2016 Resource Plan focused on seasonal storage to move excess summer energy (spilled hydro resources at YEC's existing hydro facilities) to meet winter loads.

Pumped storage has traditionally been used to shift electricity generation to peak demand hours. More recently the technology is being used to maintain grid stability and to manage the integration of intermittent renewables resources such as wind and solar by firming their energy.

Pumped storage projects provide dispatchable energy and dependable capacity. These projects are designed and operated to provide more energy and capacity in the winter when energy requirements and demand are highest on the grid.

Figure 5-33: Pumped Storage



Studies

An assessment of pumped storage potential was completed by Knight Piesold for the 2016 Resource Plan. The assessment identified viable sites for a pumped storage project within 25 km of existing or potential transmission infrastructure. Seven sites were chosen for further analysis based on inferred construction cost, and high level cost estimate was developed for these sites. The assessment report can be found in Appendix 5.16. A 2015 report on the Moon Lake Pumped Storage Project completed by Midgard was used in completing this assessment. Picacho Associates completed a study on the pumped storage potential at the Faro Mine.

Fuel description

For this assessment, the energy used to pump the water is assumed to be surplus summer energy. As the load grows, summer surplus energy could be reduced to the point where other generating assets will needed to support the pumped storage facility.

Summary of studies to date and key findings

Energy demand in the Yukon is highest during the winter months, driven by increased loads for space heating and lighting. Currently, water is spilled at Whitehorse and Mayo hydro plants during the summer when the need for electricity is lower than the generation capability, which results in spilled water. This spilled water could generate electricity to support a pumped storage facility. The pumped storage concept being assessed for the Resource Plan would be used for seasonal storage, pumping water during the summer and generating during the winter.

The assessment identified sites based on a 15 MW and 25 MW capacity as well as 50 GWh and 100 GWh of storage for each. Using these technical constraints, the following seven sites were identified:

- Tutshi Lake – Moon Lake (BC);
- Atlin Lake – Black Mountain (BC);
- Racine Lake – Moon Lake (BC);
- Racine Lake – Mt. Brown (BC);
- Lindeman Lake – Fraser Lake (BC);
- Squanga Lake – Dalayee Lake (YK);
- Canyon Lake – Ittlemit Lake (YK); and
- Vangorda (YK).

The following Table 5-99 describes the technical and financial attributes and Table 5-100 to Table 5-106 describe the environmental, social and economic attributes for pumped storage options. The average monthly energy profile is shown in Figure 5-34. The location of the pumped storage projects can be found in Figure 5-35.

Table 5-99. Pumped Storage Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Moon-Tutshi 1								
50	50	15	15	0.28	900	65	7	Y
Moon-Tutshi 2								
50	50	25	25	0.32	650	65	7	Y

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Moon-Tutshi 3								
100	100	15	15	0.19	1300	65	7	Y
Moon-Tutshi 4								
100	100	25	25	0.21	840	65	7	Y
Racine-Moon 1								
50	50	15	15	0.54	1800	65	7	Y
Racine-Moon 2								
50	50	25	25	0.61	1200	65	7	Y
Lindeman-Fraser 1								
50	50	15	15	0.56	1900	65	7	Y
Lindeman-Fraser 2								
50	50	25	25	0.64	1300	65	7	Y
Atlin-Black Mountain 1								
50	50	15	15	0.30	1000	65	7	Y
Atlin-Black Mountain 2								
50	50	25	25	0.33	660	65	7	Y
Atlin-Black Mountain 3								
100	100	25	25	0.27	1100	65	7	Y
Racine-Mt. Brown 1								
50	50	15	15	0.33	1100	65	7	Y

Annual Energy GWh/yr	Firm Energy GWh/yr	Installed Capacity MW	Dependable Capacity MW	Levelized Cost of Energy $/kWh	Levelized Cost of Capacity $/kW·yr	Project Life Years	Lead Time Years	Dispatch-able Y/N
Racine-Mt. Brown 2								
50	50	25	25	0.38	760	65	7	Y
Racine-Mt. Brown 3								
100	100	15	15	0.27	1800	65	7	Y
Racine-Mt. Brown 4								
100	100	25	25	0.29	1100	65	7	Y
Squanga-Dalayee 1								
100	100	15	15	0.34	2200	65	7	Y
Squanga-Dalayee 2								
100	100	25	25	0.36	1400	65	7	Y
Canyon-Ittlemit 1								
100	100	15	15	0.42	3300	65	7	Y
Canyon-Ittlemit 2								
100	100	25	25	0.53	2100	65	7	Y
Vangorda								
134	134	40	40	0.16	463	65	7	Y

1 *Figure 5-34: Average Energy Profile for Selected Pumped Storage Projects*

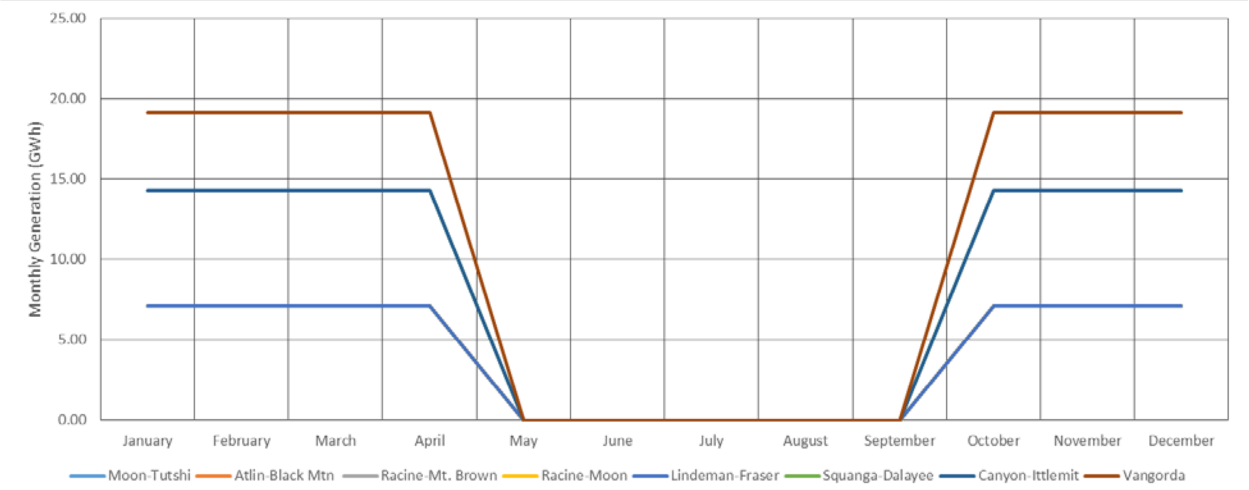


Table 5-100: Pumped Storage Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Moon Lake (Tutshi-Moon)					
🟩	🟩	🟨	🟩	🟥	🟨
Racine - Moon					
🟩	🟩	🟥	🟩	🟥	🟨
Lindeman-Fraser					
🟩	🟩	🟥	🟩	🟥	🟨
Racine - Mt. Brown					
🟩	🟩	🟥	🟩	🟥	🟨
Atlin - Black Mountain					
🟩	🟩	🟥	🟩	🟥	🟨
Squanga - Dalayee					
🟩	🟩	🟨	🟩	🟥	🟨
Canyon - Ittlemit					
🟩	🟩	🟩	🟩	🟥	🟨
Vangorda Pit					
🟩	🟥	🟥	🟩	🟥	🟨

Table 5-101: Pumped Storage Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Moon Lake (Tutshi-Moon)							
🟨	🟩	🟨	🟨	🟥	🟩	🟩	🟨
Racine - Moon							
🟨	🟩	🟨	🟨	🟥	🟨	🟩	🟨
Lindeman-Fraser							
🟨	🟥	🟨	🟨	🟥	🟨	🟩	🟩
Racine - Mt. Brown							
🟨	🟩	🟨	🟨	🟥	🟨	🟨	🟩
Atlin - Black Mountain							
🟨	🟩	🟨	🟨	🟥	🟩	🟩	🟩
Squanga - Dalayee							
🟨	🟨	🟥	🟨	🟥	🟨	🟩	🟨
Canyon - Ittlemit							
🟨	🟩	🟨	🟩	🟥	🟨	🟨	🟩
Vangorda Pit							
🟩	🟩	🟨	🟨	🟥	🟨	🟨	🟨

Table 5-102: Pumped Storage Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Moon Lake (Tutshi-Moon)		
🟩		🟩
Racine - Moon		
🟩		🟩
Lindeman-Fraser		
🟩		🟩
Racine - Mt. Brown		
🟩		🟩
Atlin - Black Mountain		
🟩		🟩
Squanga - Dalayee		
🟩		🟩
Canyon - Ittlemit		
🟩		🟩
Vangorda Pit		
🟩		🟩

Table 5-103: Pumped Storage Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	Traditional Lifestyle (S2)				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Moon Lake (Tutshi-Moon)					
🟩	🟥	🟩	🟩	🟩	🟩
Racine - Moon					
🟩	🟥	🟩	🟩	🟩	🟩
Lindeman-Fraser					
🟩	🟥	🟩	🟩	🟩	🟩
Racine - Mt. Brown					
🟨	🟥	🟩	🟩	🟩	🟩
Atlin - Black Mountain					
🟨	🟥	🟩	🟩	🟩	🟩
Squanga - Dalayee					
🟥	🟥	🟩	🟩	🟩	🟨
Canyon - Ittlemit					
🟥	🟥	🟩	🟨	🟩	🟩
Vangorda Pit					
🟥	🟥	🟨	🟩	🟩	🟩

Table 5-104: Pumped Storage Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		Cultural & Community Well-being (S5)		
Density of Heritage Resources (S3-1)	**Importance/ Cultural Value of Heritage Resources (S3-2)**	**Infrastructure & Services (S5-1)**	**Public Safety, Worker Interaction, Human & Community Health (S5-2)**	**Community, First Nation & Personal Development (S5-3)**
Moon Lake (Tutshi-Moon)				
🟩	🟩	🟥	🟥	🟩
Racine - Moon				
🟩	🟩	🟥	🟥	🟩
Lindeman-Fraser				
🟨	🟨	🟥	🟥	🟩
Racine - Mt. Brown				
🟩	🟩	🟥	🟥	🟩
Atlin - Black Mountain				
🟥	🟩	🟥	🟥	🟩
Squanga - Dalayee				
🟨	🟨	🟥	🟥	🟨
Canyon - Ittlemit				
🟨	🟨	🟥	🟥	🟨
Vangorda Pit				
🟩	🟩	🟥	🟥	🟨

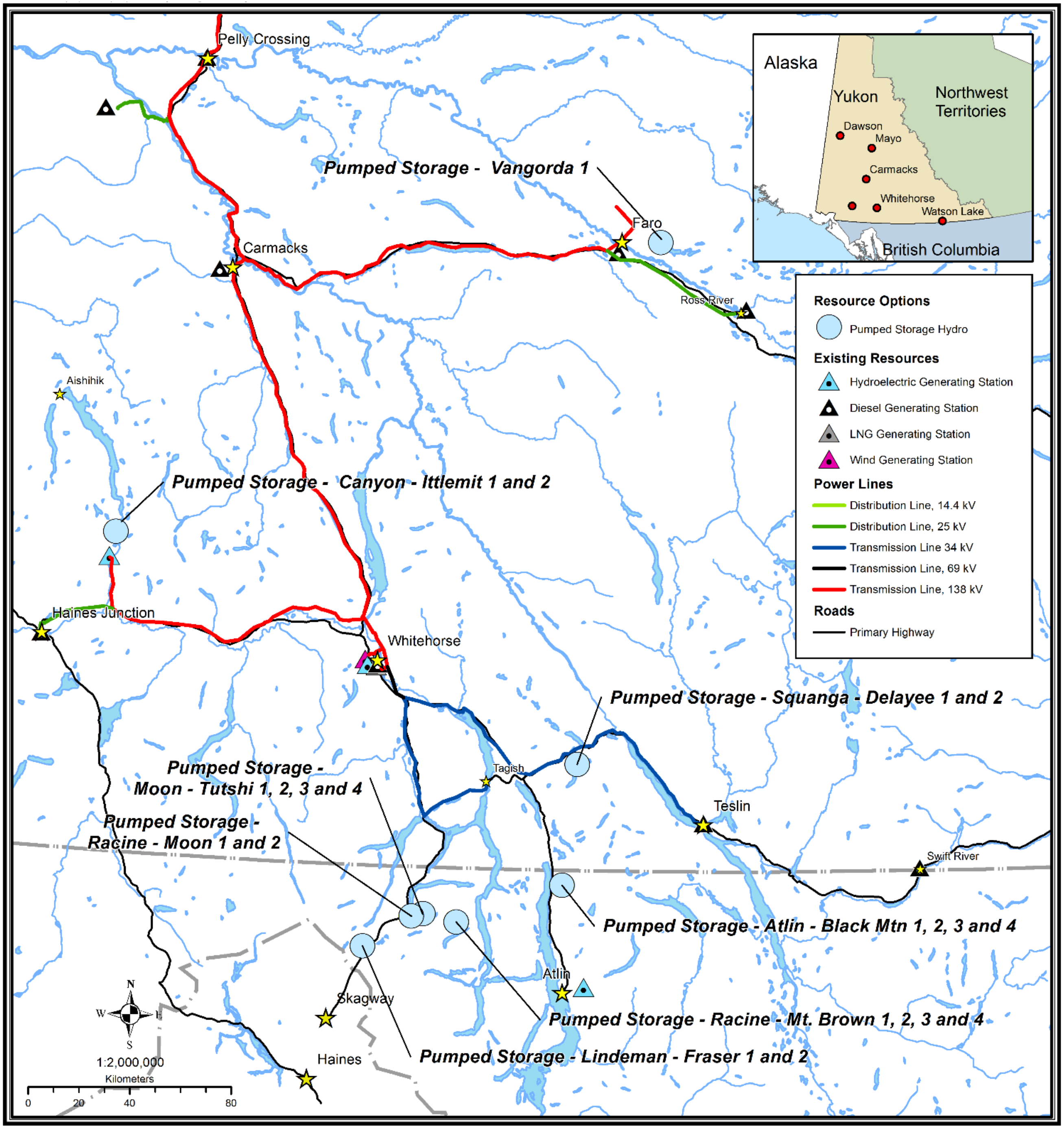
Table 5-105: Pumped Storage Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	**Tourism Values (S4-2)**	**Aesthetics (S4-3)**	**Non-renewable Resources (S4-4)**	**Other Renewable Resources (S4-5)**	**Land Use & Renewable Resources Plans (S4-6)**
Moon Lake (Tutshi-Moon)					
🟩	🟩	🟨	🟨	🟩	🟨
Racine - Moon					
🟥	🟨	🟩	🟨	🟩	🟥
Lindeman-Fraser					
🟨	🟨	🟨	🟩	🟩	🟨
Racine - Mt. Brown					
🟥	🟨	🟩	🟨	🟩	🟥
Atlin - Black Mountain					
🟩	🟩	🟩	🟨	🟩	🟥
Squanga - Dalayee					
🟥	🟨	🟨	🟨	🟩	🟨
Canyon - Ittlemit					
🟥	🟨	🟨	🟩	🟩	🟨
Vangorda Pit					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-106: Pumped Storage Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Moon Lake (Tutshi-Moon)							
🟩	🟨	🟩	🟥	🟩	🟩	🟩	🟨
Racine - Moon							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Lindeman-Fraser							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Racine - Mt. Brown							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Atlin - Black Mountain							
🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟨
Squanga - Dalayee							
🟩	🟩	🟨	🟥	🟩	🟩	🟩	🟨
Canyon - Ittlemit							
🟩	🟩	🟨	🟥	🟩	🟩	🟩	🟩
Vangorda Pit							
🟩	🟩	🟨	🟥	🟩	🟩	🟩	🟩

1 *Figure 5-35: Pumped Storage Resource Option Locations*



5.2.10 Energy Storage

Technology description

Electricity cannot be stored, which means that electricity supply must be continuously and instantaneously balanced with demand. Storage allows for electricity generated at one time to be converted to another form of energy suitable for storage (such as chemical energy), which is then converted back to electricity at a later time as shown in Figure 5-36. Due to the necessary energy conversions, storage is a net consumer of energy. Storage provided by batteries can be valuable in smoothing out the variation between the demand and supply for electricity, as well as to maintain grid stability and to manage the integration of intermittent renewables resources such as wind and solar, by firming their energy.

The most common electrical energy storage systems are batteries, but other energy storage technologies include: pumped water storage, compressed air, flywheels, hydrogen cells, capacitors, superconducting magnetic coils and molten salt. Different energy storage technologies work on different timescales. Some can store energy for seconds, while others can store for years.

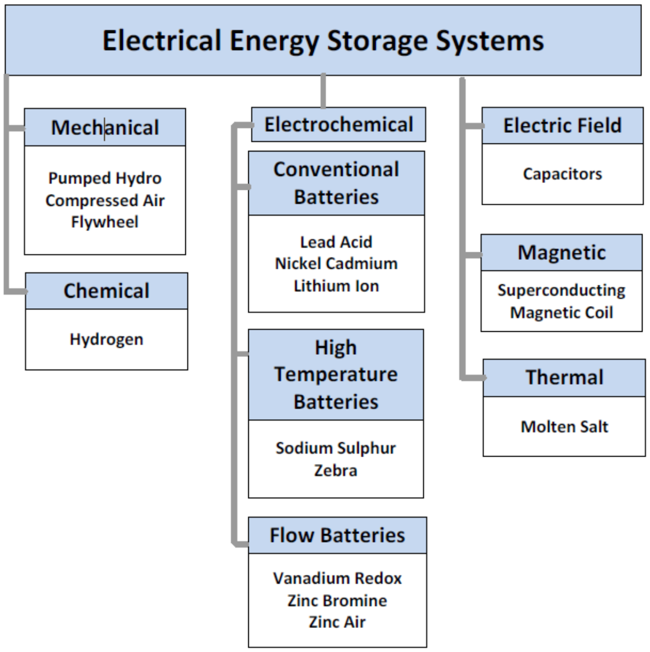
Energy storage is a net energy user that can provide dispatchable energy and dependable capacity over a limited amount of time. The operation of the energy storage system is matched to the demands on the system.

Figure 5-36: Energy Storage

Studies

TransGrid Solutions Inc. completed a review of existing energy storage technologies for the 2016 Resource Plan. This evaluation reviewed the various technologies in terms of their ability to reduce YEC’s thermal generation to meet peak load requirements, and other benefits including improved power quality, grid support, load shifting and the integration of renewables. Other factors considered included safety, environmental attributes and cost. The report can be found in Appendix 5.17. The energy storage technologies considered are summarized in Figure 5-37 below.

Figure 5-37: Energy Storage Systems and Classifications (from TransGrid Solutions Report)



Fuel description

Energy storage does not produce energy, but stores energy produced by a different generating resources.

Summary of studies to date and key findings

The inventory of energy storage technologies identified four technologies to displace thermal generation, all of which featured electrochemical batteries. Only two, lead acid and lithium ion batteries, were selected based on safety, overall cost and the maturity of the technology. One advantage of batteries is that the systems are modular. This means that the system can be installed in a reasonable timeframe, and power capacity can be added in increments as the demand grows. By adding the batteries incrementally, the utility can also take advantage of future technology improvements.

The study completed a configuration design and cost estimate for lead acid batteries at 4, 6 and 8 MW, and for lithium-ion batteries at 8 MW. These storage systems were assumed to be close to the Takhini substation.

The following Table 5-107 describes the technical and financial attributes and Table 5-108 to Table 5-114 describe the environmental, social and economic attributes for the four battery configurations. The location of the energy storage systems can be found in Figure 5-38 below.

Table 5-107. Storage Resource Option Technical and Financial Attributes

Annual Energy GWh/yr	**Firm Energy** GWh/yr	**Installed Capacity** MW	**Dependable Capacity** MW	**Levelized Cost of Energy** $/kWh	**Levelized Cost of Capacity** $/kW·yr	**Project Life** Years	**Lead Time** Years	**Dispatch-able** Y/N
Lead Acid (4 MW)								
2.4	2.4	4	3.6	$0.79	$539	30	2	Y
Lead Acid (6 MW)								
2.7	2.7	6	3.6	$1.09	$811	30	2	Y
Lead Acid (8 MW)								
2.8	2.8	8	3.6	$1.31	$1,055	30	2	Y
Lithium-ion (8 MW)								
2.8	2.8	8	3.6	$0.96	$650	30	2	Y

Table 5-108: Storage Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-109: Storage Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)							
🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Table 5-110: Storage Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Lithium Ion Battery (8 MW/40MWh, 5 hrs)		
🟩		🟩

Table 5-111: Storage Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-112: Storage Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)				
🟩	🟩	🟩	🟩	🟥

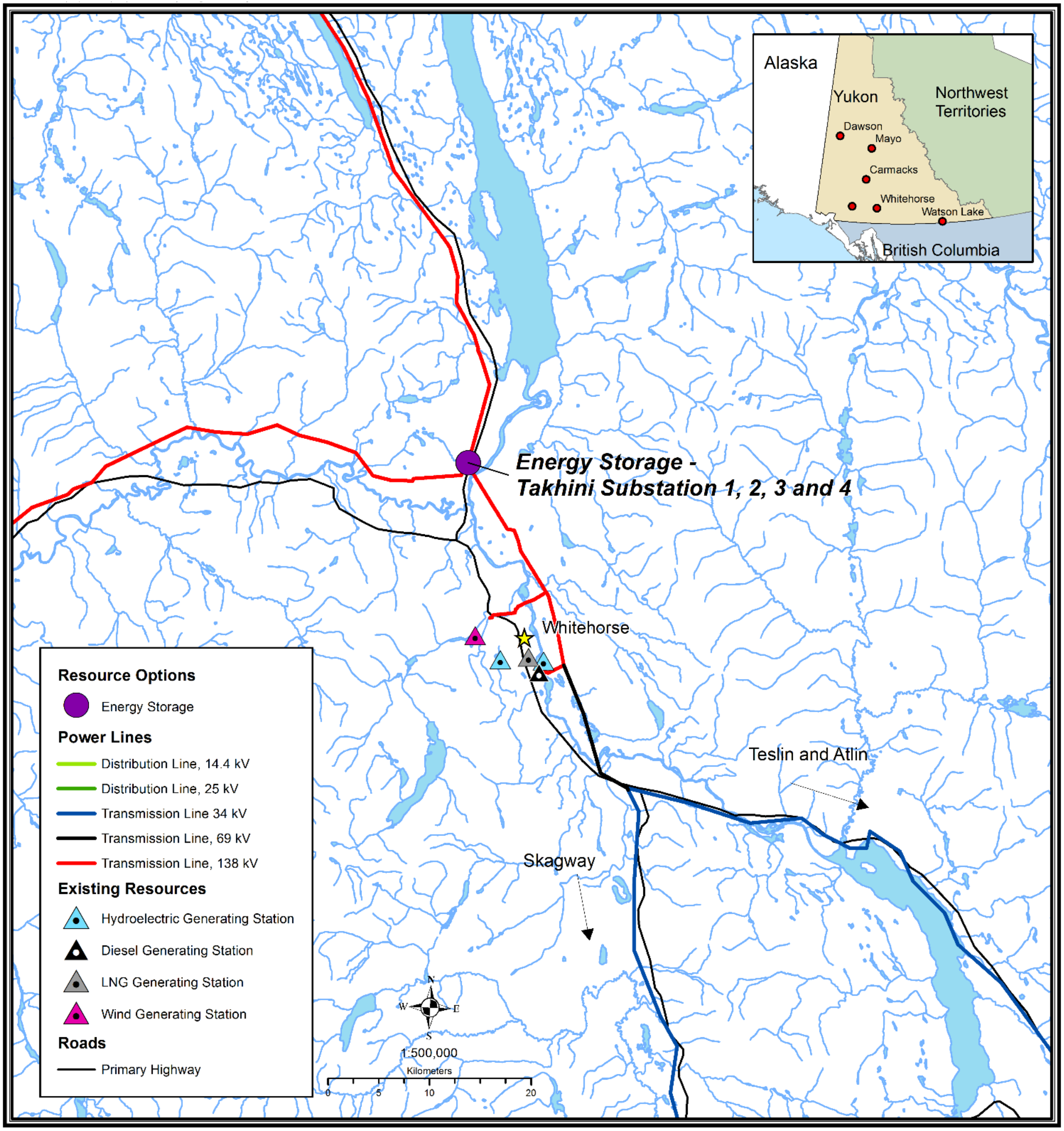
Table 5-113: Storage Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	Tourism Values (S4-2)	Aesthetics (S4-3)	Non-renewable Resources (S4-4)	Other Renewable Resources (S4-5)	Land Use & Renewable Resources Plans (S4-6)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-114: Storage Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Lithium Ion Battery (8 MW/40MWh, 5 hrs)							
🟥	🟥	🟥	🟩	🟩	🟩	🟩	🟩

Figure 5-38: Energy Storage Resource Option Location



5.2.11 Demand Side Management

Technology description

Demand side management (DSM) uses a combination of energy efficient technologies and customer behavioral changes to reduce the amount of electricity that customers demand, or shift the timing of when customers need power. This can be done by providing:

- Financial incentives to customers too help offset the cost of purchasing energy saving products;
- Financial disincentives or penalties such as taxes on high energy use products or behavior;
- Electricity rates that encourage conservation;
- Education on the benefits of conservation, both from an energy perspective as well as other factors such as comfort and safety; and
- Codes and standards such as insulation requirements for new buildings or minimum efficiency levels for appliances.

Currently YEC has used financial incentives and education in the inCharge DSM program, which is delivered to Yukon residential customers in partnership with ATCO Electric Yukon. The timing of energy-focused DSM savings cannot be controlled by the utility, but can be reasonably estimated. Demand focused DSM programs can include utility control and can be dispatched by the utility.

Studies

In 2011, a Conservation Potential Review (CPR) was completed for the Yukon by ICF International (ICFI). This study considered the level of energy savings achievable through the adoption of a range of DSM programs by Yukon homes and businesses. An update to the key exhibits in this review was completed by ICFI for the 2016 Resource Plan. This update took into consideration the change in YEC's load and population forecasts. The update also considered changes in technology and some learnings from the first few years of YEC delivering the inCharge DSM program. The updated CPR can be found in Appendix 5.18.

Fuel description

Instead of delivering electricity supply, DSM focuses on changing the demand for electricity as a way of ensuring that the utility is able to meet future load requirements.

Summary of studies to date and key findings

The 2016 CPR update indicates that there is a considerable amount of electricity conservation potential in the Yukon. The study focused on energy savings as well as the coincident peak demand savings that would result from the energy savings measures. The same rigor was applied in determining both the energy and peak demand savings. A preliminary estimate of demand reduction technologies was completed and will be investigated in more detail at a later date.

Due to the large number of energy efficiency measures considered, these were grouped from lowest to highest cost of conserved energy (CCE), which is equivalent to the LCOE of supply measures. The CCE presented is considered as the cost to both the utility and the participants for saving each kilowatt-hour of electricity. DSM has an inclining cost curve; as the cheaper DSM options are implemented, the next DSM option is more expensive. This results in the overall portfolio cost of DSM increasing as increasingly expensive measures are implemented.

The following Table 5-115 to Table 5-118 describes the technical and financial parameters of the various DSM options. An environmental, social and economic assessment was not undertaken. DSM is considered the most environmentally friendly option as it does not require the construction of generation and transmission assets. Measures greater than $0.38/kWh for commercial customers and $0.45/kWh for residential customers were not included as costs greater than this were not considered cost effective in the 2011 CPR.

Table 5-115. Energy DSM Technical and Financial Attributes – Commercial Customer Class

Annual and Firm Energy Conserved (GWh/yr)					**Cost of Conserved Energy**	**Project Life**	**In-service Lead Time**
2015	2020	2025	2030	2035	($/kWh)	years	years
Cost of Conserved Energy up to 10 ¢/kWh							
2.4	6.7	10.2	14.5	14.5	0.07	20	2
Cost of Conserved Energy between 10 -20 ¢/kWh							
1.2	3.3	5.5	7.9	7.9	0.13	20	2
Cost of Conserved Energy between 20 -30 ¢/kWh							
0.2	0.8	2.4	4.7	4.3	0.27	20	2
Cost of Conserved Energy greater than 30 ¢/kWh							
0.1	0.3	0.50	0.7	0.7	0.38	20	2

Table 5-116: Capacity DSM Technical Attributes – Commercial Customer Class

Coincident Peak Reduction (*) (MW)				
2015	2020	2025	2030	2035
Cost of Conserved Energy up to 10 ¢/kWh				
0.3	1.0	1.5	2.2	2.1
Cost of Conserved Energy between 10 -20 ¢/kWh				
0.2	0.6	0.9	1.3	1.3
Cost of Conserved Energy between 20 -30 ¢/kWh				
0.0	0.2	0.5	1.0	0.9
Cost of Conserved Energy greater than 30 ¢/kWh				
0.0	0.0	0.1	0.1	0.1

(*) The Coincident Peak Reductions are by-products of DSM Energy Efficiency measures presented in Table 4-115. Table 4-116 is presented separately from Table 4-115 because there was not enough space on the page to present a combined table.

Table 5-117. Energy DSM Technical and Financial Attributes – Residential Customer Class

Annual and Firm Energy Conserved (GWh/yr)					**Cost of Conserved Energy**	**Project Life**	**In-service Lead Time**
2015	2020	2025	2030	2035	($/kWh)	years	Years
Cost of Conserved Energy up to 10 ¢/kWh							
1.0	2.1	2.8	3.3	2.8	0.04	20	2
Cost of Conserved Energy between 10-20 ¢/kWh							
0.4	1.9	5.3	10.1	10.0	0.17	20	2
Cost of Conserved Energy between 20-30 ¢/kWh							
0.2	0.9	2.3	4.2	4.4	0.26	20	2
Cost of Conserved Energy between 30-40 ¢/kWh							
0.2	1.4	2.8	3.4	3.3	0.32	20	2
Cost of Conserved Energy greater than 40 ¢/kWh							
0.0	0.1	0.4	0.5	0.5	0.45	20	2

Table 5-118: Capacity DSM Technical Attributes – Residential Customer Class

Coincident Peak Reduction (**) (MW)				
2015	2020	2025	2030	2035
Cost of Conserved Energy up to 10 ¢/kWh				
0.0	0.1	0.1	0.2	0.2
Cost of Conserved Energy between 10-20 ¢/kWh				
0.1	0.2	0.1	0.1	0.1
Cost of Conserved Energy between 20-30 ¢/kWh				
0.1	0.2	0.1	0.1	0.1
Cost of Conserved Energy between 30-40 ¢/kWh				
0.0	0.0	0.1	0.1	0.1
Cost of Conserved Energy greater than 40 ¢/kWh				
0.0	0.0	0.1	0.1	0.1

(**) The Coincident Peak Reductions are by-products of DSM Energy Efficiency measures presented in Table 4-117. Table 4-118 is presented separately from Table 4-117 because there was not enough space on the page to present a combined table.

5.2.12 Transmission

Technology description

Power transmission allows the bulk movement of electricity through high voltage systems. The YIS consists of high voltage alternating current infrastructure conveying electricity at a voltage of 69 kV (Mayo-Dawson line and Stewart-Keno lines) or 138 kV (Whitehorse-Aishihik-Faro and Carmacks-Stewart lines).

Transmission infrastructure includes the conductors and the supporting poles and the transmission lines that allow the flow of electricity from the generating stations to the load centers as shown in Figure 5-39. Closer to the customer meters, lower voltage (25 kV or 34.5 kV) distribution wiring transmits electricity from the substations to individual customers. Although transmission can also be underground, all transmission infrastructure in Yukon is overhead.

Figure 5-39: Transmission

Studies

An evaluation of the options for eleven transmission routes of interest was conducted by Midgard Consulting for the 2016 Resource Plan. The routes were identified through an iterative process that evaluated the connection between major load centers and current or potential future generation resources. This evaluation considered transmission corridor optimization (adjacent to roadways, avoiding challenging terrain, avoiding private land and avoiding sharp bends in the line), capital and operating expenditures, power transfer capacities, development schedules and risks. The results of this technical evaluation are intended to be combined with the resource options requiring new transmission infrastructure. The routes evaluated were:

- Faro to Finlayson;
- Faro to Watson Lake;
- Aishihik to Destruction Bay;
- Whitehorse to Skagway;
- Whitehorse to Atlin;
- Whitehorse to Teslin;
- Whitehorse to Squanga - Dalayee Pumped Storage Site;
- Whitehorse to Atlin – Mount Black Pumped Storage Site;
- Whitehorse to Tutshi Windy Arm; and

- Whitehorse to Racine – Mount Brown Pumped Storage Site, Racine – Moon Pumped Storage Site, and Tutshi – Moon Lake Pumped Storage Site

The evaluation report can be found in Appendix 5.19.

Summary of studies to date and key findings

The risks that affect the development of transmission corridors were broken down into meteorological, geotechnical, social, logistical and political. The meteorological risks included extended extreme cold, extreme snow and extreme wind. The geotechnical risks included permafrost, exposed bedrock, steep side slopes and floodplains. The social risks were related to permitting in First Nations settlement land, urban or populated areas, parks and recreational areas. Logistics risks were related to planning a very large project in a remote area with little local capacity. The political risks are related to the transmission lines that cross the Yukon border into British Columbia and Alaska. Safety risks were also identified pertaining to proposed transmission line route passing near existing airport runways.

The following Table 5-119 describes the technical and financial attributes and Table 5-120 to Table 5-126 describe the environmental, social and economic attributes for the transmission lines. As the Whitehorse-Atlin 69kV line was introduced after the environmental, social and economic attributes report had been finished, no formal evaluation of the 69kV Whitehorse-Atlin transmission line was conducted. Considering the similarities between the 138kV and 69kV lines, it is a conservative assumption that the environmental, social and economic attributes determined for the Whitehorse-Atlin 138kV line can be applied to the Whitehorse-Atlin 69kV line. The location of the transmission lines can be found in Figure 5-40 and Figure 5-41.

Table 5-119. Transmission Lines Resource Option Technical and Financial Attributes

Voltage kV	**Transmission Line Length** km	**Reliable Transfer Capacity** MW	**CAPEX** $Million	**OPEX** $000/yr	**Lead Time** Years	**Line Losses** %
Whitehorse → Atlin (69 kV)						
69 kV	172	21	$104	$236k/yr	4.8	7.5%
Whitehorse → Atlin (138 kV)						
138 kV	172	97	$158	$236k/yr	4.1	4.6%
Whitehorse → Atlin- Mt. Black Pumped Storage Hydro						
138 kV	127	131	$119	$174k/yr	3.7	3.5%
Jake's Corner → Atlin						
69 kV	93	38	$54	$129k/yr	4.1	5.0%

Voltage kV	**Transmission Line Length** km	**Reliable Transfer Capacity** MW	**CAPEX** $Million	**OPEX** $000/yr	**Lead Time** Years	**Line Losses** %
Whitehorse → Skagway (138 kV)						
138 kV	170	114	$166	$285k/yr	4.1	4.6%
Whitehorse → Skagway (230 kV)						
230 kV	170	443	$251	$285k/yr	4.1	0.4%
Whitehorse → Squanga- Dalayee Pumped Storage Hydro						
138 kV	105	134	$100	$143k/yr	3.3	2.7%
Whitehorse → Tutshi Windy Arm						
138 kV	96	135	$94	$143k/yr	3.2	2.7%
Whitehorse → Racine-Mt. Brown, Racine-Moon Lake, and Tutshi-Moon Lake Pumped Storage Hydro						
138 kV	112	132	$108	$168k/yr	3.3	3.5%
Whitehorse → Lindeman- Fraser Pumped Storage Hydro						
138 kV	129	129	$125	$200k/yr	3.8	3.5%
Whitehorse → Teslin (138 kV)						
138 kV	174	95	$165	$239k/yr	4.1	4.6%
Faro → Watson Lake (230 kV)						
230 kV	414	190	$597	$613k/yr	6.0	1.6%
Faro → Finlayson (138 kV)						
138 kV	233	84	$221	$351k/yr	4.3	5.7%
Aishihik → Destruction Bay (138 kV)						
138 kV	157	122	$167	$217k/yr	3.8	3.8%

Voltage kV	**Transmission Line Length** km	**Reliable Transfer Capacity** MW	**CAPEX** $Million	**OPEX** $000/yr	**Lead Time** Years	**Line Losses** %
Aishihik → Destruction Bay (230 kV)						
230 kV	157	484	$241	$217k/yr	3.8	0.4%

Table 5-120: Transmission Lines Resource Option Environmental Attributes – Aquatic Environment

Fish & Fish Habitat (En1)			**Water Quantity & Quality (En2)**		
Salmon & Habitat (En1-1)	Species at Risk & Habitat (En1-2)	Commercial, Recreational & Aboriginal Fisheries Species & Habitat (En1-3)	Consumptive Water Use (En2-1)	Relative Scale of New Impoundment/ Flooding (En2-2)	Flow Changes (En2-3)
Whitehorse - Atlin (138 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse - Skagway (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse - Teslin (138 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Faro - Watson Lake (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Aishihik - Destruction Bay (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Stewart-Keno City (138 kV & substations)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-121: Transmission Lines Resource Option Environmental Attributes - Terrestrial Environment

Terrestrial Species & Habitat (En3)				**Terrestrial Footprint & Land Use (En4)**			
Species at Risk & Habitat (En3-1)	Protected & Conservation Areas (En3-2)	Wildlife Key Areas (En3-3)	Caribou Ranges (En3-4)	Footprint Terrestrial Area (En4-1)	Linear Dev for Roads/ Transmission (En4-2)	Permafrost En4-3)	Wetlands (En4-4)
Whitehorse - Atlin (138 kV)							
🟩	🟨	🟨	🟩	🟥	🟥	🟩	🟩
Whitehorse - Skagway (230 kV)							
🟩	🟩	🟨	🟩	🟥	🟥	🟩	🟩
Whitehorse - Teslin (138 kV)							
🟩	🟩	🟨	🟩	🟥	🟥	🟩	🟩
Faro - Watson Lake (230 kV)							
🟩	🟩	🟨	🟥	🟥	🟥	🟨	🟩
Aishihik - Destruction Bay (230 kV)							
🟩	🟥	🟨	🟩	🟥	🟥	🟨	🟩
Stewart-Keno City (138 kV & substations)							
🟩	🟩	🟨	🟩	🟥	🟥	🟨	🟩

Table 5-122: Transmission Lines Resource Option Environmental Attributes – Air

Air Quality (En5)		
GHG Emissions (En5-1)		Other Air Pollutants (En5-2)
with Biogenic CO2	without Biogenic CO2	
Whitehorse - Atlin (138 kV)		
🟩		🟩
Whitehorse - Skagway (230 kV)		
🟩		🟩
Whitehorse - Teslin (138 kV)		
🟩		🟩
Faro - Watson Lake (230 kV)		
🟩		🟩
Aishihik - Destruction Bay (230 kV)		
🟩		🟩
Stewart-Keno City (138 kV & substations)		
🟩		🟩

Table 5-123: Transmission Lines Resource Option Social Attributes – First Nations Land and Traditional Lifestyle

First Nation Lands (S1)	**Traditional Lifestyle (S2)**				
First Nation Settlement Lands/ Interim Protected Lands (S1-1)	Footprint Land Area Impact (S2-1)	Land Area Loss Re: Traditional Lifestyle (S2-2)	Land Quality Effects on Traditional Lifestyle (S2-3)	Cabins, Camps & Structures (S2-4)	Country Foods (S2-4)
Whitehorse - Atlin (138 kV)					
🟥	🟥	🟩	🟩	🟩	🟩
Whitehorse - Skagway (230 kV)					
🟥	🟥	🟩	🟩	🟨	🟩
Whitehorse - Teslin (138 kV)					
🟥	🟥	🟩	🟩	🟩	🟩
Faro - Watson Lake (230 kV)					
🟨	🟥	🟩	🟩	🟩	🟩
Aishihik - Destruction Bay (230 kV)					
🟨	🟥	🟩	🟩	🟩	🟩
Stewart-Keno City (138 kV & substations)					
🟨	🟥	🟩	🟩	🟩	🟩

Table 5-124: Transmission Lines Resource Option Social Attributes – Heritage Resources and Cultural & Community Well-being

Heritage Resources (S3)		**Cultural & Community Well-being (S5)**		
Density of Heritage Resources (S3-1)	Importance/ Cultural Value of Heritage Resources (S3-2)	Infrastructure & Services (S5-1)	Public Safety, Worker Interaction, Human & Community Health (S5-2)	Community, First Nation & Personal Development (S5-3)
Whitehorse - Atlin (138 kV)				
🟨	🟩	🟩	🟩	🟨
Whitehorse - Skagway (230 kV)				
🟨	🟨	🟩	🟩	🟨
Whitehorse - Teslin (138 kV)				
🟨	🟩	🟩	🟩	🟨
Faro - Watson Lake (230 kV)				
🟩	🟩	🟩	🟩	🟩
Aishihik - Destruction Bay (230 kV)				
🟨	🟩	🟩	🟩	🟩
Stewart-Keno City (138 kV & substations)				
🟨	🟩	🟩	🟩	🟩

Table 5-125: Transmission Lines Resource Option Social Attributes – Tourism, Recreation, Other Resources and Land Use

Tourism, Recreation & Other Resources and Land Use (S4)					
Recreational Values (S4-1)	**Tourism Values (S4-2)**	**Aesthetics (S4-3)**	**Non-renewable Resources (S4-4)**	**Other Renewable Resources (S4-5)**	**Land Use & Renewable Resources Plans (S4-6)**
Whitehorse - Atlin (138 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse - Skagway (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Whitehorse - Teslin (138 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Faro - Watson Lake (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Aishihik - Destruction Bay (230 kV)					
🟩	🟩	🟩	🟩	🟩	🟩
Stewart-Keno City (138 kV & substations)					
🟩	🟩	🟩	🟩	🟩	🟩

Table 5-126: Transmission Lines Resource Option Economic Attributes – Local Economic Impacts and Climate Change Risk

Local Economic Impacts (Ec1) (Positive Effects)			**Climate Change Risk affecting Resource Financial Attributes (Ec2)**				
Yukon Opportunities During Construction (Ec1-1) Positive Effects	Yukon Opportunities during Operation (Ec1-2) Positive Effects	Community & Other Development Opportunity (Ec1-3) Positive Effects	Susceptible to Extreme Heat/Drought (Ec2-1)	Susceptible to Extreme Precipitation - flood/snow (Ec2-2)	Susceptible to Extreme Wind Events (Ec2-3)	Susceptible to Ice Related Processes/ Events (Ec2-4)	Conditions Susceptible to Climate Change (Ec2-5)
Whitehorse - Atlin (138 kV)							
🟨	🟥	🟨	🟩	🟨	🟨	🟨	🟨
Whitehorse - Skagway (230 kV)							
🟩	🟥	🟨	🟩	🟨	🟨	🟨	🟨
Whitehorse - Teslin (138 kV)							
🟨	🟥	🟨	🟩	🟨	🟨	🟨	🟨
Faro - Watson Lake (230 kV)							
🟩	🟥	🟩	🟨	🟨	🟨	🟨	🟨
Aishihik - Destruction Bay (230 kV)							
🟨	🟥	🟩	🟨	🟨	🟨	🟨	🟥
Stewart-Keno City (138 kV & substations)							
🟥	🟥	🟩	🟨	🟨	🟨	🟨	🟨

Figure 5-40: Transmission Line Options Locations (Map 1)

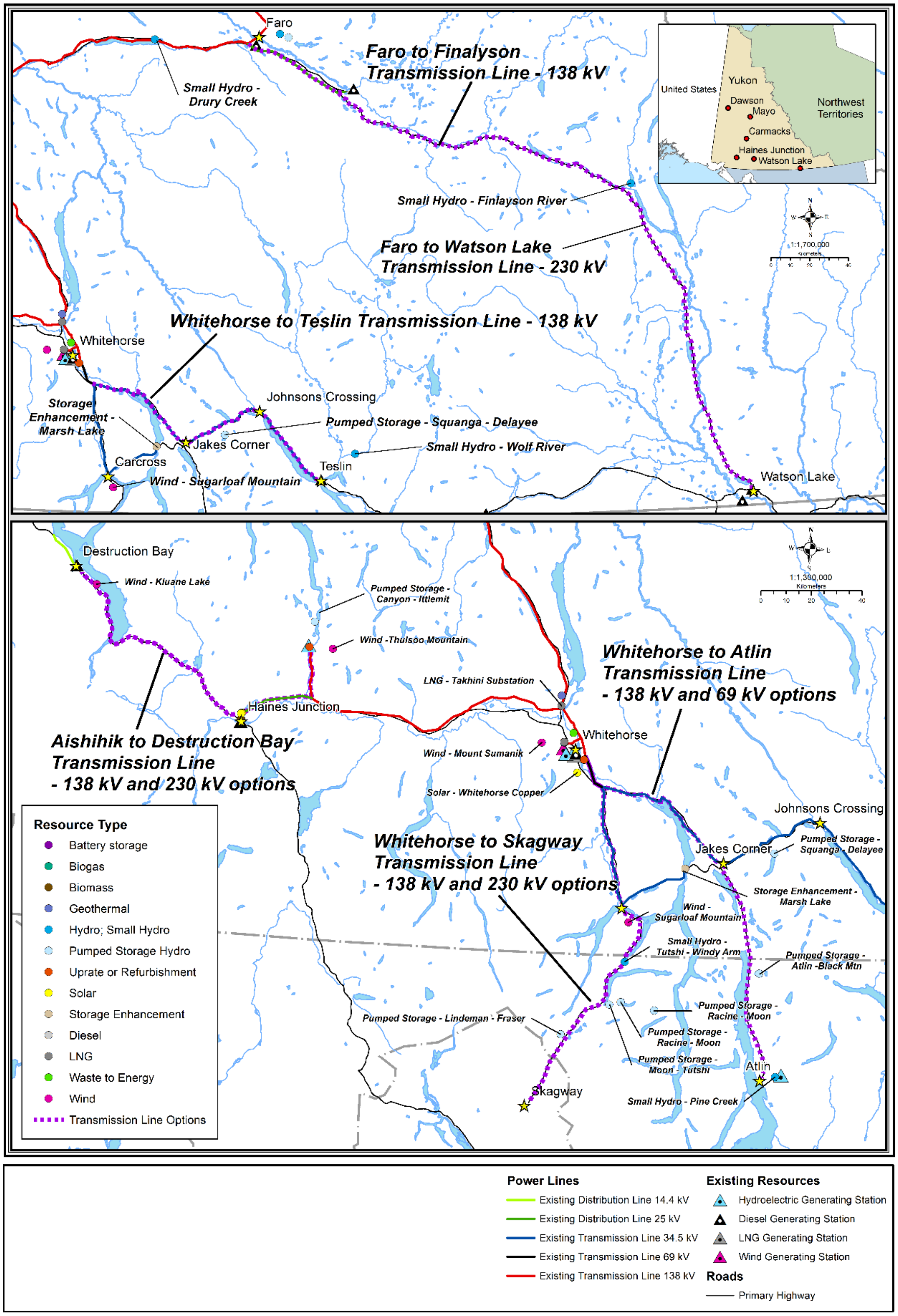
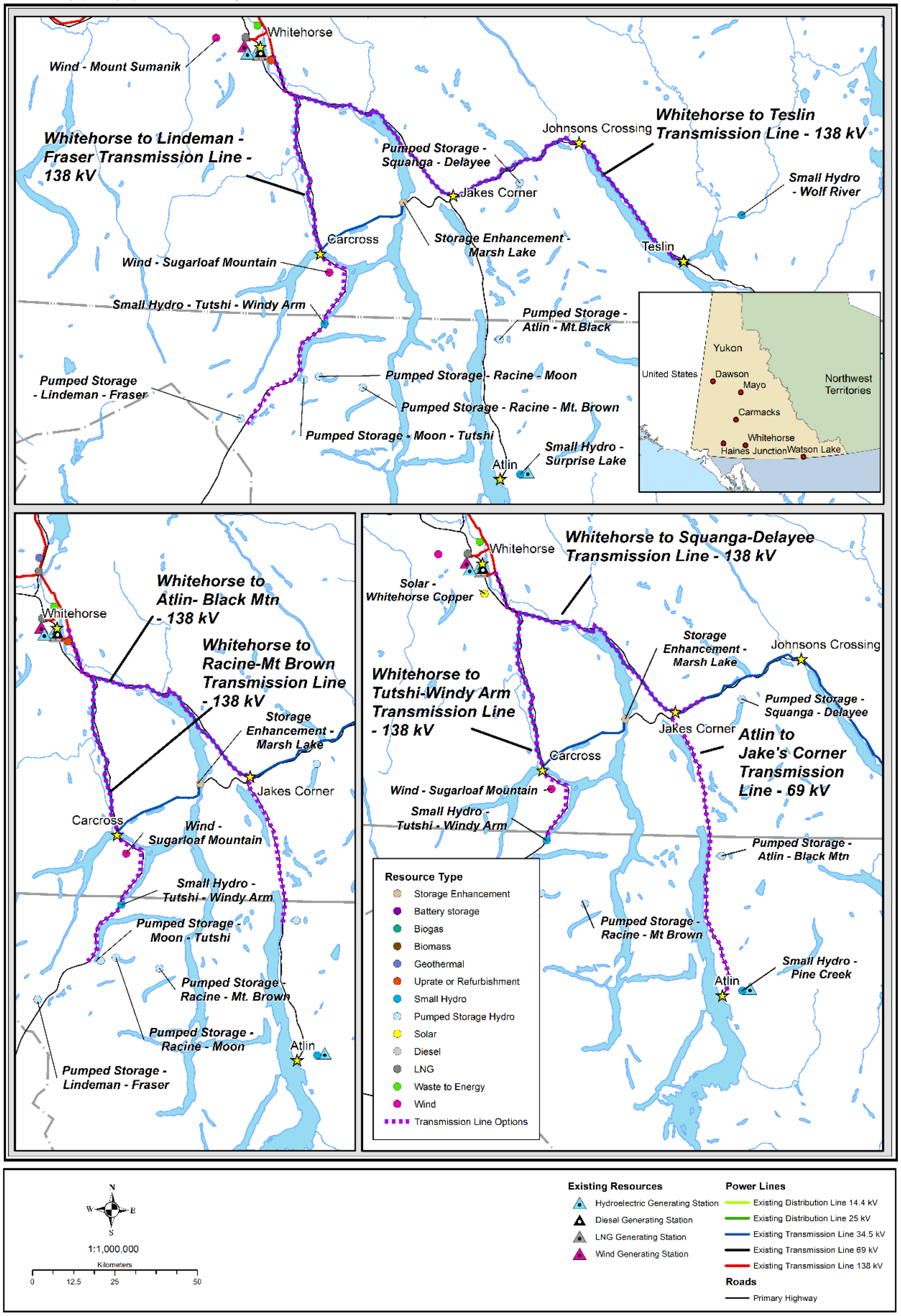


Figure 5-41: Transmission Line Options Locations (Map 2)



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6 Market Assessment

6.1 Fuel Price Forecasts

6.1.1 Background

The cost of hydrocarbon fuels, diesel and liquefied natural gas (LNG), is a major component in the cost of electricity delivered from thermal-based generation and therefore, this is a key factor in electricity generation resource decisions. This chapter summarizes the diesel and LNG price forecasts undertaken by Yukon Energy (YEC) for the purposes of long-term resource planning.

6.1.2 Forecast Approach

There are several ways to create forecasts. The simplest approach involves a trend analysis, in which recent historical prices are escalated using an inflation-based index. This was the approach used in YEC's 2011 Resource Plan. A forecast of future diesel prices was constructed by anchoring current diesel prices, and applying escalation at inflation.

YEC's 2016 Resource Plan takes a more detailed approach, in that the key components of diesel and LNG fuel price were analyzed, and specific escalation factors were applied separately to each of the cost components. These separate cost forecasts were then aggregated to generate a total diesel and LNG price forecast.

The prices of diesel and LNG delivered to YEC's thermal generation facilities are comprised of a few key components. For example, the price of delivered diesel includes the following:

- Fuel cost (crude oil)
- Refining costs (crude oil converted to diesel)
- Marketing
- Shipping
- Taxes

All the price forecasts presented in this Chapter exclude effects associated with carbon pricing. An assessment of a social cost of carbon, which has been applied to thermal generation resources in the YEC's portfolio analysis, is presented in Section 6.2. The results of the portfolio analysis are presented in Chapter 8.

In undertaking the forecast, the above costs have been grouped into two categories. The forecast costs in each category are separately created and then added together, as follows:

1. Fuel costs: The feedstocks for diesel and LNG are crude oil and gas, respectively. Therefore price forecasts for oil and gas are key forecast inputs. As oil and gas prices are denominated in US dollars (US$), a Canadian dollar (C$)-US$ exchange rate forecast was created and applied. Oil prices are largely driven by global forces of supply and demand, with some degree of producer market power. Natural gas prices are set on a continental basis, as imports and exports of natural gas (as LNG) are relatively small. Processing and shipping costs for both fuels are largely cost-based, and generally track inflation; and

2. Other non-fuel costs: this grouping includes all other costs such as shipping, liquefaction for natural gas, refining for diesel, and taxes. In the forecasts, these are escalated at a rate consistent with the supplier cost of providing the service (i.e., equivalent to the inflation rate). These costs are largely local and therefore, are denominated in C$.

The key inputs to the diesel and LNG price forecast are:

- Recent diesel and LNG prices paid by YEC: These are the actual delivered prices of the fuel, and include all other charges such as shipping and liquefaction;
- Recent market prices for oil (Brent and West Texas Intermediate) and natural gas (Sumas Hub and Henry Hub);
- Historical Exchange rates (C$/US$);
- A base C$/US$ exchange rate of 0.82, which was the exchange rate at the time this forecast was completed in June 2016, and high and low sensitivities around the base; and
- Long-term market price forecasts and scenarios for oil and natural gas, from a recent study by the National Energy Board of Canada (NEB)[1].

6.1.3 Scenarios

Energy prices are among the most uncertain and volatile of all commodities, and are subject to the future events such as technology developments, changes in taxation and energy policies, customer demand, and substitution by other fuels. A scenario-based forecasting approach was used to account for these uncertainties.

The key uncertainty in the diesel and LNG forecasts relates to the fuel costs and the exchange rates. Consequently, three exchange rate scenarios (High, Base and Low) and three long-term oil and gas price scenarios (High, Base and Low), and were considered.

6.1.3.1 Exchange Rate Scenarios

The Base Exchange rate forecast of 0.82 US$/CA$ was used, with low and high scenarios of 0.70 and 0.90 US$/C$ respectively. These scenarios fall reasonably within the historical range from the past 30 years. Exchange rates of as low as 0.60 and over 1.00 US$/C$ have occurred over this period, but these were unusual short-term events.

YEC undertook a regression analysis of the historical relationship between the Canadian dollar (relative to the US$) and the market price of oil. The results of this regression analysis is clear and consistent with previous studies. When oil prices are low, the Canadian dollar has historically been low, which supports the price of oil denominated in C$. Therefore, only certain combinations of oil prices and foreign exchange rates are sensibly aligned. This reduces the number of scenarios to be analyzed.

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[1] Canada's Energy Future 2016: Energy Supply and Demand Projections to 2040 – An Energy Market Assessment – January 2016: https://www.neb-one.gc.ca/nrg/ntgrtd/ftr/index-eng.html

6.1.3.2 Fuel Cost Scenarios

Two consistent fuel price forecasts were developed based on the NEB high and low scenarios. The low oil price case was matched with the low US$/C$ exchange rate (0.70 US$/C$), and the high oil price case was matched with the high exchange rate (0.90 US$/C$).

A correlation between Henry Hub natural gas prices and the Canadian dollar was also tested, and it did not show a strong relationship. However, for consistency, the NEB high and low gas price scenarios were matched with the same exchange-rate cases as were used with oil prices. The high natural gas price case was matched with the high exchange rate (0.90 US$/C$) and the low natural gas case was matched with the low exchange rate (0.70 US$/C$).

The forecast prices of the fuel feedstock were escalated at rates consistent with the NEB's long-term forecasts, relative to a 2016 base year. The escalation rates were applied to actual diesel and LNG prices paid by YEC in late 2015 and early 2016 to generate the fuel feedstock price forecasts[2]. High and Low fuel cost forecasts were created by escalating the fuel feedstock components by the High and Low escalators, respectively, from the NEB cases.

The potential for future local sources of natural gas supply from either local resources (e.g., through development of Eagle Plains resources), or delivered from outside the Yukon Territory by pipeline, was not considered. This forecast for diesel and LNG considers existing sourcing and modes of transportation.

6.1.3.3 Non-Fuel Costs

For the Base and Low cases, the actual non-fuel cost components of the diesel and LNG fuel costs paid by YEC were analyzed and consequently escalated at inflation, or zero escalation when expressed in Real dollars. Non-fuel costs under the High case were inflated at 1% over inflation when expressed in Real dollars. The summary of the inputs and assumptions in the scenarios is shown in Table 6.1.

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[2] The absolute values in the NEB oil and natural gas price forecasts are not used directly. They were used to construct future oil and gas price escalators that were applied to current diesel and LNG prices paid by YEC.

Table 6-1: Summary of the inputs and assumptions in the scenarios

Price Scenario	Fuel Price Assumptions	Non-Fuel Price Assumptions	Exchange Rate Assumption
Base (Reference)	Oil and natural gas prices escalated as per NEB mid-price forecast.	Starting price is based on recent diesel and LNG prices paid by YEC delivered to Whitehorse. Escalation at 0% Real.	Mid- C$/US$ exchange rate assumption.
High	Oil and natural gas prices escalated as per NEB high price forecast.	Starting price is based on recent diesel and LNG prices paid by YEC delivered to Whitehorse. Escalation at 1% Real.	High C$/US$ exchange rate assumption.
Low	Oil and natural gas prices escalated as per NEB low price forecast.	Starting price is based on recent diesel and LNG prices paid by YEC delivered to Whitehorse. Escalation at 0% Real.	Low C$/US$ exchange rate assumption.

6.1.4 Results

Based on the analysis of actual prices of diesel and LNG fuel delivered to YEC, it was determined that the majority of the delivered costs were comprised of shipping, liquefaction and taxes. The fuel (oil) feedstock made up approximately 50% of delivered diesel price, while the natural gas feedstock made up less than 20% of the delivered price of LNG.

Figure 6-1 and Figure 6-2 show the forecast delivered diesel and LNG costs to Whitehorse for the Base, High and Low scenarios. Since the majority of delivered LNG and diesel prices are made up of non-fuel components (shipping and liquefaction), and since these non-fuel cost factors are assumed to escalate at inflation in the Base and Low scenarios, the observed increase in total delivered LNG and diesel price forecasts is relatively suppressed. Table 6-2 shows the diesel and LNG price forecasts as numerical values. The forecast increase in diesel prices between 2015 and 2016 is based on the NEB's assumption (in late 2015) of increases in near-term global crude oil prices, particularly in the High scenario. Oil prices have subsequently increased, but not to the extent predicted by the NEB.

Figure 6-1: Delivered LNG costs to Whitehorse (2016 C$)

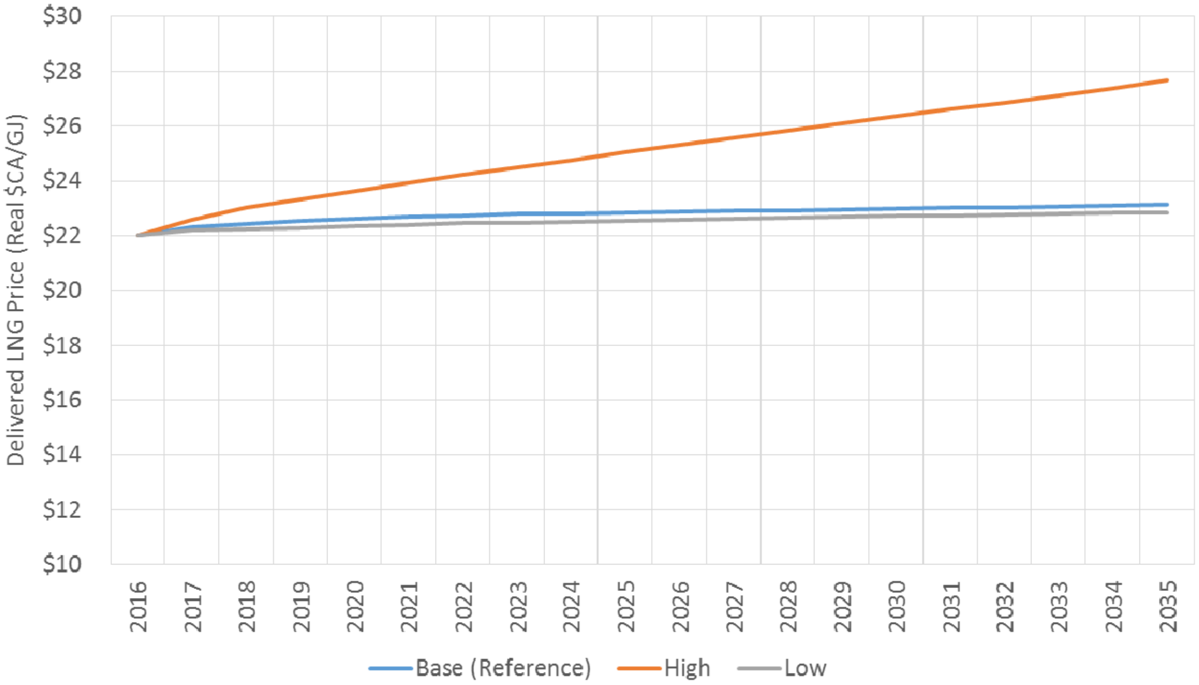


Figure 6-2: Delivered Diesel costs to Whitehorse (2016 C$)

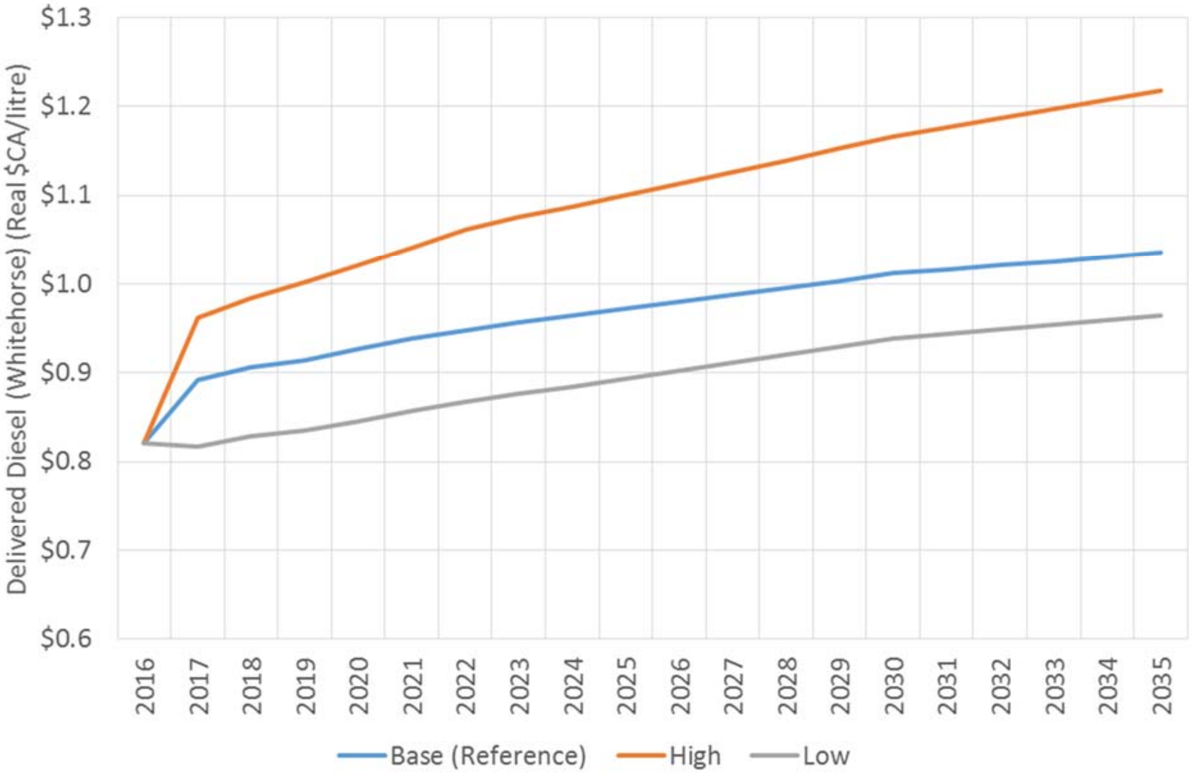


Table 6-2: Delivered Diesel and LNG costs to Whitehorse (2016 Real C$) – Base (Reference) Forecast

Year	**LNG Delivered to Whitehorse C$/GJ**			**Diesel Delivered to Whitehorse C$/litre**		
	Fuel Cost	**Non Fuel Cost**	**Total**	**Fuel Cost**	**Non Fuel Cost**	**Total**
2016	**3.00**	**19.00**	**22.00**	**0.32**	**0.50**	**0.82**
2017	3.33	19.00	22.33	0.39	0.50	0.89
2018	3.44	19.00	22.44	0.41	0.50	0.91
2019	3.53	19.00	22.53	0.41	0.50	0.91
2020	3.61	19.00	22.61	0.43	0.50	0.93
2021	3.68	19.00	22.68	0.44	0.50	0.94
2022	3.74	19.00	22.74	0.45	0.50	0.95
2023	3.79	19.00	22.79	0.46	0.50	0.96
2024	3.82	19.00	22.82	0.46	0.50	0.96
2025	3.84	19.00	22.84	0.47	0.50	0.97
2026	3.87	19.00	22.87	0.48	0.50	0.98
2027	3.90	19.00	22.90	0.49	0.50	0.99
2028	3.93	19.00	22.93	0.50	0.50	1.00
2029	3.96	19.00	22.96	0.50	0.50	1.00
2030	3.98	19.00	22.98	0.51	0.50	1.01
2031	4.01	19.00	23.01	0.52	0.50	1.02
2032	4.04	19.00	23.04	0.52	0.50	1.02
2033	4.07	19.00	23.07	0.53	0.50	1.03
2034	4.10	19.00	23.10	0.53	0.50	1.03
2035	4.13	19.00	23.13	0.54	0.50	1.04
2036	4.15	19.00	23.15	0.5	0.50	1.04

Year	LNG Delivered to Whitehorse C$/GJ			Diesel Delivered to Whitehorse C$/litre		
	Fuel Cost	**Non Fuel Cost**	**Total**	**Fuel Cost**	**Non Fuel Cost**	**Total**
20-year compounded growth	1.6%	0.0%	0.3%	2.6%	0.0%	1.2%

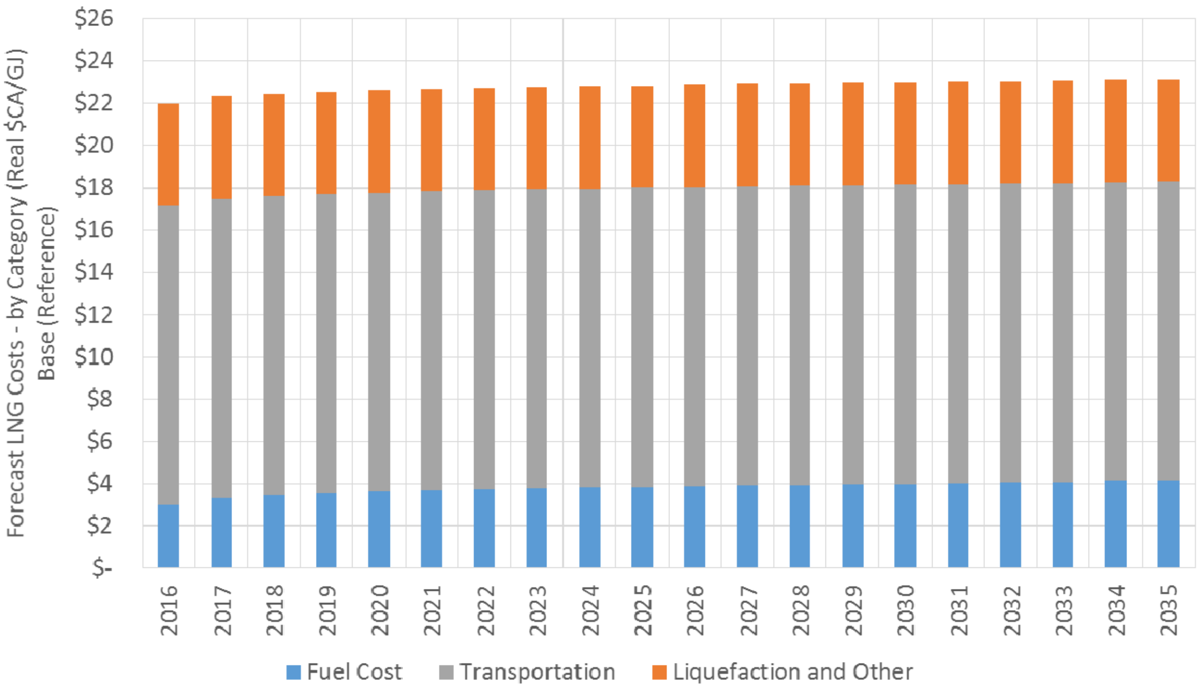
6.1.5 Potential LNG Supply Options

To augment the LNG forecast analysis, YEC recently reviewed other potential LNG delivery options, which may achieve cost savings relative to current supply. A summary of these findings is presented in this section, while details on this investigation are presented in Appendix 6.1.

YEC's current sources of LNG are from Delta (Tilbury Island), in the Lower Mainland of British Columbia (BC), approximately a 2,390 km one way trip to Whitehorse, and Elmworth, Alberta (AB), approximately a 1,524 km trip. Other potential sources of LNG supply include Dawson Creek, BC (approximately a 1,460 km trip) and Fort Nelson, BC (approximately a 988 km trip). As the largest cost component of LNG delivered to YEC is associated with transportation and because these transportation costs are highly correlated with distance, a closer LNG supply source should result in significant savings in the delivered LNG price.

Figure 6-3 shows a breakdown of forecast LNG cost components, assuming the source of LNG is Tilbury Island.

Figure 6-3: Breakdown of forecast LNG cost components – Delta, BC (Tilbury Island) Supply



Further reductions in the delivered price of LNG price could be driven by an increase in the volume of LNG per shipment, above the current volume of 60 m^3 per delivery. Design work has been completed on an optimized B-train configuration with a shipping volume in the range of 80 to 90 m^3 per load. This would represent an increase of up to 50% over current shipping volumes. The trailer design is currently under review by Provincial and Federal authorities for commercial use on the road network in Yukon, British Columbia and Alberta.

Overall, The LNG transportation charge represents the greatest opportunity for future cost savings, due to the economies of scale in larger delivery volumes, and shorter delivery distances. YEC is conservative with respect to estimating cost savings due to the availability of the optimized B-train trailer, as the trailer design has not yet received regulatory approval and has not yet been manufactured for commercial service. Therefore, availability of the optimized B-train trailer is not assumed in the Base (Reference) case LNG price forecasts.

Based on information available at the time the forecast was generated, YEC estimates an initial cost reduction of approximately $8/GJ by sourcing LNG from Dawson Creek with larger shipping volumes realized with the new B-train configuration. This saving assumption is largely based on reduced trucking distances, but it also the benefits of larger (i.e., 80 m^3) LNG loads. This savings assumption is current as of November, 2016.

Table 6-3 presents the four LNG price scenarios analyzed: medium, high, low and optimized.

Table 6-3: Delivered LNG costs with optimized supply to Whitehorse (2016 C$)

Year	**LNG Base (Reference)** **C$/GJ**	**LNG High** **C$/GJ**	**LNG Low** **C$/GJ**	**Optimized LNG** **C$/GJ**
2016	22.00	22.00	22.00	22.00
2017	22.33	22.56	22.18	22.33
2018	22.44	23.01	22.24	22.44
2019	22.53	23.32	22.29	14.64
2020	22.61	23.64	22.35	14.71
2021	22.68	23.92	22.40	14.79
2022	22.74	24.21	22.45	14.84
2023	22.79	24.49	22.48	14.89
2024	22.82	24.77	22.51	14.92
2025	22.84	25.04	22.55	14.95

Year	LNG Base (Reference) C$/GJ	LNG High C$/GJ	LNG Low C$/GJ	Optimized LNG C$/GJ
2026	22.87	25.31	22.58	14.98
2027	22.90	25.57	22.61	15.00
2028	22.93	25.83	22.65	15.03
2029	22.96	26.10	22.68	15.06
2030	22.98	26.36	22.71	15.09
2031	23.01	26.61	22.74	15.12
2032	23.04	26.87	22.78	15.14
2033	23.07	27.12	22.80	15.17
2034	23.10	27.39	22.82	15.20
2035	23.13	27.66	22.83	15.23
2036	23.15	27.93	22.84	15.26

6.1.6 Diesel and LNG price forecasts selected for portfolio analysis

The YEC portfolio analysis used three of the four LNG price scenarios, specifically:

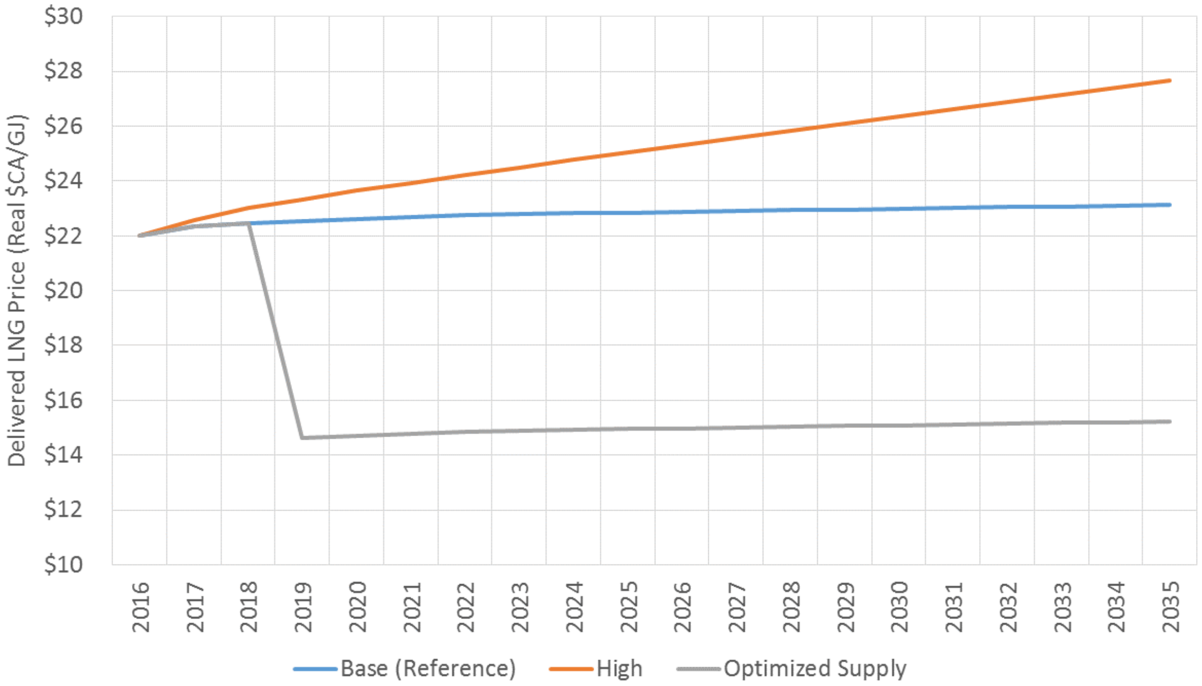
- Base;
- High; and
- Optimized.

The Low LNG scenario presented in Figure 6-1 and Table 6-3 was not selected for the portfolio analysis, as it is very close to the Base scenario.

The Base scenario assumes current LNG shipment volumes and the current LNG source as Tilbury Island. The High scenario assumes same assumptions as the Base scenario, but with the high gas fuel price forecast. The Optimized Supply scenario assumes the Base case fuel price forecast, but with 80 m^3 shipping volumes and LNG sourced from Dawson Creek. The B-train configuration with larger shipping volumes is assumed to be commercially available to serve the Dawson Creek to Whitehorse route starting in 2019.

Figure 6-4 shows the three scenarios selected as input for the portfolio analysis. The case with the potential cost reduction is labeled “Optimized Supply”. The numerical values for those three scenarios are presented in Table 6-3. Note the significant price drop in 2019; this is due to reduced transportation costs, and lower natural gas prices possible due to the alternative supply arrangements discussed above.

Figure 6-4: Delivered LNG costs to Whitehorse for selected scenarios (Real 2016 C$)



6.2 Social Cost of Carbon

On December 9, 2016, Yukon signed onto the Pan-Canadian Framework on Clean Growth and Climate Change (the Framework). The Framework is both a concrete plan with key commitments and also a launching point for further collaboration across Canada in addressing and adapting to the impacts of climate change and shifting to a clean, renewable economy. The Framework introduces carbon pricing across Canada. Application of a cost of carbon is one of the key policy instruments used by many governments to reduce greenhouse gas (GHG) emissions.

Given the eventual application of carbon pricing across Canada, YEC chose to assess the impact of a social cost of carbon (SCC) within the 2016 Resource Plan, specifically on the economics of the resource options studied and in the portfolio analysis. The SCC represents an assigned monetary value of the *net* harm of human caused by GHG emissions from burning coal, oil and natural gas (fossil fuels). The SCC is expressed in dollars per tonne of CO_2 equivalent ($/t$CO_2$e).

The SCC considers possible effects to the Earth's managed and unmanaged systems such as reduced output from agriculture, forestry, fisheries, the extinction of non-commercial species, and the destruction of major ecosystems.

The effects of human-caused GHG emissions are difficult to quantify, due to uncertainties such as:

- Accurate estimating of the global harm of GHG emissions. Climate change is a global problem and needs to be observed at global level, which introduces highly complex causes and effects.

- Accurate estimating of harms of low probability high impact events. Some SCC estimates place little value on low probability catastrophic outcomes, such as the possibility of runaway methane release in the Arctic, the collapse of the West Antarctic Ice Sheet, or the reversal of the Gulf Stream. Recent SCC estimates attempt to quantify and then incorporate these potential costs, but there is considerable uncertainty about what values to use.
- Selection of the discount rate used in the economic analysis on the SCC. A higher discount rate favours near-term actions, placing less emphasis on future harm. The SCC generally considers long-term impacts on the economy and the environment, so that relatively low discount rates are applied to the SCC.

Due to these uncertainties, the range of SCC estimates is necessarily broad. A review of current estimates deemed credible, and a benchmarking of policy-driven GHG reduction measures by Canadian jurisdiction is presented in Appendix 6.2.

A key consideration in the adoption of a SCC for YEC's Resource Plan is ratepayer, regulatory and political acceptability. The Yukon Utilities Board is primarily an economic regulator, with the mandate of approving low-cost solutions for ratepayers. The Framework adoption now makes it clear that the cost of carbon must be considered in subsequent regulatory proceedings. In addition, the Framework considerably narrows the potential range of carbon prices applicable to thermal resources in the Yukon. However, Yukon-specific legislation regarding a carbon price is still forthcoming. Therefore, YEC has adopted a conservative approach in its SCC forecast, by adopting a reputable third-party forecast.

YEC used the most recent forecast from the US Environmental Protection Agency[3] (EPA) to investigate the impact of the SCC on the selection of future generation and transmission resources. The range of SCC as provided by the EPA is shown in Table 6-4.

Table 6-4: Social Cost of Carbon ranges by EPA (2016 Canadian Dollars)

US EPA (2016 C$)	**2015**	**2035**
Lowest estimate	$60	$90
Highest estimate	$174	$279

The EPA has assessed a wide range of outlooks for the SCC by assessing proposed regulations, such as vehicle or generation plant emissions standards. However, the EPA outlook does not include the effects of low probability catastrophic outcomes listed above.

Given this consideration, together with the wide uncertainty in SCC outlooks, for its SCC, YEC has accepted the low range of the EPA outlook. That is, a SCC of $60/tCO$_2$e in 2016 and $90/tCO$_2$e in 2035 (in 2016 C$), with equal increase for each year from 2016 to 2035.

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[3] US EPA, Social Cost of Carbon, 2016. https://www.epa.gov/climatechange/social-cost-carbon

The effects of the recommended SCC values on the cost of LNG and diesel at YEC's generating facilities are presented in Table 6-5.

Table 6-5: Effects of Social Cost of Carbon on the proxy cost of LNG and diesel generation

Proxy Cost of SCC (2016 C$/kWh)	**2015**	**2035**
LNG	0.026	0.040
Diesel	0.040	0.062

If the portfolio scenarios with applied SCC were accepted, the actual cost to YEC or its ratepayers would not increase by these amounts, but future decisions made by YEC on the selection of resources would handicap GHG-emitting generating assets by these amounts, relative to non-emitting generating resources such as hydro, wind and solar power.

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7 Risks and Uncertainties

7.1 Introduction

Reliable electricity is crucial for the safety of Yukon citizens and the success of local communities and businesses. Yukon's electricity system is islanded and therefore must be self-sufficient. That is, the electricity generation in the Yukon must meet local requirements at all times. Unlike most systems in North America and around the world, the Yukon system has no interconnections to neighbors, which most electricity utilities occasionally rely on to share resources and meet peak electricity demand. The Yukon system must be totally reliant on internal resources to meet demands during periods of extreme need, which typically occurs during cold winter days. Reliability metrics and standards developed in other parts of North America need to be reviewed and applied very carefully to the Yukon, as the consequences of sustained electricity outages in the north can be severe. A long-duration power outage in most of the world carries the discomfort of heat and humidity. In contrast, a sustained power outage in a Yukon winter can be life-threatening. Such an outage could also result in significant costs such as frozen and burst water pipes leading to the flooding of residences and businesses. YEC must provide a supply solution that can deliver reliable electricity on cold and dark winter days.

To recap the steps in developing YECs Resource Plan, they are repeated from Chapter 1:

1. Forecast future electricity load (demand);
2. Create an inventory of existing energy supplies;
3. Determine potential shortfalls;
4. Create an inventory of potential energy supplies and conservation options;
5. Forecast future fuel and carbon prices;
6. Assess risks and uncertainties relevant to the Resource Plan;
7. Analyze the portfolio of options;
8. Draft an action plan; and
9. Finalize the Plan.

This Chapter, corresponding to Step 6 above, details the process undertaken for the Resource Plan risk assessment, and how this assessment informed subsequent steps 7, 8 and 9.

Step 6 is the critical process of assessing uncertainties and risks. This includes an assessment of current and future risks to the Plan, including but not limited to resources, regulatory and policy issues, the load forecast, fuel price forecast, and climate change

To provide clarity, the following definitions are provided:

- **Consequence** is an outcome or impact of relevance to the planning process. Consequences are usually tied to business of planning objectives and can be positive or negative, easily measurable or difficult to quantify;

- **Uncertainty** is the state of not knowing which one of several potential future consequences could occur, i.e. the state where there is the potential for more than one future outcome;

- **Risk** is the potential of losing something of value if a consequence occurs. The key risks to utilities are usually thought of as negative impacts such as: financial losses, damage to infrastructure, reduced reliability, or loss of reputation.

In planning to meet customer demands, it is important to separate risks from uncertainties. Some consequences may be negative, but could be excluded from in depth consideration if their likelihood is small enough. Some uncertainties may be large and complex, but can be passed over if they don't lead to large consequences. Ultimately, the focus of analysis needs to be on risk. In the planning context, risk has to be understood, quantified, and appropriately managed.

The fundamental risks to be addressed by the YEC Resource Plan are:

- Inadequate electricity supply in terms of insufficient generation and transmission capabilities, which reduces YEC's ability to 'keep the lights on', and leads to reduced reliability; and
- Over-building or over-procuring electricity supply, which could lead to higher rates. Capital intensive projects pose major risks to ratepayers if the future load projections used to justify these projects do not materialize.

The major uncertainties identified in the 2016 Resource Plan are related to the following four broad categories:

- Resources,
- Regulatory and Policy,
- Load Forecast, and
- Climate Change.

The uncertainties and associated risks are discussed in detail in the following section.

7.2 Uncertainties and Risks

7.2.1 Resource Uncertainties and Risks

The following uncertainties are related to resources:

- **Generation fuel price volatility and escalation uncertainty, both short and long-term.** The resulting risk is a rate increase caused by increased portfolio cost;
- **Hydrology uncertainty.** The potential for a multi-year drought could result in lower hydro generation than expected. The resulting risk is insufficient supply of energy and/or capacity;
- **Project feasibility uncertainty.** The potential for technical, financial or regulatory problems during project planning or construction, which could result in abandoning specific lower cost resources in favor of more expensive resources and/or delays. The resulting risk is a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply;
- **Equipment reliability uncertainty.** The possible failure of generation and transmission assets which can lead to outages. The resulting risk is insufficient energy and/or capacity supply;
- C**onservation delivery uncertainties.** YEC enabled conservation activities may not produce expected savings. The resulting risk a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply;
- **IPP supply uncertainty.** The possibility of bankruptcy or failure of contracted generation assets, or the failure of contracted IPPs to reach commercial operation (multiple causes) can result is some projects not being completed or delayed. The resulting risk a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply;
- **Labour and resource uncertainty.** Future periods of high economic activity could cause labour and resource constraints. The high economic activity could be caused by a coincident boom in mining, oil & gas and YEC's own projects. As a consequence the projects could be delayed and

their costs increased. The resulting risk a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply; and

- **Capital availability uncertainty.** The capital required to execute the action plan proposed by the Resource Plan could be unavailable. This is particularly possible in financing for very large capital projects which could involve multiple levels of government and/or private sector interests. The resulting risk is a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply.

7.2.2 Regulatory and Policy Uncertainties and Risks

The following are uncertainties related to regulation and policy:

- **Regulatory uncertainties.** These uncertainties could lead to proposed electricity supply projects being disallowed by the regulator or to protracted legal and regulatory processes delaying project approvals or relicensing. The resulting risk is a rate increase caused by increased portfolio cost and/or insufficient energy and/or capacity supply due to introducing more expensive replacement projects and delaying project in-service date;
- **Policy uncertainties related to specific generation types.** These uncertainties could cause specific generation types become significantly disadvantaged, such as a carbon tax disadvantaging the operations of diesel and LNG, after those assets are operational. The resulting risk is a rate increase caused by increased portfolio cost.

7.2.3 Load Forecast Uncertainties and Risks

Uncertainty is inherent in forecasting. Actual electricity demand will invariably differ from forecasts. Nevertheless, electricity providers including YEC must forecast future demand requirements, and responsibly plan to meet these needs. To mitigate the uncertainty in forecasting, a plan with flexibility needs to be prepared to avoid unnecessarily over-building of supply, or avoid consequences of not building sufficient supply to meet the demand.

There are several substantial uncertainties in the load forecast:

- **Economic development uncertainties.** Federal transfer payments and mining are the major economic drivers in the Territory and a change in either of these can affect the load. Mining load can develop relatively quickly, potentially in a shorter timeframe than it takes to serve these customers with electricity generation or transmission grid upgrades. For example, a single new connected metal mine could increase YEC's load by 25% or more. The development and subsequent operation of mines is a relatively risky venture due to cyclical and volatile global commodity prices, and due to financing and permitting risks. Based on the data provided by mining companies operating in the Yukon, the average expected mine life is 10 years. Attrition in a large electricity load, such as a mine, served by YEC can result in stranded assets (investments). Also, a future reduction in federal transfer payments can reduce economic activity and consequently reduce forecast load. If the load forecast does not capture the discussed developments, the resulting risk is insufficient energy and/or capacity supply and/or increased rates caused by reduced load and, consequently, reduced sales.
- **Electrification uncertainties, as driven by policy or technological change.** This includes the potential for increased numbers of electric vehicles and the changeover of space heating in buildings. The resulting risk is the resulting risk is insufficient energy and/or capacity supply;
- **Technological uncertainties,** either due to policy changes (such as the introducing more stringent local building codes), or as-yet unanticipated developments in technology such as what

has already occurred with LED lighting. The resulting risk is increased rates caused by reduced load and, consequently, reduced sales; and

- **Uncertainties over distributed electrical generation technologies** such as solar panels, which could lead to the risk of lower electricity demand to be serviced by YEC, or a significant change in the annual pattern of demand. The resulting risk is increased rates caused by reduced load and, consequently, reduced sales.

7.2.4 Climate Change Uncertainties and Risks

The following are uncertainties related to climate change[1]:

- **Hydrology uncertainty.** Climate change could result in seasonal hydrology patterns outside of historical variability. Although the early indications of the effects of climate change in the Yukon are a net increase in precipitation, the impacts would be particularly problematic if overall flows into YEC's hydro generation assets were to decrease. Another consequence is if the seasonal or yearly precipitation variability was accentuated, leading to floods or extended periods of drought. The resulting risk is oversupply of energy and/or capacity, or insufficient energy and/or capacity supply. YEC is in the process of developing the hydrological models that will incorporate the impact of climate change into the future inflow forecasts for all the existing hydropower plants. The climate change affected inflow forecasts will be used in the future updates of the technical attributes of the affected resources;

- **Temperature uncertainty.** Overall warming could decrease winter demand due to reduced space heating. The resulting risk is reduced load and consequently increased rates increased rates caused by reduced loads and, consequently, reduced sales; and

- **Climate change uncertainties.** Long-term climate changes could result in changes in net migration to the Yukon, with the associated impact on Yukon electricity demand. For example, an influx of climate change refugees from other parts of the world, or an influx of people from other parts of Canada due to increasingly temperate Yukon winter conditions. Climate changes could also introduce economic opportunities to the Yukon economy and industry. For example, a longer growing season in the Territory could increase electricity demand in the agricultural sector. Decreased sea ice could cause increased Arctic Ocean shipping. The resulting risk is increased load and consequently insufficient energy or/capacity supply.

7.3 Incorporating Uncertainty

The previous section laid out key uncertainties and risks that could potentially influence the comparison of resource options with respect to the Resource Plan's key questions. Where possible, YEC quantified these uncertainties in the analysis, results and conclusions of the Resource Plan. This section describes the approaches to incorporating uncertainty in the Resource Plan analysis. These approaches are addressed in more detail in the Chapter 8: Portfolio Analysis.

As presented in Table 7-1, the Resource Plan analysis uses a mix of approaches to explore how uncertainty impacts the comparison of options and the strategies to manage the residual risks of the

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[1] In compiling this risk summary, the following report was referenced: Streicker, J., 2016. Yukon Climate Change Indicators and Key Findings 2015. Northern Climate ExChange, Yukon Research Centre, Yukon College, 84 p. The report presents indicators of temperature, precipitation, fire history, sea ice melt, ocean oscillation patterns, and greenhouse gas emissions. Sources of information contained in the report include both scientific and traditional knowledge.

Action Plan. Professional judgment informed by quantitative analysis and qualitative information is required when interpreting data, balancing objectives, and making decisions.

Table 7-1: Approach to Incorporating Uncertainty

Approach	Brief Description	Example of Application
Scenario Analysis	Using a few, select combinations of uncertain variables.	- Mining development scenarios within the load forecast. - Fuel price scenarios for thermal resources. - Social cost of carbon to accommodate regulatory uncertainty related to greenhouse gas emissions costing
Conservative Point Estimates	Incorporating uncertainty in a key parameter by adopting a 'conservative' value.	Adopting a conservative (historically low) value for firm energy and dependable capacity from YEC's existing hydro assets.
Subjective Probability Elicitation	In cases where good historical data does not exist, uses knowledgeable specialists to construct a description of the range of uncertainty.	Savings from demand side management (DSM).
Parameterization of Historical Observations	Uses historical data to derive a statistical description of the range of uncertainty.	Water inflows into the YEC hydro system.
Best Estimates	Does not take into account uncertainty in any fashion; usually reserved for variables where uncertainty is assumed to have a small or manageable impact.	Energy from wind projects.

Further details of these approaches and the modeling involved can be found in Chapter 4: Load Resource Balance and Chapter 8: Portfolio Analysis.

7.4 Risk Mitigation

The goal of the Resource Plan with respect to risk is to recommend measures that will efficiently allocate capital and other resources to bring risks to appropriate levels. This wording is selected deliberately, in that the risks inherent in providing electricity service cannot be completely eliminated. That is, there will always be residual risks, regardless of the systems, practices, and backup infrastructure that is put in place to manage risk. The measures taken to decrease risks often involve exponentially increasing expenditures for increasingly marginal gains. Providing electricity service is a complex tradeoff between rate impacts, supply reliability, environmental and social requirements. YEC has attempted to strike the appropriate balance between these factors, through the use of utility best practices, and through the solicitation and review of stakeholder and customer feedback.

The following is a high-level overview of mitigation measures proposed by YEC to manage risks. Key specific measures, such as recommended new resources needed to meet future reliability requirements, are presented in the Action Plan Chapter (Chapter 9).

Some active risk mitigation measures that YEC has undertaken in the preparation of the Resource Plan include:

- **Scenarios.** Development and analysis of scenarios. Faced with the uncertainties inherent in the industrial load forecasts, the forecast approach focuses on assessing a range of industrial-related scenarios. The fourteen scenarios reviewed cover a wide but plausible range of industrial sector outcomes. To address uncertainties in the diesel and LNG price forecast, three scenarios were developed for each of the diesel and LNG price forecasts. Similarly, two scenarios were analyzed to address uncertainty of the carbon pricing by comparing portfolios with the social cost of carbon and without it. Resource plans tested and developed for these scenarios allow YEC to balance the tradeoff between risk and cost with respect to future possible outcomes;

- **Prudent planning criteria**, for example, the N-1 criteria. When applied by YEC throughout the planning period, this criteria allows for customer reliability despite major generation and transmission equipment failures;

- **Regulatory participation.** Active participation in and support of regulatory and legal processes.

- **Load Monitoring.** YEC is constantly monitoring developments with respect to new large potential loads. This includes ongoing communications with potential industrial development proponents and government departments, particularly with respect to potential mining projects;

- **Updates.** YEC will update elements of the Resource Plan in the event of a significant and material change to the external environment. This could include major changes to government policy, transformative new technologies, climate change, or major new customer loads;

- **Plan Flexibility and Replacement Resources.** YEC's Resource Plan will incorporate the need for flexibility to deal with risks such as major and sudden changes in grid loads, and the inability to develop a preferred resource proposed in the Action Plan. In light of ongoing uncertainties, the Action Plan needs to be resilient and robust under various potential load scenarios and regulatory, financial and development outcomes. For example, a portfolio of relatively small, scalable and modular assets presents a lower risk than a single large asset, in terms of regulatory approvals, financing, fuel diversity, policy changes and resourcing. YEC will continuously consider the scalability of proposed generation and transmission assets planned to meet electricity demand growth. As an example of scalability, YEC's LNG facility completed in 2015 was built with the expansion potential for a third unit, which is now recommended in the Action Plan as an attractive capacity option. YEC will consider the balance between potential lower costs due to economies of scale for larger solutions, versus the ability of smaller, incremental supply solutions to more closely match growth; and

- **Rate Risk Mitigation.** The servicing of new large industrial electricity demand will require project-specific negotiations and joint planning to determine if mutually acceptable arrangements and opportunities can be found, including appropriate risk management and mitigation measures to protect all other grid-served customers from unacceptable rate risks. In the case of the larger off-grid mine projects, initial operation could commence using fossil fuels and on-site power generation (as was the case with the Minto Mine prior to connecting to the grid in 2008), with any grid connected generation commitments being linked to the completion of new infrastructure with appropriate third-party contributions towards planning and construction costs. Such an approach was followed with Carmacks Stewart Transmission Project[2] and Mayo B. A sufficiently large and stable load extending over 20 or more years would also likely be needed to ensure that the energy generated by new bulk power assets is fully utilized over a reasonable period of years.

Table 7-2 summarizes uncertainties, risks and mitigation measures.

Table 7-2: Summary of Uncertainties, Risks and Mitigation Measures

Resources			
Uncertainty Category	**Uncertainty**	**Risk**	**Proposed Mitigation within the Resource Plan**
1	Generation fuel price	Increased rates due to Increased portfolio cost	Scenario Analysis. Test the portfolios under different fuel price scenarios.
2	Hydrology	Insufficient supply of energy and/or capacity	Prudent Planning Criteria. Implement prudent planning criteria to provide reasonable reserve margins (backup) to account for reduced water inflows.
3	Project Feasibility	Increased rates due to Increased portfolio cost and/or insufficient energy and/or capacity supply	Plan Flexibility and Replacement Resources. Recommend replacement resources with similar attributes, in the event that one resource becomes infeasible and follow stagegate process to reduce risk.
4	Equipment reliability	Insufficient energy and/or capacity supply	Prudent Planning Criteria. Implement prudent planning criteria to provide reasonable reserve margins, such as single contingency (N-1) criterion.

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[2] Carmacks Stewart Transmission Project would not have proceeded absent YEC securing a material contribution towards the Carmacks Stewart Main Line from Minto mine through a Power Purchase Agreement.

Resources			
Uncertainty Category	**Uncertainty**	**Risk**	**Proposed Mitigation within the Resource Plan**
5	Conservation delivery	Increased rates due to increased portfolio cost and/or insufficient energy and/or capacity supply	Plan Flexibility and Replacement Resources. Recommend replacement resources with similar attributes, in the event that one resource becomes infeasible.
6	IPP Supply	Increased rates due to increased portfolio cost and/or insufficient energy and/or capacity supply	Plan Flexibility and Replacement Resources. Recommend replacement resources with similar attributes, in the event that one resource becomes infeasible.
7	Labour and resources	Increased rates due to increased portfolio cost and/or insufficient energy and/or capacity supply	Plan Flexibility. A portfolio of relatively small, scalable and modular assets presents a lower risk than a single large asset in terms of resourcing.
8	Capital availability	Increased rates due to increased portfolio cost and/or insufficient energy and/or capacity supply	Plan Flexibility. A portfolio of relatively small, scalable and modular assets presents a lower risk than a single large asset in terms of financing.

Regulatory & Policy			
Uncertainty Category	**Uncertainty**	**Risk**	**Proposed Mitigation within the Resource Plan**
1	Regulatory	Increased rates due to increased portfolio cost and/or insufficient energy and/or capacity supply	Regulatory Participation. Active participation in and support for regulatory and legal processes. Plan Flexibility and Replacement Resources. Recommend replacement resources with similar attributes, in the event that one resource becomes infeasible.
2	Policy	Increased rates due to Increased portfolio cost	Plan Flexibility. A portfolio of relatively small, scalable and modular assets presents a lower risk than a single large asset, in terms of policy.

Regulatory & Policy			
Uncertainty Category	Uncertainty	Risk	Proposed Mitigation within the Resource Plan
			Rate Risk Mitigation. Outside funding to be provided to offset rate increase.

Load Forecast			
Uncertainty Category	Uncertainty	Risk	Proposed Mitigation within the Resource Plan
1	Economic development	Insufficient energy and/or capacity supply and/or increased rates due to reduced loads and, consequently, reduced sales	Load monitoring. Regular monitoring of the Yukon economy and industrial developments and load forecast updates. Plan Flexibility. A portfolio of relatively small, scalable and modular assets presents a lower risk than a single large asset, in terms of policy.
2	Electrification	Insufficient energy and/or capacity supply	Scenarios. Develop Resource Plan under different load scenarios.
3	Technology	Increased rates due to reduced loads and, consequently, reduced sales	Scenarios. Develop Resource Plan under different load scenarios.
4	Distributed generation	Increased rates due to reduced loads and, consequently, reduced sales	Scenarios. Develop Resource Plan under different load scenarios.

Climate Change			
Uncertainty Category	**Uncertainty**	**Risk**	**Proposed Mitigation within the Resource Plan**
1	Hydrology (water inflows)	Insufficient energy and/or capacity supply or oversupply of energy and/or capacity	Updates. Update technical attributes of affected resources to reflect the change. Update Resource Plan to incorporate climate-change induced effects.
2	Temperature	Increased rates due to reduced loads and, consequently, sales	Updates. Update load forecast to reflect the temperature caused change. Update Resource Plan to incorporate climate-change induced effects.
3	Climate change	Insufficient energy and/or capacity supply	Updates. Update load forecast to reflect the climate caused change. Update Resource Plan to incorporate climate-change induced effects.

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8 Portfolio Analysis

8.1 Portfolio Analysis Methodology

The goal of portfolio analysis is to select an optimum set of resources that best meet YEC's future energy and capacity needs at the minimum cost while meeting environmental, social and economic objectives. A portfolio is a combination of resource options, such as energy conservation, wind power, hydroelectricity and thermal generation, and the associated transmission lines required to bring electricity to customers. Each portfolio contains a unique mix of conservation and generation assets, with each asset being developed at the appropriate time to meet YEC's future needs over the planning horizon. Each portfolio needs to meet the technical, financial, environmental, social and economic objectives of YEC and its customers.

Energy planning is an exercise in tradeoffs between cost, reliability, environmental, social and economic considerations. Some of these factors are easier to quantify, such as the strict costs arising from the procurement and ongoing operation of generation assets. Some environmental impacts, such as the cost of GHG emissions can also be quantified. However, many remaining factors cannot be easily quantified.

The future is far from certain, and responsible planning requires YEC to consider and address future uncertainties, such as electricity demand, fuel prices, government policies, and/or capital availability. Therefore, a scenario-based approach was used in which scenarios were developed, and then portfolios were assembled and tested for each scenario.

The portfolio analysis was performed in two sequential steps. First, a quantitative technical and financial evaluation was completed to identify portfolios which meet future energy and capacity needs, while minimizing total capital and operating costs. In the second step, a primarily qualitative environmental, social and economic evaluation was completed on each portfolio. The goal was to create portfolios that meet technical, environmental, social and economic requirements, while minimizing total capital and operations & maintenance costs.

The following sections outline the methodology used for both the steps of the portfolio analysis and scenario development, as well as present the results of the portfolio analysis.

8.1.1 Technical and Financial Evaluation Methodology

The technical and financial evaluation is aimed to identify a set of resource options that meets the energy and capacity planning criteria at the lowest cost. The cost is expressed as the present value of all annualized capital and operating & maintenance (O&M) expenditures over the planning period.

Portfolio optimization is an exercise similar to filling in a series of puzzles (the portfolio) with the puzzle pieces representing different resource options. The size of the puzzle grows with time as forecast load changes. Filling the portfolio in every year is mandatory in order to meet expected load growth. There is nearly an infinite number of possible solutions, given the range of different resource options available, the ability to scale up or down the size of these resources, the timing of resources construction, and their locations. The goal of the exercise is to financially evaluate each portfolio that meets the energy and capacity planning criteria and select one with the minimal present value of all the expenditures.

Given the complexity of the exercise, a sophisticated, industry-accepted, capacity expansion optimization model, the System Optimizer, was used for the portfolio analysis. This is the first time YEC has used this type of a rigorous analytical optimization approach to identify the optimum portfolios, consistent with large-utility best-practices. This approach is more sophisticated than that used by YEC in the 2011 Resource Plan. The 2011 Resource Plan portfolio analysis methodology was similar, with the objective of minimizing the present value of all the expenditures, while meeting energy and capacity planning criteria. Instead of using an optimization model to financially evaluate a large number of portfolios meeting the planning criteria and select the optimal one, the analysis in the 2011 Resource Plan was focused on evaluating only a limited number of portfolios satisfying a plausible range of resource combinations. The portfolios were developed using professional judgement, with the selection of the generation resources within each portfolio and determination of portfolio costs undertaken manually. The present value of all the expenditures was calculated for each portfolio and the portfolio with the minimal present value was selected as the optimal portfolio. The 2016 Resource Plan provided a more cost effective solution as a consequence of evaluating a significantly larger number of portfolios, while the methodology used in the 2011 Resource Plan did not guarantee the most cost effective solution due to a limited number of portfolios evaluated.

Considering the high cost of the System Optimizer model and the low expected frequency of its use by YEC, the purchase of the model could not be justified. Consequently, the System Optimizer model owned by BC Hydro was used for portfolio analysis. The model simulations were performed by BC Hydro staff with YEC staff providing the input data and analyzing the output data.

The System Optimizer Model is a mixed integer programming optimization model developed by Ventyx /ABB (formerly Global Energy Decisions, Henwood) and has been adopted by several utilities in North America to aid in the development of resource plans. The model selects an optimal generation and transmission resource expansion sequence given a set of input assumptions (e.g. load forecast, fossil fuel prices, available resource options including DSM, Social Cost of Carbon, energy and capacity planning criteria, resource generation profiles) and constraints (e.g. transmission line limits, installed and dependable capacity of resources). The objective of the model is to minimize the present value of costs, including the capital and operating costs for new resources, as well as operating costs of existing resources to meet a given load forecast and planning criteria.

The model takes into account characteristics of resources beyond the LCOE and LCOC rankings, such as firm energy, dependable capacity, average energy and monthly energy profiles of resources. The model also takes into account the transmission system, which allows a selection of resources that are located favorably in terms of transmission losses and constraints. As a consequence, the model provides the optimal selection of the resource options that best complement the existing system and its constraints.

To ensure that the model generated meaningful outputs, all the model outputs were quality controlled.

The major portfolio analysis inputs were:

- Energy and peak demand forecast (20 year horizon);
- Resource financial attributes (capital and operating & maintenance expenditures);
- Resource technical attributes (annual energy, firm energy, installed capacity, dependable capacity, project life, construction lead time, dispatchability, transmission line transfer capabilities and losses);
- Discount rate. In converting future to present costs, a real discount rate of 3.38% was used, consistent with YEC's cost of capital; and
- Social cost of carbon.

The major portfolio analysis outputs are:

- A set of resource options (generation, transmission, DSM) that meets the energy and capacity planning criteria, while minimizing the present value of both the capital and O&M expenditures; and
- Monthly energy generated by each resource in the portfolio.

The major portfolio analysis constraints were:

- Firm energy of all the existing and future resources needed to meet or exceed the energy load. Hydro energy generation was modelled under lowest water conditions;
- Dependable capacity of all the existing and future resources needed to meet or exceed the peak demand. Dependable capacity planning criterion was assessed under single contingency (N-1) criterion;
- Minimum and maximum capacities of generating stations;
- Transfer capability of transmission lines; and
- Sequential stations investment constraints (e.g., all units of resource A must be built before the first unit of resource B is built).

To mimic decision making that would take place in real world, the following assumptions were made in the portfolio analysis:

- Operational expenditures were expressed as the present value of the entire portfolio over the 20 year planning horizon, under average conditions for each resource. For example, to determine the operational expenditures, hydro energy generation was modelled under average water inflow conditions.
- If the firm energy and/or dependable gap could not be closed due to resource unavailability caused by long lead time to introduce the resource, another resource with a shorter lead time was recommended, even though it could potentially have less preferred financial attributes.
- If a decision needed to be made between: a) overbuilding significantly and b) not meeting planning constraints marginally, a decision was made not to overbuild. As a consequence, it was preferred to have a minimal deficiency in not meeting planning criteria within few years in the planning period, rather than significant overbuilding. For example, if a capacity gap under the single contingency (N-1) criterion of 1MW could be closed only by using a resource with capacity of 10 MW, a decision was made to keep the marginal gap in a year, rather than overbuild. As the portfolio analysis presented in the following sections demonstrated, the only instance the dependable capacity criterion was not met under conditions described above was for the Low Industrial Activity Scenario in 2025.
- The resources' life would continue after the end of the planning period unless resources' end of life was within the planning period. As a consequence, the salvage value of the resources at the end of the planning period was not deducted from the present value of the expenditures. The present value was determined as the sum of annualized capital and O&M expenditures over the planning period. This was consistent with the expectation that the long life resources would be used after the end of the planning period in 2035 since YEC would need to meet load after 2035.

The technical and financial attributes of each resource options used as inputs to the System Optimizer model are presented in Chapter 5.

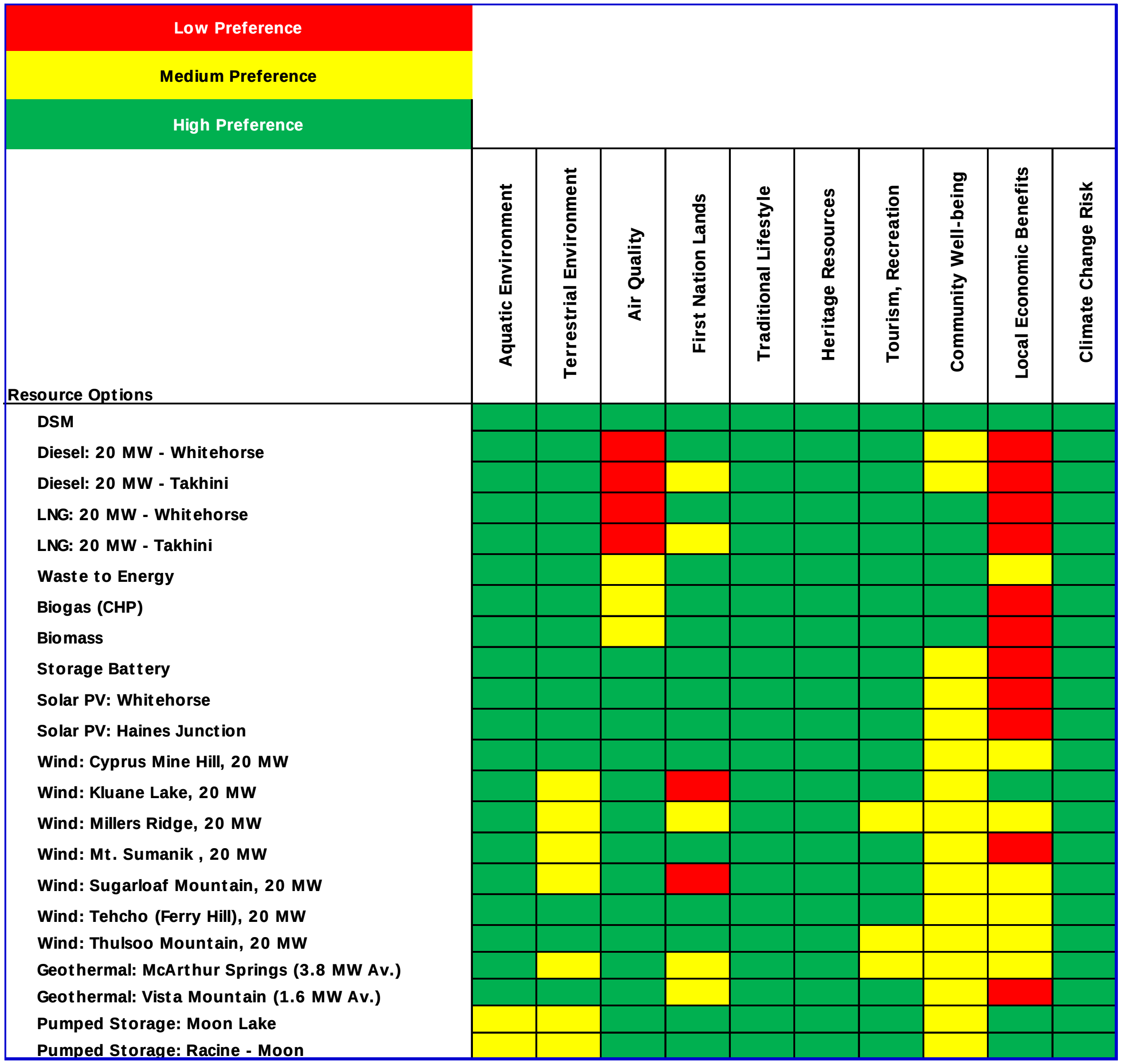
8.1.2 Environmental, Social and Economic Evaluation Methodology

The environmental, social and economic evaluation was based on the environmental, social and economic attributes presented in Chapter 5. The selection of the environmental, social and economic attributes for each resource option was based on an understanding of stakeholder interests, including those commonly included in project impact assessments and permitting processes. Attributes were also selected based on industry best practices and knowledge gained from previous resource planning exercises and from the public interests identified in the Electricity Values Survey. Figure 8-1 presents the environmental, social and economic evaluations of all of the resource options considered in the Resource Plan.

Each resource portfolio generated by the System Optimizer model was examined with respect to environmental, social, and economic characteristics. The first test was to examine a portfolio for adverse effects that could not be mitigated. If this test was passed, each resource option included in the portfolio would be examined in detail to understand the overall benefits, challenges and potential effects of the portfolio.

In addition, an analysis was conducted to determine whether there were environmentally, socially, or economically comparable options available that were not strictly output from the technical and financial modelling. By doing so, those resources options excluded for technical or financial reasons could be reconsidered for inclusion if the options selected in the technical and financial evaluation could not be pursued for various reasons, such as for example geotechnical problems for a small hydro project discovered in the next, more detailed, project stage.

1 *Figure 8-1: Environmental, Social and Economic Attribute Analysis – All Resource Options*



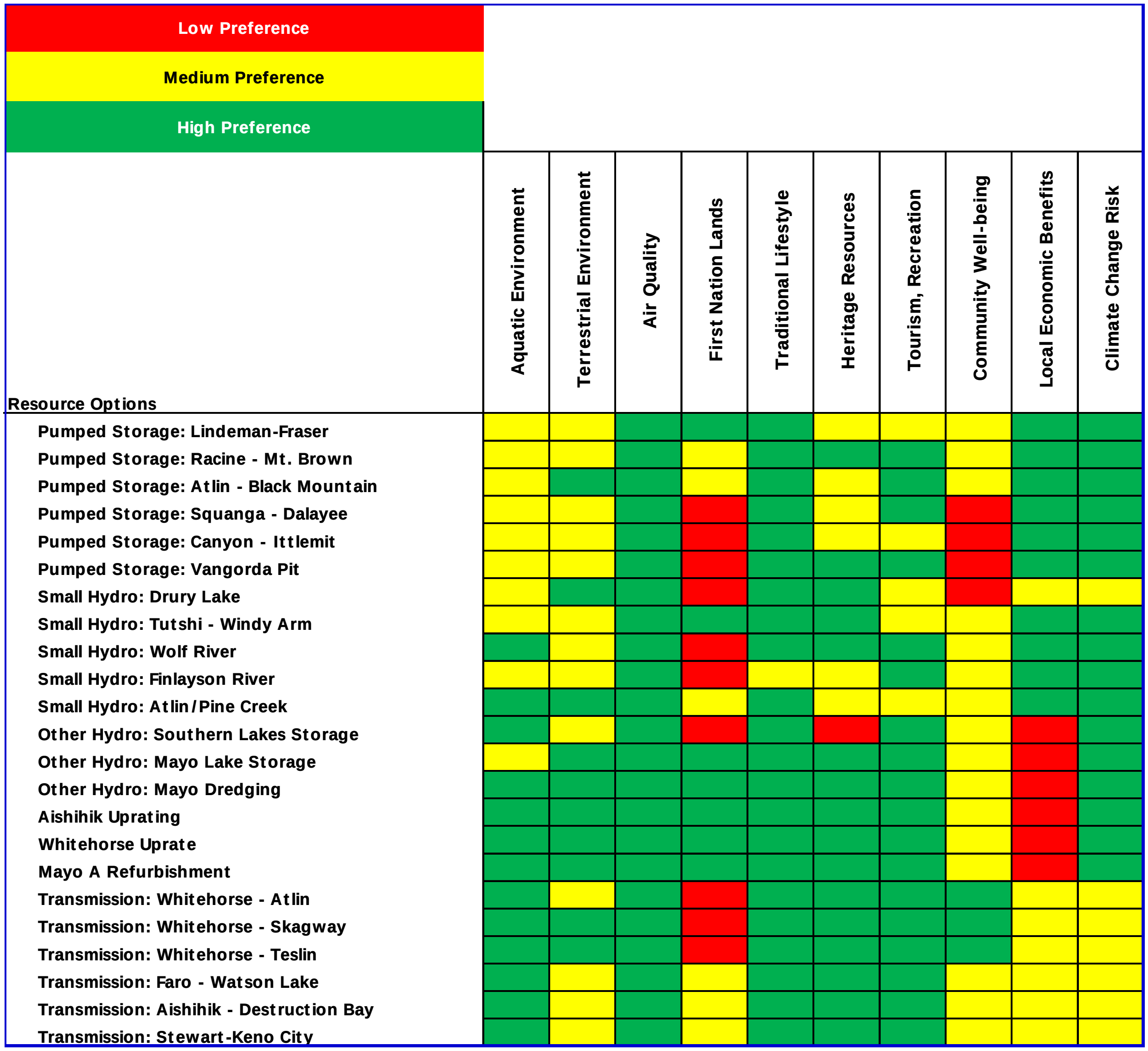
🟥 **Low Preference**

🟨 **Medium Preference**

🟩 **High Preference**

Resource Options	Aquatic Environment	Terrestrial Environment	Air Quality	First Nation Lands	Traditional Lifestyle	Heritage Resources	Tourism, Recreation	Community Well-being	Local Economic Benefits	Climate Change Risk
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Diesel: 20 MW - Whitehorse	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Diesel: 20 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG: 20 MW - Whitehorse	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
LNG: 20 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟩	🟥	🟩
Waste to Energy	🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩
Biogas (CHP)	🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Biomass	🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Solar PV: Whitehorse	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Solar PV: Haines Junction	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Wind: Cyprus Mine Hill, 20 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩
Wind: Kluane Lake, 20 MW	🟩	🟨	🟩	🟥	🟩	🟩	🟩	🟨	🟩	🟩
Wind: Millers Ridge, 20 MW	🟩	🟨	🟩	🟨	🟩	🟩	🟨	🟨	🟨	🟩
Wind: Mt. Sumanik , 20 MW	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Wind: Sugarloaf Mountain, 20 MW	🟩	🟨	🟩	🟥	🟩	🟩	🟩	🟨	🟨	🟩
Wind: Tehcho (Ferry Hill), 20 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟩
Wind: Thulsoo Mountain, 20 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟨	🟨	🟩
Geothermal: McArthur Springs (3.8 MW Av.)	🟩	🟨	🟩	🟨	🟩	🟩	🟨	🟨	🟨	🟩
Geothermal: Vista Mountain (1.6 MW Av.)	🟩	🟩	🟩	🟨	🟩	🟩	🟩	🟨	🟥	🟩
Pumped Storage: Moon Lake	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩
Pumped Storage: Racine - Moon	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩

2 Figure 8-1 is continued on the next page.



🟥	Low Preference
🟨	Medium Preference
🟩	High Preference

Resource Options	Aquatic Environment	Terrestrial Environment	Air Quality	First Nation Lands	Traditional Lifestyle	Heritage Resources	Tourism, Recreation	Community Well-being	Local Economic Benefits	Climate Change Risk
Pumped Storage: Lindeman-Fraser	🟨	🟨	🟩	🟩	🟩	🟨	🟨	🟨	🟩	🟩
Pumped Storage: Racine - Mt. Brown	🟨	🟨	🟩	🟨	🟩	🟩	🟩	🟨	🟩	🟩
Pumped Storage: Atlin - Black Mountain	🟨	🟩	🟩	🟨	🟩	🟨	🟩	🟨	🟩	🟩
Pumped Storage: Squanga - Dalayee	🟨	🟨	🟩	🟥	🟩	🟨	🟩	🟥	🟩	🟩
Pumped Storage: Canyon - Ittlemit	🟨	🟨	🟩	🟥	🟩	🟨	🟨	🟥	🟩	🟩
Pumped Storage: Vangorda Pit	🟨	🟨	🟩	🟥	🟩	🟩	🟩	🟥	🟩	🟩
Small Hydro: Drury Lake	🟨	🟩	🟩	🟥	🟩	🟩	🟨	🟥	🟨	🟨
Small Hydro: Tutshi - Windy Arm	🟨	🟨	🟩	🟩	🟩	🟩	🟨	🟨	🟩	🟩
Small Hydro: Wolf River	🟩	🟨	🟩	🟥	🟩	🟩	🟩	🟨	🟩	🟩
Small Hydro: Finlayson River	🟨	🟨	🟩	🟥	🟨	🟨	🟩	🟨	🟩	🟩
Small Hydro: Atlin/Pine Creek	🟩	🟩	🟩	🟨	🟩	🟨	🟨	🟨	🟩	🟩
Other Hydro: Southern Lakes Storage	🟩	🟨	🟩	🟥	🟩	🟥	🟩	🟨	🟥	🟩
Other Hydro: Mayo Lake Storage	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Other Hydro: Mayo Dredging	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Aishihik Uprating	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo A Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Transmission: Whitehorse - Atlin	🟩	🟨	🟩	🟥	🟩	🟩	🟩	🟩	🟨	🟨
Transmission: Whitehorse - Skagway	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟨	🟨
Transmission: Whitehorse - Teslin	🟩	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟨	🟨
Transmission: Faro - Watson Lake	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟨	🟨	🟨
Transmission: Aishihik - Destruction Bay	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟨	🟨	🟨
Transmission: Stewart-Keno City	🟩	🟨	🟩	🟨	🟩	🟩	🟩	🟨	🟨	🟨

If two portfolios were compared, such as for example Medium Industrial Activity Scenario including thermal portfolio vs. Medium Industrial Activity Scenario – Renewable, the attributes that were ranked predominately equally across all resource options in both portfolios were removed from further consideration and therefore had no additional influence on the comparison. Attributes that scored relatively consistently for both portfolios, were no longer considered in the comparison, thereby simplifying the remaining analysis. To proceed to the next stage of the comparison, trade-off analysis, the remaining environmental, social and economic attributes had to be assigned a qualitative weighting. The results of the Electricity Values Survey were used for this purpose, as the Electricity Values Survey focused on the same environmental, social and economic attributes used to evaluate resource options. The values (attributes) most favoured in the Electricity Values Survey were assigned the most weight in the comparison of portfolios. Following the results of the Electricity Values Survey, the goal was to create balanced portfolios that were environmentally friendly, cost effective, reliable and socially responsible. At the end of the process, a judgement call was made to decide on the preferred portfolio. For example, if one portfolio was marginally environmentally preferred (eg. generating higher percentage of renewable energy), but significantly more expensive (eg. being double the cost) than the other portfolio, all other attributes being equal, it could not be favoured, even though it was environmentally preferred. Or, for example, if one portfolio was environmentally preferred and slightly more expensive than the other portfolio, all other attributes being equal, the decision could be made in its favour.

The results of this analysis are presented in Section 8.3.

8.1.3 Economic Scenarios and Resource Option Sensitivities

When forecasting future energy and capacity needs over the planning horizon, fourteen economic scenarios were developed and modelled to account for key uncertainties, such as future economic growth. Energy and peak demand forecasts related to different economic scenarios were developed, and are presented and discussed in Section 4.1 of Chapter 4.

Prior to the portfolio analysis, the load forecast scenarios were compared for similarities in order to eliminate redundant/similar scenarios, thereby minimizing the number of analyzed cases. Five load scenarios were down-selected for the portfolio analysis: Very Low, Low, Low with Early Minto Closure, Medium and High Industrial Activity. These selected scenarios were expected to cover a plausible range of future energy and capacity requirements. The discarded scenarios were judged redundant, and not needed to provide additional information to inform the portfolio analysis and the Action Plan. Subsequent to the completion of the Load Forecast in mid-2016, Capstone Mining have confirmed that the Minto mine will cease operations at the end of 2017. Therefore, the Low with Early Minto Mine Closure scenario was analyzed to provide additional insights into the portfolio that would result from the early closure of the Minto mine.

In addition to analyzing portfolios for selected future load scenarios, additional uncertainties were reviewed through sensitivities on the following parameters:

- Social Cost of Carbon (SCC): To account for a potential future government policy with respect to the cost of greenhouse gas emissions, a long term social cost of carbon forecast was developed and applied. The SCC forecast is presented in Chapter 6. Portfolios were analyzed with and without the inclusion of the SCC to determine the impact of carbon pricing on the selection of future resources. The details on the portfolios included in the SCC sensitivity analysis are presented in Section 8.2.2.
- Global Warming Potential (GWP): To account for a potential future changes in the accounting of the impacts of greenhouse gas emissions, a sensitivity analysis was conducted on two different GWPs. One analysis considered the GWP limited to 20 years, and a second extended to 100 years (the assumed base assumption). The details on the GWP analysis are presented in Appendix 5.1. The details on the portfolios included in the GWP sensitivity analysis are presented in Section 8.2.2.
- Diesel Fuel Price: To account for the uncertainty in future fossil fuel prices, three long term diesel price forecast scenarios were developed and reviewed. The scenarios are presented in Chapter 6. The diesel price forecast scenarios were combined with LNG price forecast scenarios to cover a broad but plausible range of future outcomes. The details of the diesel price scenarios are presented in Section 8.2.3.
- LNG Fuel Price: to account for the uncertainty in future fossil fuel prices, three long term LNG price forecast scenarios were developed and reviewed. These scenarios are presented in

Chapter 6. The LNG price forecast scenarios were combined with diesel price forecast scenarios to cover a broad but plausible range of future outcomes. The details of the LNG price scenarios are presented in Section 8.2.3.

- Renewable portfolios: to account for potential future government policy mandating the development of only renewable future resource options, an analysis was conducted to analyze future portfolios which excluded all new thermal resources. The portfolios introducing exclusively renewable resources in the future are referred in the entire 2016 Resource Plan document as “renewable portfolios” even though they are, strictly speaking, mixed portfolios consisting of future renewable resources, existing renewable resources and existing thermal resources. The details of the renewable portfolios included in this sensitivity analysis are presented in Section 8.2.4.
- Zero cost of specific transmission lines: to account for potential future government funding to support the construction of future transmission infrastructure, an analysis was conducted to determine the impact of the make-up of the portfolios if specific transmission lines were assumed to have a zero cost (i.e. fully funded by Government). These specific cases were considered - a potential transmission line connecting the Moon Lake pump storage project to the existing Yukon grid, and a line connecting the potential Pine Creek small hydro project to the existing grid. The details of the transmission lines included in this sensitivity analysis are presented in 8.2.5.

8.2 Portfolio Analysis – Financial and Technical Evaluation

Fourteen energy and peak demand forecast scenarios were generated for the 20-year planning period. Industrial activity and government spending were determined to be the major economic drivers influencing future energy and capacity demand growth. As discussed in Section 8.1.3, of the fourteen scenarios, five were selected to cover the range of load uncertainties: Very Low, Low, Low with early Minto closure, Medium and High industrial Activity. These five scenarios formed the foundation of the portfolio analysis modelling.

Additional analysis was performed to explore portfolio sensitivities based on the uncertainties of fuel prices, the introduction of social carbon pricing, the GWP of greenhouse gas emissions, the absence of transmission costs for specific new transmission lines, and the introduction of portfolios consisting of all renewable future resources. To analyze all of these combinations would have required 1,440 System Optimizer model runs, requiring at least a full year. Given the similarities among the many of the cases, most of the computer simulations would not provide any additional information. To reduce the workload to a manageable level, sensitivity runs were eliminated in two phases. First, the runs deemed to be of marginal importance were eliminated up front, before any computer modeling was conducted. Once the five basic runs related to the load forecast were completed and their outputs analysed, additional sensitivity runs which were not expected to provide any usable information were eliminated.

Given the inherent constraints of renewable resources related to the electricity grid stability, a 20 MW limit on the penetration of intermittent resources was invoked in all the portfolio optimization runs to reflect reasonable operational system stability constraints related to the maximum penetration of intermittent resources to the YEC system. In isolation, most intermittent renewable resources do not provide the voltage and frequency support attributes required to keep the electricity grid stable. They are not firm, not dispatchable in the event of undersupply, and not curtailable in the event of oversupply. Storage technologies such as batteries can effectively augment renewable resources in order to provide the above attributes, and such an approach is taken in the portfolio analysis, with storage correctly treated as separate resource option.

To deliver on the Standing Offer Program (SOP), which is a key element of Yukon Government's IPP Policy, an allowance for IPP-sourced firm energy for future supply options was made at 10 GWh/year starting in 2022 for all the major scenarios and sensitivity analysis scenarios. Consequently, this resource was a part of all the resulting portfolios starting in 2022.

The list of industrial scenarios and sensitivity analysis scenarios run in the portfolio analysis are presented in Table 8-1. The columns in Table 8-1 list the loads, the SCC, GWP, diesel price, LNG price, renewable portfolio, absence of transmission cost for the Atlin to Whitehorse transmission line, and absence of the Whitehorse to Skagway transmission line. Each row in Table 8-1 presents a portfolio analyzed. The parameters modified in the sensitivity scenarios are highlighted and italicized.

Table 8-1: Summary of Parameters in Industrial and Sensitivity Scenario

Scenario and Load	Social Cost of Carbon (SCC)	Global Warming Potential (GWP)	Diesel Price	LNG Price	Renewable Portfolio	Atlin Zero Cost Transmission	Skagway Zero Cost Transmission
Industrial Activity Scenarios							
Very Low	Yes	100-Year	Medium	Medium	No	No	No
Low	Yes	100-Year	Medium	Medium	No	No	No
Low with Early Minto Closure	Yes	100-Year	Medium	Medium	No	No	No
Medium	Yes	100-Year	Medium	Medium	No	No	No
High	Yes	100-Year	Medium	Medium	No	No	No
Social Cost of Carbon Scenarios							
Low	*No*	100-Year	Medium	Medium	No	No	No
Medium	*No*	100-Year	Medium	Medium	No	No	No
Global Warming Potential Scenarios							
Medium	Yes	*20-Year*	Medium	Medium	No	No	No
Fuel Price Scenarios							
Low	Yes	100-Year	*High*	*High*	No	No	No
Medium	Yes	100-Year	*High*	*High*	No	No	No
Low	Yes	100-Year	Medium	*Low*	No	No	No
Medium	Yes	100-Year	Medium	*Low*	No	No	No
Zero Cost Transmission Scenarios							
Medium	Yes	100-Year	Medium	Medium	No	*Yes*	No
Medium	Yes	100-Year	Medium	Medium	No	No	*Yes*
New Renewable Only Scenarios							
Medium	Yes	100-Year	Medium	Medium	*Yes*	No	No
High	Yes	100-Year	Medium	Medium	*Yes*	No	No

The following parameters were assumed as the base case for the sensitivity and a single parameter adjusted for each sensitivity model run.

- SCC included,
- GWP of 100 years,
- Medium diesel Price,
- Medium LNG Price,
- Future Thermal resources allowed, and
- Transmission resources with costs included.

The five industrial activity portfolios noted above were used as the foundation for the sensitivity analysis. The sensitivity analysis was completed by varying one parameter at a time, with the other parameters remaining unchanged, as presented in Table 8-2.

The sensitivity on the SCC was tested with two different industrial activity scenarios: Low and Medium. As discussed in the following sections, given the similarities among the portfolios generated for the Low, Medium and High Industrial Activity scenarios, it was not deemed necessary to run the SCC sensitivity on the High Industrial Activity scenario.

The sensitivity on a GWP was tested on the Medium Industrial Activity scenario only. Given the similarities between the portfolio contents of the Low, Medium and High Industrial Activity scenarios, it was not deemed necessary to run the GWP sensitivity on the Low and High Industrial Activity scenarios.

The sensitivity on diesel and LNG prices was tested in combination with different loads. The combinations of loads, and diesel and LNG pricing presented in Table 8-1 were deemed to cover likely outcomes that would potentially affect the portfolios. Consequently, the following potential future states were investigated in the fuel price sensitivity analysis: a) the price of LNG decreases compared to diesel, and b) the price of both diesel and LNG increase. As discussed in the following sections, given the similarities among the portfolio content of the Low, Medium and High Industrial Activity scenarios, it was not deemed necessary to run the diesel and LNG price sensitivities on the High Industrial Activity scenario, or additional combinations of diesel vs. LNG pricing. For example, if the LNG thermal options were not selected for the portfolio even if the price of LNG was lower than that of diesel, the LNG thermal options would not be selected if the price of LNG were higher than that of diesel.

The sensitivity on a renewable portfolio was tested with two Industrial Activity scenarios: Medium and High. Considering that additional firm energy was not required under the Very Low and Low Industrial Activity scenarios, and the similarity between the Medium and Low with Early Minto Closure Industrial Activity scenarios, those three load scenarios were not considered for the sensitivity analysis.

The sensitivity on the zero cost of transmission lines for the Atlin to Whitehorse transmission line was tested with Medium Industrial Activity scenario.

The sensitivity on the zero cost of transmission lines for the Whitehorse to Skagway transmission line was tested the Medium Industrial Activity scenario. This transmission line is considered important as it would connect Moon Lake pumped storage, one of the promising capacity resources, to the existing grid.

The resource portfolios for the five industrial activity energy and peak demand scenarios are presented in Section 8.2.1, followed by the sensitivity analysis portfolios in Sections 8.2.2 to 8.2.5.

All the portfolios were generated by the System Optimizer model, with quality control and quality assurance completed on each portfolio to ensure that the model generated meaningful results. The System Optimizer model identified specific sites for each project, as site-specific information was presented to the model. The development of the selected specific sites is not binding, and as many projects presented in the portfolio analysis are at an early stage of development, the final decisions on any project development have not been made.

The portfolios are presented in the following format:

- Energy graphs: These graphs show the energy requirement as a line, existing energy capability under average water conditions as bars in the shades of gray and future energy of new resources shown in different colored bars. Note that the portfolio analysis considered firm energy production requirements to meet the energy planning criterion as discussed in Section 4.3, while it considered energy under average water conditions to calculate operating costs. The firm energy planning criterion was met for each portfolio. The firm energy graphs were not shown since it was judged that the average energy graphs would be more informative as they show how much each resource would be used under average operational conditions. By doing so, it is possible to check how much thermal generation is used in real operations, as opposed to how much thermal energy is available.

- Peak demand graphs: These graphs show the peak demand requirement under N-1 conditions as a line, existing dependable capacity as bars in the shades of gray and future dependable capacity of new resources shown in different colours.
- Summary table with the list of new resources accompanied by the in-service date and installed capacity. For sensitivity scenarios, the resources selected for the base scenarios were presented along with the resources selected for the sensitivity scenarios for easier comparison. For example, for the case of examining the impact of SCC on the Low Industrial Activity scenario, resources selected for both the base scenario (Low Industrial Activity without SSC) and sensitivity scenario (Low Industrial Activity with SCC) were presented.
- Portfolio cost table showing the following:
    1. Portfolio capital cost: this is the simple (undiscounted) value of all capital expenditures over the 20-year planning period. This cost was presented for illustration purposes only to demonstrate the magnitude of undiscounted capital investment over the planning period. It is useful information for capital constrained conditions.
    2. The present value: this represents the sum of annualized: a) fixed and b) operational & maintenance portfolio costs discounted over the planning period of 20 years.
    3. Total cost: this is the sum of the fixed and operational & maintenance portfolio costs presented in 2 above.

  The portfolio capital cost represents the simple (undiscounted) dollar value of all capital expenditures over the 20-year Plan horizon, while the total cost presents the discounted cost of fixed and operational & maintenance costs over the planning period of 20 years.

  Although the resources usually have a useful life beyond the planning horizon of 20 years, the calculation of portfolio present value both for fixed and variable costs is limited to the 20 years planning horizon of the Plan.

- The average percentage of renewable energy generated by each portfolio for the 20 year planning period, calculated under average water conditions. Depending on the load from one year to another and resource availability, the annual renewable generation percentage can be less or greater than the average renewable generation percentage listed in the table.
- The data generated from the portfolio analysis can be found in Appendix 8.1.

8.2.1 Industrial Activity Portfolio Analysis

These resource portfolios were generated using the energy and peak demand forecasts presented in Section 4.1. The analysis of these portfolios also assumed the SCC as presented in Chapter 6, a 100-year GWP for greenhouse gas emissions, a medium price forecast for diesel and a medium price forecast for

LNG, both as presented in Chapter 6, thermal resources allowed in the portfolio, and actual costs for transmission options. The details on the portfolio analysis inputs are presented in Table 8-2 to Table 8-6.

In the following sections, Figure 8-2 to Figure 8-11 show the five selected scenarios of Very Low, Low, Low with early Minto closure, Medium and High industrial Activity for both capacity and energy.

8.2.1.1 Very Low Industrial Activity

Figure 8-2: Very Low Industrial Activity Portfolio, Energy

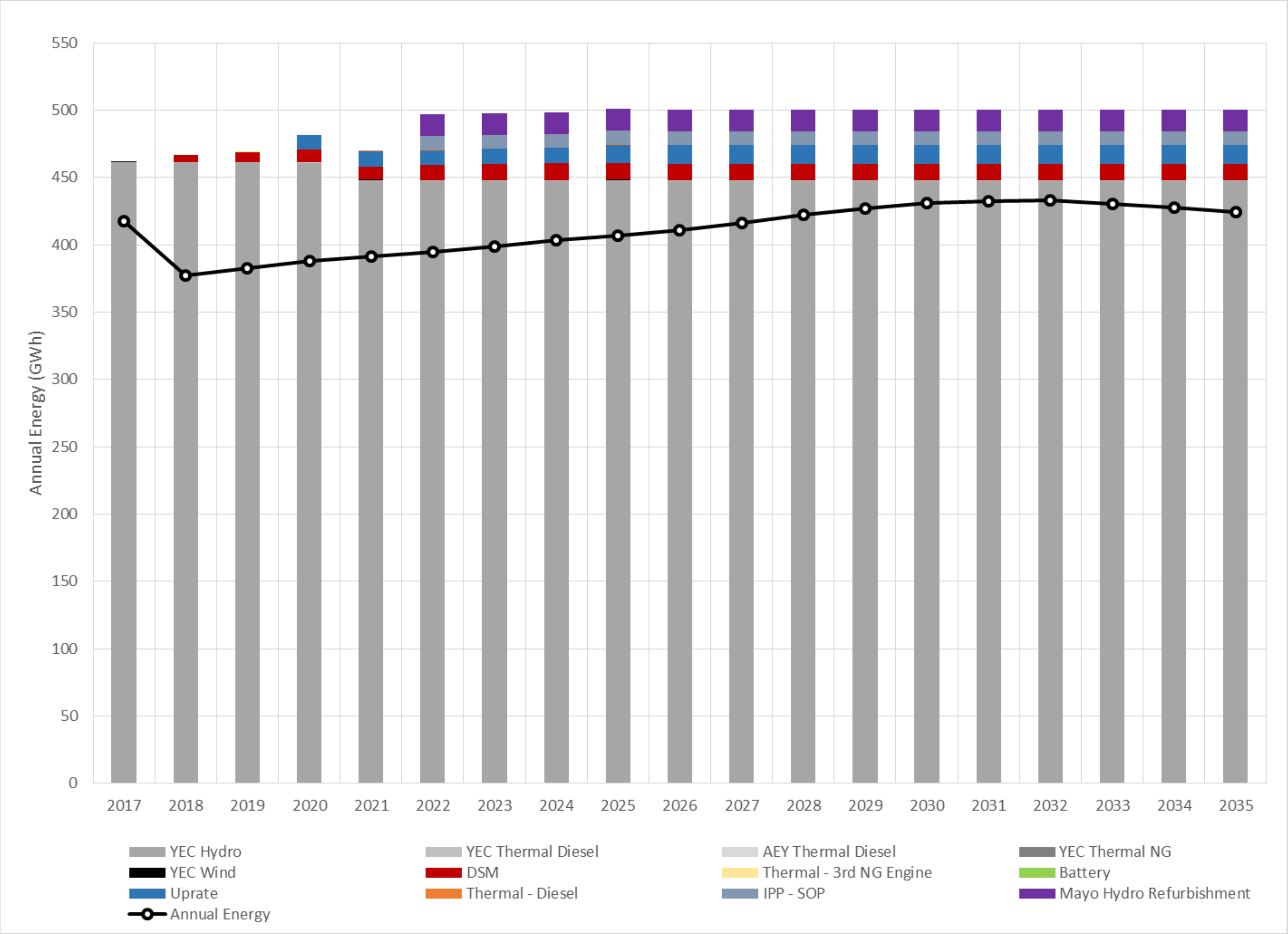


Figure 8-3: Very Low Industrial Activity Portfolio, Capacity

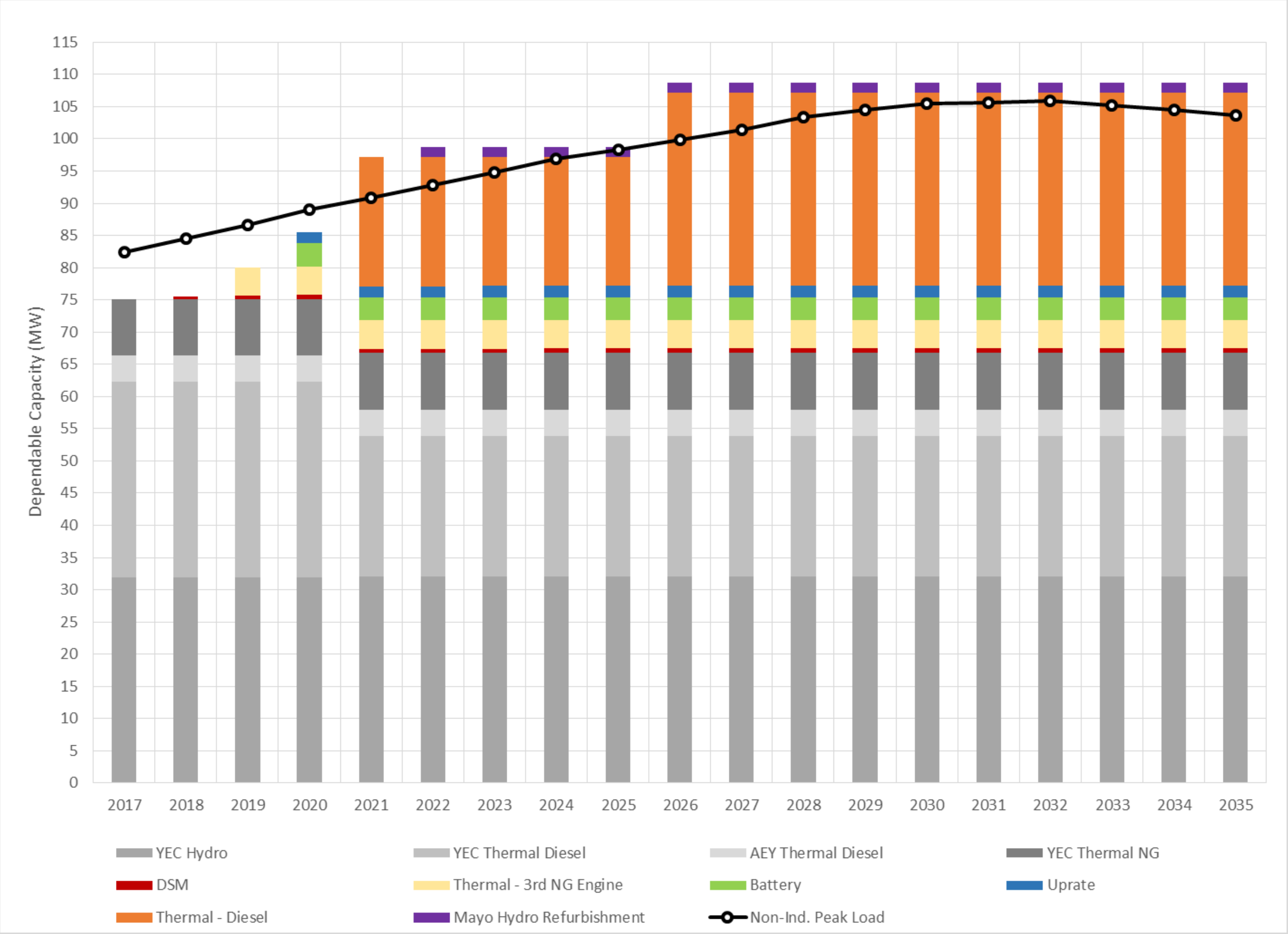


Table 8-2: Very Low Industrial Activity Portfolio Summary

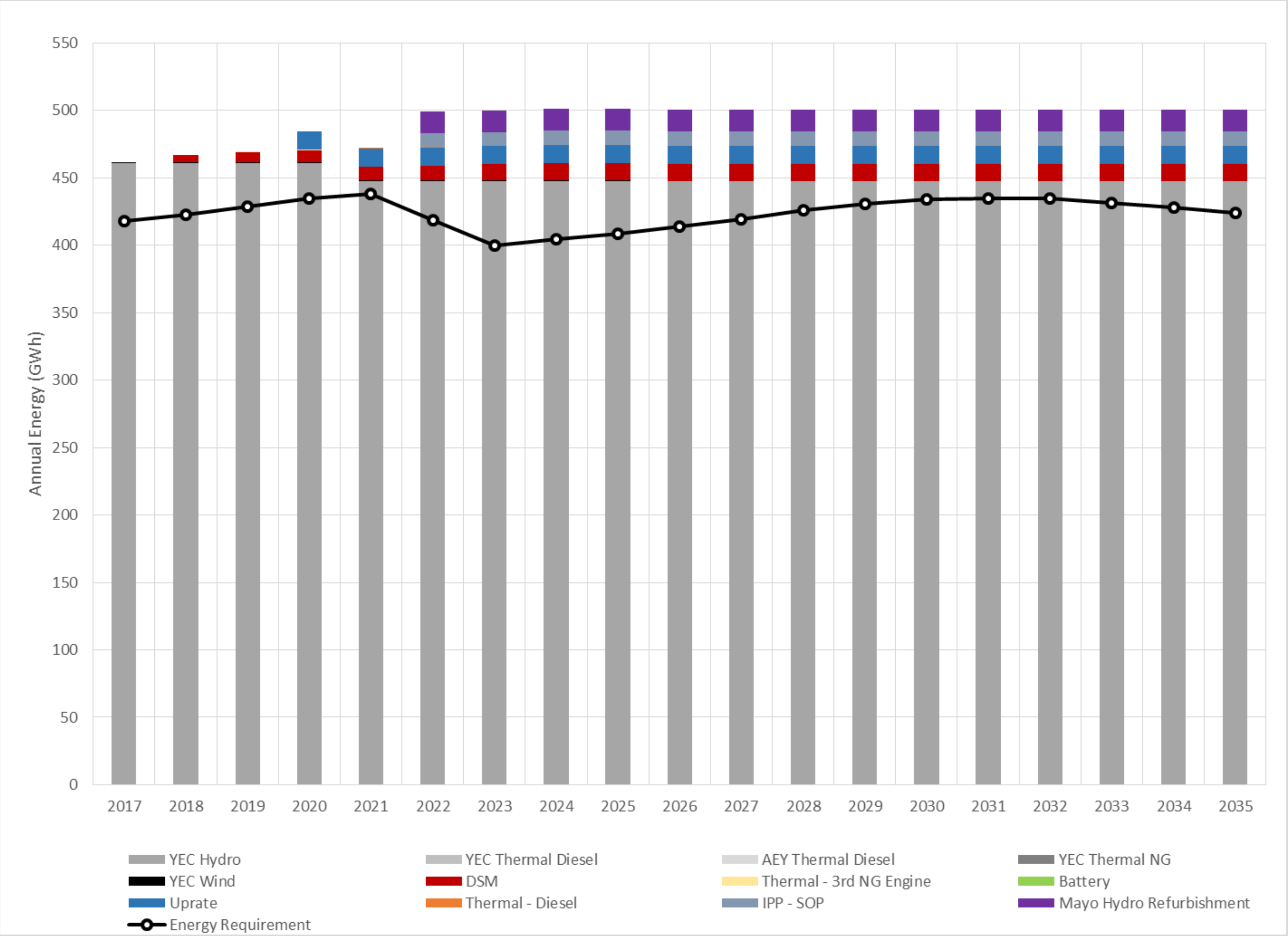
Resource Option	Installed Capacity [MW]
2018	
Demand Side Management	1.3
2019	
Thermal - 3rd NG Engine at Whitehorse	4.4
2020	
4 MW Battery - Takhini Substation	4.0
Whitehorse Uprate	1.7
2021	
Thermal Diesel - Takhini Substation	20.0
2022	
Mayo Hydro Refurbishment	2.3
2025	
Aishihik Uprate	1.3
2026	
Thermal Diesel - Takhini Substation	10.0
Grand Total	45.0

Cost Components	Cost [2016 $Millions]	Comment
Portfolio Capital Cost:	$ 207.4	
Present Value:		
Fixed Costs	$ 97.6	[A]
Variable Costs	$ 37.0	[B]
Total Costs	$ 134.5	[C] = [A] + [B]

This portfolio generates an average of 99.8% renewable energy over the 20 year planning period, under average water assumptions.

8.2.1.2 Low Industrial Activity

Figure 8-4: Low Industrial Activity Portfolio, Energy



1 *Figure 8-5: Low Industrial Activity Portfolio, Capacity*

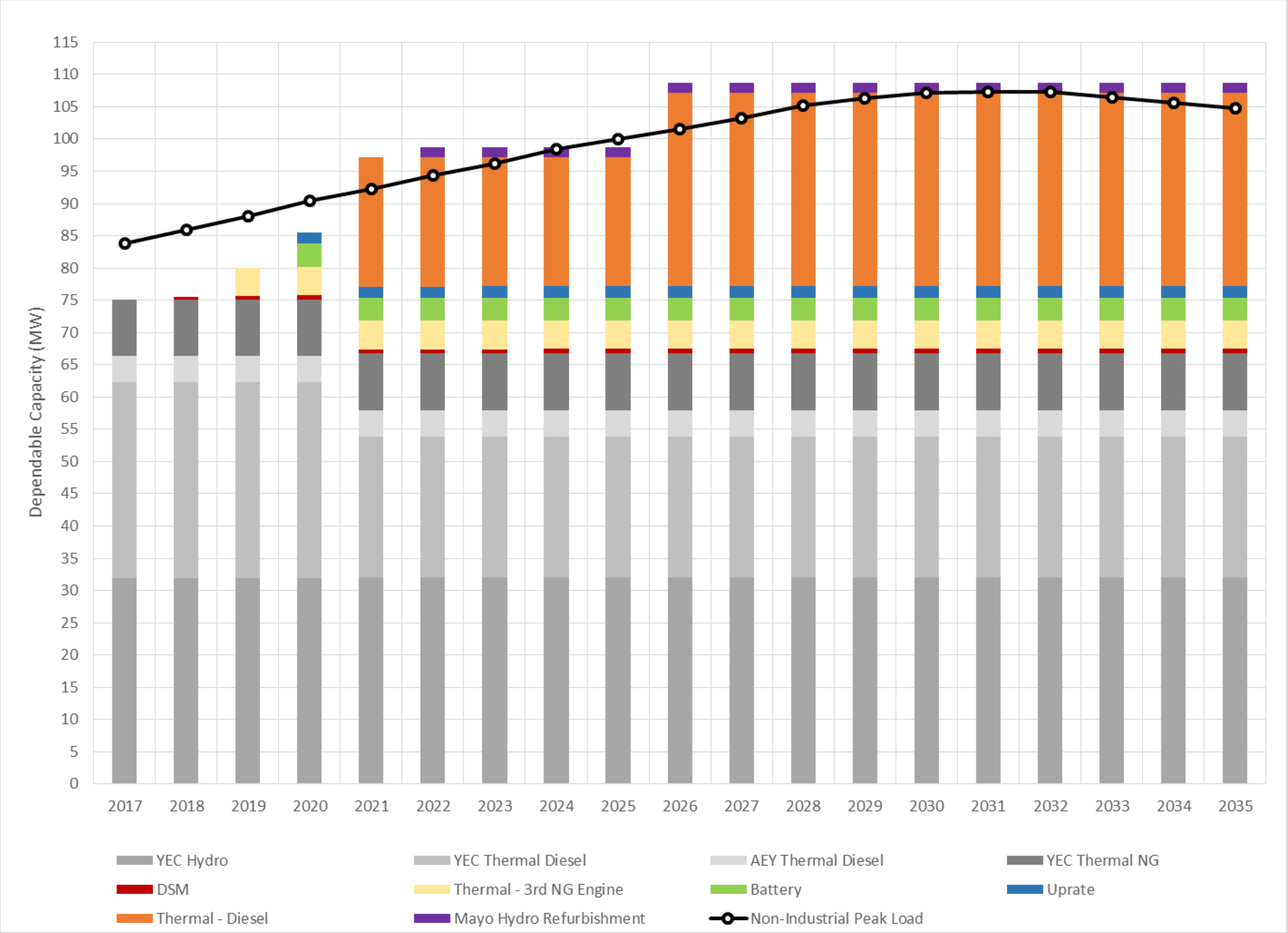


Table 8-3: Low Industrial Activity Portfolio Summary

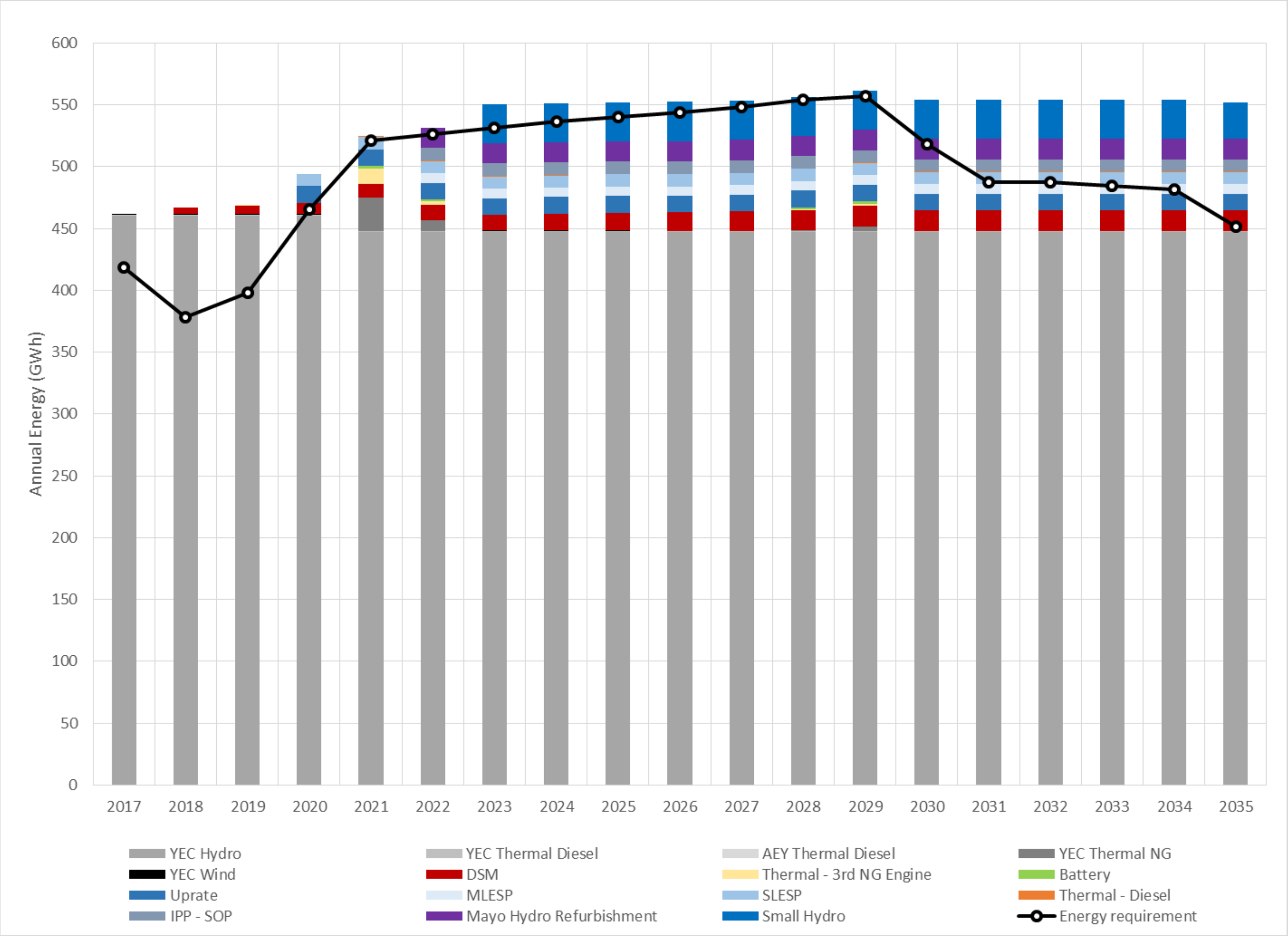
Resource Option	**Installed Capacity [MW]**
2018	
Demand Side Management	1.3
2019	
Thermal - 3rd NG Engine at Whitehorse	4.4
2020	
4 MW Battery - Takhini Substation	4.0
Aishihik Uprate	1.3
Whitehorse Uprate	1.7
2021	
Thermal Diesel - Takhini Substation	20.0
2022	
Mayo Hydro Refurbishment	2.3
2026	
Thermal Diesel - Takhini Substation	10.0
Grand Total	45.0

Cost Components	**Cost [2016 $Millions]**	**Comment**
Portfolio Capital Cost	$ 207.4	
Present Value		
Fixed Costs	$ 97.6	[A]
Variable Costs	$ 37.8	[B]
Total Costs	$ 135.4	[C] = [A] + [B]

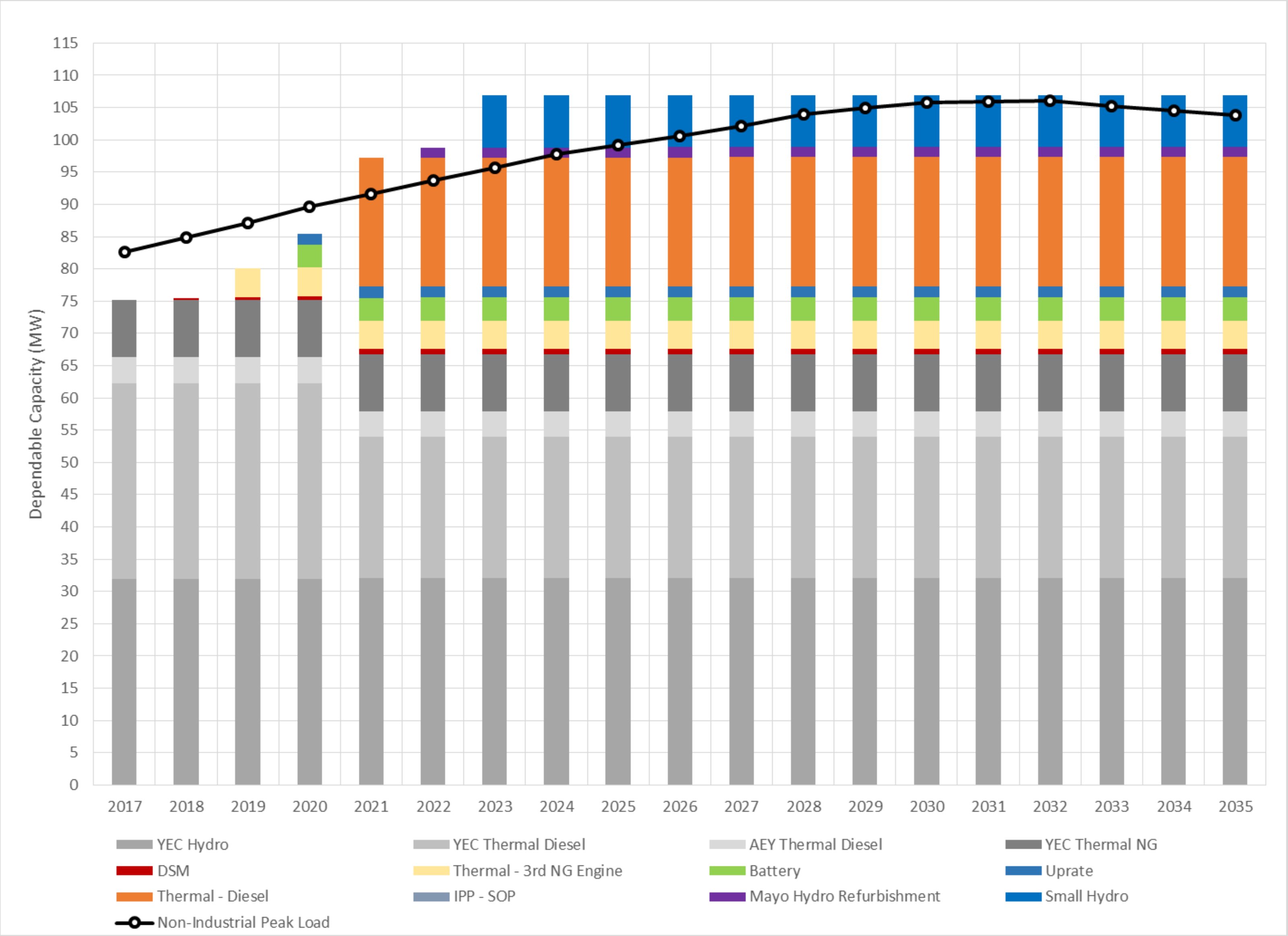
This portfolio generates an average of 99.8% renewable energy over the 20 year planning period, under average water assumptions.

8.2.1.3 Low Industrial Activity with Minto Mine Closing Early and Eagle Gold Project

Figure 8-6: Low Industrial Activity with Minto Closing Early and Eagle Gold Project Portfolio, Energy



1 *Figure 8-7: Low Industrial Activity with Minto Closing Early and Eagle Gold Project Portfolio, Capacity*



1 *Table 8-4: Low Industrial Activity with Minto Closing Early and Eagle Gold Project Portfolio Summary*

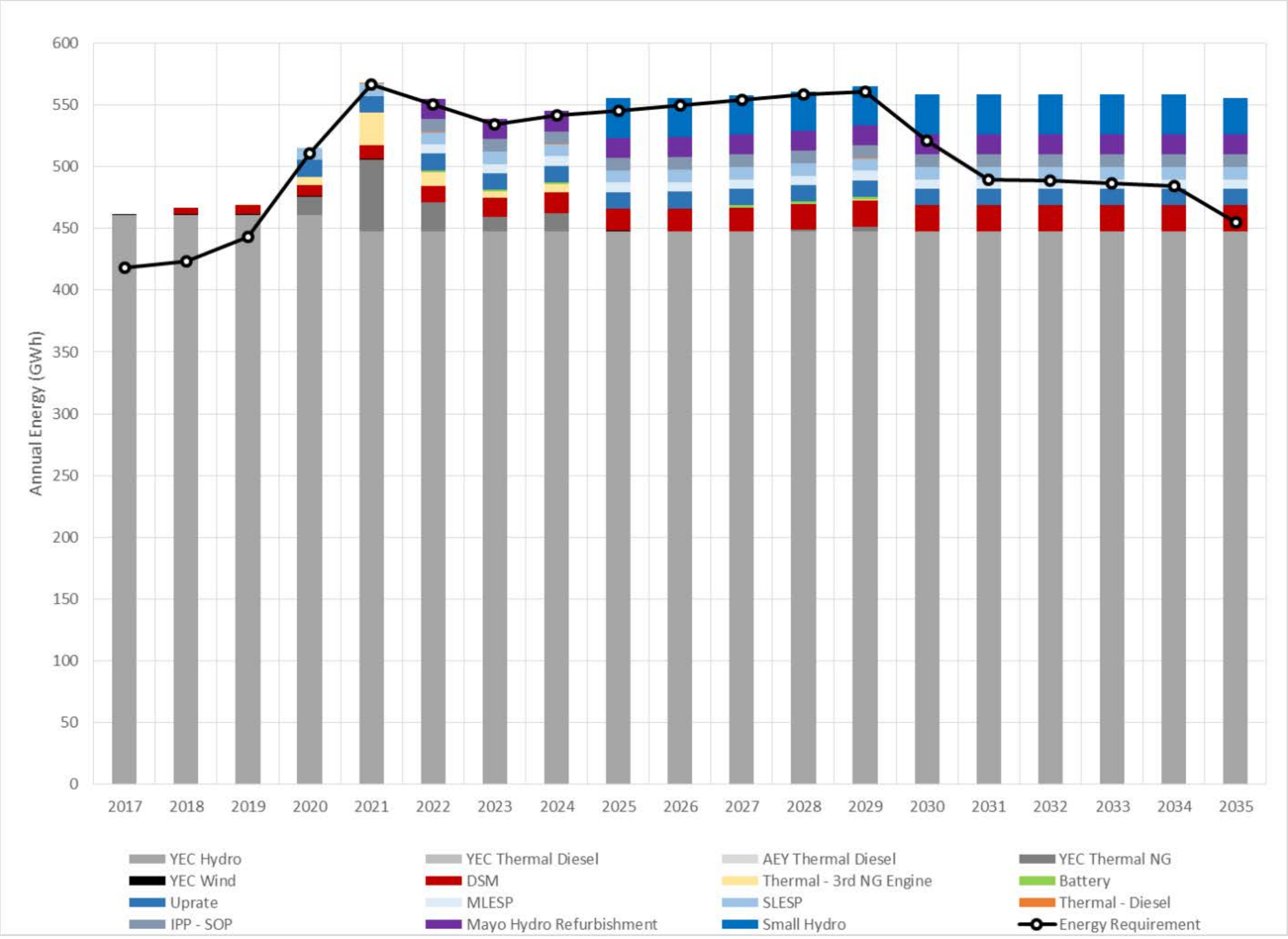
Resource Option	Installed Capacity [MW]
2018	
Demand Side Management	1.5
2019	
Thermal - 3rd NG Engine at Whitehorse	4.4
2020	
4 MW Battery - Takhini Substation	4.0
Aishihik Uprate	1.3
Whitehorse Uprate	1.7
Southern Lake Enhancement Storage Project	0.0
2021	
Thermal Diesel - Takhini Substation	20.0
2022	
Mayo Hydro Refurbishment	2.3
Mayo Lake Enhancement Storage Project	0.0
2023	
Drury Lake Small Hydro	8.1
Grand Total	43.3

Cost Components	Cost [2016 $Millions]	Comment
Portfolio Capital Cost	$ 298.6	
Optimization Results (Present Value)		
Fixed Costs	$ 130.2	[A]
Variable Costs	$ 49.1	[B]
Total Costs	$ 179.4	[C] = [A] + [B]

This portfolio generates an average of 99.3% renewable energy over the 20 year planning period, under average water assumptions.

8.2.1.4 Medium Industrial Activity

Figure 8-8: Medium Industrial Activity Portfolio, Energy



1 *Figure 8-9: Medium Industrial Activity Portfolio, Capacity*

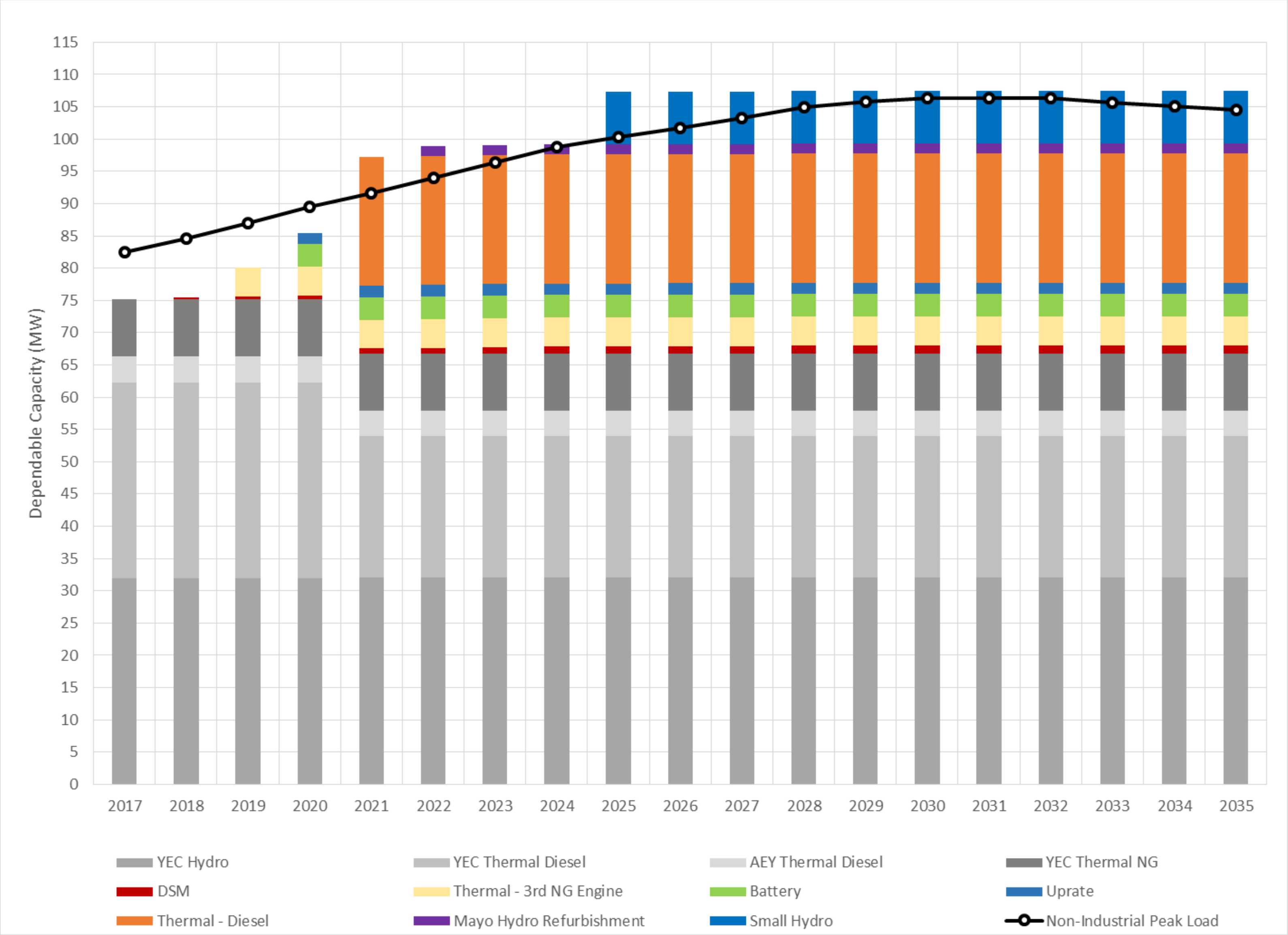


Table 8-5: Medium Industrial Activity Portfolio Summary

Resource Option	Installed Capacity [MW]
2018	
Demand Side Management	1.9
2019	
Thermal - 3rd NG Engine at Whitehorse	4.4
2020	
4 MW Battery - Takhini Substation	4.0
Aishihik Uprate	1.3
Whitehorse Uprate	1.7
Southern Lake Enhancement Storage Project	0.0
2021	
Thermal Diesel - Takhini Substation	20.0
2022	
Mayo Hydro Refurbishment	2.3
Mayo Lake Enhancement Storage Project	0.0
2025	
Drury Lake Small Hydro	8.1
Grand Total	43.7

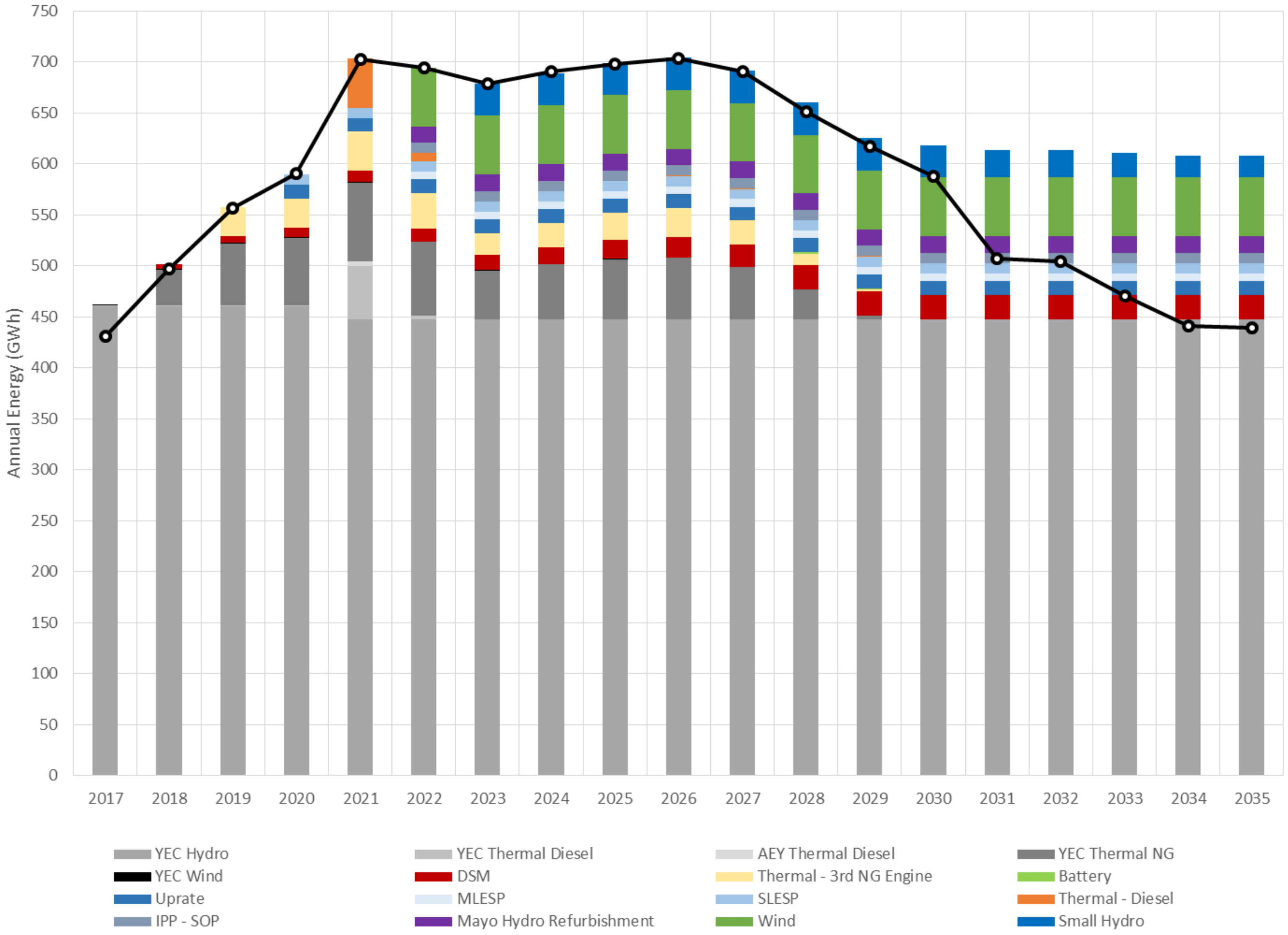
Cost Components	Cost [2016 $Millions]	Comment
Portfolio Capital Cost	$ 298.6	
Present Value		
Fixed Costs	$ 122.7	[A]
Variable Costs	$ 74.4	[B]
Total Costs	$ 197.1	[C] = [A] + [B]

This portfolio generates an average of 98.1% renewable energy over the 20 year planning period, under average water assumptions.

8.2.1.5 High Industrial Activity Scenario

Considering a need to create a realistic Action Plan that can be executed sequentially under each load scenario, new resources suggested in the Low Industrial Activity portfolio were considered as committed when modelling the High Industrial Activity scenario. As a consequence, the High Industrial Activity scenario was modelled with selected Low Industrial Activity scenario resources assumed to be already committed. This approach allows the Action Plan to be staged to respond to a potential future increases in load.

1 *Figure 8-10: High Industrial Activity with Capped Intermittent and Committed Resources Portfolio, Energy*



1 *Figure 8-11: High Industrial Activity with Capped Intermittent and Committed Resources Portfolio, Capacity*

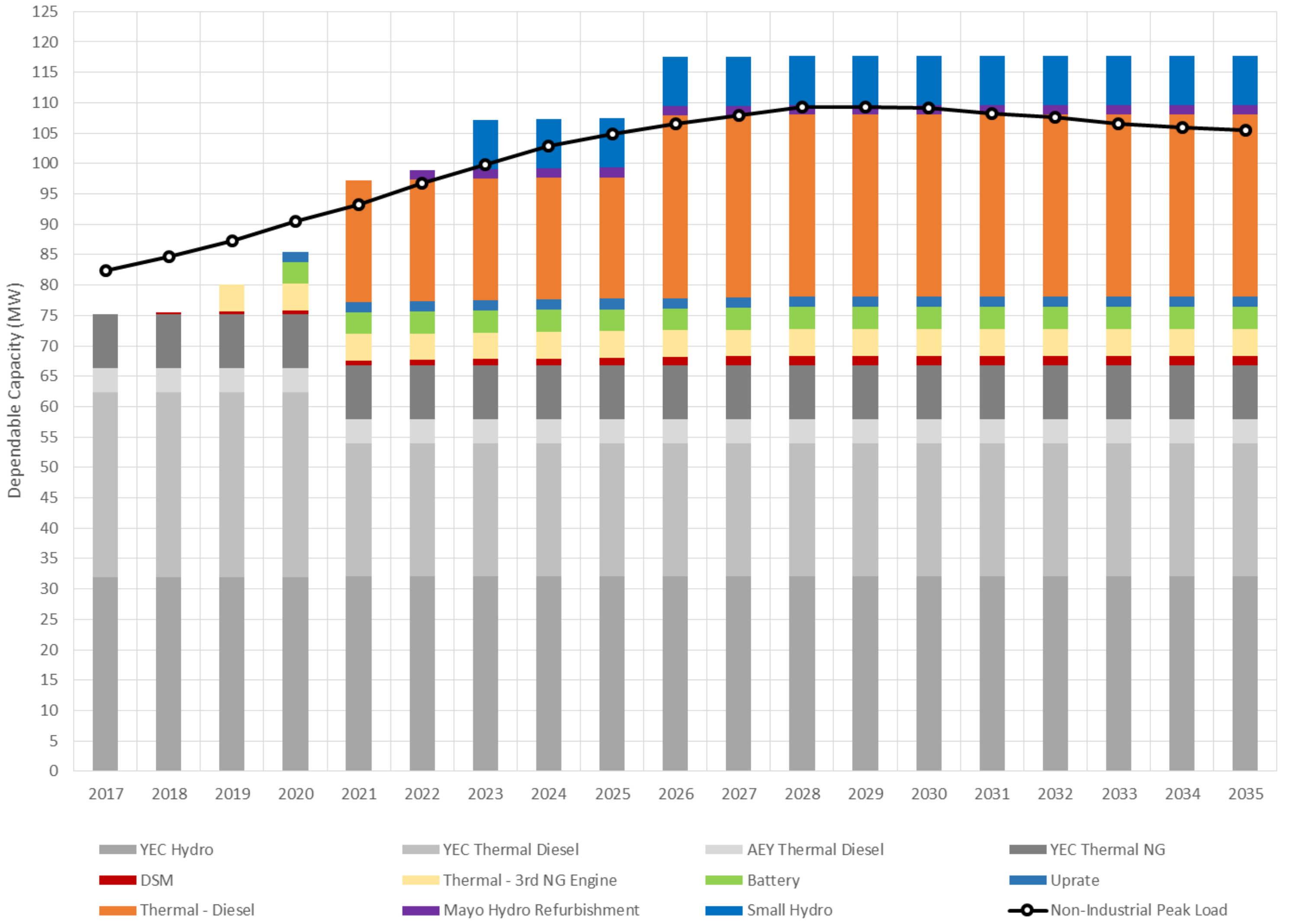


Table 8-6: High Industrial Activity with Capped Intermittent and Committed Resources Portfolio Summary

Resource Option	Installed Capacity [MW]
2018	
Demand Side Management	2.2
2019	
Thermal - 3rd NG Engine at Whitehorse	4.4
2020	
4 MW Battery - Takhini Substation	4.0
Aishihik Uprate	1.3
Whitehorse Uprate	1.7
Southern Lake Enhancement Storage Project	0.0
2021	
Thermal Diesel - Takhini Substation	20.0
2022	
Mayo Hydro Refurbishment	2.3
Mayo Lake Enhancement Storage Project	0.0
Wind - Miller's Ridge	20.0
2023	
Drury Lake Small Hydro	8.1
2026	
Thermal Diesel - Takhini Substation	10.0
Grand Total	74.0

Cost Components	Cost [2016 $Millions]	Comment
Portfolio Capital Cost	$ 414.0	
Optimization Results (Present Value)		
Fixed Costs	$ 150.9	[A]
Variable Costs	$ 294.8	[B]
Total Costs	$ 445.7	[C] = [A] + [B]

This portfolio generates an average of 91.9% renewable energy over the 20 year planning period, under average water assumptions.

8.2.1.6 Industrial Activity Portfolio Analysis Discussion

The summary of the five major industrial activity portfolios is presented in Table 8-7. A common set of resources are included in the portfolios for all the scenarios from 2018 until 2022. These common resources include DSM, a third LNG engine at the Whitehorse generating facility, battery-based storage, hydro uprating at Whitehorse, new diesel generators and refurbishment of Mayo A. This commonality helps streamline the execution of the Action Plan as discussed in Chapter 9.

An uprate of Aishihik Hydro is also required for all of the scenarios in the first five years, except in the Very Low Industrial Activity scenario, where it could be deferred until 2025.

The Southern Lakes and Mayo Lake Enhanced Storage Projects were also included in the first five years, except under the Very Low and Low Industrial Activity scenarios.

As a consequence of long lead times for all the available resources, all the portfolios show a shortfall in dependable capacity until 2021, when new diesel capacity is introduced.

After the first five years, the portfolios diverge in their composition. The Very Low and Low Industrial Activity scenarios require a second diesel unit in 2026. The Low with Early Minto Mine Closure, and Medium Industrial Activity scenarios require a future small hydro project, while the High Industrial Activity scenario requires small hydro, wind and diesel resources.

A more detailed analysis of the commonalities in the portfolios and their consequences to the Action Plan is presented in Chapter 9.

1 *Table 8-7: Resources selected for the Five Major Industrial Scenario*

Scenario	Very Low	Low	Early Minto Closure	Medium	High
2018	DSM	DSM	DSM	DSM	DSM
2019	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine
2020	Battery (Takhini) Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP
2021	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)
2022	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP Wind 20 MW (Thulsoo Mt.)
2023			Small Hydro (Drury Lake)		Small Hydro (Drury Lake)
2025	Aishihik re-runnering			Small Hydro (Drury Lake)	
2026	Diesel 10 MW (Takhini)	Diesel 10 MW (Takhini)			Diesel 10 MW (Takhini)
Renewable Energy (%)	99.8	99.8	99.3	98.1	91.9
Total Cost $M	$134.5	$135.4	$179.4	$197.1	$445.7
Fixed Cost $M	$97.6	$97.6	$130.2	$122.7	$150.9
Variable Cost $M	$37.0	$37.8	$49.1	$74.4	$294.8
Portfolio Capital Cost $M	$207.4	$207.4	$298.6	$298.6	$414.0

8.2.2 Social Cost of Carbon and GWP Sensitivity Analysis

All of industrial activity scenarios discussed in Section 8.2.1 were modelled assuming the inclusion of a SCC and 100 year GWP of greenhouse gases.

To estimate the impact of removal of the SCC on the preferred portfolio content, the Low and Medium Industrial Activity scenarios were modelled without the SCC. Given the similarities between the Medium and Low with Early Minto Closure Industrial Activity scenarios in terms of load and portfolio content, it was reasoned that the Medium Industrial Activity scenario would provide a reasonable representation for both the Medium Industrial Activity and Early Minto closure scenarios. Given that the High Industrial Activity scenario portfolio is built based on the Low Industrial Activity scenario, it was reasoned that the Low Industrial Activity scenario would provide a plausible representation for the High Industrial Activity scenario.

To estimate the impact of different GWP values on the portfolio content the Medium Industrial Activity scenarios was modelled with a shorter (20-year) GWP. Given that the impact of 20-year GWP would be negative with respect to the selection of LNG compared to diesel, and as new LNG was not dominant in any scenario, the Medium Industrial Activity scenario was considered sufficient to provide insight into the impact of GWP.

The results for the portfolio analysis for the sensitivities to the SCC and GWP are presented below in Table 8-8 to Table 8-10. The data generated from the portfolio analysis can be found in Appendix 8.1.

8.2.2.1 Low Industrial Activity without Social Cost of Carbon

Table 8-8: Low Industrial Activity with No Price on Carbon Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Low Industrial Activity without SCC	**Low Industrial Activity**
2018		
Demand Side Management	1.3	1.3
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	-	1.3
Whitehorse Uprate	1.7	1.7
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
2023		
Aishihik Uprate	1.3	-
2026		
Thermal Diesel - Takhini Substation	10.0	10.0
Grand Total	45.0	45.0

Cost Components	**Cost [2016 $Millions]**	
	Low Industrial Activity without SCC	**Low Industrial Activity**
Portfolio Upfront Capital	$207.4	$207.4
Optimization Results (Present Value)		
Fixed Costs	$97.6	$97.6
Variable Costs	$36.7	$37.8
Total Costs	$134.2	$135.4

This portfolio generates 99.8% energy under average water assumptions.

8.2.2.2 Medium Industrial Activity without Social Cost of Carbon

Table 8-9: Medium Industrial Activity with No Price on Carbon Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity without SCC	**Medium Industrial Activity**
2018		
Demand Side Management	1.8	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2025		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.6	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity without SCC	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$298.6
Optimization Results (Present Value)		
Fixed Costs	$122.5	$122.7
Variable Costs	$66.4	$74.4
Total Costs	$188.9	$197.1

This portfolio generates 98.1% energy under average water assumptions.

8.2.2.3 Medium Industrial Activity with 20-Year GWP

Table 8-10: Medium Industrial Activity with 20-Year GWP Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with GWP 20	**Medium Industrial Activity**
2018		
Demand Side Management	1.9	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2025		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.7	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity with GWP 20	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$298.6
Optimization Results (Present Value)		
Fixed Costs	$122.7	$122.7
Variable Costs	$74.6	$74.4
Total Costs	$197.3	$197.1

This portfolio generates 98.1% energy under average water assumptions.

8.2.2.4 Social Cost of Carbon and GWP Sensitivity Analysis Discussion

The sensitivity of adopting a GWP of 20 years versus the default of 100 years also did not impact the makeup of the portfolio. Such a result was expected considering that the diesel was selected even for GWP 100, which theoretically should favour LNG because of the higher GHG emissions of methane at a GWP of 20 years than at a GWP of 100 years.

8.2.3 Fuel Price Sensitivity Analysis

All of the industrial activity scenarios discussed in Section 8.2.1 previously were modelled assuming the medium (base) price forecasts for both diesel and LNG.

To estimate the impact of different diesel and LNG prices on the portfolio content, a sensitivity on fuel prices was tested in combination with the Low and Medium Industrial Activity scenarios. Four combinations of loads, and diesel and LNG prices were modeled. These are outlined in Table 8-1. The rationale of this approach was to test the following potential future states: a) that the price of LNG decreases compared to diesel, and b) that the price of both diesel and LNG increase. Given the similarities among the portfolio content of the Low, Medium and High Industrial Activity scenarios, it was not deemed necessary to run the diesel and LNG price sensitivities on the High Industrial Activity scenario, or additional combinations of diesel vs. LNG prices, such the case of a LNG price increase compared to diesel. If the LNG thermal options are not favoured if the price of LNG is lower than the price of diesel, it will not be favoured if the price of LNG increases relative to the price of diesel.

The results for the portfolio analysis for the sensitivities to the fuel prices are presented in Table 8-11 to Table 8-14 in the following sections. The data generated from the portfolio analysis can be found in Appendix 8.1.

8.2.3.1 Low Industrial Activity with High Diesel and High LNG Price

Table 8-11: Low Industrial Activity with High Diesel and LNG Price Portfolio Summary

Resource Option	Installed Capacity [MW]	
	Low Industrial Activity with High Diesel and LNG Price	Low Industrial Activity
2018		
Demand Side Management	1.2	1.3
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	-	1.3
Whitehorse Uprate	1.7	1.7
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Aishihik Uprate	1.3	-
Mayo Hydro Refurbishment	2.3	2.3
2026		
Thermal Diesel - Takhini Substation	10.0	10.0
Grand Total	44.9	45.0

Cost Components	Cost [2016 $Millions]	
	Low Industrial Activity with High Diesel and LNG Price	Low Industrial Activity
Portfolio Upfront Capital	$207.4	$207.4
Optimization Results (Present Value)		
Fixed Costs	$96.9	$97.6
Variable Costs	$37.7	$37.8
Total Costs	$134.6	$135.4

This portfolio generates 99.8% energy under average water assumptions.

8.2.3.2 Medium Industrial Activity with High Diesel and High LNG Price

Table 8-12: Medium Industrial Activity with High Diesel and High LNG Price Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with High Diesel and LNG Cost	**Medium Industrial Activity**
2018		
Demand Side Management	1.9	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2024		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.7	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity with GWP 20	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$298.60
Optimization Results (Present Value)		
Fixed Costs	$127.1	$122.70
Variable Costs	$72.3	$74.40
Total Cost	$199.4	$197.1

This portfolio generates 98.3% energy under average water assumptions.

8.2.3.3 Low Industrial Activity with Medium Diesel and Low LNG Price

Table 8-13: Low Industrial Activity with Medium Diesel and Low LNG Price Portfolio Summary

Resource Option	Installed Capacity [MW]	
	Low Industrial Activity with Medium Diesel and Low LNG Price	Low Industrial Activity
2018		
Demand Side Management	1.3	1.3
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	-	1.3
Whitehorse Uprate	1.7	1.7
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Aishihik Uprate	1.3	-
Mayo Hydro Refurbishment	2.3	2.3
2026		
Thermal Diesel - Takhini Substation	10.0	10.0
Grand Total	45.0	45.0

Cost Components	Cost [2016 $Millions]	
	Low Industrial Activity with Medium Diesel and Low LNG Price	Low Industrial Activity
Portfolio Upfront Capital	$207.4	$207.4
Optimization Results (Present Value)		
Fixed Costs	$97.6	$97.6
Variable Costs	$37.4	$37.8
Total Costs	$135.0	$135.4

This portfolio generates 99.8% energy under average water assumptions.

8.2.3.4 Medium Industrial Activity with Medium Diesel and Low LNG Price

Table 8-14: Medium Industrial Activity with Medium Diesel and Low LNG Price Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with Medium Diesel and Low LNG Price	**Medium Industrial Activity**
2018		
Demand Side Management	1.8	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2025		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.6	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity with Medium Diesel and Low LNG Price	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$289.6
Optimization Results (Present Value)		
Fixed Costs	$122.5	$122.7
Variable Costs	$64.3	$74.4
Total Costs	$186.8	$197.1

This portfolio generates 98.1% energy under average water assumptions.

8.2.3.5 Fuel Price Sensitivity Analysis Discussion

Lower LNG prices did not affect the content of the modeled portfolios. As the new diesel resource is used mostly for meeting capacity requirements and not for energy generation, it is still the preferred choice due to a lower LCOC than that of LNG. The capital investment for diesel is lower than that of LNG and using a resource to meet capacity requirements favours the resource with the lower capital investment. If thermal is needed for energy, the existing LNG units would be operated instead of diesel units because of LNG's lower operating costs.

Raising the price of both diesel and LNG did not result in a change in resources selected for the portfolios. The sensitivity in which the LNG price alone is increased results in the same outcome, as diesel was favoured even at the lower LNG price.

8.2.4 Renewable Portfolio Sensitivity Analysis

All of the industrial activity scenarios discussed in Section 8.2.1 were modelled assuming that thermal resources could be included in future portfolios.

To investigate the impact of potential future government policy prohibiting the construction of new thermal resources, a sensitivity analysis was completed excluding all new thermal resources from the portfolio. Portfolios were generated for the Medium and High Industrial Activity scenarios. Existing thermal resources (diesel and LNG) were assumed to continue to be available.

The results for the portfolio analysis of a sensitivities to the renewable portfolio are presented Table 8-15 and Table 8-16 in the following sections. The data generated from the portfolio analysis can be found in Appendix 8.1.

8.2.4.1 Medium Industrial Activity – Renewable Portfolio

Table 8-15: Medium Industrial Activity – Renewable Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with only New Renewable	**Medium Industrial Activity**
2018		
Demand Side Management	2.4	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	-	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal - Diesel at Takhini Substation	-	20.0
Geothermal - MacArthur	7.7	-
Geothermal - Vista Mountain	3.6	-
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2023		
Drury Lake Small Hydro	8.1	8.1
2024		
Pumped Storage - Moon Lake	20.2	-
2035		
Biomass (ORC) - Haines Junction	0.6	-
Waste-to-Energy - Whitehorse	1.6	-
Grand Total	53.6	43.7

Table 8-15 continues on the next page.

Cost Components	Cost [2016 $Millions]	
	Medium Industrial Activity with only New Renewable	**Medium Industrial Activity**
Portfolio Upfront Capital	$784.6	$298.6
Optimization Results (Present Value)		
Fixed Costs	$155.8	$122.7
Variable Costs	$163.8	$74.4
Total Costs	$319.6	$197.1

This portfolio generates an average of 99.4 % renewable energy over the 20 year planning period, under average water assumptions.

8.2.4.2 High Industrial Activity – Renewable Portfolio

Table 8-16: High Industrial Activity – Renewable Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	High Industrial Activity with only New Renewable	**High Industrial Activity**
2018		
Demand Side Management	2.0	2.2
2019		
Thermal - 3rd NG Engine at Whitehorse	-	4.4
Solar - Whitehorse	5.0	-
Waste-to-Energy - Whitehorse	1.6	-
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
Biomass (Gasification) - Haines Junction	0.5	-
Biomass (ORC) - Haines Junction	0.6	-
2021		
Thermal Diesel - Takhini Substation	-	20.0
Geothermal - MacArthur	7.7	-
Geothermal - Vista Mountain	3.6	-
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0	0.0
Wind - Miller's Ridge	20	20
2023		
Drury Lake Small Hydro	8.1	8.1
2024		
Pumped Storage - Moon Lake	20.2	-
2026		
Thermal Diesel - Takhini Substation	-	10.0
Grand Total	78.67	74.0

Table 8-15 continues on the next page.

Cost Components	**Cost [2016 $Millions]**	
	High Industrial Activity with only New Renewable	**High Industrial Activity**
Portfolio Upfront Capital	$909.6	$414
Optimization Results (Present Value)		
Fixed Costs	$156.3	$150.9
Variable Costs	$382.2	$294.8
Total Costs	$538.5	$445.7

This portfolio generates an average of 96.6 % renewable energy over the 20 year planning period, under average water assumptions.

8.2.4.3 Renewable Portfolio Sensitivity Analysis Discussion

The resulting portfolios with only new renewables were characterized by:

- Significantly higher costs compared to mixed (some thermal) portfolios;
- The inability to close the capacity gap until 2024;
- Penetration of intermittent resources of 25MW raising concerns over the operability of the electricity system; and
- Only marginal increase in the overall percentage of renewable generation, when compared to the portfolios with mixed resources.

8.2.5 Transmission Line Cost Sensitivity Analysis

All of the industrial activity scenarios discussed in Section 8.2.1 were modelled assuming that the costs of future transmission resources would be borne by YEC.

To estimate the impact of potential capital funding from an entity outside YEC, sensitivity analyses were conducted assuming the absence of costs for two potential future transmission lines: Atlin to Whitehorse, and Whitehorse to Skagway. These sensitivities were run under the Medium Industrial Activity scenario.

The portfolio analysis results for the sensitivities related to zero cost transmission lines are presented below in Table 8-17 and Table 8-18. The data generated from the portfolio analysis can be found in Appendix 8.1.

8.2.5.1 Medium Industrial Activity with No Transmission Cost to Moon Lake

Table 8-17: Medium Industrial Activity with No Transmission Cost to Moon Lake Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with no Transmission Cost to Moon Lake	**Medium Industrial Activity**
2018		
Demand Side Management	2.0	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2025		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.8	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity with no Transmission Cost to Moon Lake	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$298.6
Optimization Results (Present Value)		
Fixed Costs	$123.0	$122.7
Variable Costs	$74.1	$74.4
Total Costs	$197.1	$197.1

This portfolio generates an average of 98.1% renewable energy over the 20 year planning period, under average water assumptions.

8.2.5.2 Medium Industrial Activity with No Transmission Cost to Atlin

Table 8-18: Medium Industrial Activity with No Transmission Cost to Atlin Portfolio Summary

Resource Option	**Installed Capacity [MW]**	
	Medium Industrial Activity with no Transmission Cost to Atlin	**Medium Industrial Activity**
2018		
Demand Side Management	1.9	1.9
2019		
Thermal - 3rd NG Engine at Whitehorse	4.4	4.4
2020		
4 MW Battery - Takhini Substation	4.0	4.0
Aishihik Uprate	1.3	1.3
Whitehorse Uprate	1.7	1.7
Southern Lake Enhancement Storage Project	0.0	0.0
2021		
Thermal Diesel - Takhini Substation	20.0	20.0
2022		
Mayo Hydro Refurbishment	2.3	2.3
Mayo Lake Enhancement Storage Project	0.0	0.0
2025		
Drury Lake Small Hydro	8.1	8.1
Grand Total	43.7	43.7

Cost Components	**Cost [2016 $Millions]**	
	Medium Industrial Activity with no Transmission Cost to Moon Lake	**Medium Industrial Activity**
Portfolio Upfront Capital	$298.6	$298.6
Optimization Results (Present Value)		
Fixed Costs	$122.7	$122.7
Variable Costs	$74.4	$74.4
Total Costs	$197.1	$197.1

This portfolio generates an average of 98.1% renewable energy over the 20 year planning period, under average water assumptions.

8.2.5.3 Transmission Line Cost Sensitivity Analysis Discussion

Removing the costs associated with either of these transmission projects did not change the resources selected. Given the low load flows expected through the transmission lines, and the power losses due to the long distances, these lines were not material to the portfolio selection process.

8.2.6 Existing Transmission Grid Adequacy Assessment

A load flow analysis was completed to assess the adequacy of the existing YEC transmission grid to accommodate the development of all of the new resource options suggested in the High Industrial Activity scenario portfolio, with the peak load including the industrial loads. The High Industrial Activity scenario with industrial loads was selected as the worst case scenario for the assessment of the existing transmission grid adequacy. If the existing YEC transmission grid is capable of accommodating the highest load scenario, it would be capable of accommodating all the remaining, less demanding loads.

The simulation assumed the system peak demand of 136.5 MW, including 107.8 MW of non-industrial peak demand and 28.7 MW of industrial peak demand. The non-industrial peak demand was spatially distributed according to historical peak information with all the forecast increases applied to Whitehorse, which is the main load centre. The location of the new industrial peak demand was selected based on publicly available information. The analysis was completed in-house using ETAP, the widely used commercially available model for the electrical power system analysis

The analysis demonstrated that the existing YEC transmission grid could accommodate the increased generation under the High Industrial Activity scenario to meet the forecasted peak demand.

8.2.7 Financial and Technical Evaluation - Conclusions

The key conclusions of the technical and financial evaluation are:

- YEC is in imminent need for new capacity to meet requirements under N-1 contingency conditions. Given the lead time in constructing new resources, the expected electricity demand under all load cases is expected to exceed YECs generating capacity until the year 2021.
- For the Very Low, Low, Low with Early Minto Closure and Medium Industrial Activity scenarios, YEC is expected to have sufficient firm energy without introducing new resources, as long as it is acceptable to run YECs existing thermal resources. Despite the fact that there is sufficient firm energy for those scenarios, new renewable resources that are cheaper to operate than thermal resources are proposed to provide lower cost energy when needed. The increased load of the High Industrial Activity scenario would require incremental new energy resources.
- Thermal assets are included in most portfolios to meet capacity requirements. However, these thermal assets are not operated often for energy production over the 20 year planning period. Therefore, all of the portfolios contain a high percentage of renewable energy, most in excess of 95% on the average over the 20 year planning period.
- All the base portfolios have common resources for the first five years, which makes developing a consistent and sequential action plan possible, reducing the implementation risk of stranded investments if the future unfolds somewhat differently than under the base assumptions.
- The LNG third engine is common for all the base scenarios - it is the cheapest source of incremental capacity as it is an addition to an existing plant. For additional capacity beyond this, diesel was preferred over LNG because of its lower LCOC.

- Grid-scale battery storage is included in most portfolios as a near-term solution to address the capacity gap under N-1 conditions. While the battery has a higher LCOC than diesel, it is included in all portfolios as it has a shorter construction lead time that diesel and can be brought into service earlier to meet capacity requirements.
- Intermittent renewables such as wind provide energy but not capacity. Wind was included in the portfolio for the High Industrial Activity scenario, as there is a significant energy deficit under this scenario.
- Small hydro is a part of the Low with Early Minto Closure, Medium and High Industrial Activity scenarios even though its use for energy generation is low during late last several years of the planning period. Regardless of its low energy use at the end of the planning period, it is a lower cost solution for meeting both energy and capacity needs than a combination of thermal resources and intermittent renewable resources.
- In several of the portfolios, there is a drop-off in energy load near the end of the 20-year planning period as grid-connected mines reach end-of-life. In portfolio planning, there always exists the risks and associated cost that capital expenditures required to service customer demand growth may ultimately be ‘stranded’ if load disappears. The Yukon economy is cyclical, with the potential for a resurgence of load growth after the end of the 20-year Plan horizon. Thus, the selected Action Plan needs to be robust to respond to a surge in future electricity demands. The System Optimizer model took this reduction in energy demand into consideration, which is reflected in the cost implications to YEC and its customers.
- The preferred portfolios were not materially sensitive to the social cost of carbon, the global warming potential, fuel prices, or low-cost new transmission lines.
- The portfolio containing only new renewables was significantly more expensive than the corresponding mixed (including thermal) portfolios. In addition, the renewable portfolio did not meet YECs capacity needs until 2024. Finally the renewable portfolio provided only marginally more renewable energy generation overall than the mixed (including thermal) portfolios.

The conclusions above are specific to the technical and financial attributes of the selected portfolios. Conclusions related to the environmental, social and economic evaluations are presented in Section 8.3.2. The overall portfolio analysis and action plan conclusions are provided in Chapter 9.

8.3 Portfolio Analysis - Environmental, Social and Economic Evaluation

As discussed in in Section 8.1.2, after passing through the various technical and financial filters of the optimization modelling, each resource option was further characterized according to its unique environmental, social and economic attributes. These evaluations were conducted using five environmental, five social, and two economic criteria to address different aspects of each important resource attribute. Each criteria consisted of multiple indicators resulting in sixteen environmental indicators, seventeen social indicators and eight economic indicators. Each resource option was evaluated separately for each indicator. The attribute and indicator analyses for all resource options are presented in detail in Chapter 5 and Appendix 5.2.

8.3.1 Industrial Activity Portfolio Analysis

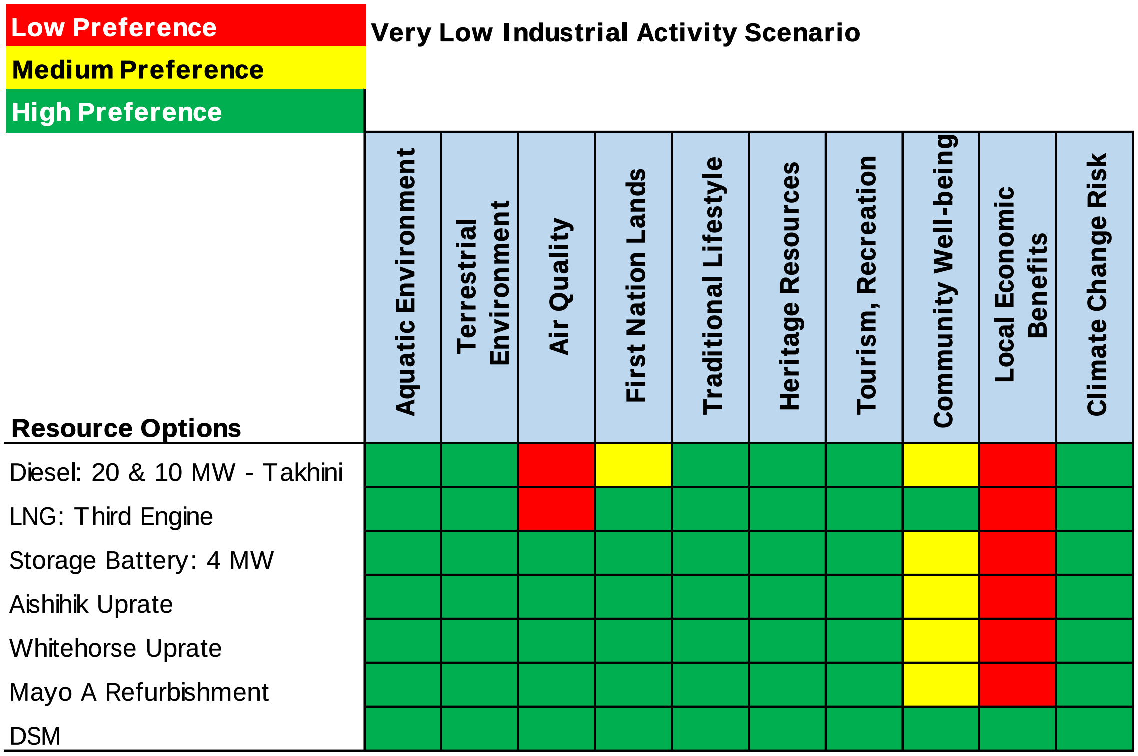
The resource options contained within the five industrial activity portfolios and the renewable portfolio were assembled into tables summarizing their respective environmental, social, and economic characteristics (refer from Figure 8-12 to Figure 8-16). The analysis showed that all portfolios contain resources that have some degree of adverse environmental, social or economic impacts. No portfolio contains resources that will not cause some impact on the human and/or biophysical environment, or without challenges to be managed.

The data in Figure 8-12 to Figure 8-16 illustrate that there are consistent outcomes for some of the key indicators for each scenario. These include:

- Air Quality: The air quality indicator for thermal generation portfolios clearly distinguished them from the portfolio containing only new renewables. Thermal resources are needed to meet near-term capacity requirements in every scenario. While not ideal, the human health issues associated with thermal generation are manageable, and not likely to result in significant adverse health effects. In addition, given that the thermal resource options are included to meet capacity requirements, these resources are not expected to be run consistently for energy generation. Therefore, GHG emissions from these thermal assets will not be significant, as demonstrated by the high renewable content of the energy generated from all portfolios over the 20 year planning period. In addition, by including the social cost of carbon into the financial analysis, the damage caused by GHG emissions from thermal resources is accounted for. Contemporary engineering standards, assessment and permitting/enforcement processes will ensure appropriate environmental and human health considerations are a part of developing thermal resources.
- Community Well-Being: The presence of mostly medium preferences for the Community Well-Being attribute is also common across all portfolios, which is associated with effects on community infrastructure and services (e.g., will the construction project strain local municipal resources), effects on community wellness (e.g., influx of temporary transient workers for construction), and community development opportunities (e.g., opportunities for training and transfer of knowledge).
- Local Economic Benefits: Finally, the presence of predominantly low preference results for the Local Economic Benefits attribute is common for almost all resource options except those that offer significant benefits for local labour and suppliers, such as with local small hydro and pumped storage options. This indicator does not imply that the other resource options are completely deficient in local benefits, but rather that the opportunities for local labour and ability to direct project capital dollars to local businesses are fewer with these smaller sized projects. This will simply challenge Yukon Energy to be more creative and to work harder to maximize local economic benefits.

Individually and taken together, the attribute profiles of the core portfolios are not significantly negative from an environmental, social and/or economic perspective. Overall, the portfolios are mostly in the environmentally friendly or otherwise characterized by challenges to attributes that can be mitigated.

Figure 8-12: Environmental, Social and Economic Characteristics of the Very Low Industrial Activity Scenario

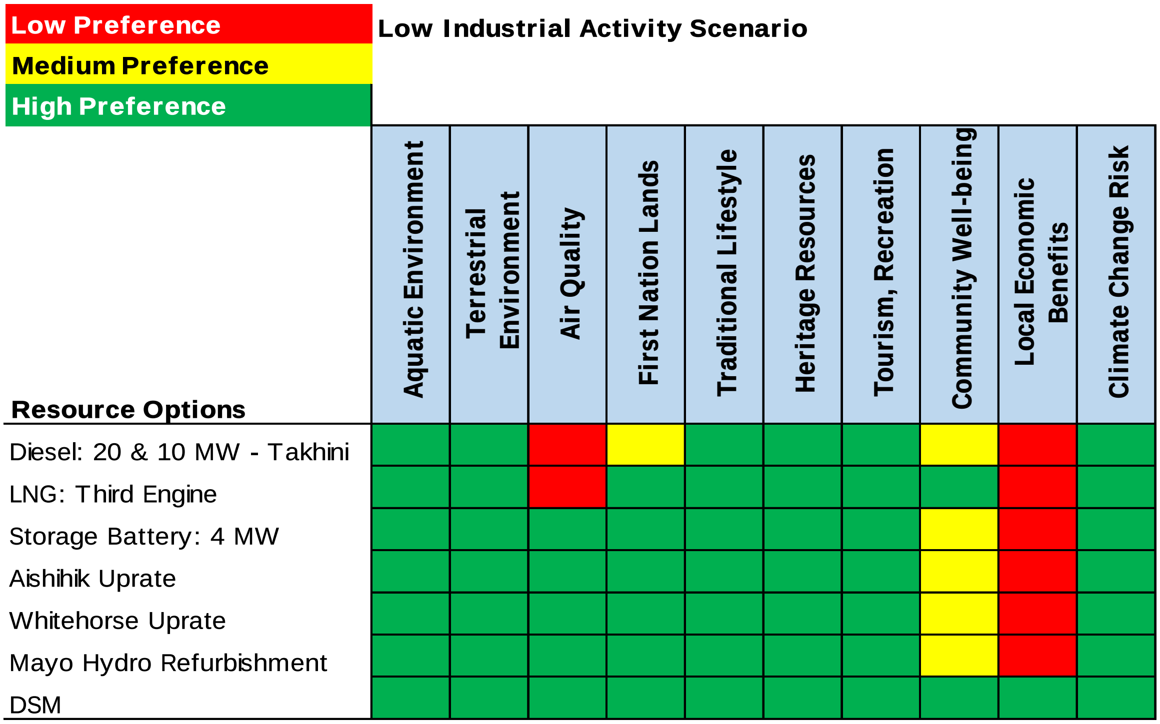


🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

Very Low Industrial Activity Scenario

Resource Options	**Aquatic Environment**	**Terrestrial Environment**	**Air Quality**	**First Nation Lands**	**Traditional Lifestyle**	**Heritage Resources**	**Tourism, Recreation**	**Community Well-being**	**Local Economic Benefits**	**Climate Change Risk**
Diesel: 20 & 10 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG: Third Engine	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo A Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

Figure 8-13: Environmental, Social and Economic Characteristics of the Low Industrial Activity Scenario



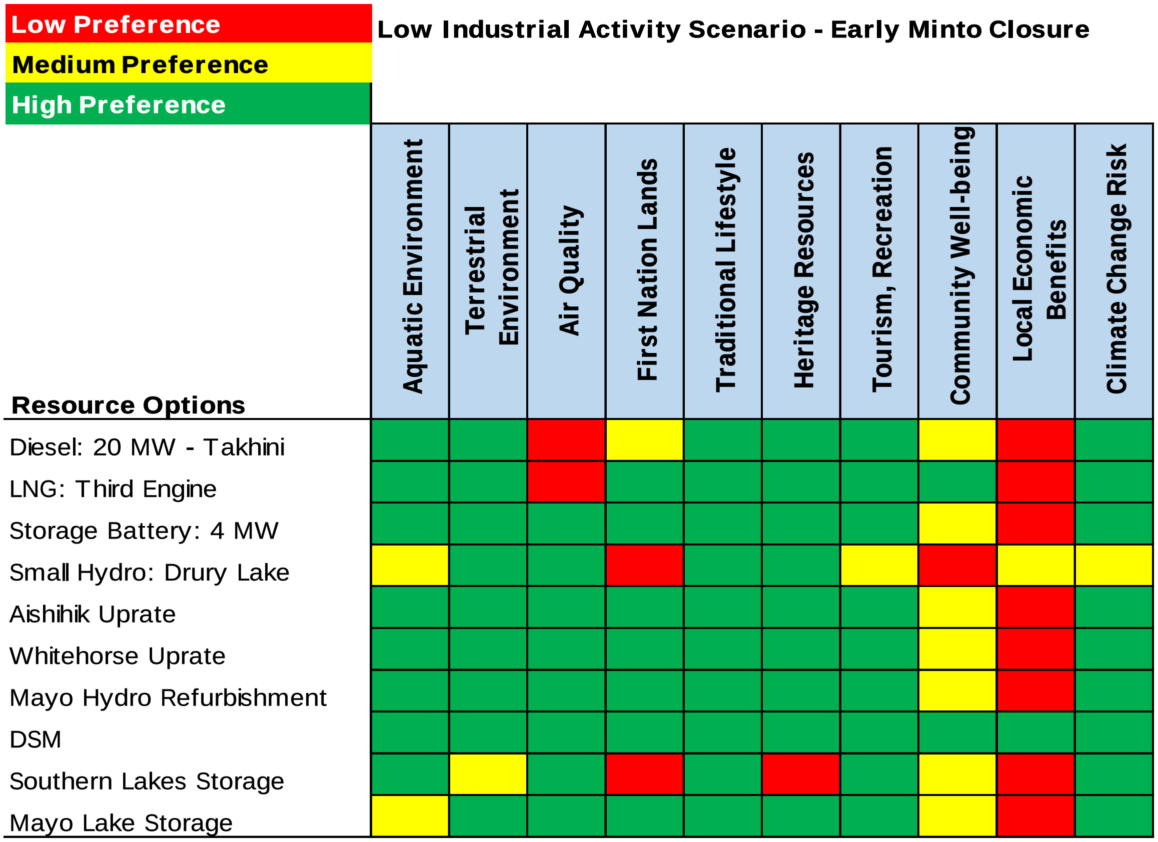
🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

Low Industrial Activity Scenario

Resource Options	**Aquatic Environment**	**Terrestrial Environment**	**Air Quality**	**First Nation Lands**	**Traditional Lifestyle**	**Heritage Resources**	**Tourism, Recreation**	**Community Well-being**	**Local Economic Benefits**	**Climate Change Risk**
Diesel: 20 & 10 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG: Third Engine	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo Hydro Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩

The Early Minto Closure scenario shown in Figure 8-14 introduces three additional hydro-related resource options. These clean energy sources from an air emissions standpoint, have associated environmental effects on land and water, as well as challenges associated with potential effects to first nations settlement lands and heritage resources requiring special attention. The presence of permafrost in the location of the Drury Lake Small Hydro introduces additional engineering challenges that drive a lower preference score under the *Climate Change Risk* criteria.

Figure 8-14: Environmental, Social and Economic Characteristics of the Low Economic Activity Scenario – Early Minto Closure



🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

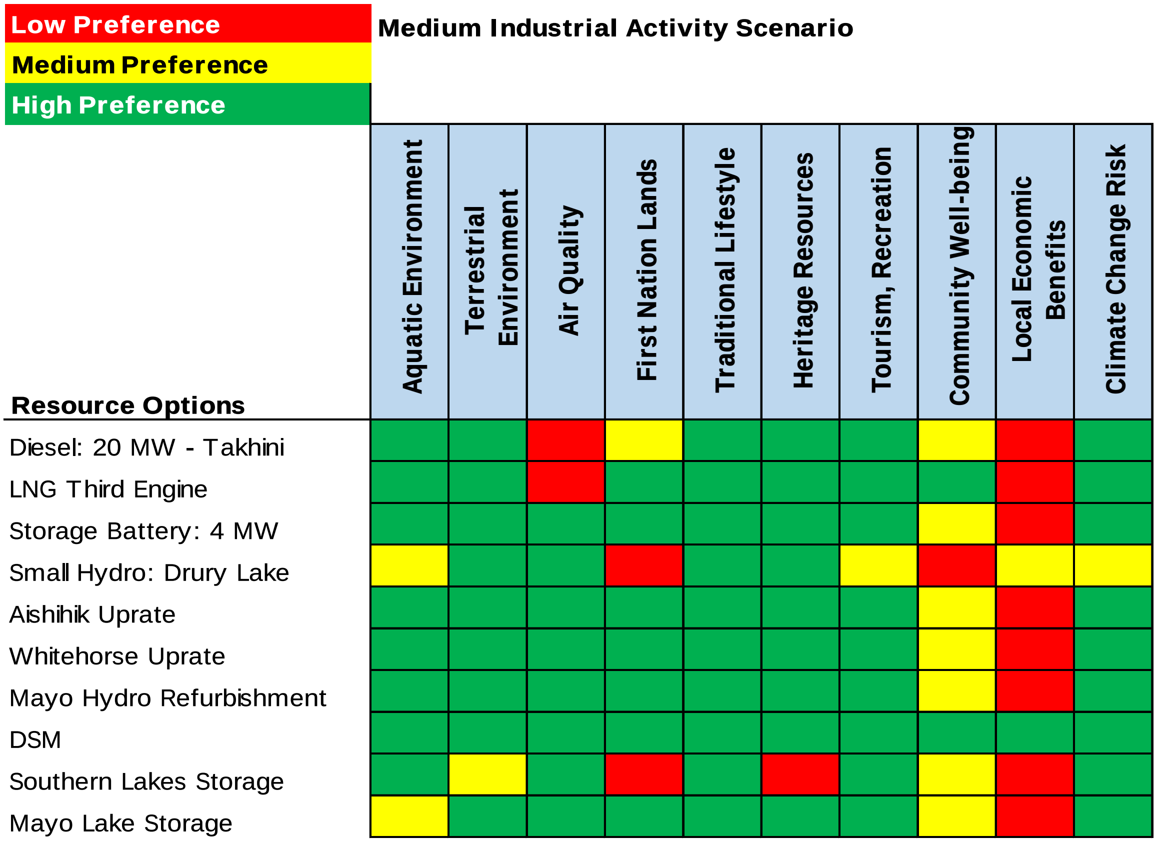
Low Industrial Activity Scenario - Early Minto Closure

Resource Options	**Aquatic Environment**	**Terrestrial Environment**	**Air Quality**	**First Nation Lands**	**Traditional Lifestyle**	**Heritage Resources**	**Tourism, Recreation**	**Community Well-being**	**Local Economic Benefits**	**Climate Change Risk**
Diesel: 20 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG: Third Engine	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Small Hydro: Drury Lake	🟨	🟩	🟩	🟥	🟩	🟩	🟨	🟥	🟨	🟨
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo Hydro Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Southern Lakes Storage	🟩	🟨	🟩	🟥	🟩	🟥	🟩	🟨	🟥	🟩
Mayo Lake Storage	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩

The Medium Industrial Activity scenario shown in Figure 8-15 contains the same resource options as the Low Industrial Activity scenario with Early Minto Closure, but includes more diesel capacity. As such, the environmental and socio-economic characterizations are similar.

The High Industrial Activity scenario as shown in Figure 8-16 includes wind to the resource mix, which introduces additional potential effects related to the terrestrial environment, such as migratory birds and bats, as well as and socio-economic impacts related to aesthetics.

1 *Figure 8-15: Environmental, Social and Economic Characteristics of the Medium Economic Activity Scenario*

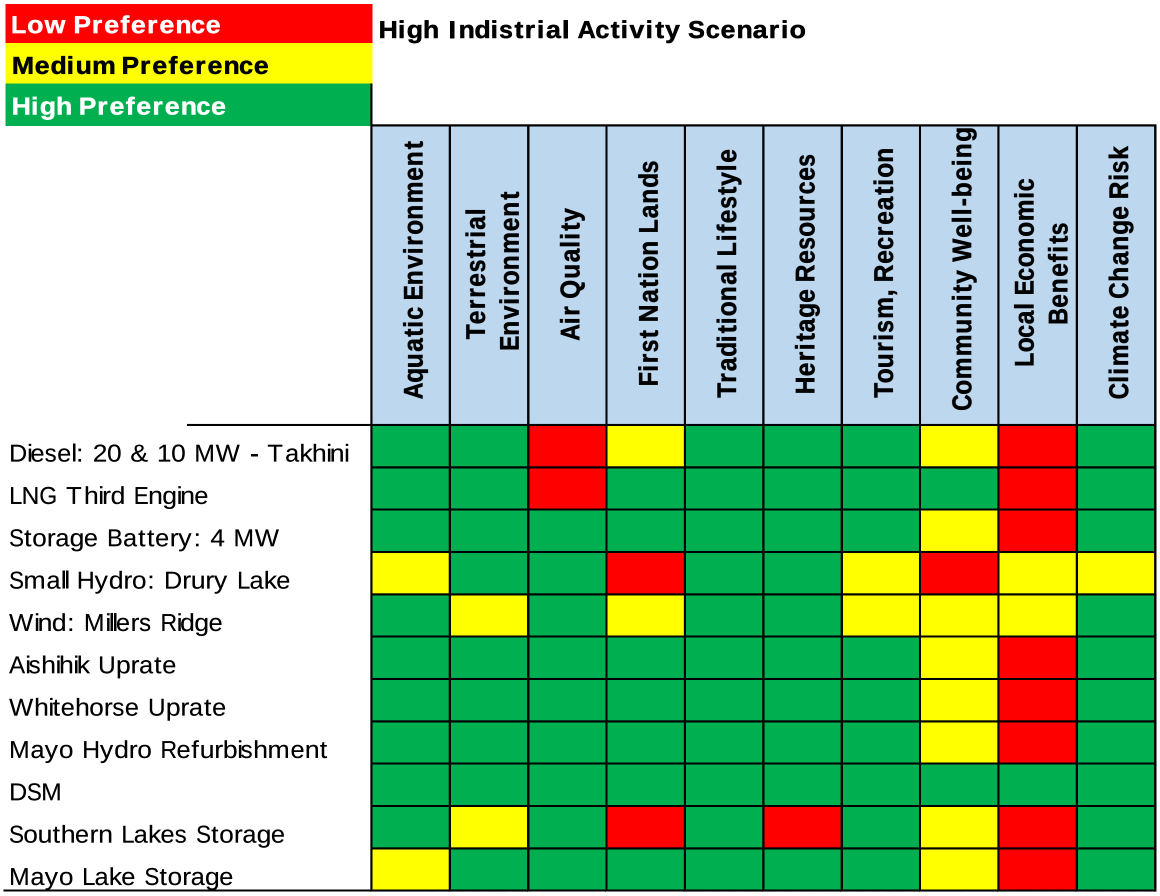


🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

Medium Industrial Activity Scenario

Resource Options	**Aquatic Environment**	**Terrestrial Environment**	**Air Quality**	**First Nation Lands**	**Traditional Lifestyle**	**Heritage Resources**	**Tourism, Recreation**	**Community Well-being**	**Local Economic Benefits**	**Climate Change Risk**
Diesel: 20 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG Third Engine	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Small Hydro: Drury Lake	🟨	🟩	🟩	🟥	🟩	🟩	🟨	🟥	🟨	🟨
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo Hydro Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Southern Lakes Storage	🟩	🟨	🟩	🟥	🟩	🟥	🟩	🟨	🟥	🟩
Mayo Lake Storage	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩

Figure 8-16: Environmental, Social and Economic of the High Economic Activity Scenario



🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

High Indistrial Activity Scenario

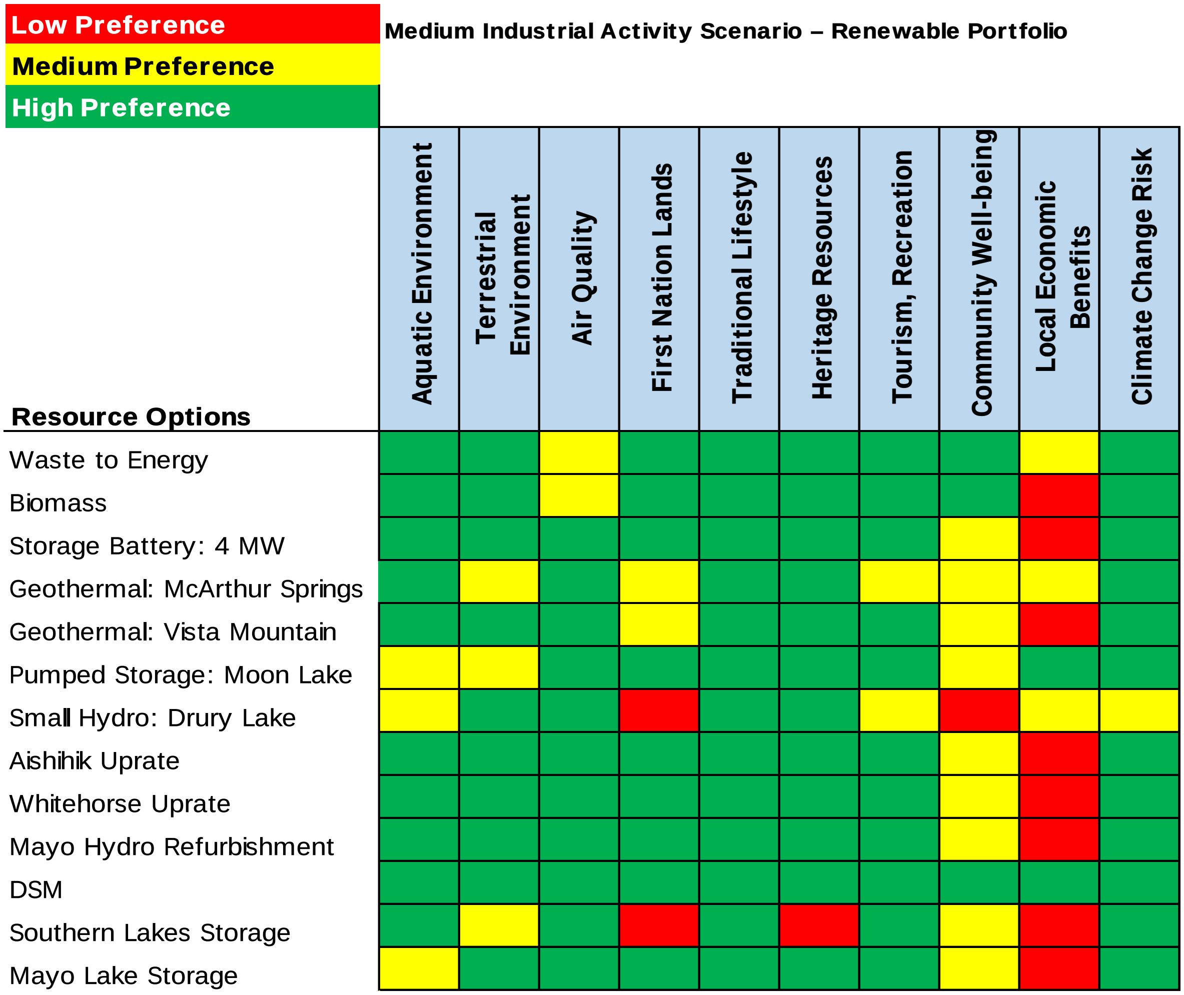
	Aquatic Environment	Terrestrial Environment	Air Quality	First Nation Lands	Traditional Lifestyle	Heritage Resources	Tourism, Recreation	Community Well-being	Local Economic Benefits	Climate Change Risk
Diesel: 20 & 10 MW - Takhini	🟩	🟩	🟥	🟨	🟩	🟩	🟩	🟨	🟥	🟩
LNG Third Engine	🟩	🟩	🟥	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Small Hydro: Drury Lake	🟨	🟩	🟩	🟥	🟩	🟩	🟨	🟥	🟨	🟨
Wind: Millers Ridge	🟩	🟨	🟩	🟨	🟩	🟩	🟨	🟨	🟨	🟩
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo Hydro Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Southern Lakes Storage	🟩	🟨	🟩	🟥	🟩	🟥	🟩	🟨	🟥	🟩
Mayo Lake Storage	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩

8.3.2 Renewable Portfolio Analysis

The renewable portfolio was assembled to examine the costs and benefits of constructing only new renewable resource options. The analysis was undertaken for both the Medium and High Industrial Activity scenarios, but is only presented for the Medium Industrial Activity scenario, because of the prohibitive costs of the portfolio under High Industrial Activity scenario. As shown in Figure 8-17, the renewable portfolio is not without potential effects. It has similar characteristics to the other portfolios that include thermal resources with respect to the social and economic attributes, but introduces some previously unseen challenges with some environmental and social criteria, such as greater impacts on aquatic and terrestrial ecosystems and distinct tourism and/or recreational effects.

As the scenario attribute analysis demonstrates, no portfolio offers a perfect solution from an environmental, social and economic perspective. The portfolios generated by the System Optimizer include a mix of resource options, which on balance represent what could be considered a reasonable or acceptable mix of resource options to meet forecasted demand at the lowest cost. The identified portfolios provide more than 98% of renewable generation for all the scenarios except for the High Industrial Activity scenario which has 92% of renewable generation. Even if the renewable portfolio were considered as an alternative to the mixed portfolio for the Medium Industrial Activity scenario, it would not offer material benefits.

Figure 8-17: Environmental, Social and Economic Characteristics of the Medium Economic Activity Scenario – Renewable Portfolio



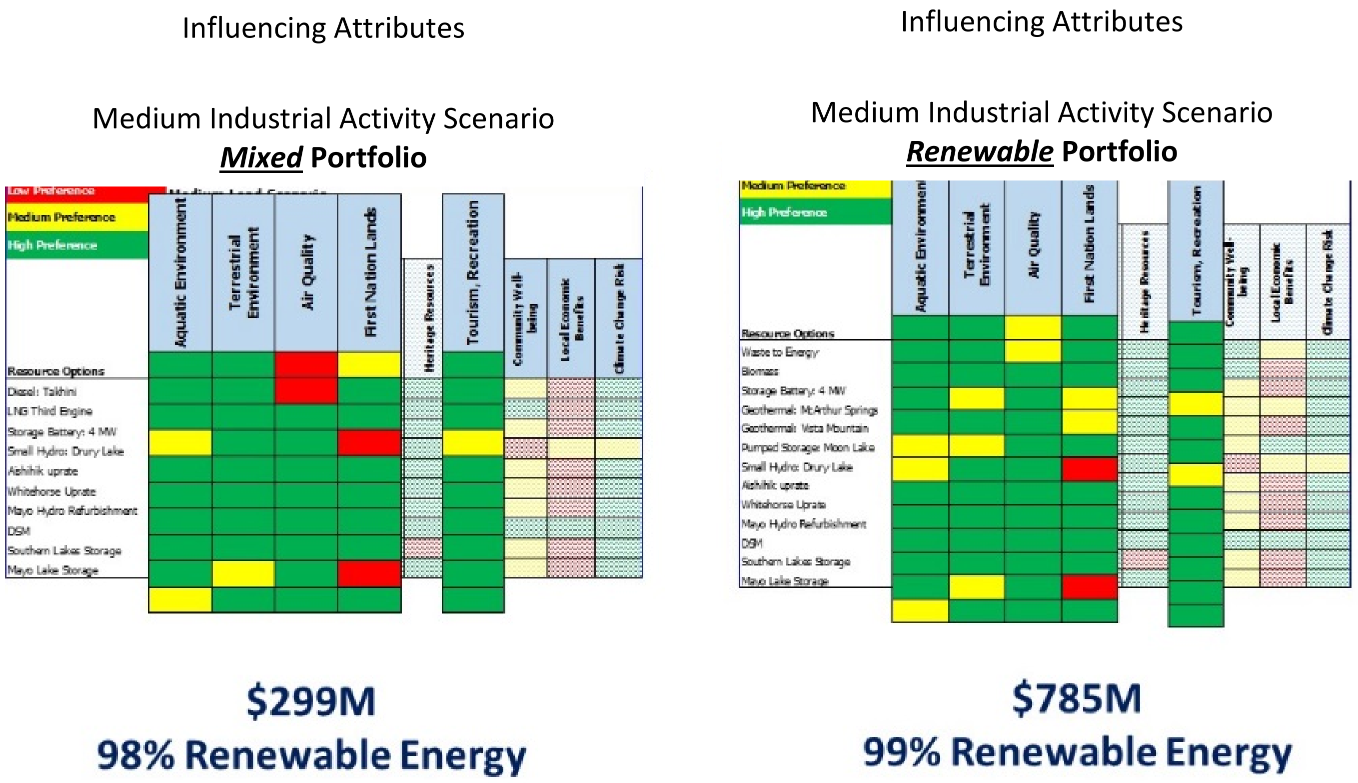
🟥 **Low Preference**
🟨 **Medium Preference**
🟩 **High Preference**

Medium Industrial Activity Scenario – Renewable Portfolio

Resource Options	Aquatic Environment	Terrestrial Environment	Air Quality	First Nation Lands	Traditional Lifestyle	Heritage Resources	Tourism, Recreation	Community Well-being	Local Economic Benefits	Climate Change Risk
Waste to Energy	🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩
Biomass	🟩	🟩	🟨	🟩	🟩	🟩	🟩	🟩	🟥	🟩
Storage Battery: 4 MW	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Geothermal: McArthur Springs	🟩	🟨	🟩	🟨	🟩	🟩	🟨	🟨	🟨	🟩
Geothermal: Vista Mountain	🟩	🟩	🟩	🟨	🟩	🟩	🟩	🟨	🟥	🟩
Pumped Storage: Moon Lake	🟨	🟨	🟩	🟩	🟩	🟩	🟩	🟨	🟩	🟩
Small Hydro: Drury Lake	🟨	🟩	🟩	🟥	🟩	🟩	🟨	🟥	🟨	🟨
Aishihik Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Whitehorse Uprate	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
Mayo Hydro Refurbishment	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩
DSM	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩	🟩
Southern Lakes Storage	🟩	🟨	🟩	🟥	🟩	🟥	🟩	🟨	🟥	🟩
Mayo Lake Storage	🟨	🟩	🟩	🟩	🟩	🟩	🟩	🟨	🟥	🟩

Figure 8-18 further illustrated that there are few clear environmental, social, or economic drivers for selecting the renewable portfolio over the mixed portfolio, which contains some thermal resources. For example, while the mixed portfolio has a less preferable profile with regard to air emissions, the renewable portfolio has a less preferable profile with regards to aquatic, terrestrial, and tourism/recreation attributes. When considering the relative importance of the various environmental and socio-economic attributes (as revealed by the Electricity Values Survey, see Chapter 3) there is no strong direction indicating either portfolio over the other. Figure 8-18 also presents the portfolio capital cost and percentage renewable energy generation of each portfolio. The renewable portfolio is considerably more expensive than the mixed portfolio, while delivering only a modest increase in the overall renewable energy content of the portfolio. Overall, the cost advantage of the mixed portfolio presents a strong case for pursuing this portfolio over the renewable portfolio.

Figure 8-18: Example Environmental & Socio-Economic Attribute Trade-Off Analysis – Medium Industrial Scenario mixed portfolio vs. Medium Industrial Scenarios renewable portfolio



8.3.3 Environmental, Social and Economic Evaluation - Conclusions

These key conclusions of the Environmental, Social and Economic evaluations are:

- All resource options, and all portfolios represent trade-offs with respect to the potential for environmental, social and economic impacts. Consistent with the compromises inherent in resource planning, there was no portfolio without some negative attributes.
- The least-cost portfolios selected by the System Optimizer model were relatively balanced and positive from an environmental, social and economic perspective. This outcome made the environmental, social and economic attribute trade-off screening less challenging. The least cost portfolios identified did not contain onerous negative attributes that would cause them to be disqualified early.
- Most portfolios generated a high percentage of (92% to 98%) energy from renewable sources over the 20 year planning period. This indicates that the portfolios were aligned with the findings of the Electricity Values survey, which showed that Yukoners have a strong preference for renewable sources of energy.
- The portfolio containing only new renewables was reviewed. The resources contained in that portfolio featured some degree of environmental, social and economic impacts and on balance the overall attribute scorings of the renewable portfolio were relatively close to those of the mixed portfolio that contained some thermal resources. The renewable portfolio substitutes any future potential thermal resources with all renewables, for an overall increase of 1% renewable

energy. Despite a modest change in the environmental, social and economic attributes, the renewable portfolio requires an additional capital investment of $486 million, which is 2.5 times greater than that of the mixed portfolio. This significant cost difference is too great to recommend the all-renewables option in the Action Plan.

- The Action Plan does not preclude the option to substitute additional renewable resources in the future, but this substitution could incur potentially significant additional costs with potentially little gain in the net renewable energy percentage.

Action Plan: Table of Contents

Action Plan: List of Tables

9 Action Plan

This chapter presents the key considerations in developing the Action Plan, and the proposed steps to be undertaken towards the implementation of the 2016 YEC Resource Plan.

9.1 Key Action Plan Considerations

The assessment of the environmental, socio-economic and financial attributes of each of the portfolios presented in Chapter 8 illustrated that all portfolio choices inevitably involve tradeoffs, as each resource option has challenges or potentially less desirable effects. Notwithstanding, portfolios were selected to meet expected load growth at the lowest cost, and the portfolio analysis subsequently demonstrated that these portfolios were well aligned with Yukoners values as laid out in the Electricity Values Survey, Appendix 3.1. The Electricity Values survey found that Yukoners valued environmental protection first, then minimizing the cost of energy, followed by reliability and finally social responsibility.

Given the current high percentage of renewable energy within the proposed portfolios, the renewable portfolio resulted in a marginal increase from 98% to 99% renewable energy generation overall, when compared to the mixed portfolio including thermal resources under the medium industrial activity scenario. However, the capital cost of the renewable portfolio was 2.5 times higher than that of the mixed portfolio. In addition, the renewable portfolio presented its own set of environmental challenges, and if implemented would be not be able to meet YEC's peak demand requirements under the single contingency criterion (N-1) until 2024. It was felt that the additional cost did not warrant such a marginal increase in renewable generation.

YEC's Action Plan has incorporated the need for flexibility to deal with risks such as major and sudden changes in grid loads, and the potential inability to develop a preferred resource proposed in the Action Plan. In light of ongoing uncertainties, the Action Plan needs to be resilient and robust under various potential load scenarios and regulatory, financial and development outcomes. A portfolio of relatively small, scalable and modular assets to meet load growth, as proposed in YECs Action Plan, presents a lower risk than a single large asset, in terms of regulatory approvals, financing, fuel diversity and resourcing. Such an approach is also aligned with public values. As an example of scalability, YEC's LNG facility completed in 2015 was built with the expansion potential for a third unit, which is now recommended in the Action Plan as an attractive option to provide additional capacity. YEC will consider the balance between potential lower costs due to economies of scale for larger solutions, versus the ability of smaller, incremental supply solutions to more closely match growth.

The portfolio analysis sensitivity on social cost of carbon, transmission cost and fuel prices discussed in Chapter 8 did not result in significant changes to the resource options selected.

The recommended Action Plan is based on the resource portfolios generated for the five major industrial activity scenarios: Very Low, Low, Low with Early Minto Closure, Medium and High. The Low with Early Minto Closure and Medium industrial activity scenarios are considered more likely to occur than the remaining three scenarios.

The portfolio analysis integrated the research and analysis presented in the previous chapters, while the Action Plan describes how YEC proposes to implement the results of the portfolio analysis. Professional judgment and stakeholder input were used to translate the portfolio analysis into the Action Plan.

The methodology followed in the portfolio analysis identified specific projects, as presented in Table 9.1, such as, the Drury Lake small hydro project and the Thulsoo Mountain wind project. Considering that many projects presented in the portfolio analysis are in an early stage of development, the final decisions on any project development have not been made. Projects with comparable technical, financial, environmental, social and economic attributes may be considered before the final project selections are made. For example, the Pine Creek small hydro project has similar technical, environmental, social and economic attributes to the Drury Lake project, and, as such, both projects may be considered during the early stages of planning of the identified small hydro project. YEC will follow the rigorous stagegate process discussed in Section 9.5 to make the final decision on resources that will be built.

The content of the five portfolios presented in Table 9.1 indicated that there were commonalities among the portfolios. The common resources for each portfolio at the beginning of the planning period helped develop the recommended Action Plan in two stages. Those two stages are:

1) Short Term Action Plan (present to 2022): The Short Term Action Plan is a recommendation based on common resources. In addition to the common resources, a) resources that were not a part of the lower probability scenarios (Very Low and Low industrial activity scenarios), but deemed essential for the remaining scenarios and b) resources that were part of all the portfolios but whose timing was not identical for all the portfolios, were included in the Short Term Action Plan recommendations. The details are presented in Section 9.2.
2) Long Term Action Plan (2022 to 2035): The Long Term Action Plan is a recommendation of additional resources to be developed over the longer term, contingent on the specific future industrial activity scenario that develops over time. Unlike the Short Term Action Plan recommendations that are common for all the scenarios, the Long Term Action Plan recommendations depend on the specific industrial activity scenario that unfolds in the future. The Long Term Action Plan consists of four different paths depending on the future industrial activity scenario. The details are presented in Section 9.3.

Table 9-1: Portfolios for five major industrial activity scenarios

Scenario	Very Low	Low	Early Minto Closure	Medium	High
2018	DSM	DSM	DSM	DSM	DSM
2019	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine	3rd NG Engine
2020	Battery (Takhini) Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP	Battery (Takhini) Aishihik uprate Whitehorse uprate SLESP
2021	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)	Diesel 20 MW (Takhini)
2022	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP	Mayo Refurbishment Standing Offer Program MLESP Wind 20 MW (Thulsoo Mt.)
2023			Small Hydro (Drury Lake)		Small Hydro (Drury Lake)
2025	Aishihik re-runnering			Small Hydro (Drury Lake)	
2026	Diesel 10 MW (Takhini)	Diesel 10 MW (Takhini)			Diesel 10 MW (Takhini)

9.2 Short Term Action Plan

The portfolio analysis results presented in Table 9.1 identified the following resources which are common to all the portfolios until 2022: DSM (conservation), LNG Third Engine, Battery, Diesel Plant, Whitehorse Hydro Plant uprate, Mayo Hydro Plant refurbishment, and the Independent Power Producer (IPP) Standing Offer Program (SOP). Consequently, those resources are included as key elements of the Short Term Action Plan. The IPP SOP is a part of the Yukon Territorial Government IPP Policy that sets a target of 10 GWh/year of energy to be supplied by independent power producers. YEC included this energy source in all portfolios starting in 2022.

In addition to the common resources listed above, three additional resources are included in the Short Term Action Plan: the Southern Lakes Enhanced Storage Project (SLESP), Mayo Lake Enhanced Storage Project (MLESP), and Aishihik hydro plant uprate.

Despite the fact that the SLESP and MLESP developments are not required for the Very Low and Low industrial activity scenarios, they are included from 2020 onwards in the Medium, Early Minto Closure and High portfolios. The Very Low and Low industrial activity scenarios are considered less ikely to occur than the Early Minto Closure and Medium scenarios. Therefore, it was considered prudent to include the SLESP and MLESP projects in recommended Short Term Action Plan, recognizing that timing for any related physcial works can be optimized subsequent to securing all necessary approvals.

The Aishihik Hydro Plant uprate is included in all the portfolios, but the project timing depends on the scenario. This project is included from 2025 onwards in the Very Low Industrial Activity scenario, while it is included from 2020 onwards in all the remaining portfolios. Considering that the lower likelihood of the very low scenario than the remaining scenarios and the need for this resource for the remaining, it was considered prudent to include work on the Aishihik hydro plant uprate in the recommended Short Term Action Plan.

The new diesel plant will be designed to be scalable, so that additional diesel engines can be added if required, for example if the Low Industrial Activity scenario develops and an additional 10MW capacity of diesel is required. Such an approach was undertaken with the design of the existing LNG plant, which was designed for three engines, but only two engines were installed in the initial plant construction.

The resources recommended in the Short Term Action Plan and their in service years are presented in Table 9-2. Those resources are common for all the industrial activity scenarios.

Table 9-2: Resource Options in the recommended Short Term Action Plan

Year	**Resource Option**
2018	DSM
2019	LNG Third Engine (4.4 MW)
2020	Aishihik Hydro Plant Uprate
2020	Whitehorse Hydro Plant Uprate
2020	Batteries (4 MW)
2020	SLESP
2021	Diesel (20 MW)
2022	Mayo A Refurbishment
2022	MLESP
2022	Standing Offer Program

9.3 Long Term Action Plan

The recommended Long Term Action Plan consists of two components:

- Continued implementation of the resource options included in the Short Term Action Plan, and
- Development of additional resource options which are dependent on the specific industrial activity scenario that develops over time.

Therefore, specific additional resources included in the recommended Long Term Action Plan have been identified for each scenario. Growth in energy use and peak demand will be closely monitored to help guide the utility on which long term actions are required. An updated load forecast scheduled for 2018 should provide better insights into the load scenario unfolding in the future in sufficient time to develop the resources to meet the load.

Table 9-3 presents the resource options included in the recommended Long Term Action Plan, and the projected in-service years.

Table 9-3: Resource Options in the recommended Long Term Action Plan

Scenario	Very Low and Low	Early Minto Closure	Medium	High
2022				Wind 20 MW (Thulsoo Mt)
2023		Small Hydro (Drury Lake)		Small Hydro (Drury Lake)
2025			Small Hydro (Drury Lake)	
2026	Diesel 10 MW			Diesel 10 MW

There are commonalities among the additional resource options included in recommended Long Term Action Plan. For example the Small Hydro is included in the Medium, Early Minto Closure and High industrial activity scenarios, while the 10 MW Diesel project is common to the Very Low, Low and High industrial scenarios. Considering the likelihood of Early Minto Closure and Medium industrial activity scenarios, and the long lead time for development of a hydro project, YEC plans to start planning work on the small hydro project in the short term.

Table 9-4 summarizes the Short and Long Term Action Plan recommendations. The first column in the table presents resource options that will be developed in the Short Term Action Plan; the second column distinguishes among the industrial activity scenarios that would lead to different recommended Long Term Action Plans, while the third column presents additional resources that are targeted for development in the recommended Long Term Action Plans, for different industrial activity scenarios.

Table 9-4: Short and Long Term Action Plan Recommendations

Short Term Action Plan	Industrial Activity Scenario	Long Term Action Plan
DSM (2018) **3rd Engine (2019)** **Whitehorse, Aishihik uprates (2020)** **Battery (2020)** **SLESP (2020)** **Diesel 20 MW (2021)** **MLESP (2022)** **Mayo A (2022)** **Standing Offer Program (2022)**	Very Low, Low	Diesel 10 MW (2026)
	Early Minto Closure	Small Hydro 8MW (2023)
	Medium	Small Hydro 8MW (2025)
	High	Wind 20 MW (2022) Small Hydro 8MW (2023) Diesel 10 MW (2026)

9.4 Constraints

It should be noted that there are a number of practical constraints that could potentially impact the execution of both the recommended Short and Long Term Action Plans. These constraints are currently unknown, and without undue speculation could not be addressed formally in the portfolio analysis or the development of the recommended Action Plans. These constraints are:

- Access to Capital: an assumption was made in the development of the recommended Short and Long Term Action Plans that YEC will have access to the required debt and equity to finance the assets included in the plan. Any constraints in the availability of capital may impact the scope and timing of project execution, and the recommended Action Plans will be adjusted in response to any capital constraints that materialize.
- New Government Policy: existing government policies over the planning period were considered in the development of the Action Plans, including for example the application of a social cost of carbon in the determination of the economics resources. The recommended Short and Long Term Action Plans do not take future government policies into account. The Action Plans will be reassessed through YEC's annual business planning process and the formal Resource Plan update process, and adjustments will be made in response to potential new Government Policies that directly impact the Action Plan.
- Internal Resource Constraints: as a small utility, YEC has finite resources available to both plan and manage the construction of new resources. YEC leverages these internal resource through the use of external consultants to enhance the company's project development capacity. The finite availability of internal and external resources could limit the number of new projects that can be developed in any given year. The timing of projects included in the Action Plan may be adjusted in response to potential internal and external resource constraints.

9.5 Next Steps

In accordance with precedence established in the 2006 Resource Plan proceedings before the YUB, YEC has continued to update the resource plan every five years. Following the completion of the 2016 Resource Plan and submission to the YUB, detailed planning will begin for the studies, design, and permitting required to implement the resource options presented in the recommended Short Term Action Plan.

YEC will follow the stagegate project framework to define and develop resource options (new projects). The framework covers the full set of activities from project conception to construction and commissioning. The framework is a consistent industry standard approach in which large projects are divided into stages, with appropriate authorization gates between the stages. The stages in the YEC framework are: prefeasibility, feasibility, preliminary engineering, regulatory, detailed engineering, and construction. The activities associated with each stage are: engineering, socio-economic and environmental assessment, contracting and procurement, First Nation engagement and public engagement. Decision gates, positioned at the end of project stages, ensure the appropriate oversight and control by YEC management and the YEC Board. Each gate is a formal approval point (proceed to the next stage of the project, conditionally proceed to the next stage of the project, or close the further development of the project), involving a review of key project information including costs, resources, schedule, scope and residual risks. The specific evaluation approach and criteria applied at each gate may vary depending on the preceding stage, and the purpose of the gate, but in general it aims to provide answers to the following questions:

- Quality of execution: Was the previous step executed adequately.
- Viability of project: Is the continuation of the project still desirable. i.e. is the project still the best choice from technical, financial, environmental, social and economic perspectives. As a consequence, a project substitution can potentially be pursued.
- Action plan: Are the proposed action plan and the requested resources reasonable and sound.

The end of the preliminary engineering stage is followed by the major project approval gate, requiring Board of Directors approval. Projects passing this gate will typically be advanced for regulatory review and approval. The regulatory approval stage typically consists of a review by the Yukon Environmental and Socio-economic Assessment Board (YESAB) and, depending on the type of the project, Yukon Water Board. In some instances a review by the Yukon Utilities Board may also be required.

As collaboration with First Nations and stakeholders will be critical to the success of these projects, YEC will continue to work on different aspects of planning and execution of new energy projects with:

- First Nations,
- Yukon Territorial Government,
- ATCO Electric Yukon,
- Municipal governments,
- Potential IPP proponents, and
- Consumer, business, community and environmental advocacy groups.

As work on satisfying YEC customer demands is ongoing, economic activity and consequent growth of energy and peak demand will be monitored as an indication of which Long Term Action Plan is most probable to be implemented. The Resource Plan is a living process and is updated every five years with the energy and peak demand forecasts scheduled for updating in 2018.

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