Modelling Process Information Session

2023 Integrated Resource Plan (IRP)

Manitoba Hydro

Land acknowledgment

Manitoba Hydro has a presence across this province on Treaty 1, Treaty 2, Treaty 3, Treaty 4 and Treaty 5 lands and the original territories of the Anishinabe, Cree, Oji-Cree, Dakota, Dene peoples and homeland of the Métis nation.

We acknowledge these lands and pay our respects to the ancestors of these territories.

Manitoba Hydro

Good day! My name is Dave Bowen, I work for Manitoba Hydro and I am the Director of the Integrated Resource Planning Division. I would like to welcome everyone here today and thank you in advance for again taking time to be part of our Integrated Resource Planning process.

Over the past months, we have taken the 4 scenarios with the key inputs and started the modelling process where we, have been learning how we could meet the potential needs of our customers over the next 20 years.

One challenge we have, is that the modelling process is complex. We've created this session to build an understanding of a number of key concepts that should help with the next conversations about Initial Modelling results in a few weeks. An example we will touch on today is the difference between energy and capacity.

Today we are excited to provide you with a better understanding of the modelling process; specifically a greater knowledge of how we use electricity in Manitoba, how it’s relevant to our model and the modelling process.

Our team is represented by Lindsay Hunter, the Project Manager for the IRP project and Ryan Bernier, Resource Planning Engineer who will be sharing with you today.

Thanks. As it has been a few months since we last met, I'm going to start today's session with a quick re-introduction to our Integrated Resource Planning process.

Purpose of Integrated Resource Planning

Manitoba Hydro must:

- Ensure a sufficient supply of safe, reliable energy that responsibly meets the evolving energy needs of Manitobans

Integrated Resource Planning:

- Is a structured process to help understand how the future may unfold and identify steps needed to prepare

Manitoba Hydro

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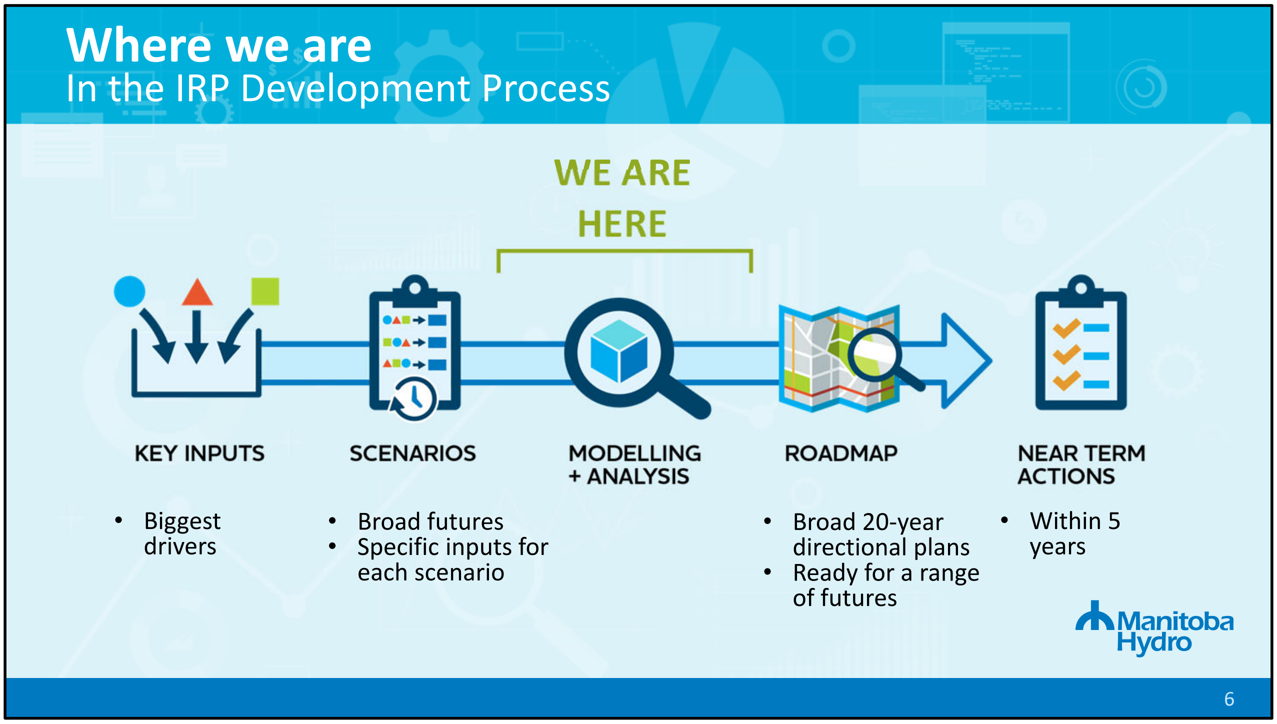
At Manitoba Hydro, we supply electricity and natural gas to customers across the province of Manitoba.

That means we have to make sure there is enough supply of these energy sources to meet demand – ensuring the light comes on when a switch is flipped or the heat comes on when a thermostat is turned up.

For over 60 years, Manitoba Hydro has been planning to ensure a reliable supply of energy for our customers, while balancing any financial impacts. We've also been planning for the infrastructure that delivers this energy to our customers. This includes the pipelines, transmission towers, distribution lines and the various stations that move energy around the province.

Now, the evolving energy landscape is changing how our customers will use their energy at home, for their vehicles and at work. So we need to evolve our planning process to help us prepare. Developing an Integrated Resource Plan is one change we've made.

This process is not about how the future **should** unfold, but ensuring that the path forward can respond to how it **might** unfold.

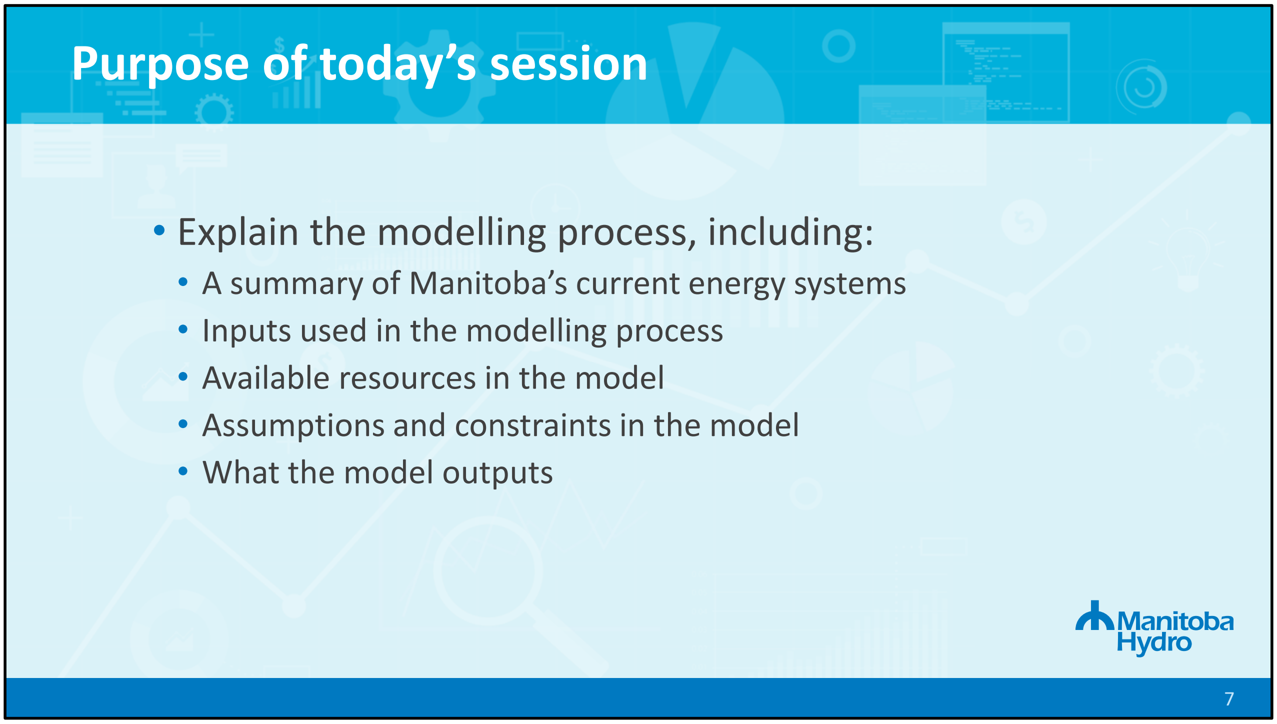


Our IRP process breaks down into 5 stages as shown on this slide. We are now in the modelling and analysis stage. That means we are reviewing the scenarios we discussed with you last round and their impacts on resources, cost, and other factors through a technical lens.

As we conclude our modelling and analysis, we will use the information gained to develop the Integrated Resource Plan, including the roadmap and near-term actions.

This 20-year roadmap will include long-term strategies to prepare for the evolving energy landscape. It will help define where we want to go, or may need to go, and identify a number of ways we can get there. The roadmap will also allow us the flexibility so we can change direction as the future unfolds.

The IRP planning process is also likely to identify a number of more near-term steps to increase readiness for the future – steps that could happen in the next 5 years. These steps will be detailed in the near-term actions and are likely to include further interpretation of results, developing a more detailed understanding of potential strategies and defining the steps for informing potential major infrastructure development or investment decisions.

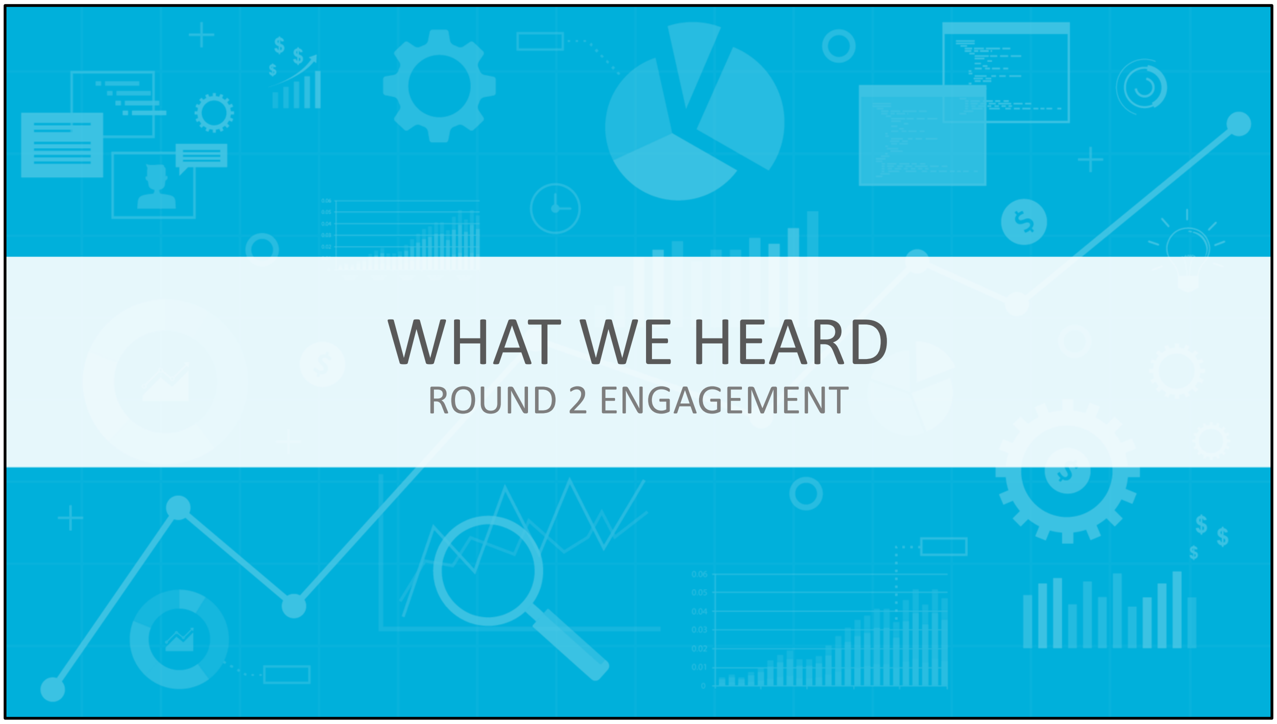


That brings us to today. The purpose of this session is to share how the modelling process works, from the inputs to the modelling process all the way to the outputs that are produced. Our next sessions, starting in late November, will be an opportunity to discuss some of the initial results from our modelling process.

We are covering a lot of information today on our modelling process, and it is very much in context of what is done for the IRP.

Our goal is to share as much as we reasonably can in the time allotted, but we cannot cover everything. We will pause periodically throughout the session to try and answer questions looking to clarify what we are sharing. Any questions we don’t have time to answer in the session will be responded to afterwards and shared with participants.

We also appreciate that you might have additional questions about the modelling process or an interest in more detailed information. If that is the case, please reach out to us at IRP@hydro.mb.ca and we will be happy to follow-up. We will also have the email address on the screen at the end of the presentation.



As we move through our IRP Development process, our work continues to build upon previous work. This is also true of our discussions with you. Before we get into the modelling process, I want to review what we discussed during our last round of engagement in the spring and how this is influencing our modelling and analysis work now.

This graphic illustrates the conversations we are having throughout our IRP process. The engagement conversations complement the development process and are aligned with key IRP development milestones.

In our last round of engagement, we discussed the preliminary work to develop the key inputs and scenarios that are the backbone to our analysis of the different energy futures. We hosted a number of different workshops to seek feedback on our initial thoughts on the Key Inputs and Scenarios.

We also presented the same information to the general public through our website and to our list of 5,000 subscribers who identified they wanted to participate in our IRP Development.

We also conducted research with some of our larger customers to understand how their energy use may transition in the future.

Today we will run through the details of our modelling process for the IRP.

Coming up in a few weeks, we will share our initial modeling results, with specific outputs on load projections, our key findings of our initial results, and our next steps to conclude the modelling and analysis.

Scenarios
Key Input comparisons

	Scenario 1: Slow decarbonization & slow decentralization	Scenario 2: Modest decarbonization & modest decentralization	Scenario 3: Steady decarbonization & modest decentralization	Scenario 4: Accelerated decarbonization & steady decentralization
Economic growth	●	●●	●●	●●●
Decarbonization policy	●	●●	●●●	●●●●
Electric vehicles	●	●●	●●●	●●●●
Natural gas changes	●	●●	●●●	●●●●
Customer self-generation	●	●●	●●	●●●

● represents amount of change

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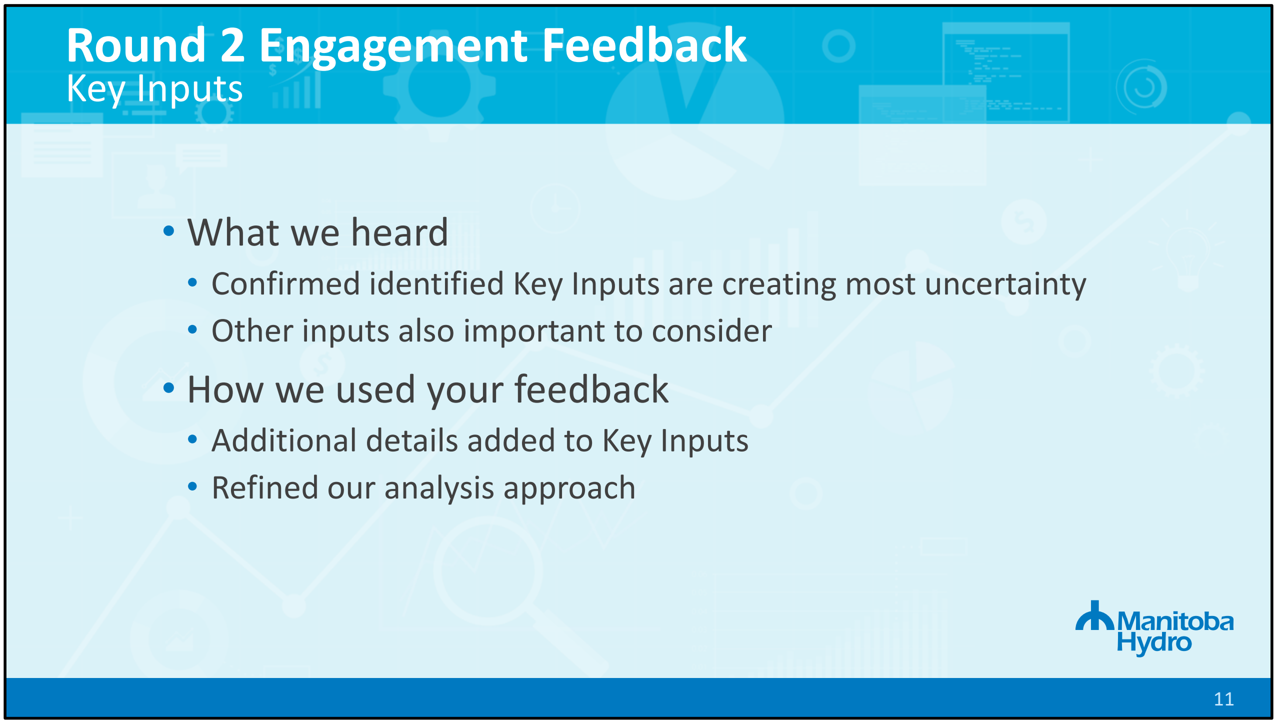
Let's review these 5 key inputs and 4 scenarios that were the basis of our last round of engagement. The key inputs were developed to represent the changes that will have a significant impact on future energy needs.

They are economic growth, decarbonization policy, electric vehicles, natural gas changes and customer self-generation.

The 4 scenarios use a combination of the key inputs to represent a specific energy future. The scenarios were set to represent broad possibilities of what the future may be, using different amounts of change for each of the 5 key inputs.

The feedback you shared during the last round of engagement helped us finalize the details of these key inputs and scenarios so we could start the modelling. We have previously shared this feedback and how it was used, but let's review that here quickly.



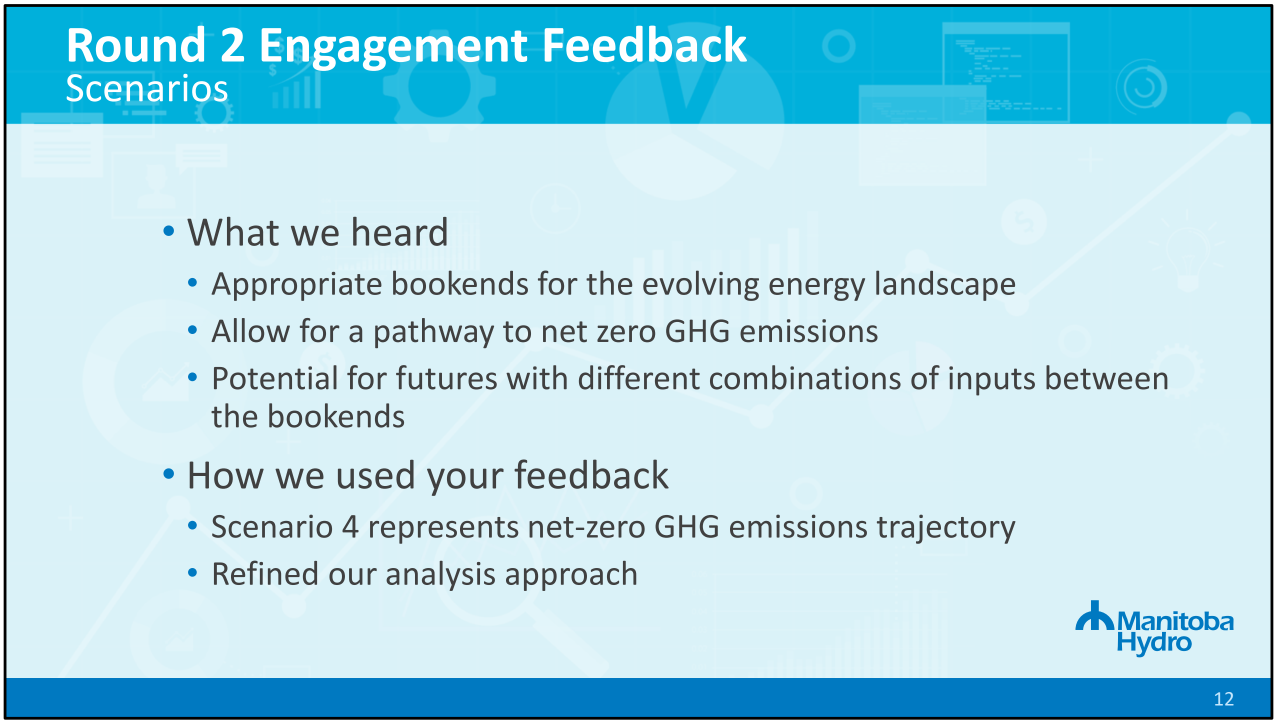
First, the key inputs... During our discussions last spring, we received a lot of feedback on the key inputs -- feedback that helped us feel confident we had correctly identified the key inputs creating the most uncertainty in the evolving energy landscape. We also heard from you that factors driving net-zero GHG emissions are top of mind.

In addition, we had feedback telling us other inputs are important to consider, such as:

- Reconciliation with Indigenous peoples
- Sustainable development
- Energy efficiency, and
- Factors influencing economic growth.

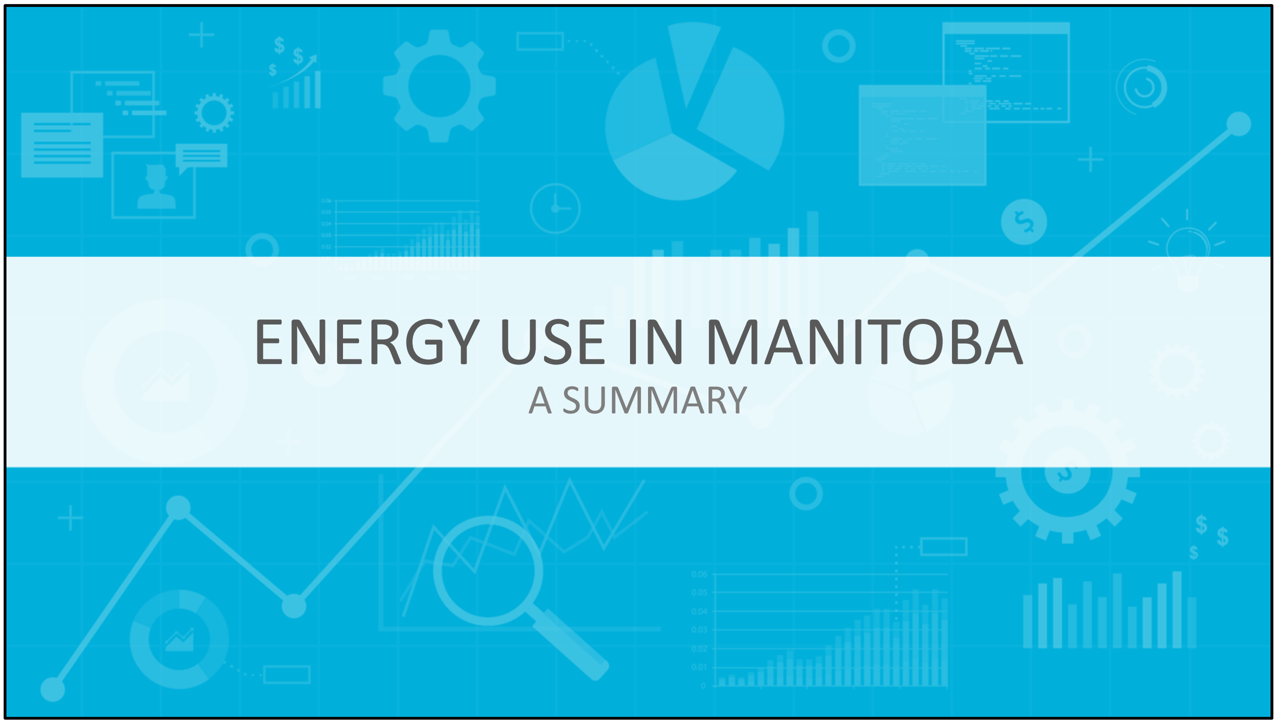
We've used this feedback in multiple ways. For example, we clarified additional factors that were driving the key inputs, such as technology availability and viability, particularly with electric vehicles.

The feedback you shared on these other important inputs was also used to help refine and finalize our analysis approach. We will discuss this analysis approach further at our sessions on preliminary results in a few weeks.



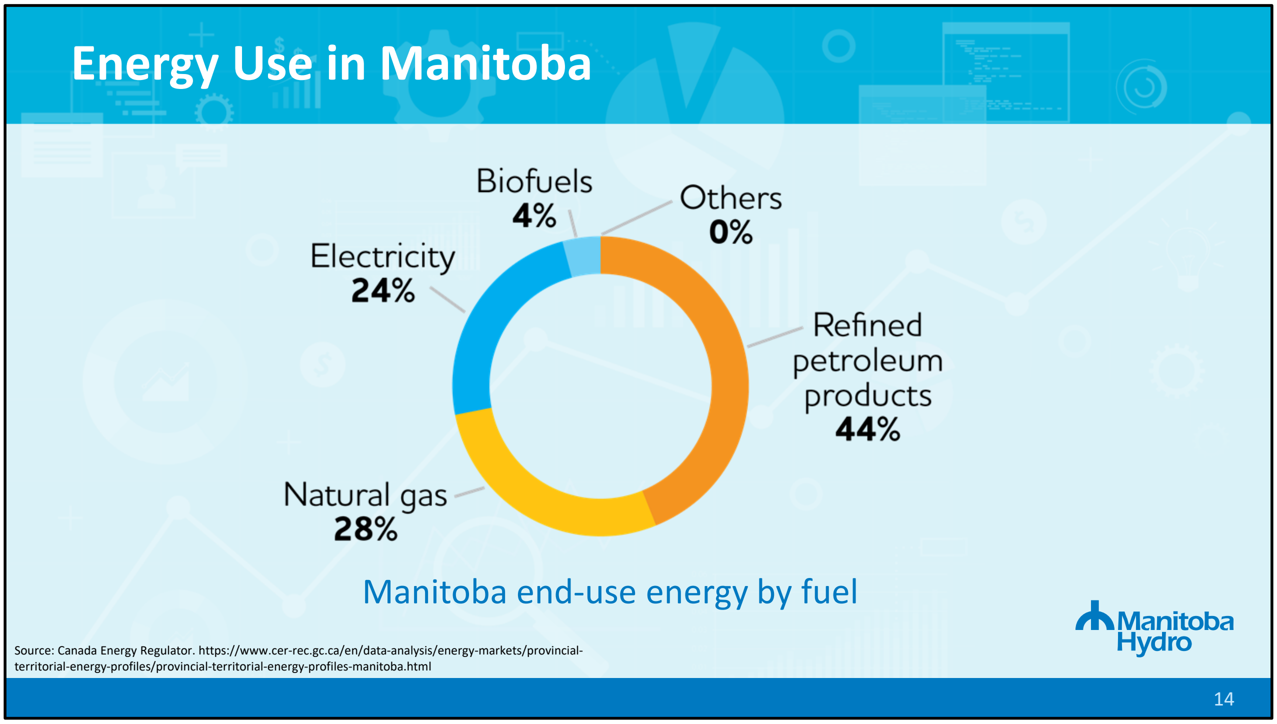
Now let's talk about the scenarios... When we asked you about the scenarios we presented, your feedback was that they were appropriate bookends for the evolving energy landscape, so long as Scenario 4 reflected a path towards net zero GHG emissions. We used this feedback to ensure that Scenario 4 did in fact represent such a path.

You also shared that you thought there is potential for futures that are different combinations of inputs between the bookends than what we presented. We used this feedback to help refine and finalize our analysis approach, which again we will discuss further in our next conversation in a few weeks.



In addition to what we've heard in our engagement, there's one more topic I want to review before handing the presentation over to Ryan to get into the modelling process, and that is energy use in Manitoba today.

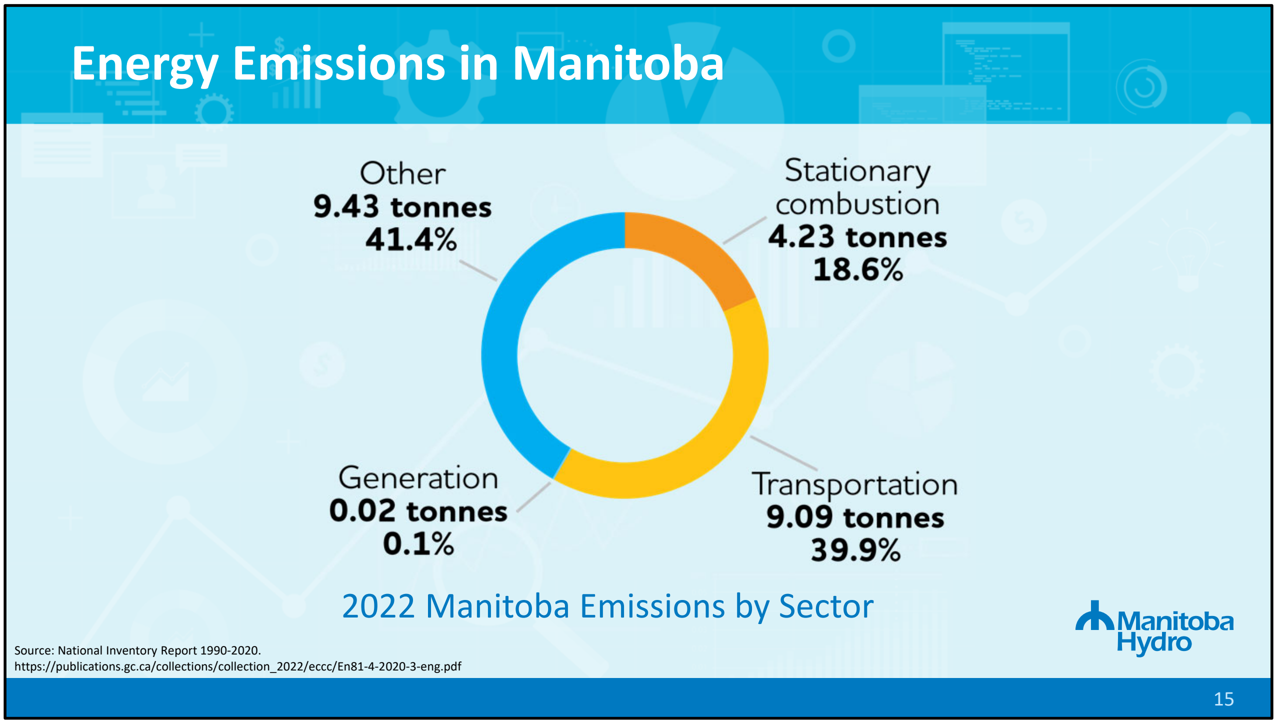
We are using modelling for the IRP to understand the potential energy futures being driven by the evolving energy landscape. But, to understand how the energy landscape can evolve in Manitoba, it can be helpful to understand our current energy landscape -- how energy is currently used in this province, and how Manitoba Hydro and the energy we provide fits into this larger picture.



The electricity and natural gas supplied by Manitoba Hydro contributes to just over 50% of the total energy used in Manitoba. The remaining energy used is mainly refined petroleum products, which are generally used to fuel vehicles.

Decarbonization is one of the main forces driving the evolving energy landscape. As part of our work to understand the potential energy futures, the IRP scenarios are looking at various levels of decarbonization, generally through electrification of other energy sources.

The scale of this potential change can be seen in the graph above. Overall, the existing electricity supply and delivery system accounts for only 24% of the energy used in the province. If other fuels for transportation and uses of natural gas are decarbonized through electrification, this would result in a significant increase in electricity use compared to what we see today.



It is also important to understand sources of GHG emissions in Manitoba because some of these sources could change based on future energy choices. As you can see on this chart, GHG emissions are separated into four categories: stationary combustion, transportation, generation and other.

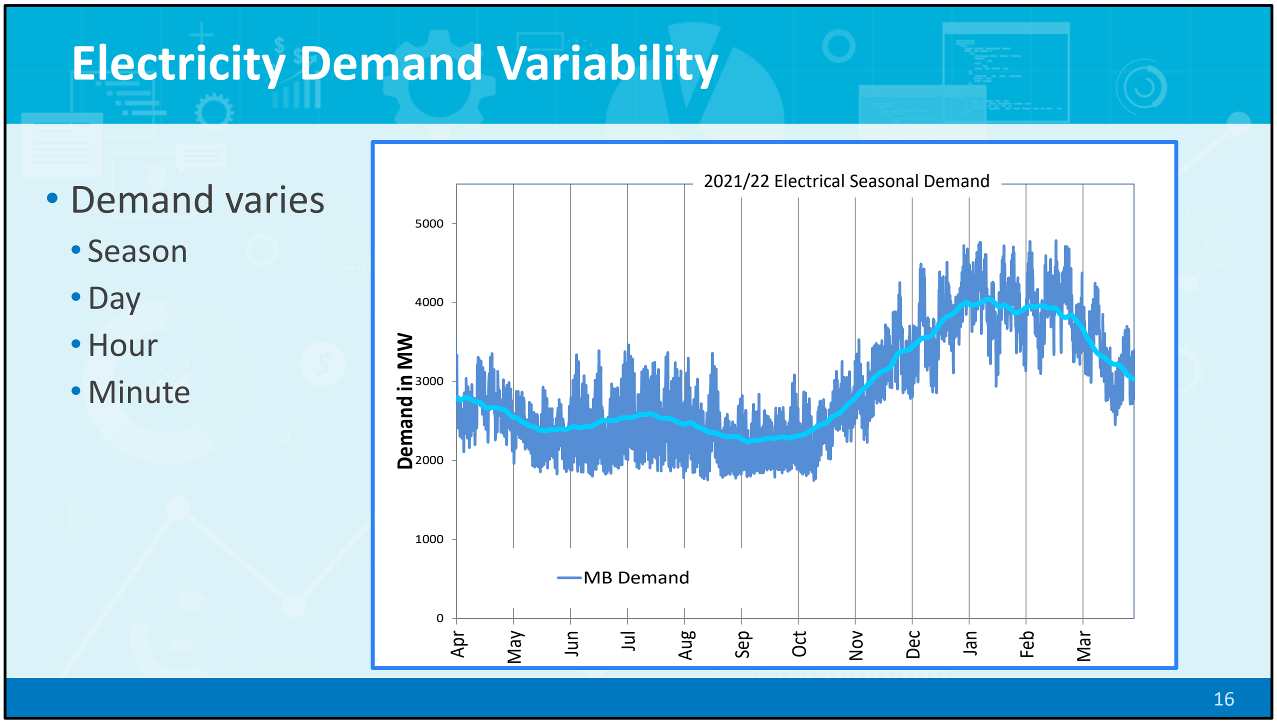
Manitoba Hydro can directly impact three of these categories by supporting decarbonization efforts:

- First in the orange segment, stationary combustion emissions. These emissions include those from space heating, as well as industrial process uses.
- Second as shown in yellow, transportation emissions. Moving from internal combustion engines to electric vehicles will directly impact

electricity needs and future emissions.

- Finally the skinny segment (that is light blue if you could see it) are current emissions from electricity generation, which is the another form of stationary combustion. Differences in fuel sources may impact future emissions.

The “other” category (in dark blue) refers to the emissions that Manitoba Hydro cannot impact. These are generally GHG emissions from processes related to agricultural production and are not energy dependent.

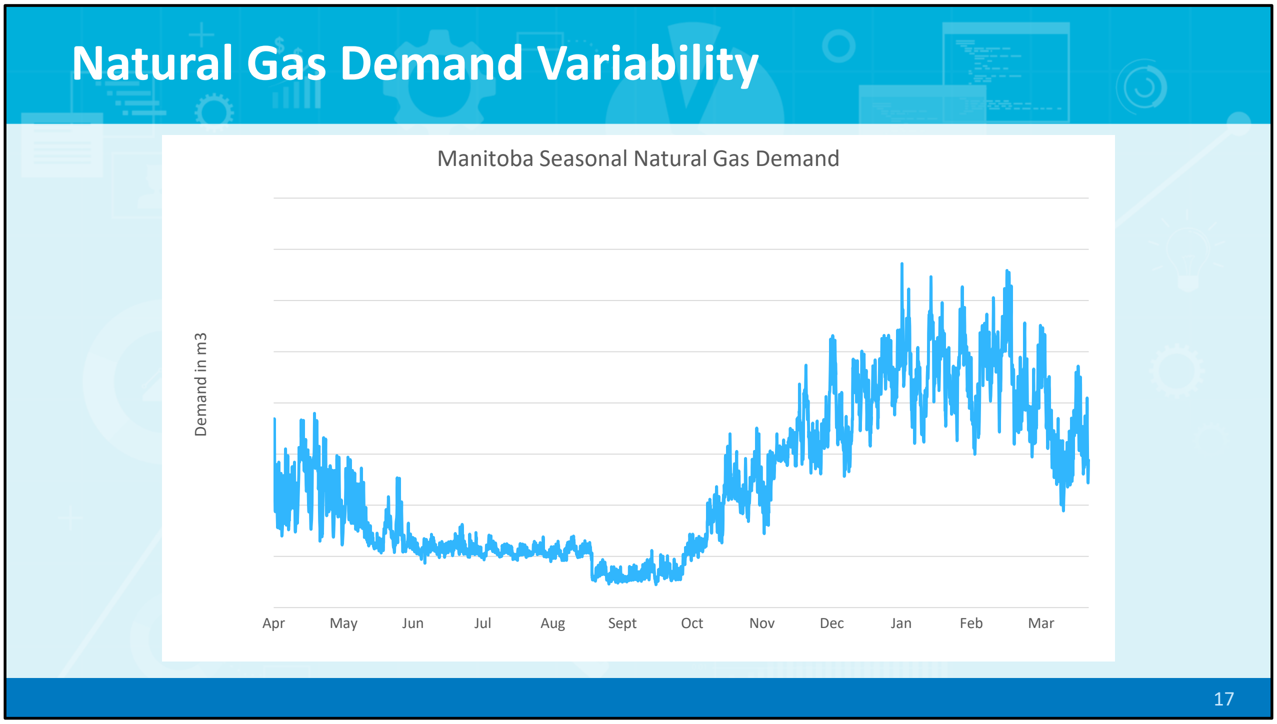


Another important aspect of energy use in Manitoba is the variability in the demand for electricity. Electricity demand varies significantly by season, day of the week and time of day.

This graph demonstrates the seasonal variation of Manitoba's electrical use. As you can see, we are a winter peaking province, meaning we have the most demand for electricity in the winter…this is probably not a surprise.

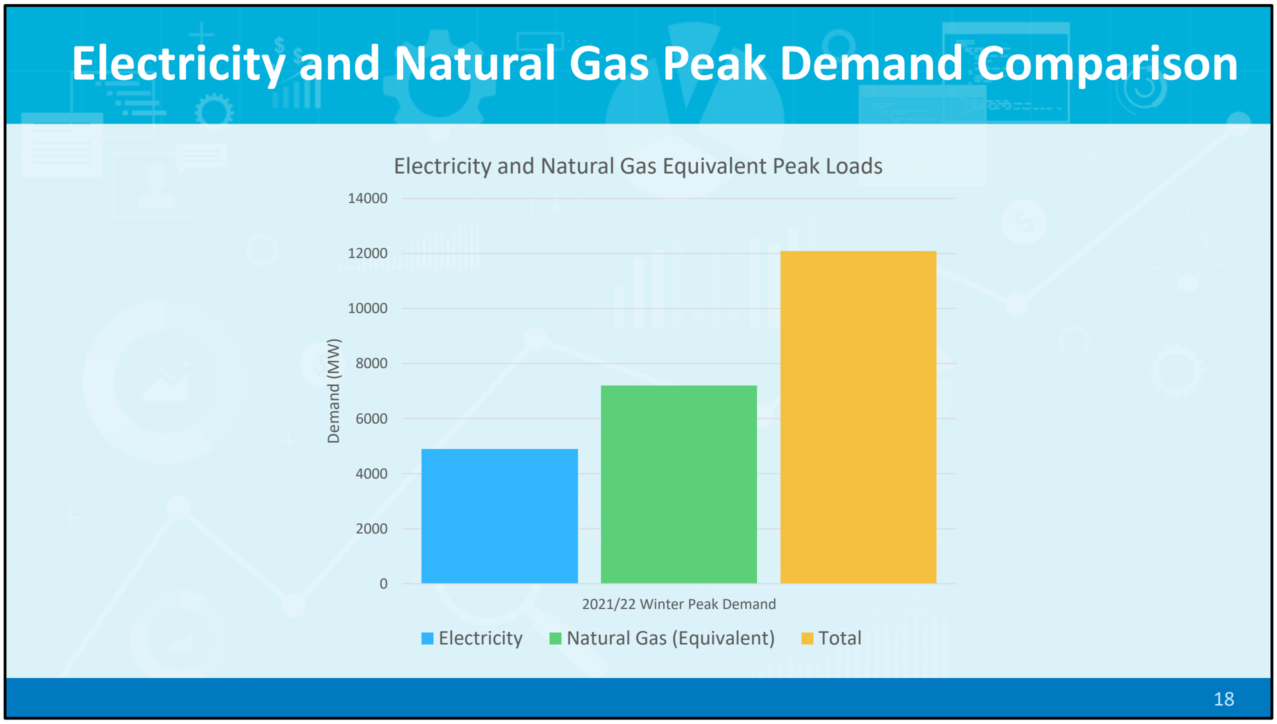
There are also daily variations in electricity demand between weekdays and weekends, as well as throughout the day. The demand can vary by as much as 30% in a single day. You can see this in the peaks and valleys overlaying the seasonal demand line.

This variation needs to be considered in our planning so customers are supplied with electricity when they require it.



Just like electricity, natural gas demand in Manitoba has a lot of variability. As this graph shows, natural gas demand in Manitoba is extremely weather sensitive and very seasonal, mostly due to Manitoba's winter heating needs.

Industrial use is also part of the total gas demand. This load is more constant throughout the year.

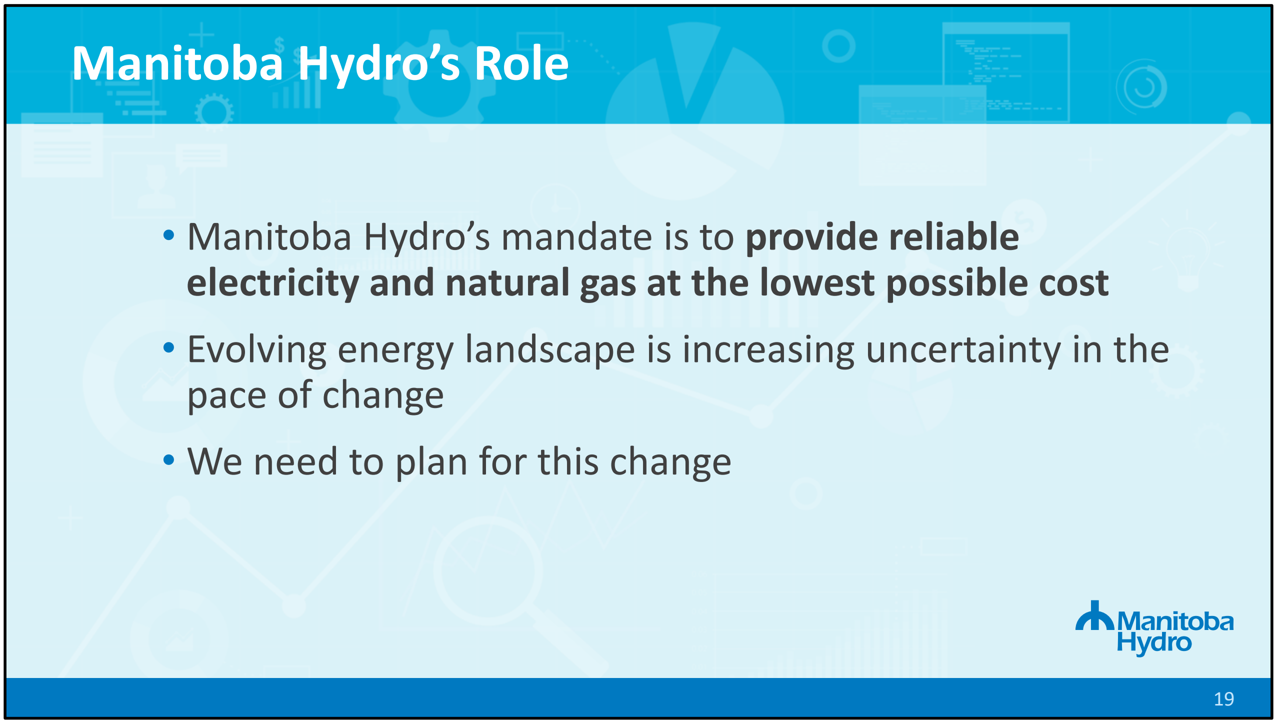


If we compare the peak demand for both natural gas (in green) and electricity (in blue), we can see that Manitoba's peak natural gas demand when converted to an electrical equivalent is much higher compared to the peak electricity demand.

If you consider decarbonization through electrification, you can start to see that electrifying this peak natural gas demand could have a significant impact on overall electricity demand in Manitoba -- particularly because of the fact that both natural gas and electricity demand peak in winter.

To explain this with specifics, two years ago peak electrical demand in Manitoba was approximately 4,900 MW. During that winter, the natural gas hourly peak demand in Manitoba was the electric equivalent of more than 7,000 MW. To serve this demand exclusively with electricity, Manitoba Hydro would have to more than double the size of our current electricity system. This is show in the difference between the yellow total bar and the blue electricity bar.

This leads me to my final point – Manitoba Hydro’s role in Manitoba's energy landscape.

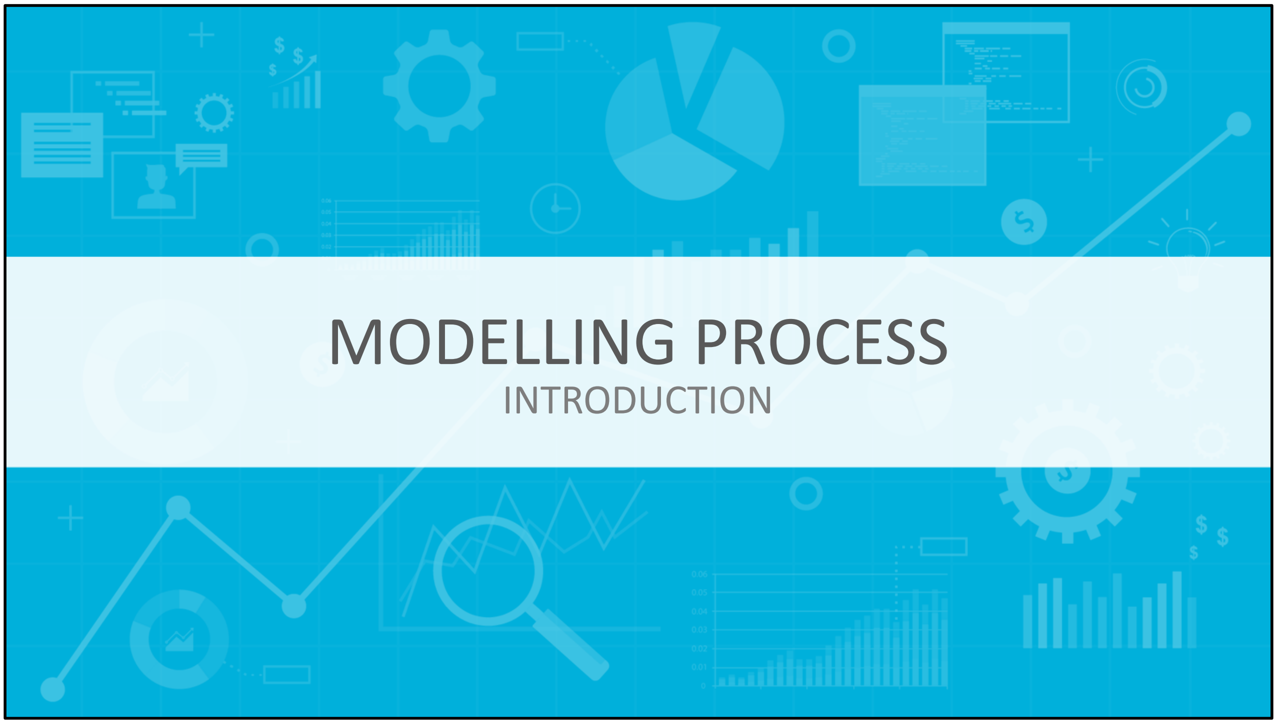


Simply put, Manitoba Hydro's role is to provide reliable electricity and natural gas to Manitobans at the lowest possible cost.

This means we must aim to provide electricity regardless of time of day, season, or weather condition, and over a range of water conditions, including severe drought. We cannot just consider the average, we must plan for the extremes.

The energy landscape is evolving and this is increasing uncertainty in the pace of change.

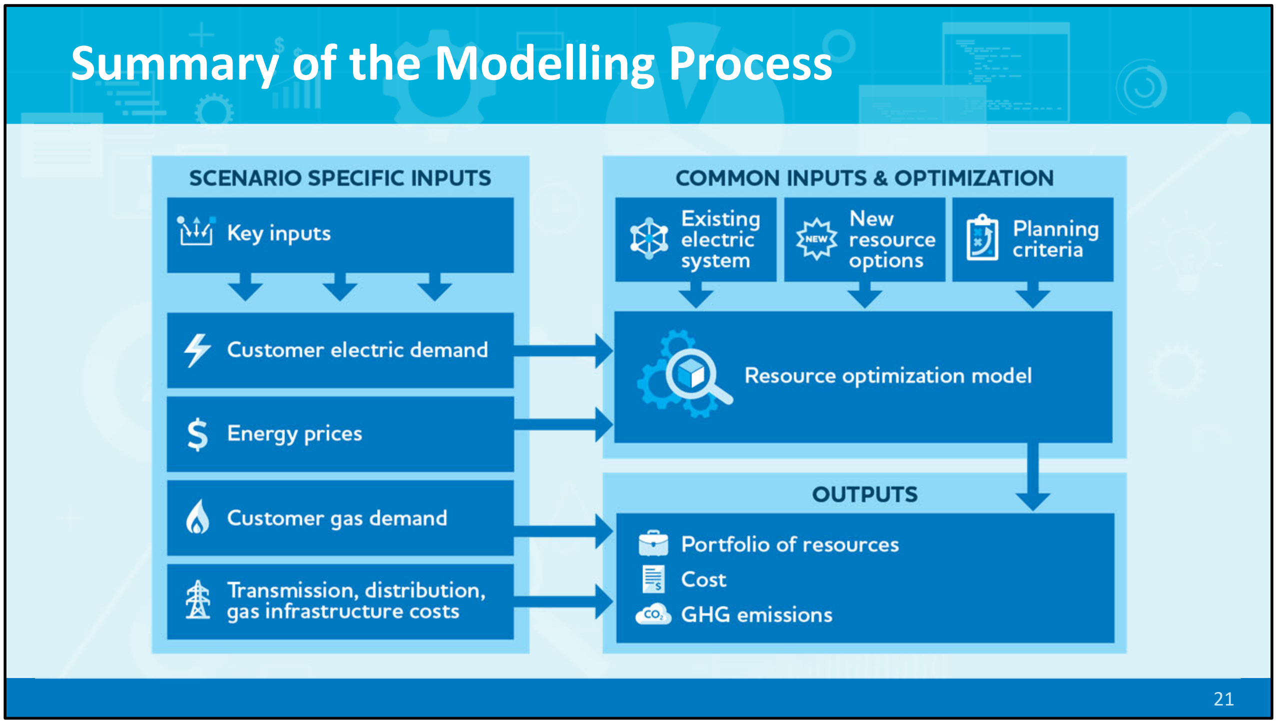
Developing an Integrated Resource Plan and doing the modelling and analysis that is part of that process, will help us ensure we can continue fulfilling our role.



Thank you, Lindsay.

My name is Ryan Bernier, and I'm a Resource Planning Engineer in the Energy Resource Planning Department.

We'll now provide an overview of the modelling process that Manitoba Hydro utilizes in this next section of the presentation.



Here is a flow chart showing the overall IRP modelling process.

I know there's a lot on this slide. Don't worry, we'll go through each of these boxes to explain what they mean and how they fit into our modelling process.

The purpose of this modelling process is to simulate the electrical system so that we can explore how best to meet our future energy needs, for a range of different scenarios.

The modelling process is mainly focused on the electrical system, although assumptions for natural gas have been factored in.

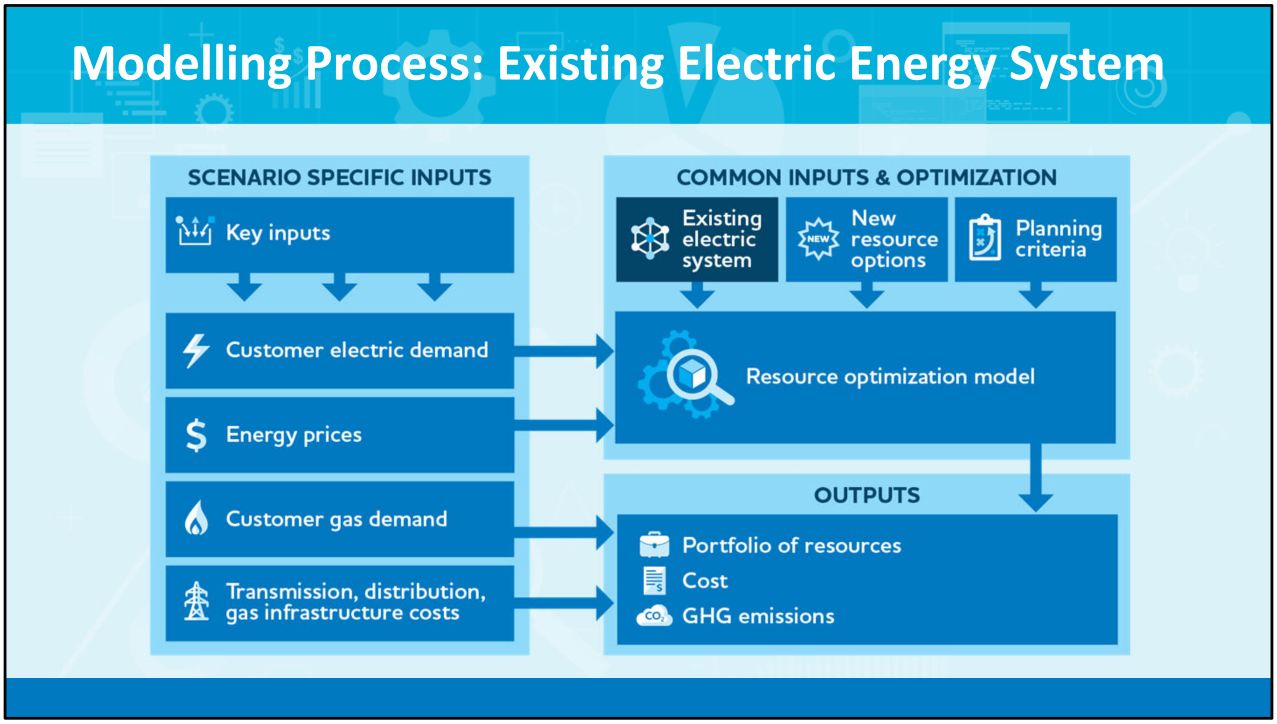
The key components of this process include:

- The Existing electric system
- Planning Criteria
- Transmission & Distribution costs

- New Resource Options
- Scenario Specific Key Inputs, with a focus on customer demand for electricity and natural gas
- Energy Prices for imported and exported energy
- The Optimization Model itself
- And the Model Outputs

Overall, this process results in outputs for each scenario, including a portfolio of potential resource options, costs, and resulting green house gas emissions.

We'll now walk through each part of this modelling process to explain the component.



This section will provide an overview of Manitoba Hydro's existing electrical system, which is a key component of the planning process.

Existing Energy System

Resource	Rated Capacity Megawatts (MW)
Hydropower (16 Stations)	5,768
Natural Gas Fueled Combustion Turbines (1 Station)	278
Wind Turbines (2 wind farms)	258

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Here is a quick snapshot of Manitoba Hydro's existing generating system.

Manitoba Hydro operates 16 hydropower stations, 1 natural gas fueled station, and has power purchase agreements with 2 wind farms.

As you can see, the majority of our system is hydropower.

In fact, on average over 99% of energy generated in Manitoba is renewable with 97% from hydropower and 2% from wind generation.

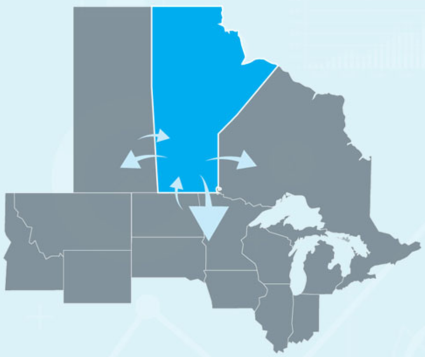
On the other hand, many people don't realize that we have a generating station in Brandon that uses natural gas to produce electricity.

Although it's rarely used, this station has a very important role in the overall supply system. Its' primary role is to serve customers during the highest load periods (typically during the winter), and to supply energy during extreme drought.

Another key component of our system is our large reservoirs which enables energy to be stored and released for use later at our hydropower stations.

Each of our existing generation resources, and each of the large reservoirs, are included in the model so that it can simulate our existing system.

Connections to Other Markets



	Export	Import
United States	2858 MW	1400 MW
Ontario	100 MW	0 MW
Saskatchewan - North	25 MW	60 MW
Saskatchewan – South	290 MW	0 MW

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Manitoba Hydro's system also interacts with neighboring systems in Saskatchewan, Ontario, and the United States.

This happens through interconnections, which are transmission lines linking Manitoba Hydro to our neighbors.

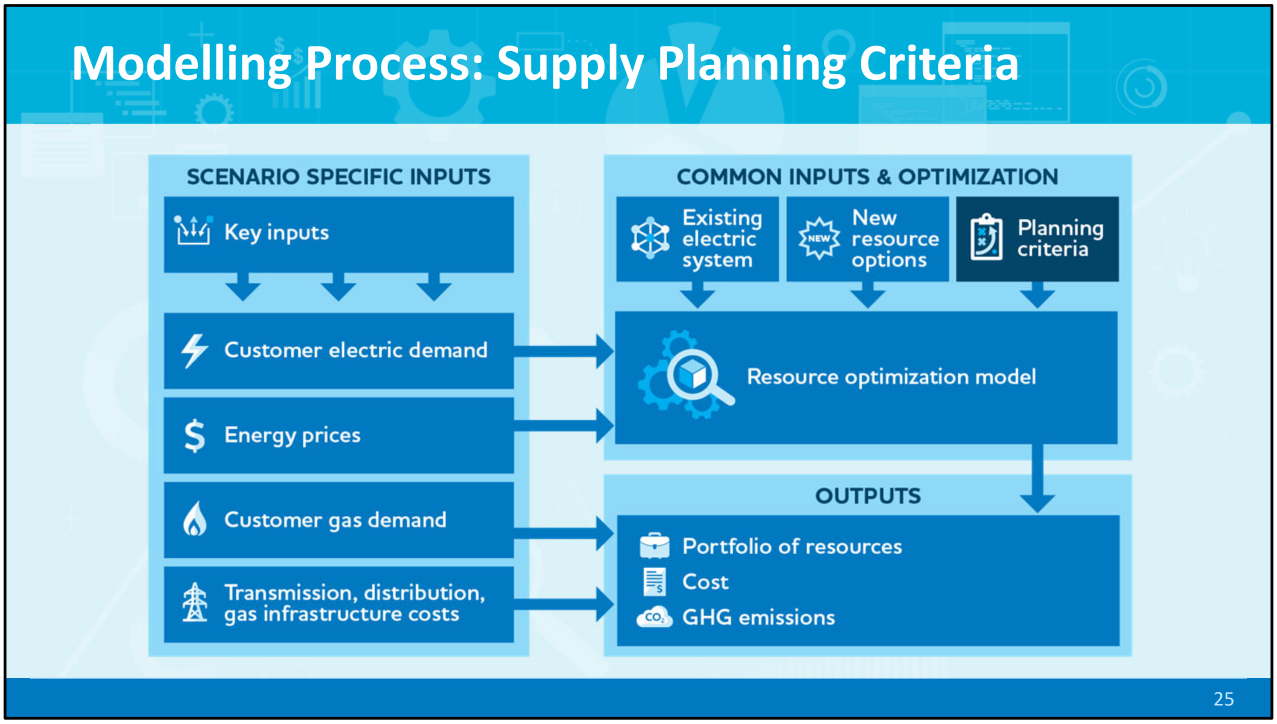
The slide lists the capacities for these interconnections as of this year.

These Interconnections serve three major roles in our hydro dominated system:

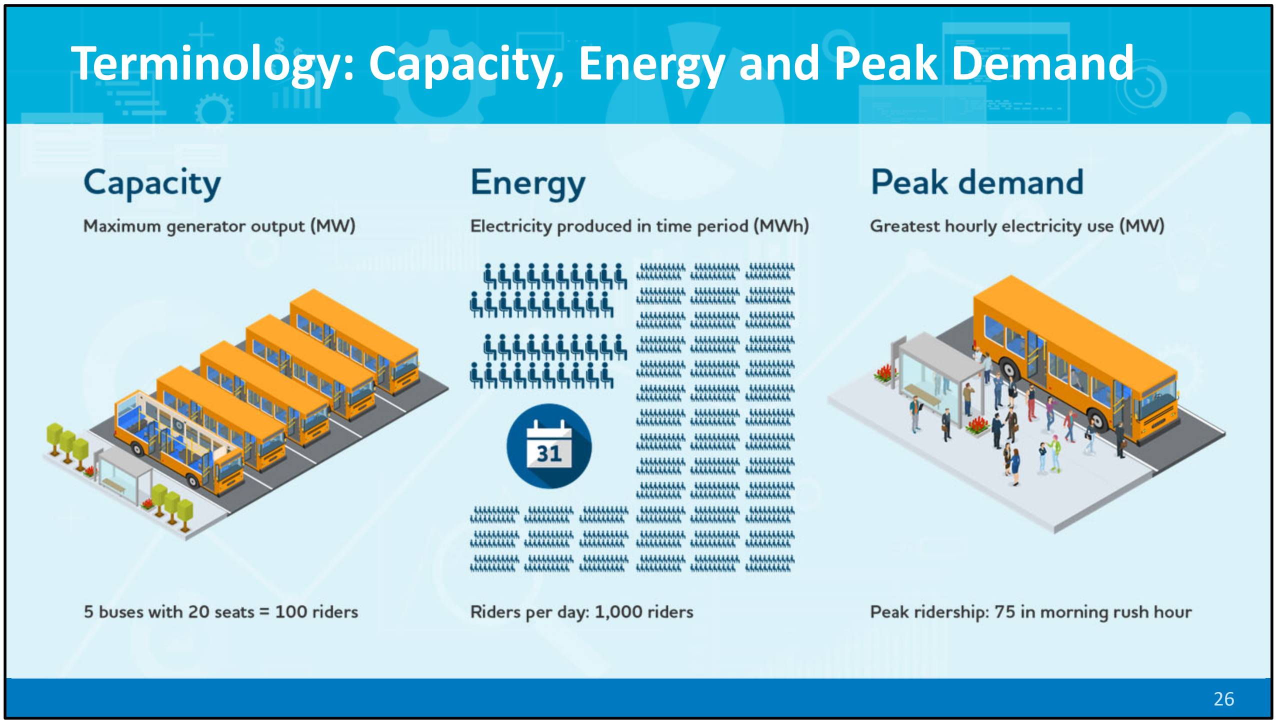
- First, they facilitate the export of surplus hydro to outside markets, which provides an important source of revenue
- Second, they enable energy to be imported during low water conditions to ensure reliability

- Lastly, they provide a means of managing short term reliability issues when dealing with unexpected outages. During times of need, these interconnections have helped the Manitoba Hydro system and neighboring systems aid each other to minimize the impact of outages.

In summary, these interconnections are essential for operating a reliable electrical system at the lowest cost possible, while at the same time maximizing its benefits. The model includes all of these interconnections, as well as projected prices for imported and exported energy.



This section of the presentation is on our **Planning Criteria**, and will explain ‘**how’** Manitoba Hydro plans its electrical supply system.



To understand some of the information we are presenting, there are a few key terms that we want to clearly define. Manitoba Hydro's electrical generation system provides both **energy** and **capacity**, which are different ways to think about electricity.

We've included an analogy here, using transit buses to help understand these terms. In this analogy buses represent the electrical system and passengers represent electricity.

Capacity: is the maximum amount of electricity that can be made by generators at any particular time, measured in megawatts.

- For the bus analogy, it is the **maximum** number of people that can get on the bus at any one time, limited by the number of seats on each bus. So, in this example, 5 buses with 20 seats means you have a capacity of 100 riders.

Energy: speaks to both what is made and used *over a period of time*. So, the amount of electricity produced throughout a 24 hour period, for example.

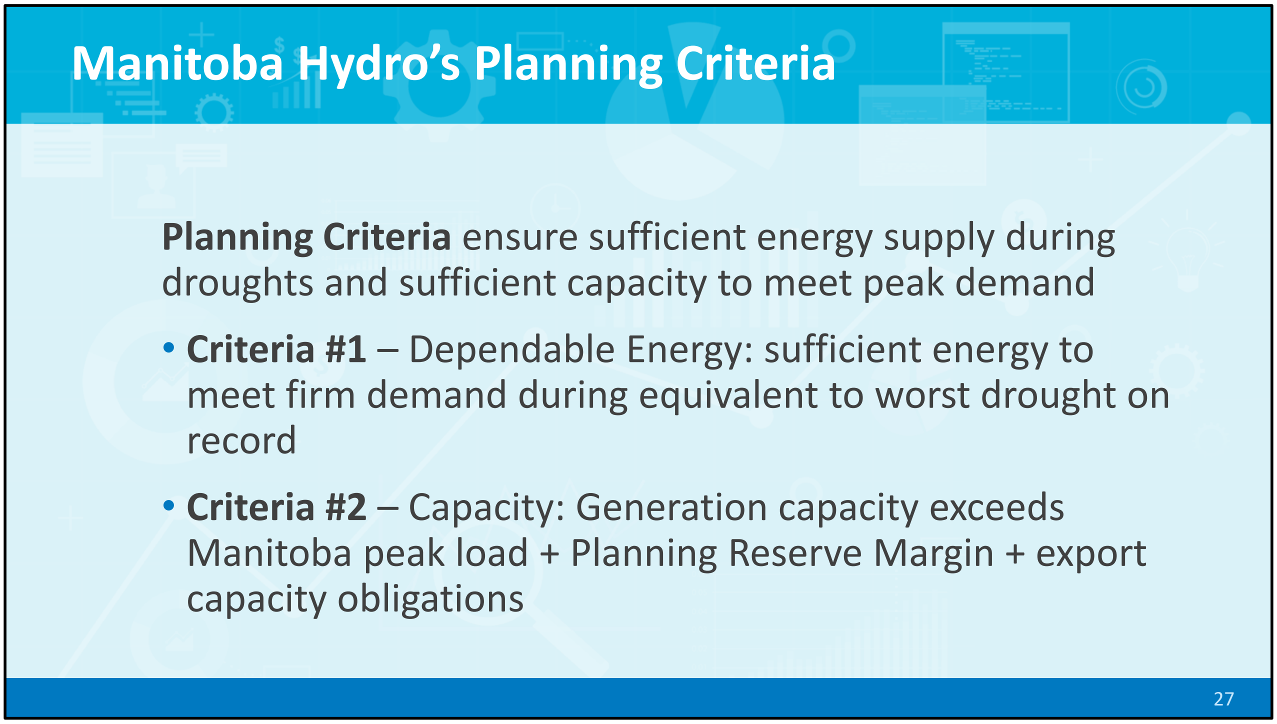
- For the bus analogy, it is how **many** people are transported in a day using the 5 buses. So, during the course of one full day you might move 1,000 riders.

Peak demand: is the specific time of the day that has the single greatest requirement for energy. For Manitoba, this happens in the winter when we have customers heating with electricity.

- For the bus analogy, peak demand is the **highest** number of passengers at a given point in the day. In this case, you see peak ridership at 75 people during the morning rush hour.

All three of these need to work together when planning the electrical system. The system has to have capacity to meet the peak demand that customers place on it (i.e. number of rush hour passengers), and be able to provide the energy required throughout the day.

When the peak demand is greater than the system capacity, or energy supply over time is short, we either need to add more generation capacity to the system (i.e.. more buses during the peak) or reduce demand (have less people on the bus during peak times). But, still need to make sure that all passengers can be moved throughout the whole day.



Now that we've explained capacity, energy, and peak demand, we will explain the criteria that Manitoba Hydro uses to plan the electrical system, also known as "**Planning Criteria**". These planning criteria are included in the model to determine **when** and **how much** new supply resources are needed to meet the demand in each scenario.

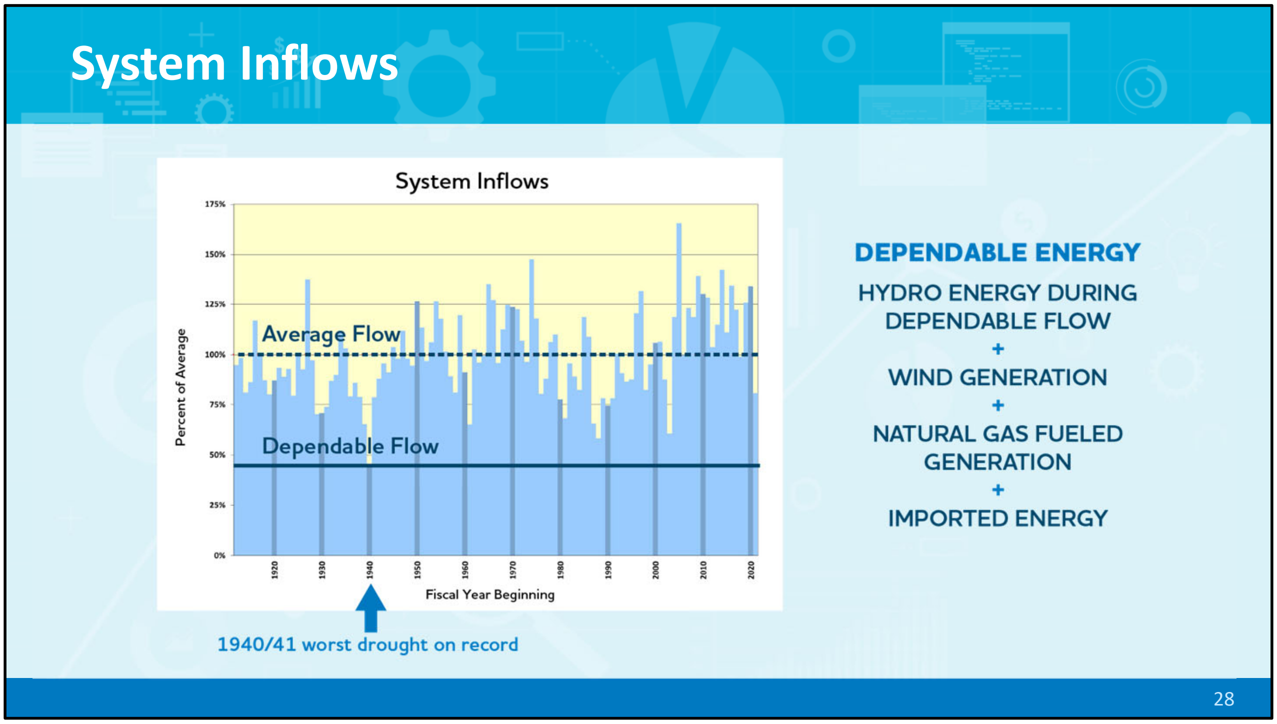
The first Criteria is for **Dependable Energy.** The system must be planned to ensure that there is sufficient **energy** supply to meet demand during a repeat of the worst drought on record. This amount of energy is referred to as "Dependable Energy" and will be explained in more detail later in this presentation.

- Continuing with the bus analogy. Dependable Energy would be similar to the lowest number of seats that has ever been available throughout the bus fleet in a day.

The second Criteria is for **Capacity**. The system must be planned to ensure there is sufficient generating capacity to meet Manitoba's peak load plus any committed export contracts. In addition, generators do break down from time to time and we do experience extreme weather events, so a Planning Reserve Margin is utilized to increase the required capacity to ensure we are prepared for such events.

- For the bus analogy; capacity would be the number of buses required during the busiest rush hour of the year, taking into account the number of buses that might break down.

To summarize the planning criteria, we plan to have enough energy for a repeat of the worst drought on record, and if you recall the earlier discussion on our demand, we plan to provide enough power on the coldest days during the winter. These requirements are included in the model to ensure the system has enough resources to reliably meet our customer's needs.



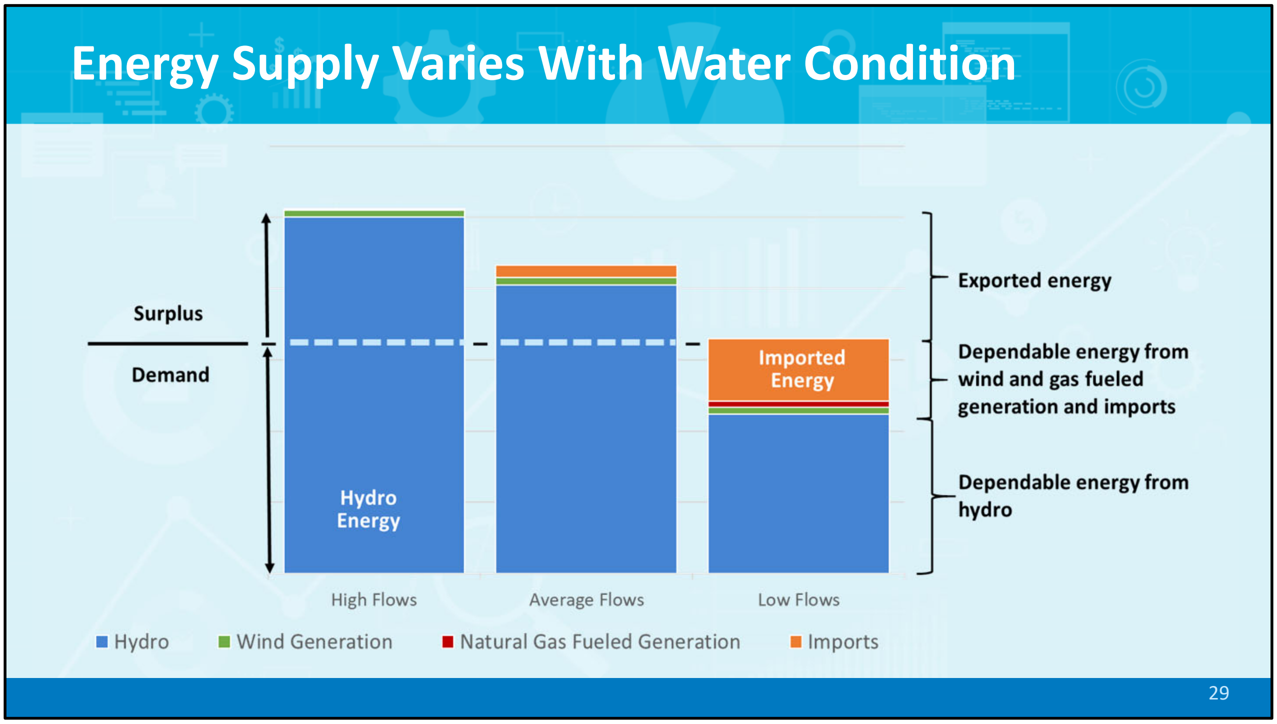
As we've recently seen in Manitoba, water conditions can vary significantly from year-to-year, so it is important to consider this variability within our planning. The model includes over 100 years of historical system inflows to represent future water conditions.

Dependable Flow is the lowest system inflow on record, which corresponds with the most severe drought we've experienced (highlighted by the arrow).

Dependable Energy is the amount of electrical energy supplied during the Dependable Flow. But while this graphic only shows dependable flow, Dependable Energy also includes generation from wind turbines, natural gas generators, and imported electricity, to determine the total system dependable energy.

Manitoba Hydro designs the supply system to ensure there is sufficient electricity supply during the lowest flow on record. This **Dependable Energy Planning Criteria** is included in the model as a constraint.

This relationship between water conditions, dependable energy, and surplus energy are all simulated in the model.



We've established that the model simulates energy production for a wide range of water conditions based on over 100 years of the historical flow records.

The graph on this slide illustrates how the **volume** of energy is produced, and how that supply **varies** with water conditions.

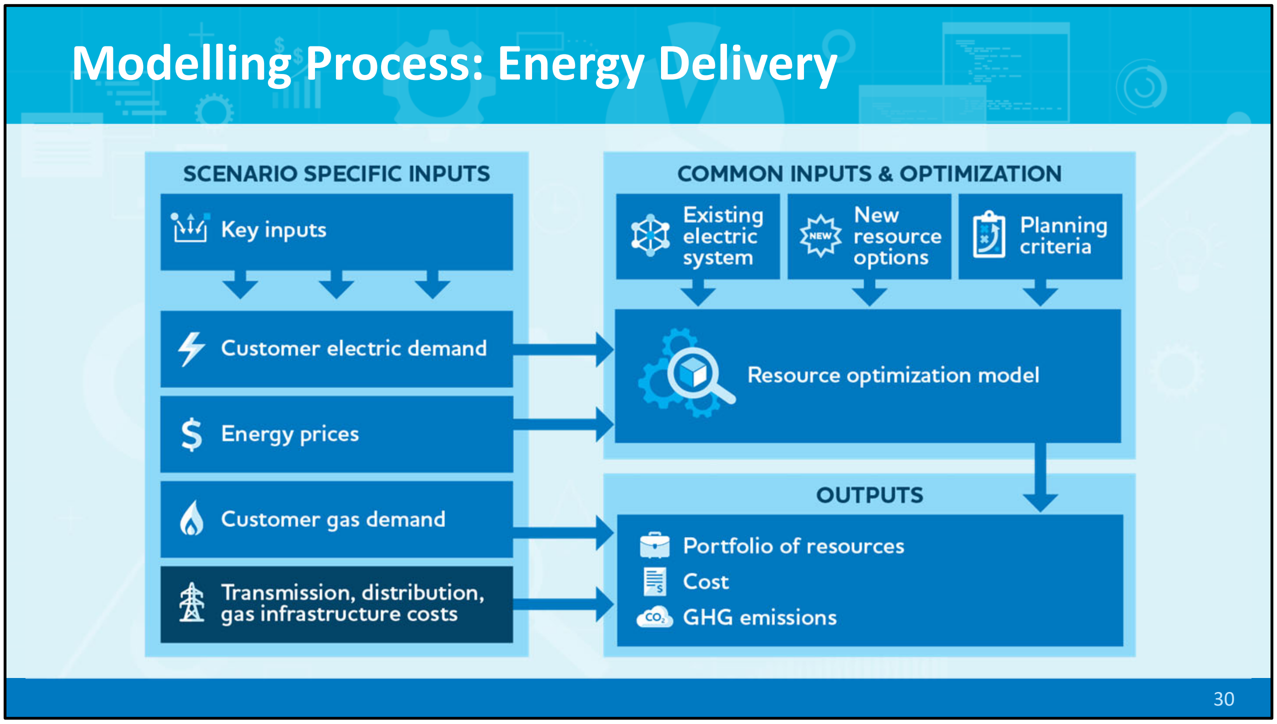
The bars show the total energy in our system for high flows, average flows, and low flow conditions.

During low flow conditions, shown here on the right, there is not enough energy from hydro generation alone to meet demand, as a result, other sources of energy are required. This includes energy from wind farms, imported energy from other markets, and utilizing Manitoba Hydro's natural gas turbines to help meet demand.

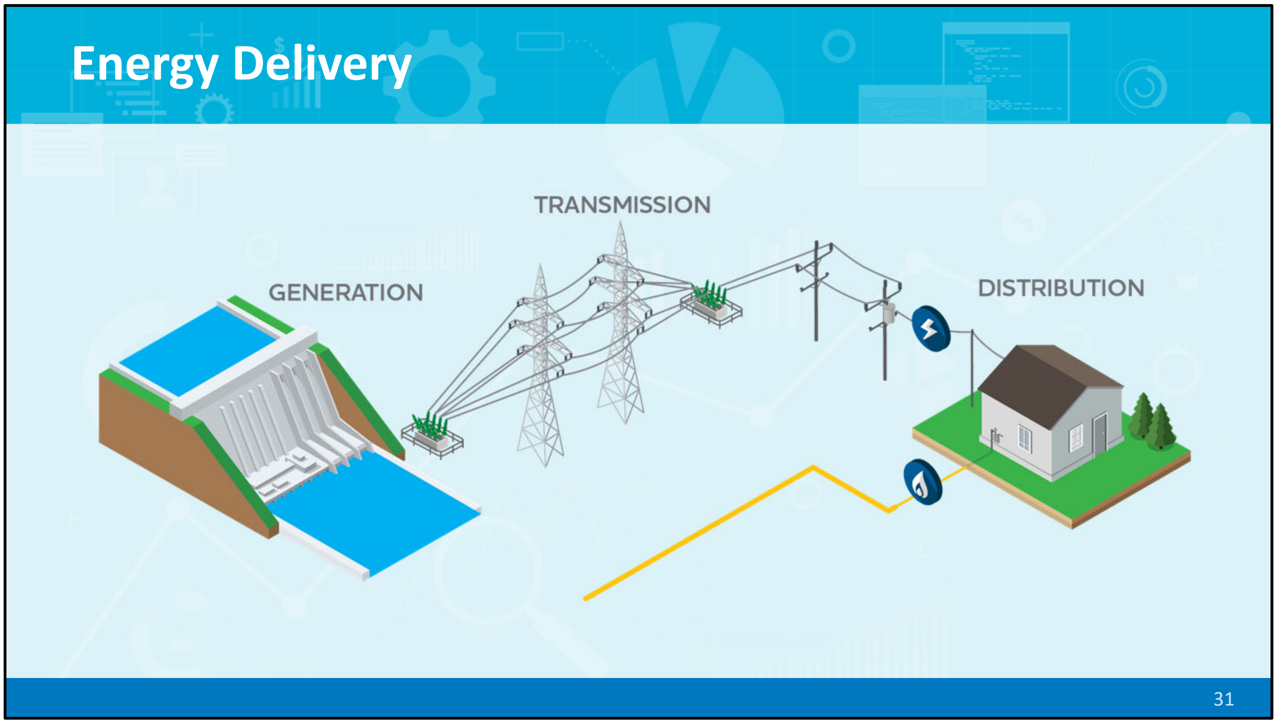
On the other side of the chart, we see that during high flows there is more hydro energy than is needed to meet demand. The additional hydro energy is first used to meet demand and avoid importing energy, or running natural gas turbines to meet demand. Once demand is met, the remaining energy, also known as **Surplus Energy**, can then be exported for revenue.

Because our system is designed to be reliable even under severe drought, even during average water conditions there is more hydro energy than needed to meet demand, resulting in an exportable surplus. However, there is less Surplus Energy for this condition, which illustrates that Surplus Energy cannot be relied upon each year because of the varying water conditions.

All of these relationships between water conditions, these different sources of energy supply, and the interactions with the export market are simulated by the model.



Next, we'll talk about the infrastructure used for delivering energy to customers.



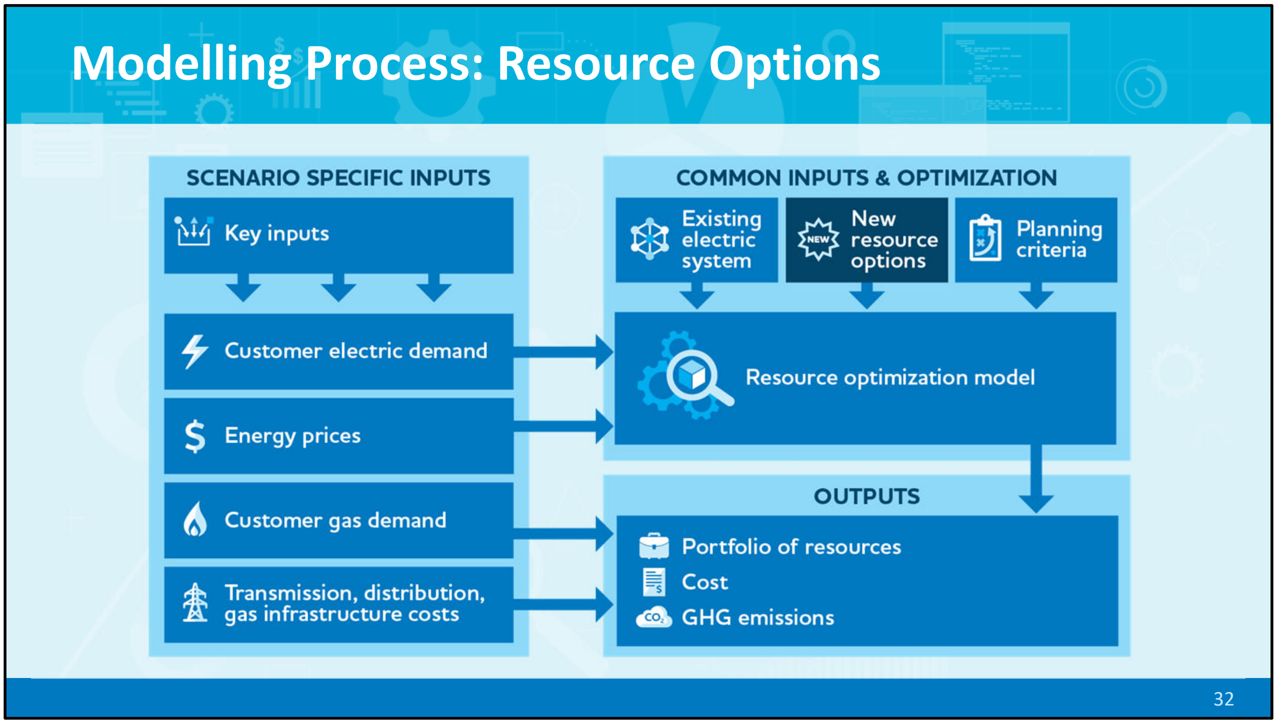
So far, we've mainly focused on the electricity system as its the main focus of the model. However, natural gas is also a factor in our planning, so assumptions have been made on natural gas consumption and costs.

Back to the electrical system, transmission and distribution systems are used to deliver electricity from generation resources to customers.

Similar to generation expanding to meet growing demand, the transmission and distribution systems would also need to be modified to meet growing demand.

When planning the transmission and distribution systems, they must avoid being overloaded, and they must minimize interruptions to customers. These costs are included in the final modelling output when calculating the total cost for each scenario.

Also, when connecting new generators to the system, new transmission infrastructure is also needed. This cost is **specific** to each of the new resources, and is included within the cost of each Resource Option, which we'll describe next.



Now that we've explained how the energy supply system works, and how it is planned, we'll now review the Resource Options that are included within the model. These resource options form the inventory that the model can select from in order to meet growing demand.

A broad range of supply resources are included in the model. These resource options include the following:

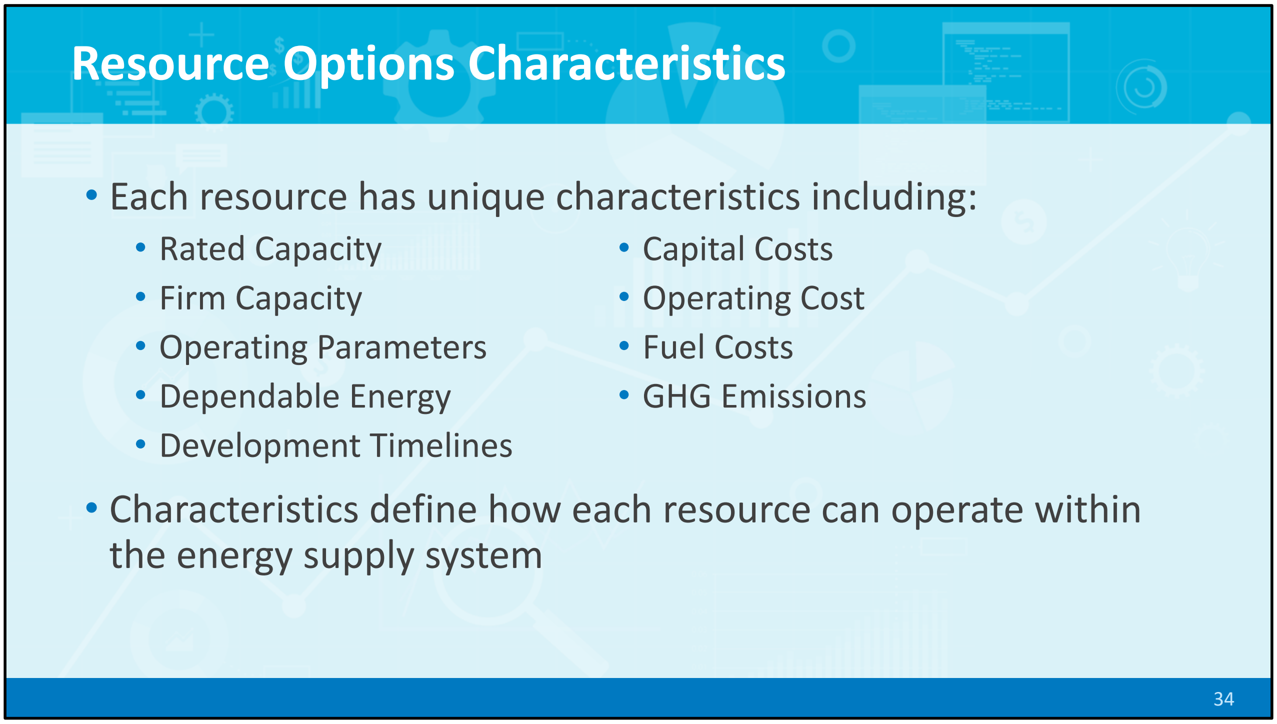
1. New Hydropower as well as upgrades to existing hydropower stations.
2. Wind and solar generation are also included as they have shown to be a source of low-cost energy, while the economics of these resources continue to evolve over time.
3. Energy Efficiency is included and refers to measures that can be implemented by customers to reduce their total demand.
4. Batteries are considered and enable short term storage of energy that can be used to help balance short term changes in demand.
5. Biomass steam turbines have potential in Manitoba.

6. A couple of different types of natural gas turbines are also included. There is also an option to add carbon capture to reduce the turbine's overall emissions.

7. Turbines that are fueled with hydrogen are an emerging technology that can potentially help reduce emissions. In the model this resource option provides a way to store energy from one season to the next to help meet winter peak demand.

8. Purchases from neighboring markets is also an option.

9. And lastly, Small Modular Nuclear Reactors are also an emerging technology that's being explored in the model.



Each of these resources have unique characteristics that are included in the model. These characteristics **define** how each resource is simulated, and enables the model to evaluate the potential role of each resource option in the system. These characteristics include the following:

- **Rated Capacity** which is the maximum power output that a generator can produce

- **Firm Capacity** is the power output that can be counted on during peak demand. In many cases this is linked to the variability of a resource such as wind.

- Operating Parameters.

- Dependable Energy.

- Development Timelines, which is the minimum time to get a new resource in-service and operating.

- Capital Costs & Operating Cost, which are the costs to construct and then operate a resource over its lifetime.
- Fuel Costs.
- GHG Emissions.

The data for this information came from a range of different sources and includes:

- previous studies undertaken by Manitoba hydro for resources such as hydro,
- and a range of publicly available sources for resources such as wind and carbon capture.

Resource Options Characteristics Example

	Wind	Natural Gas Turbines
Rated Capacity	■■■■■	■■■■■
Firm Capacity	■	■■■■■
Operating Parameters	Wind Profile Assumed	Model Determines Operation
Dependable Energy	■■■■	■■■■■
Development Timelines	■■■■	■■■■
Capital Costs	■■	■
Operating Costs	■■■	■
Fuel Costs		■■■■■
GHG Emissions		■■■■

■ represents relative magnitude of characteristic

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To help better understand what is meant by each of the characteristics and the tradeoffs between the different resource types, here's an example comparing wind generation and natural gas turbines.

The rated capacity of both wind and natural gas turbines are effectively the same.

However, the firm capacity of the two are quite different. The variability of wind blowing when it’s needed to meet demand, results in a reduced capacity value. In comparison, the natural gas turbine has no such reduction because it can be operated when it is needed to meet demand.

Dependable energy for the two are comparable as they both provide energy during a drought.

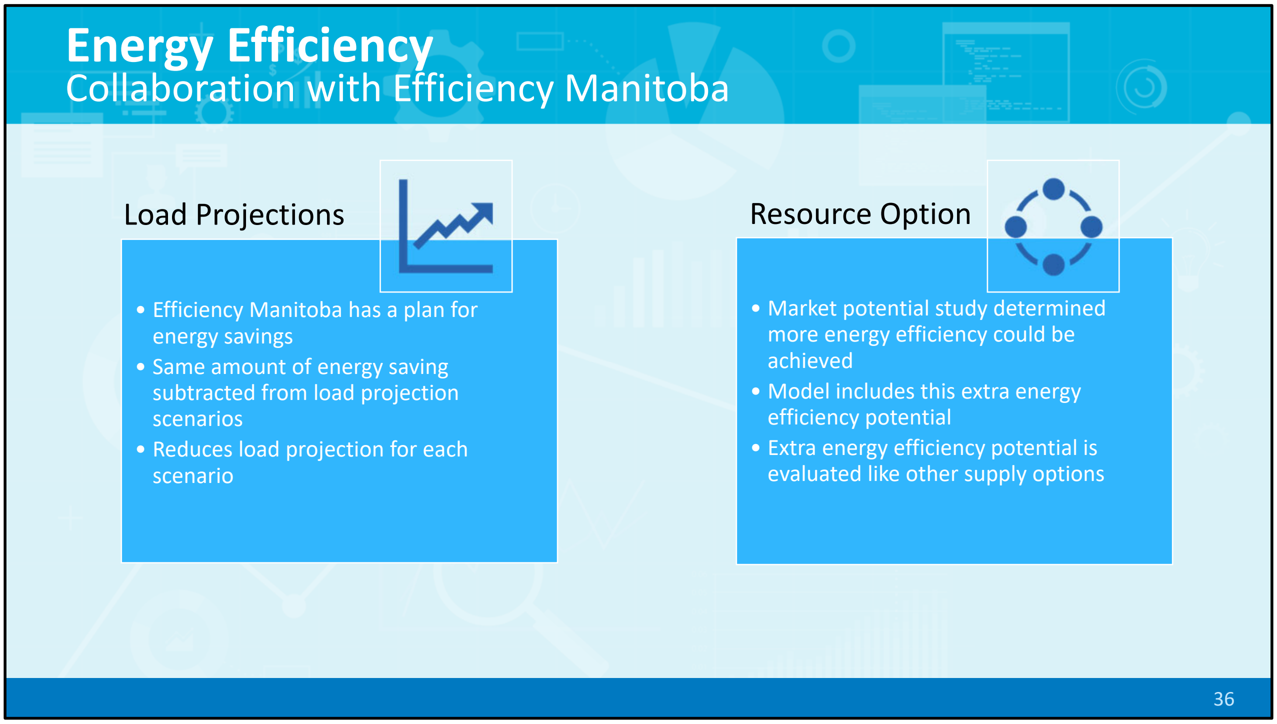
Development timelines for building these resources are similar.

Capital costs for the natural gas turbines are very low as they have the lowest construction cost. Wind capital costs are higher than the turbines but still relatively modest.

Similar to capital costs, the operating costs of a wind farm is more than the cost to operate a natural gas turbine, excluding fuel costs.

The biggest difference is seen in the fuel costs and the associated GHG emissions. The turbines burn natural gas as a fuel, while wind uses no fuel and produces no GHG emissions.

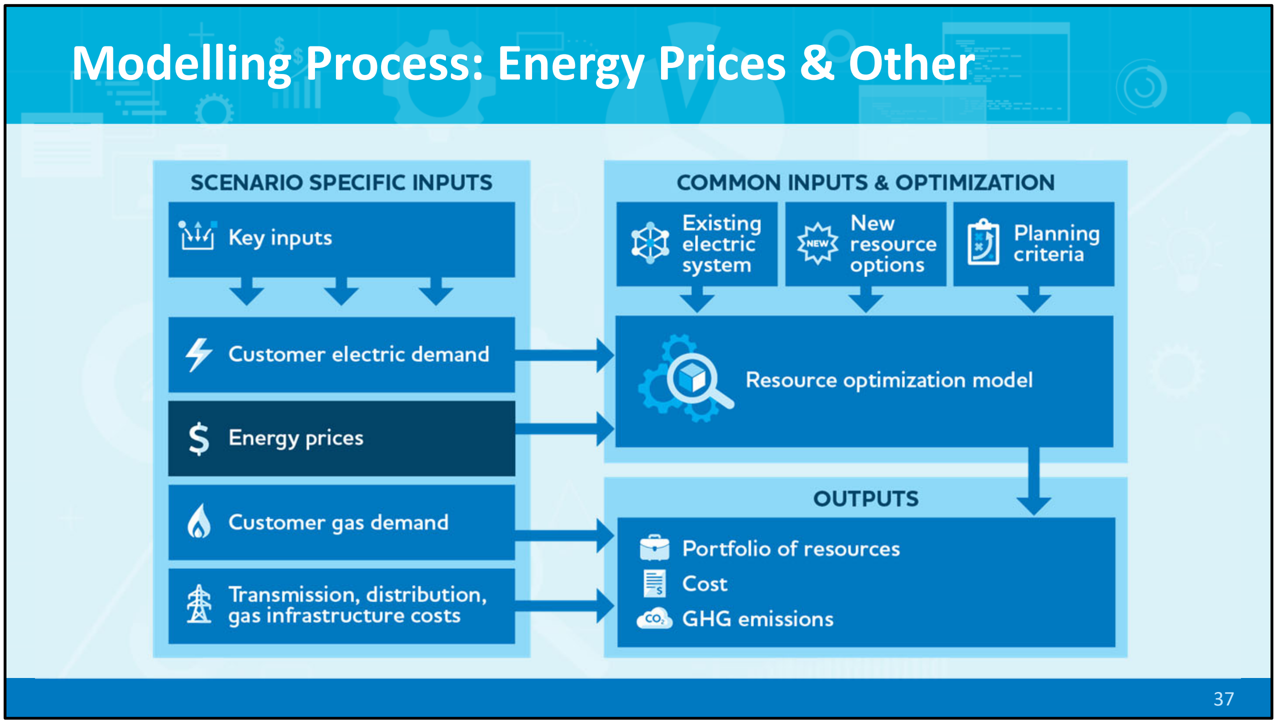
This is just an example, and is repeated for all of the resources.



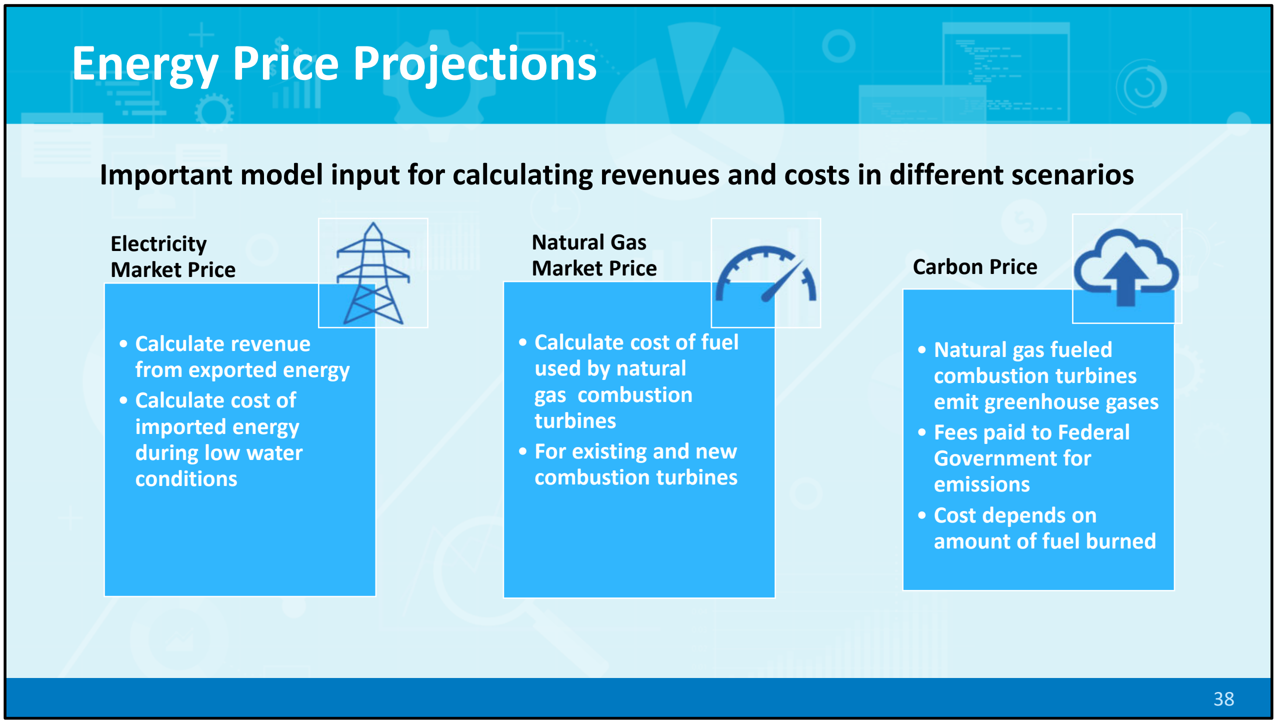
We're going to now focus in on Energy Efficiency measures as a supply option. This option is included in the model because we'd like to explore how energy efficiency can reduce load, and how it can contribute to reducing the amount of overall generation required. To achieve this, Manitoba Hydro is collaborating with Efficiency Manitoba.

First, some energy efficiency is assumed to be achieved. This is based on Efficiency Manitoba's energy saving projections. This amount of energy is subtracted from the load projections for each scenario. This results in less load then otherwise would need to be met for each scenario.

Second, a market potential study determined that more energy efficiency could be achieved. This extra energy efficiency potential is included in the model and competes on a level playing field with other supply options. By having this in the model, it can select extra energy savings as an option to meet future energy needs. This is above and beyond what is already assumed elsewhere.



We are now going to discuss how energy prices and other forecasts are included in our modelling process.

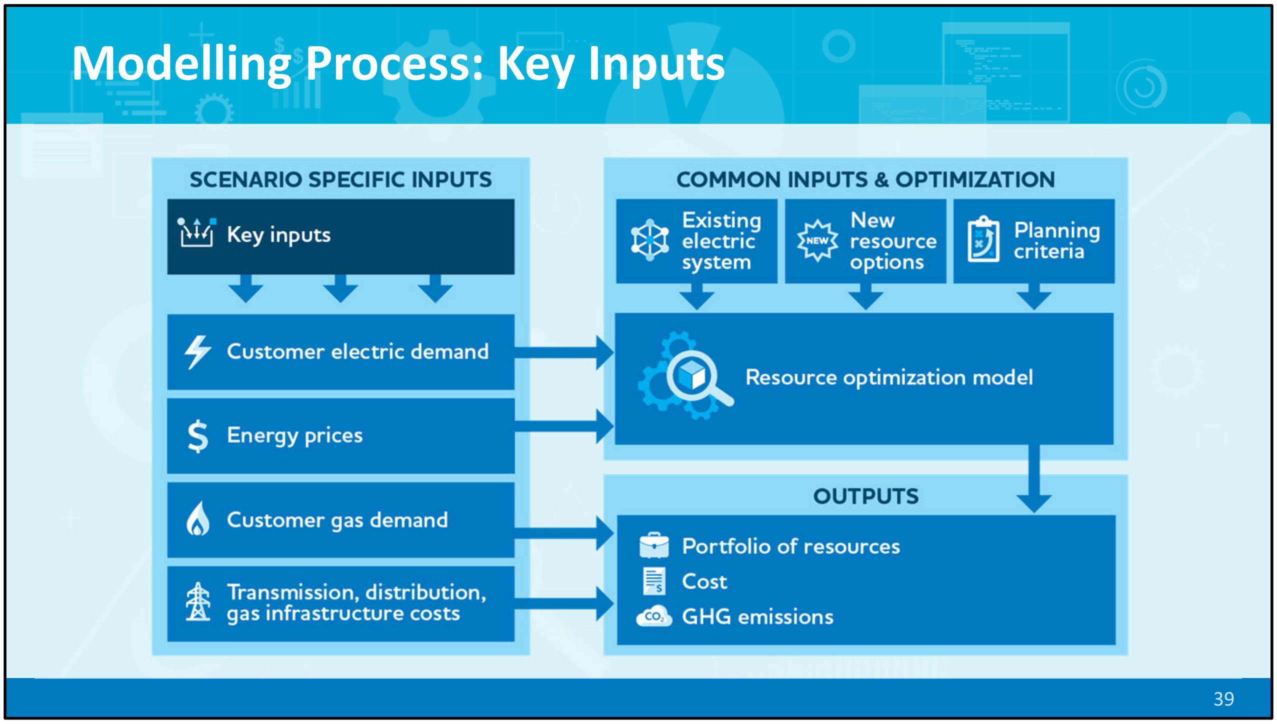


We've already talked about the role of interconnections to import and export electricity, as well as the role of natural gas generation to help meet peak demand. However, in order to simulate these components, it is necessary to incorporate various energy price projections to calculate their associated costs and revenues.

As a result, Manitoba Hydro has acquired price projections for wholesale electricity from multiple independent price forecasters. These price projections are used to simulate the revenue from exports, and the costs of imports.

Similarly, Manitoba Hydro has acquired price projections for natural gas. This model input is used to calculate the cost of operating natural gas turbines both for the existing system and for new turbines.

Finally, there is a cost for running natural gas turbines due to their greenhouse gas emissions. This is comprised of fees paid to the Federal Government for the emissions, which is dependent on how much fuel is burned. These GHG costs require their own price projection for use in the model. If natural gas turbines are not run very often, then the emissions and costs are relatively low.



The last component of the scenario inputs are the *key inputs*. We will now review these before we get into the resource optimization tool and its outputs.

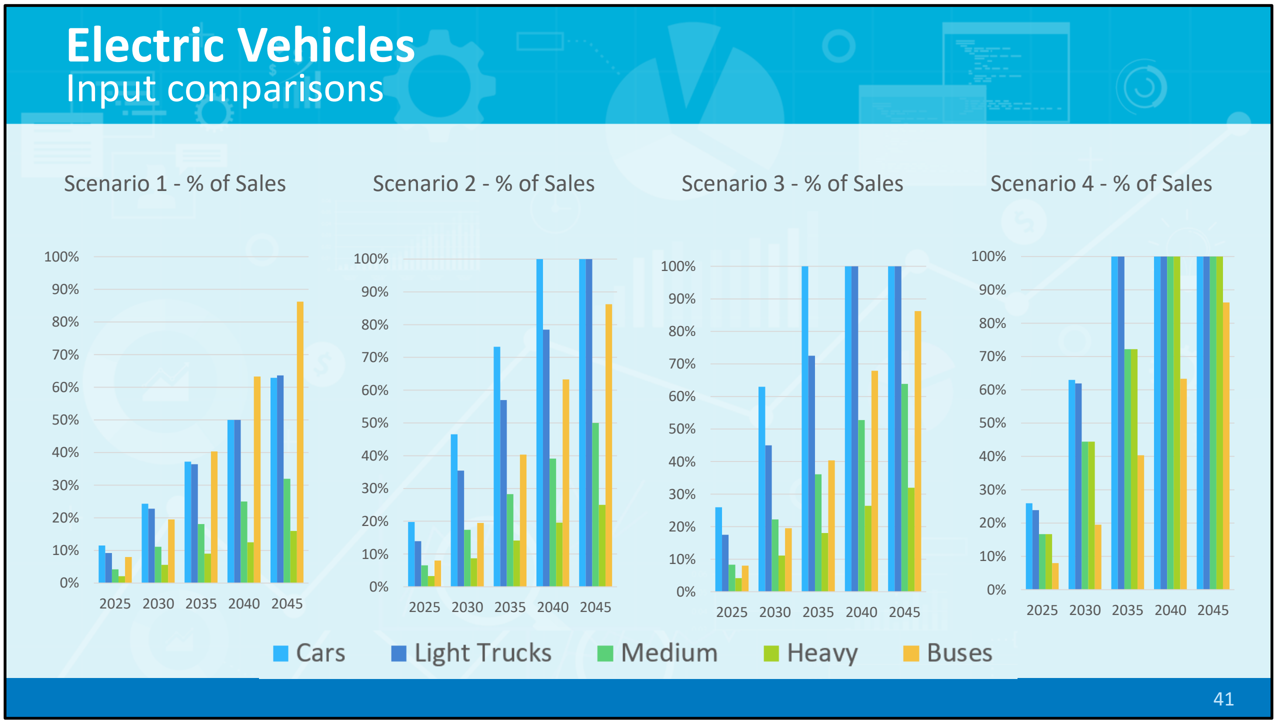
Scenarios are used in the IRP to represent a reasonable range of what the energy future might look like in Manitoba, regardless of how likely it is to occur. They are based on specific values associated with the inputs.

The 5 key inputs – economic growth, decarbonization policy, electric vehicles, natural gas changes, and customer self-generation – are a summary of the inputs creating the most uncertainty in the pace of change.

Setting specific values for the key inputs allows us to calculate load projections for each scenario, which the model uses to evaluate potential new resources to meet increased demand.

In addition to the 4 scenarios, we also run sensitivity analysis, or “what if” analysis, to understand how individual inputs or constraints are driving output of the model. This “what if” modelling allows us to introduce constraints and other interventions, such as encouraging customers to charge their EV at a specific time of day.

We will speak more to these sensitivities and the load projections in our next conversation in a few weeks.



Based on our research and feedback through our round 2 engagement, we associate specific values to each of these different inputs that ultimately make each scenario.

This slide shows an example of the type of data used to establish the inputs, in this case for electric vehicles.

There is a lot of information shown here, but the pace of change and its uncertainty are ultimately reflected in the future vehicle sales that are assumed to be electric. This is necessary, as establishing the shift in customer energy use with electric vehicle adoption will directly impact future electricity demand.

Overall, you can see in the graphs the pace of change established for electric vehicles throughout the 20-year IRP analysis period, as well as the difference in level of uptake between the scenarios. Different sources of information are used together to establish these specific values, everything from historical data to new studies by independent contractors, in order to understand what future uptake may be.

A few examples of drivers of the different input values are;

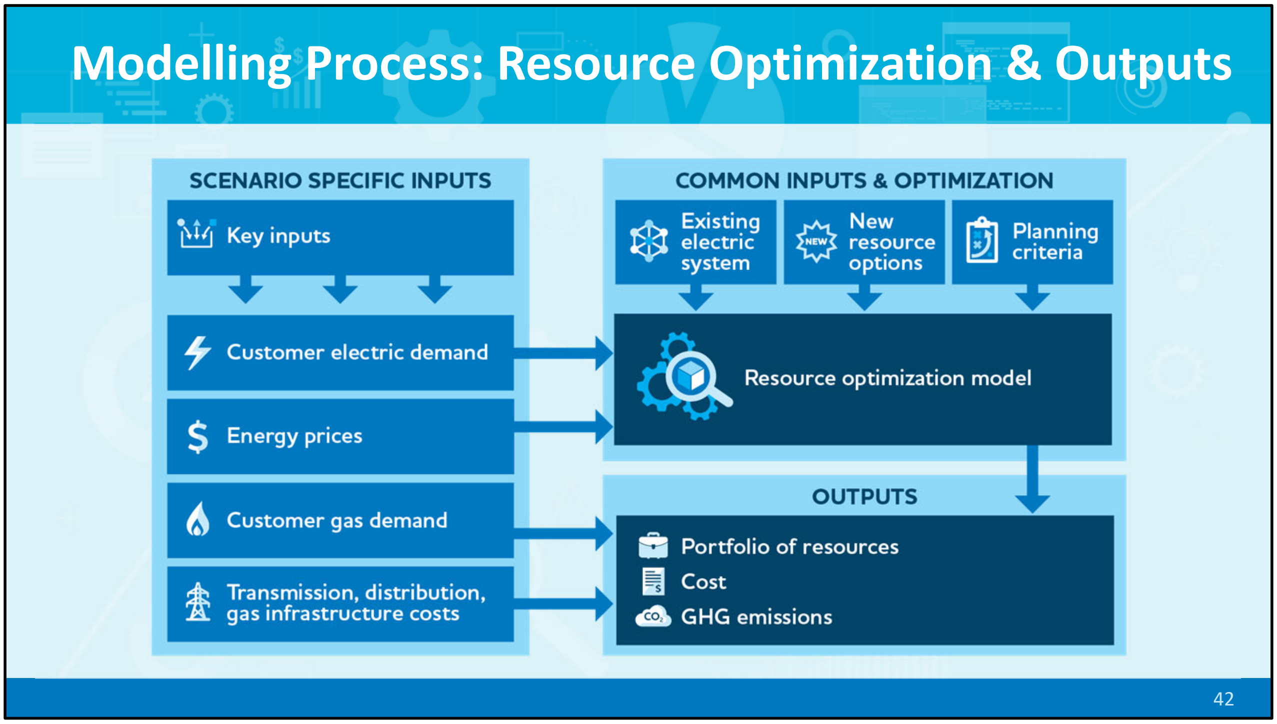
- **The scenario narratives** assume different amounts of change related to future decarbonization and decentralization. These drive different assumptions in the uptake of electric vehicles between the scenarios.

- There are also **proposed federal sales mandates** for electric vehicles which are worked in differently for each scenario.

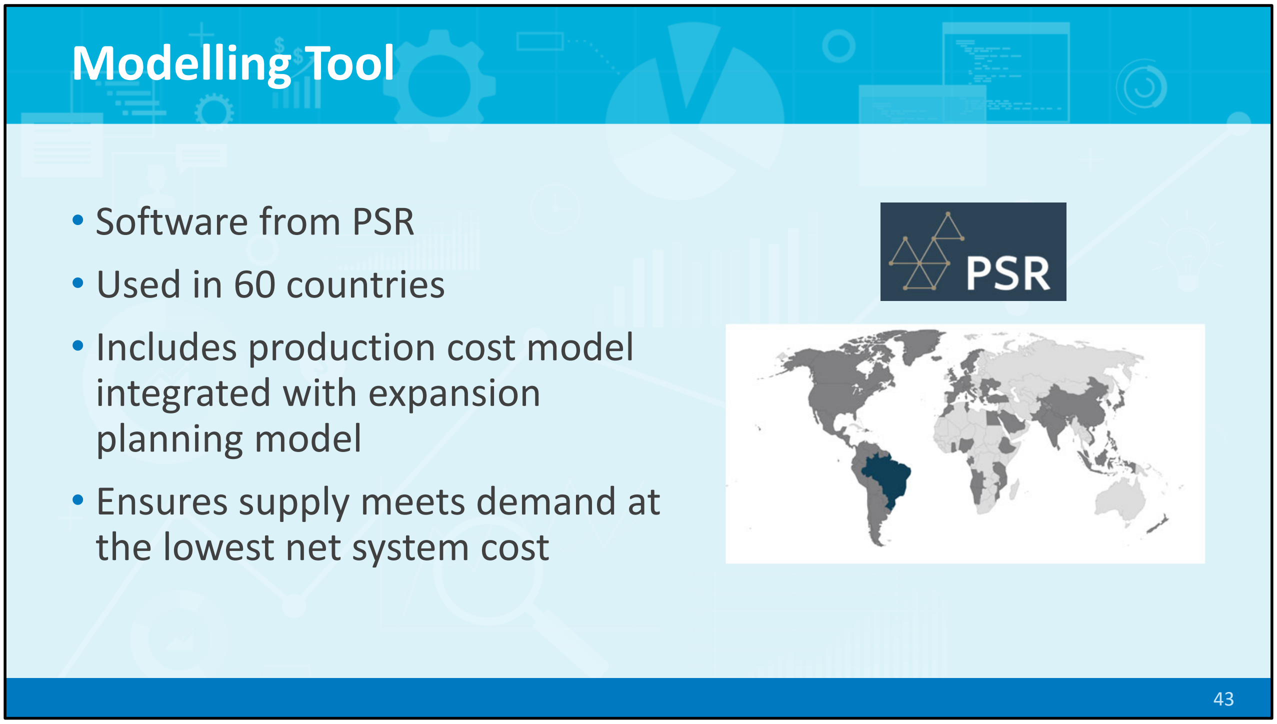
- And, **Historical data** is used to establish how quickly people are likely switch to electric vehicles.

There are also other drivers, such as the total cost of owning an electric vehicle.

This process is repeated for every key input that is used within the modelling process.



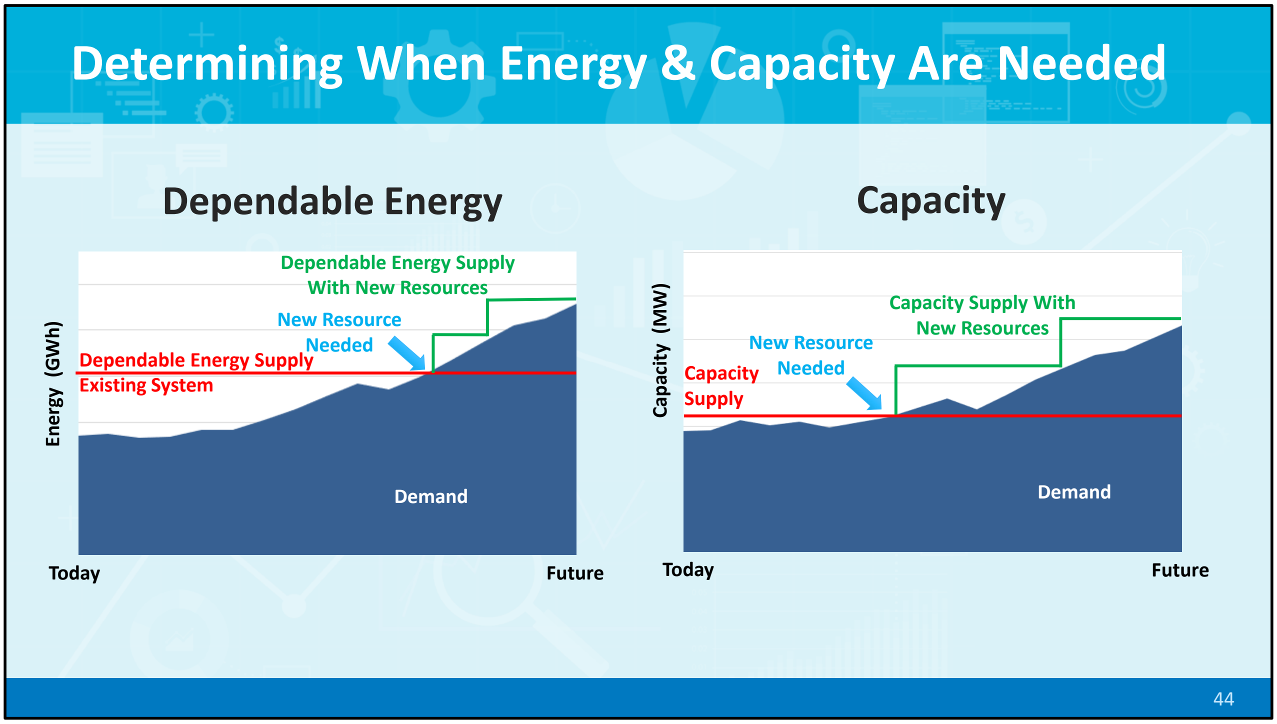
We will now review the model that is being used, and the resulting study outputs (highlighted here).



First off, is the model itself.

Modelling power systems is complicated, so Manitoba Hydro uses specialized modelling software designed specifically for electric utilities. This software was purchased from a company called PSR, based in Brazil. Their software is used in over 60 countries worldwide. Manitoba Hydro is using this software in particular because it specializes in modelling hydropower systems.

The software that we are using includes two tools. The first is a **production cost model** which is used to simulate power systems to determine the cost of producing energy. The second tool is an **expansion planning model** which is used to explore adding new generating resources to an existing system to meet growing demand. Both models are integrated to work together to simulate each of the scenarios to ensure supply meets demand in the lowest cost way.



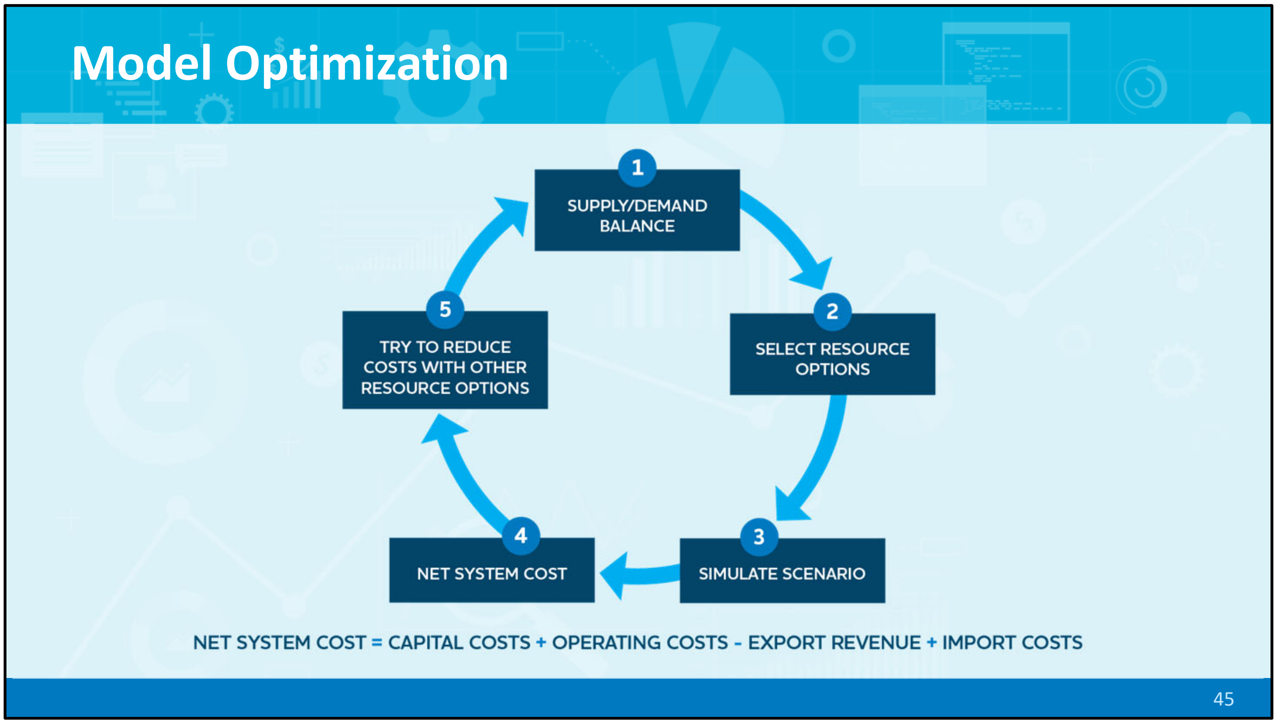
Now that we've talked about all of the different modeling inputs, Manitoba Hydro's planning criteria, and the modelling tools, we'll bring this all together to explain how the model establishes the portfolio of resource options for each scenario. Let's use these graphs to explain how the model does this.

The red lines display the amount of **dependable energy** and **capacity** that are available from our existing supply system. This includes all hydropower, wind, natural gas generation, and imports. Dependable Energy is on the left and Capacity is on the right.

The graphs also show future projected demand, which includes Manitoba's load, export contracts, and the planning reserve margin in the capacity chart.

Where these two supply and demand lines intersect, it establishes when new supply is needed for either energy or capacity. This is when new resources are added by the model, which may be at different times for either energy or capacity.

The area above the red line is the demand that the model is attempting to solve by adding new resources over the 20-year planning horizon. The model goes through several iterations to establish the resources needed to meet this demand. The green lines on the chart illustrate the amount of energy and capacity supplied with the new resources.



Once the model has all the inputs, it proceeds through a series of steps to develop an optimized solution for each scenario.

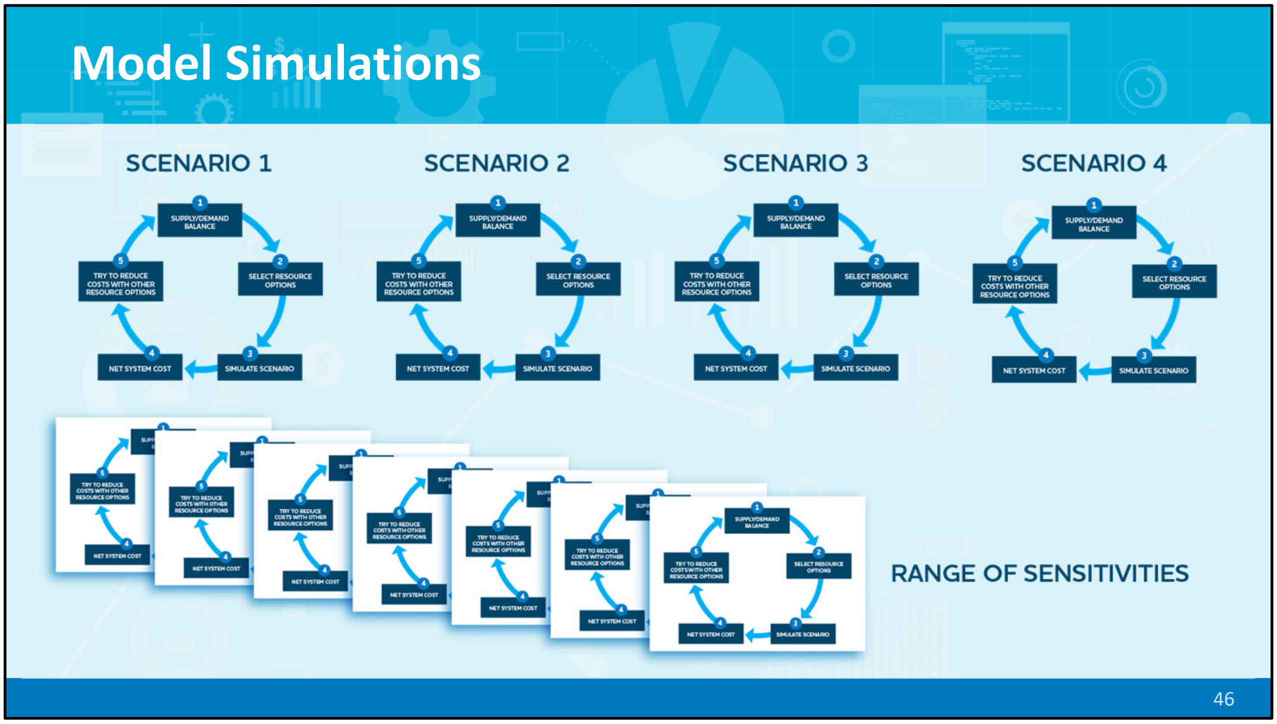
Step 1 – As previously mentioned, the model first determines **when** and how **much** is needed to satisfy the planning criteria for **both** energy and capacity.

Step 2 - The model picks resources that meets the demand based upon the planning criteria.

Step 3 - The model simulates the operation of the Manitoba Hydro system over the next 20 years using over 100 years of inflow records. This simulation includes existing generating stations, imported and exported energy, as well as the new resources.

Step 4 – The model calculates the **Net System Cost**, which is the summation of all Capital Costs, Operating Costs, Export Revenues, and Import Costs.

Step 5 - The model then assesses whether or not the Net System Cost can be reduced with different resource options. If the cost can be reduced, then the process continues. The model will continue this optimization process until it identifies a portfolio of resources that has minimized the Net System Cost.



On the previous slide we showed the modelling steps required to undertake a full simulation to evaluate a single scenario. This process is then repeated for each scenario, as well as for a range of different sensitivities.

Each model simulation can take **several hours** to complete using **high powered computers**. More time is then required to review the results, confirm they are correct, and interpret the results. A number of iterations is not uncommon to complete and validate each simulation.

Modelling Process Outputs

- Portfolio of resources that together, meet load projections at the lowest net system cost
- GHG emissions
- Further post modelling analysis is needed to fully understand model outputs before developing a roadmap and near-term actions

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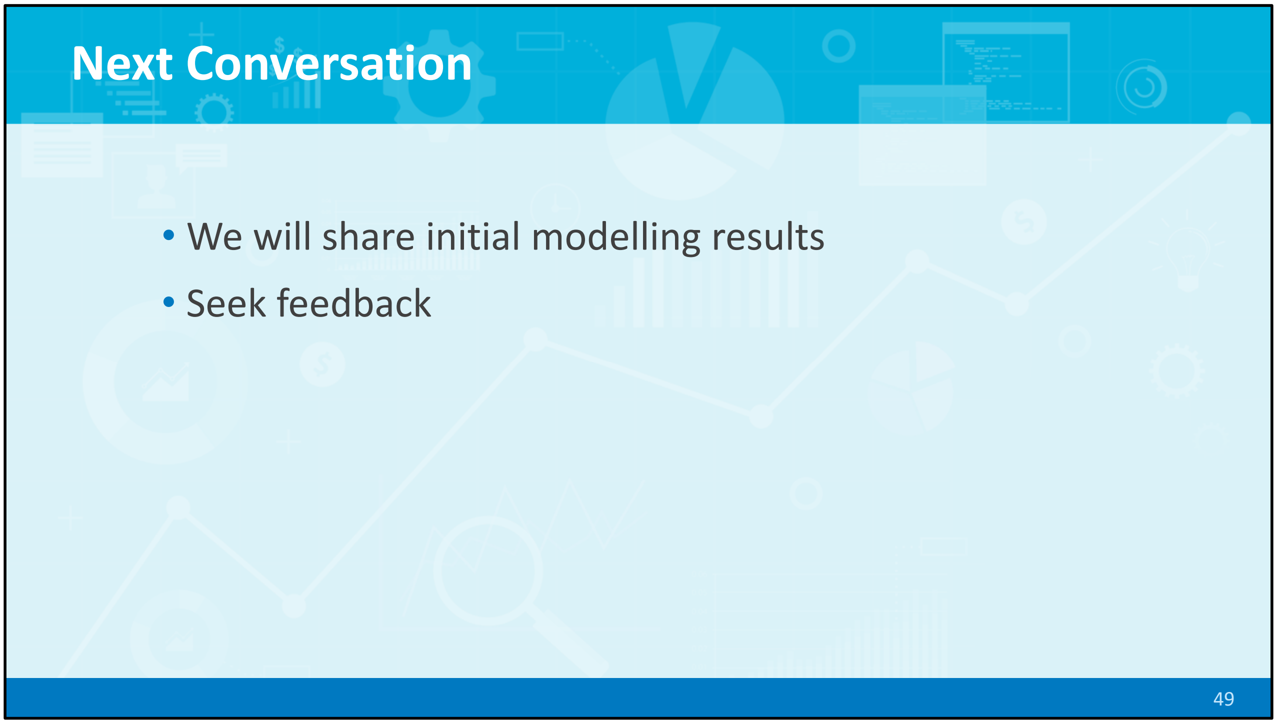
The modelling process results in a range of outputs for each scenario simulation. These outputs include the following:

- A portfolio of resources that meets the defined load projection at the lowest net system costs
- Total Net systems costs; including all generation capital costs, transmission and distribution capital costs, operating costs, fuel costs, import costs, and export revenue.
- Total Greenhouse Gas Emissions for Manitoba Hydro's electrical and natural gas systems.
- And, we are also exploring the total emissions at the provincial level to understand the impact of different scenarios. This includes emissions from other energy use sectors such as the transportation sector.

Overall, the modelling process results in outputs to help compare results for the different scenarios. However, further analysis of modelling results is needed to fully understand the outputs before developing a roadmap and near-term actions.

That’s the introduction to our modelling processes, if you have any comments or questions please reach out at IRP@hydro.mb.ca

WHAT IS NEXT?



There will be a second presentation in a couple of weeks and it will focus on the initial **results** of the modeling process.

This will include information on:

- Load projections
- A review of key findings from the initial modelling results
- And, the next steps to conclude the modelling process.

In addition, we'll be seeking feedback in those sessions on other considerations to conclude our modelling and analysis.

If you have any comments or questions please reach out at IRP@hydro.mb.ca.

Available in accessible formats upon request.