Completed Modelling and Analysis

2023 Integrated Resource Plan (IRP)

April 2023

Available in accessible formats upon request

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Outline

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Introduction
Purpose of this document

- This document is intended as a pre-read prior to preliminary outcomes engagement.
- It summarizes the 2023 IRP modelling and analysis.
- Since Fall 2022, additional modelling and analysis was completed:
    - Some model assumptions were adjusted
    - Scenario results were updated
    - Additional sensitivity analysis was completed integrating feedback received during Round 3 engagement completed in Fall 2022.
- Modelling and analysis results inform the development of the roadmap, including near-term actions.

Introduction

How this document relates to previous versions

- Initial modelling results were shared Fall 2022, including:
  - Four IRP scenarios
  - Select sensitivities; dual fuel for heating, restricted gas generation usage, carbon capture required for gas generation.
- Refer to previous materials for further details on initial modelling results, as well as details behind the data presented.
  - https://www.hydro.mb.ca/corporate/planning/modelling/initial_results/
- This document updates data and charts originally shared and includes results of additional sensitivity modelling and analysis.

Round 3 Engagement

We asked: What additional IRP analysis would you like to see?

INITIAL MODELLING RESULTS

WHAT WE HEARD

- Customer self-generation, solar
- Ground source heat pump, including use in district heating
- How large customers can help manage peaks
- Hydrogen production increases for transportation decarbonization
- Rate impacts and customer costs

WHAT WE DID

- Additional sensitivity modelling & analysis completed: customer solar generation, ground source heat pumps, demand response
- Some suggested sensitivities deferred to possible future IRP analysis

MODELLING & ANALYSIS RESULTS

SCENARIOS & SELECTED SENSITIVITIES

Executive Summary

- No significant changes from initial modelling results summary.
- Minor updates in scenario results include:
  - Some resource selections change, but changes are not material
  - Further investigation of renewable fuels is needed
- Summary of notable results from sensitivity analysis:
  - Increasing restrictions on natural gas generation increase costs and reliance on less mature technologies
  - Demand response measures are cost-effective
  - Cold climate heat pumps for dual fuel space heating can further reduce emissions but at a higher cost as compared to standard air-source heat pumps
  - Ground source heat pumps have a range of performance and cost, and may provide value in an ability to be deployed more quickly than other capacity resources; further investigation is required

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Reference Materials

Links to round 3 materials (for background if desired)

- Modelling Process Presentation
  - https://www.hydro.mb.ca/corporate/planning/pdf/modelling-process-presentation-EN.pdf
- Modelling Key Input Assumptions
  - https://www.hydro.mb.ca/corporate/planning/pdf/modelling-key-input-assumptions-EN.pdf
- Initial Modelling Results Presentation
  - https://www.hydro.mb.ca/corporate/planning/pdf/initial-modelling-results-presentation-EN.pdf

Initial Modelling Results Summary

No changes since initial modelling results

Electrification as a means of decarbonization results in our customers needing significantly more electricity.

All scenarios result in increased winter peak demand, new generation capacity resources, and impacts on transmission and distribution requirements.

There are many options to reliably meet long term needs and future choices will have significant impact on cost.

Strategic use of natural gas can reduce overall greenhouse gas emissions and mitigate cost impacts.

MODELLING & ANALYSIS RESULTS

SCENARIOS UPDATE

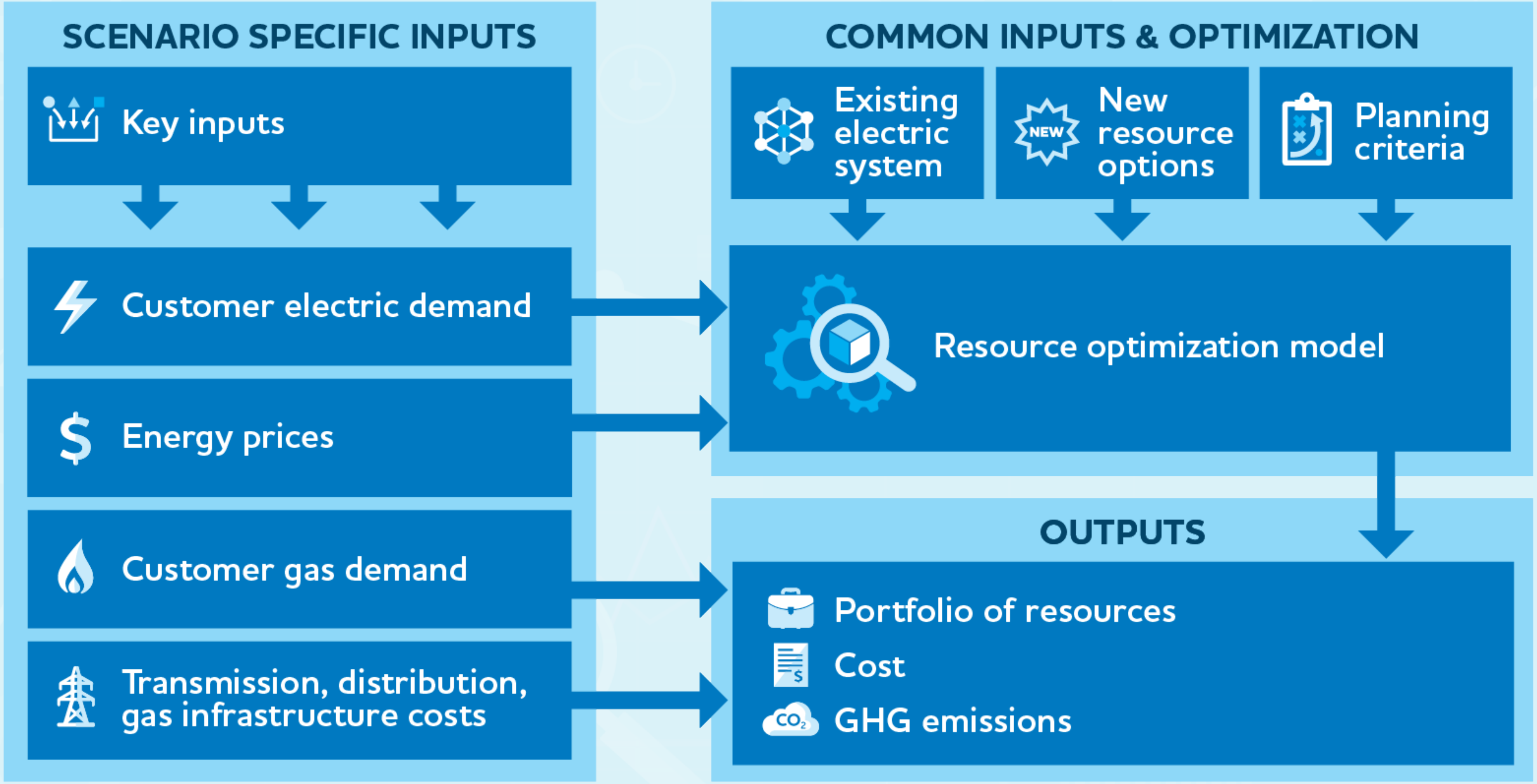
Scenarios

A reasonable range of futures based on the Key Inputs

	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	●	●●	●●	●●●

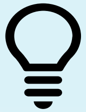
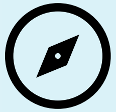
● represents amount of change

IRP Modelling Process Overview



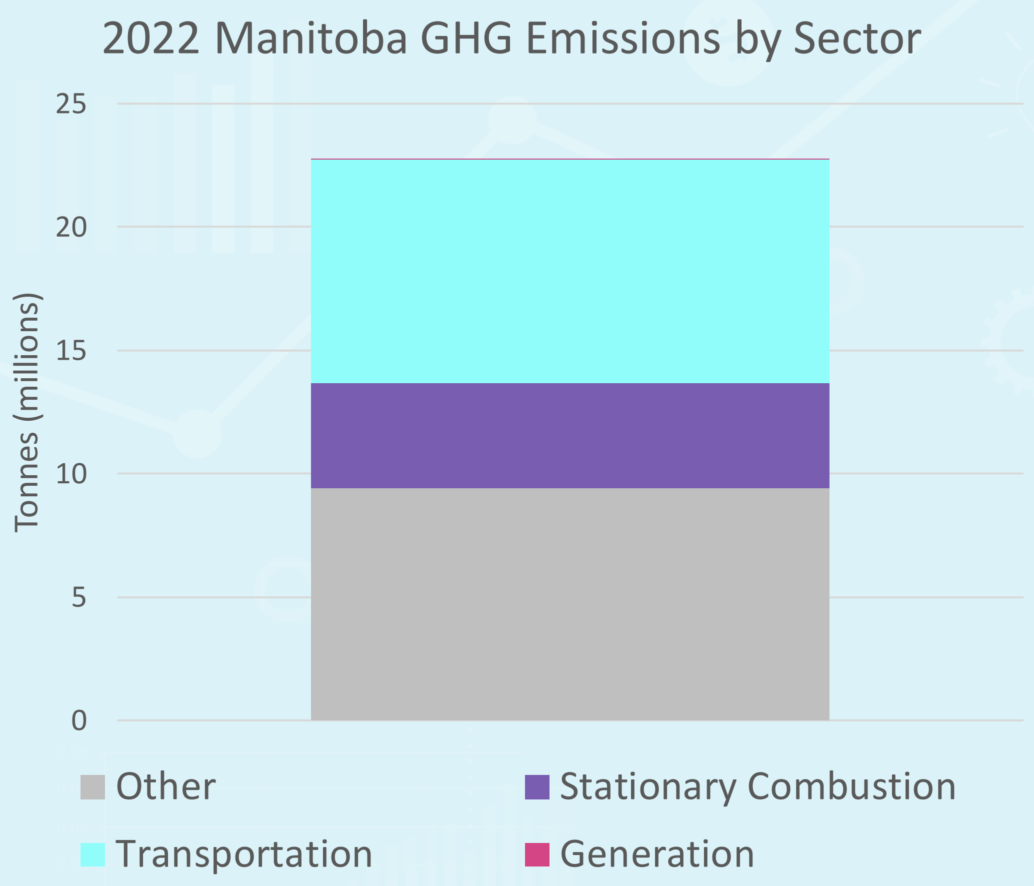
Modelling & Analysis Outputs
Outputs shared in this deck

- Energy and Capacity Supply Mix
- Net system costs:
  - Includes breakdown of generation, transmission, distribution and natural gas costs
    - Select other costs (e.g. heat pumps)
  - Does not factor in inflation
- Greenhouse gas (GHG) emissions in Manitoba:
  - Includes breakdown by sector

Icon	Denotes
	Observations
	Background information
	Key information

Provincial GHG Emission Sources

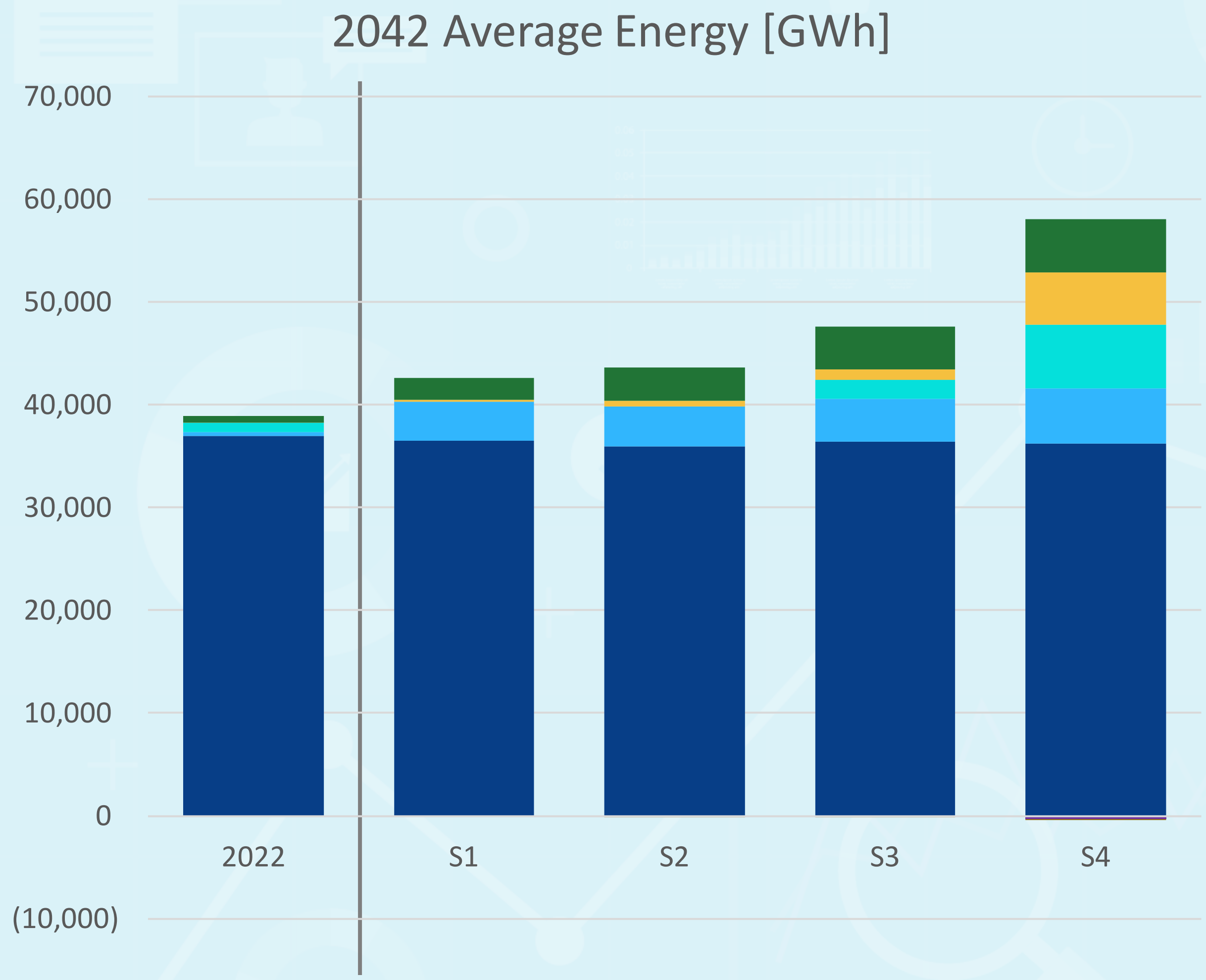
- Analysis focuses on sectors influenced by energy choices:
  - Stationary combustion
  - Transportation
  - Electricity generation.
- Other sectors, which include agriculture and waste are not included.

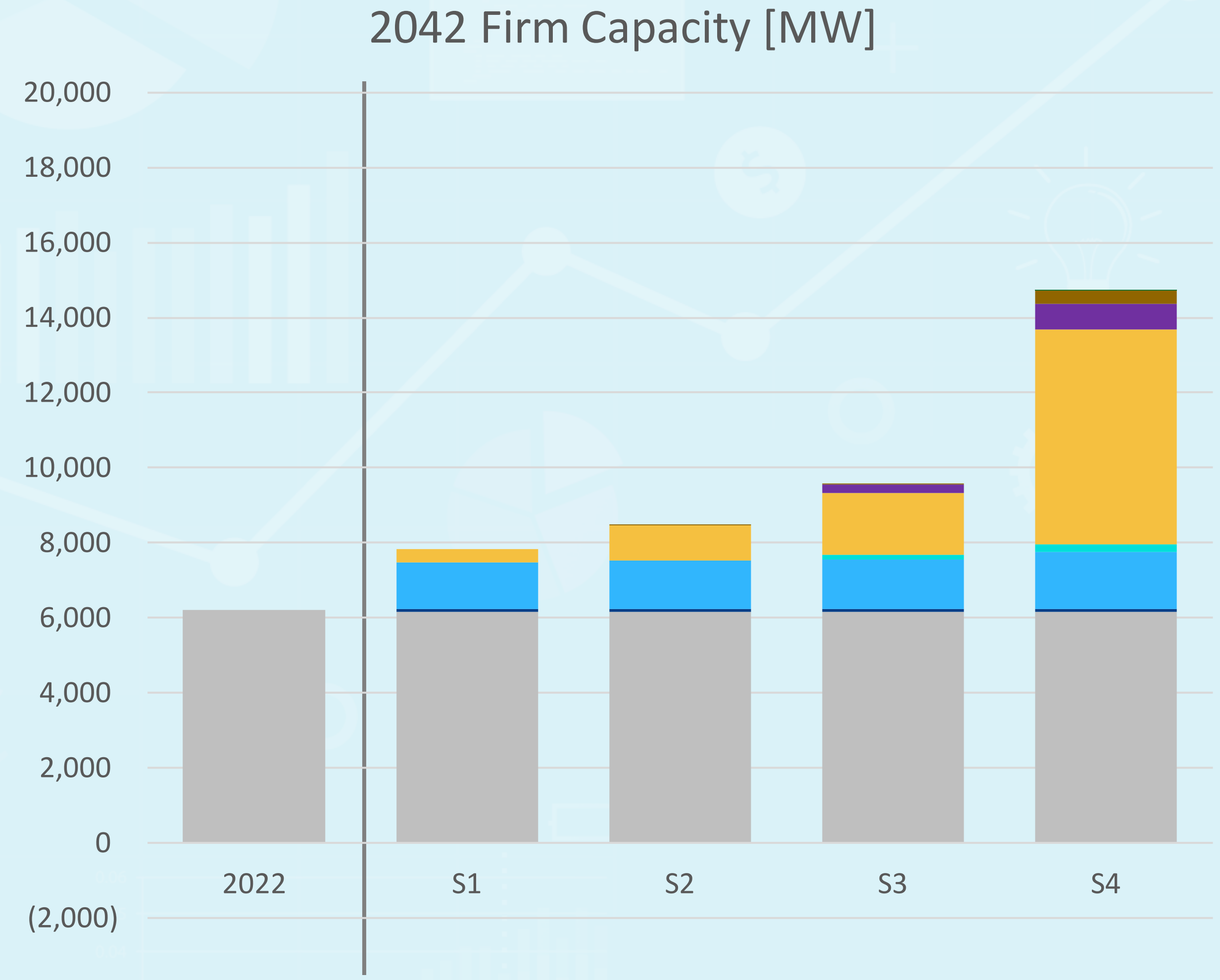


Source: National Inventory Report 1990-2020. https://publications.gc.ca/collections/collection_2022/eccc/En81-4-2020-3-eng.pdf

Scenario Outputs
Energy and Capacity Supply Mix

Minor changes in proportion of each resource type





Existing Capacity Hydro DSM Wind Solar Thermal Hydrogen Battery Imports

Demand Side Management (DSM) is referred to elsewhere as Energy Efficiency

Resource Observations
Energy and Capacity Supply Mix

Energy efficiency observation updated

Maintain existing hydropower

Upgrade existing hydropower

Wind is a low-cost energy resource

New hydropower and solar are not selected

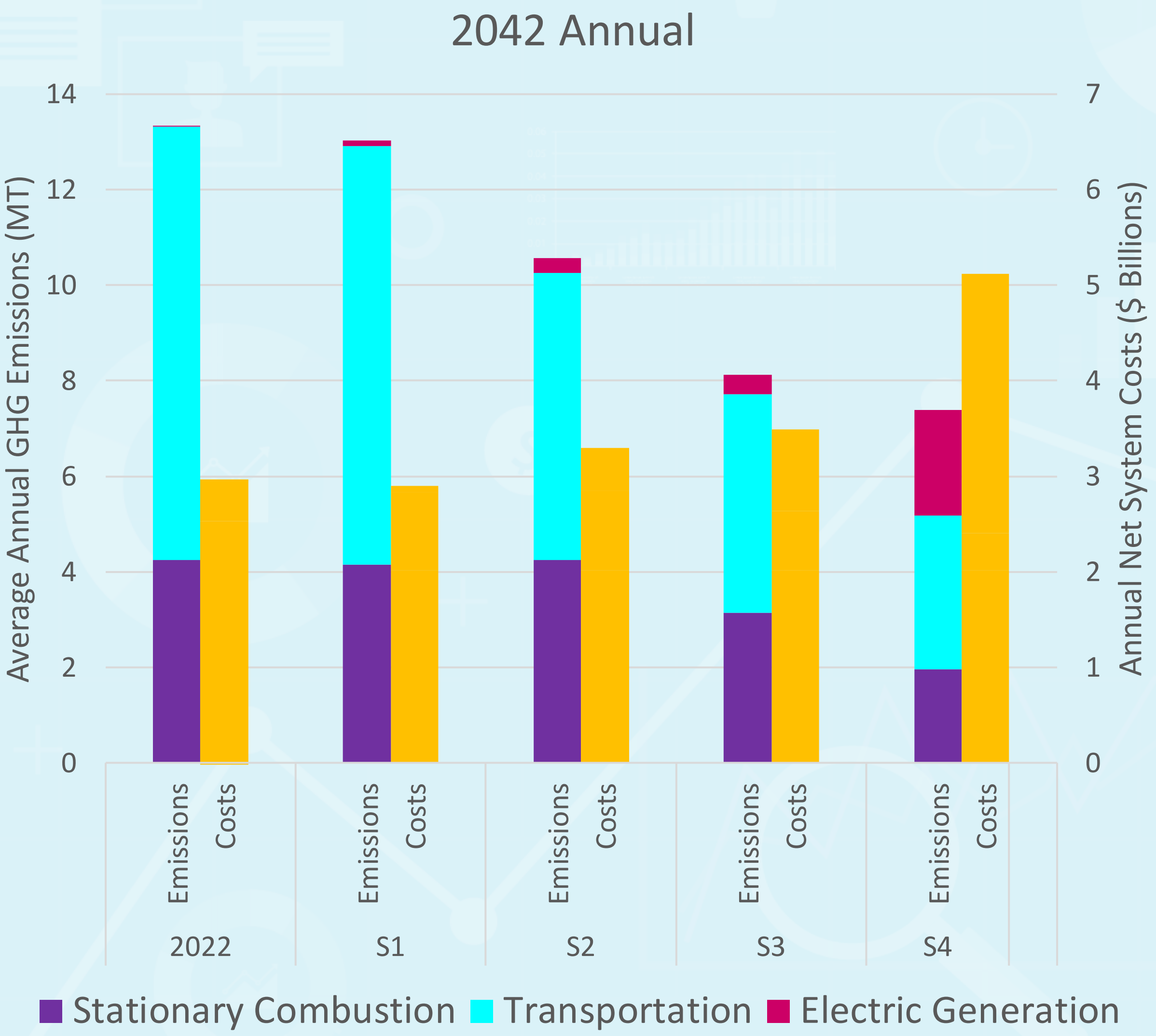
Natural Gas Turbines are a low-cost capacity resource

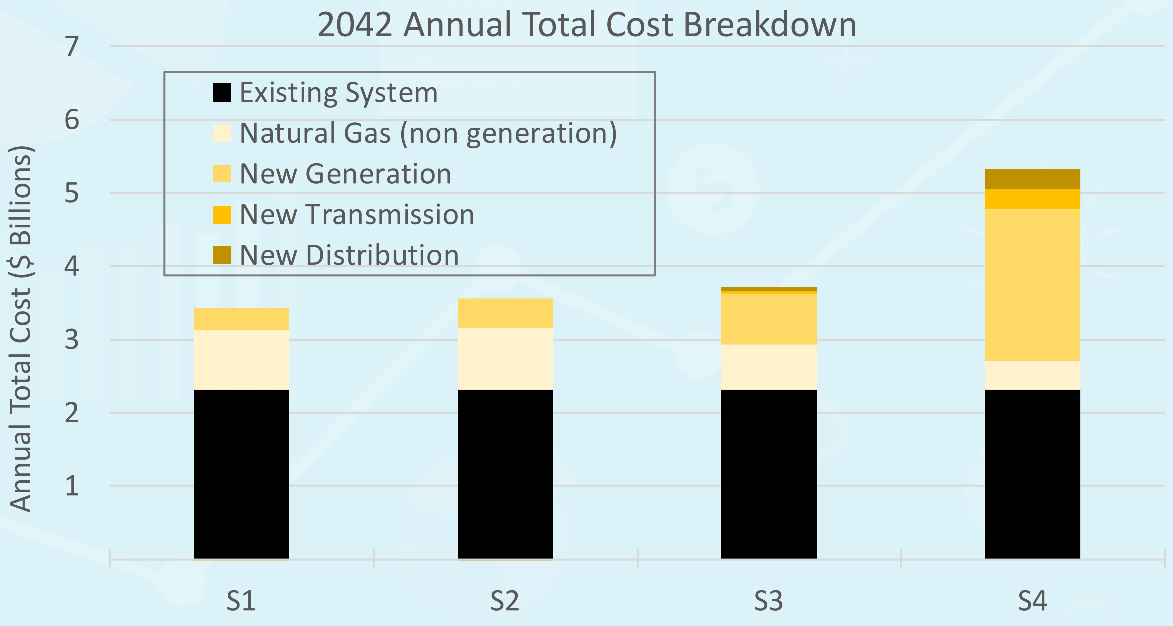
Imports are an important source of energy

Some energy efficiency measures are cost-effective and require further study

Scenario Outputs
Annual Costs and GHG Emissions

No material changes since initial modelling results





GHG emissions remain at the end of the study period in all scenarios. GHG emissions may be further reduced through additional uptake in electric vehicles, alternative electric generation options, or use of alternative space heating methods. The use of renewable fuels, such as renewable natural gas or hydrogen may also reduce GHG emissions. The 2023 IRP does not include net-zero optimization analysis.

* Manitoba GHG emissions shown do not include non-energy dependent sources, like agricultural based emissions.

Observations
Cost and GHG Emissions

New observation re. renewable fuels

Financial investment is needed in all scenarios

Different levels of electrification result in different net system costs

Need for capacity resources are driving cost

Energy related emissions drop in all scenarios

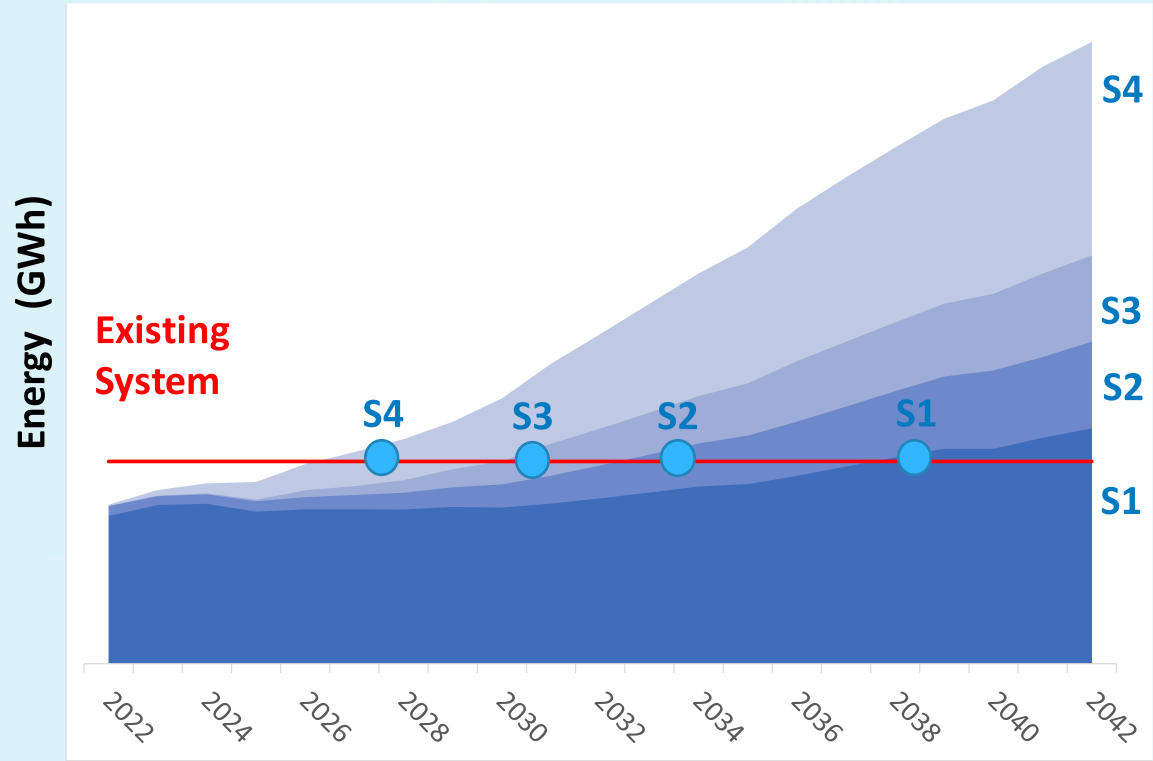
Increases in emissions from electric generation enable overall emission decreases

Use of renewable fuels to decarbonize by leveraging existing gas infrastructure needs further investigation

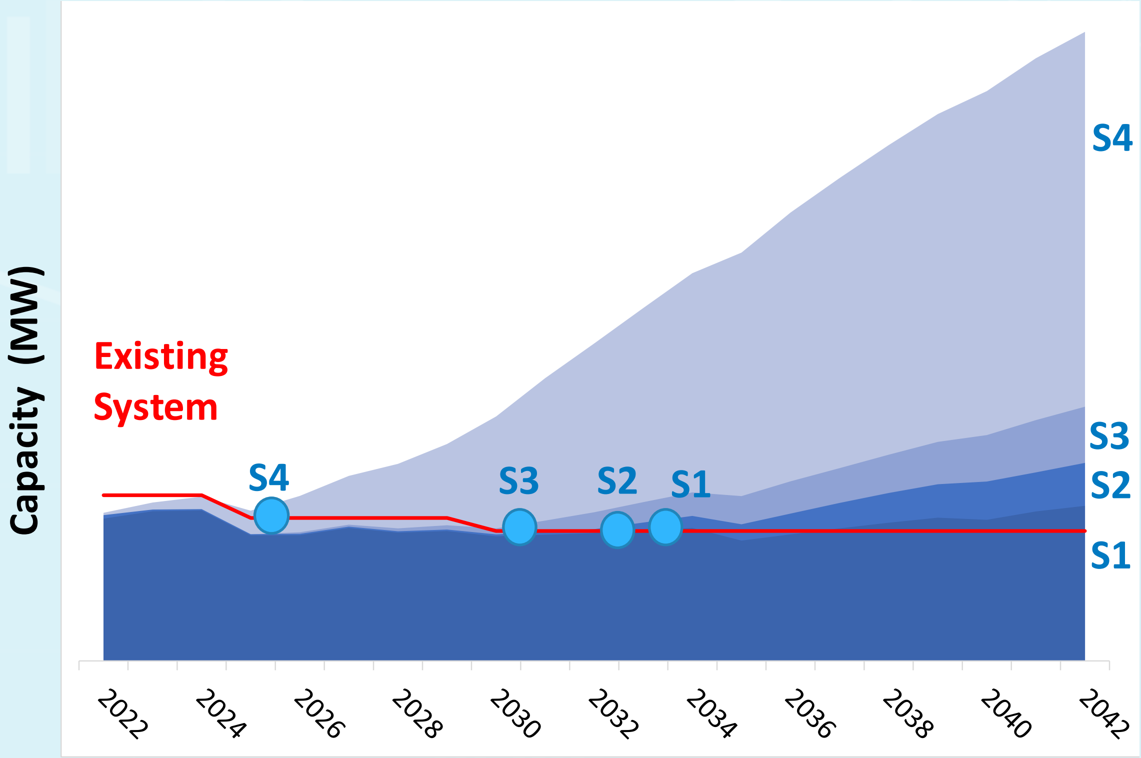
Scenario Outputs
Energy and Capacity Supply Need

No changes since initial modelling results

Dependable Energy



Capacity



Indicates investment is needed

Observations

Pace of change

Observations updated since initial modelling results

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Investment is needed in all scenarios to support growth, and to maintain and modernize existing assets

Existing system meets early demand in scenario 1, 2, and 3

Meeting early demand in scenario 4 will be challenging

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MODELLING & ANALYSIS RESULTS

SENSITIVITY GROUPINGS

Modelling & Analysis Results

Select sensitivities

Gas Generation Grouping
Restricted gas generation usage
Carbon capture required for gas generation
No new natural gas generation*

Customer Grouping
Demand Response*
Dual fuel for heating*
Ground source heat pump*
Solar*
Energy Efficiency*

Other Grouping
Energy Price & Market Interactions*
Climate Change*
New hydropower*

Over 70 different model runs were completed.

The following provides select observations from this modelling and analysis.

* New sensitivities completed since initial modelling results shared in Round 3 Engagement

MODELLING & ANALYSIS RESULTS

GAS GENERATION GROUPING

Gas Generation Grouping
Summary of Sensitivities

Sensitivity	What was changed from the scenarios?	Why was this sensitivity done?
Restricted gas generation usage	Assume natural gas generation cannot be used to satisfy energy planning criteria.	Understand the impact to scenario results by requiring additional resources to limit electric generation GHG emissions.
Carbon capture required for gas generation	Assume new natural gas generation must include carbon capture and storage.	Understand the impact to scenario results, in particular to cost and GHG emissions.
No new natural gas generation	New natural gas generation was removed as a resource option.	Understand impact of removing option to build any natural gas generation (including using carbon capture and sequestration).

Restricted gas generation usage

Carbon capture required for gas generation

No new natural gas generation

Gas Generation Grouping
Capacity Supply Mix

New observations since initial modelling results

<u>S4 sensitivity: No New Natural Gas Generation</u>

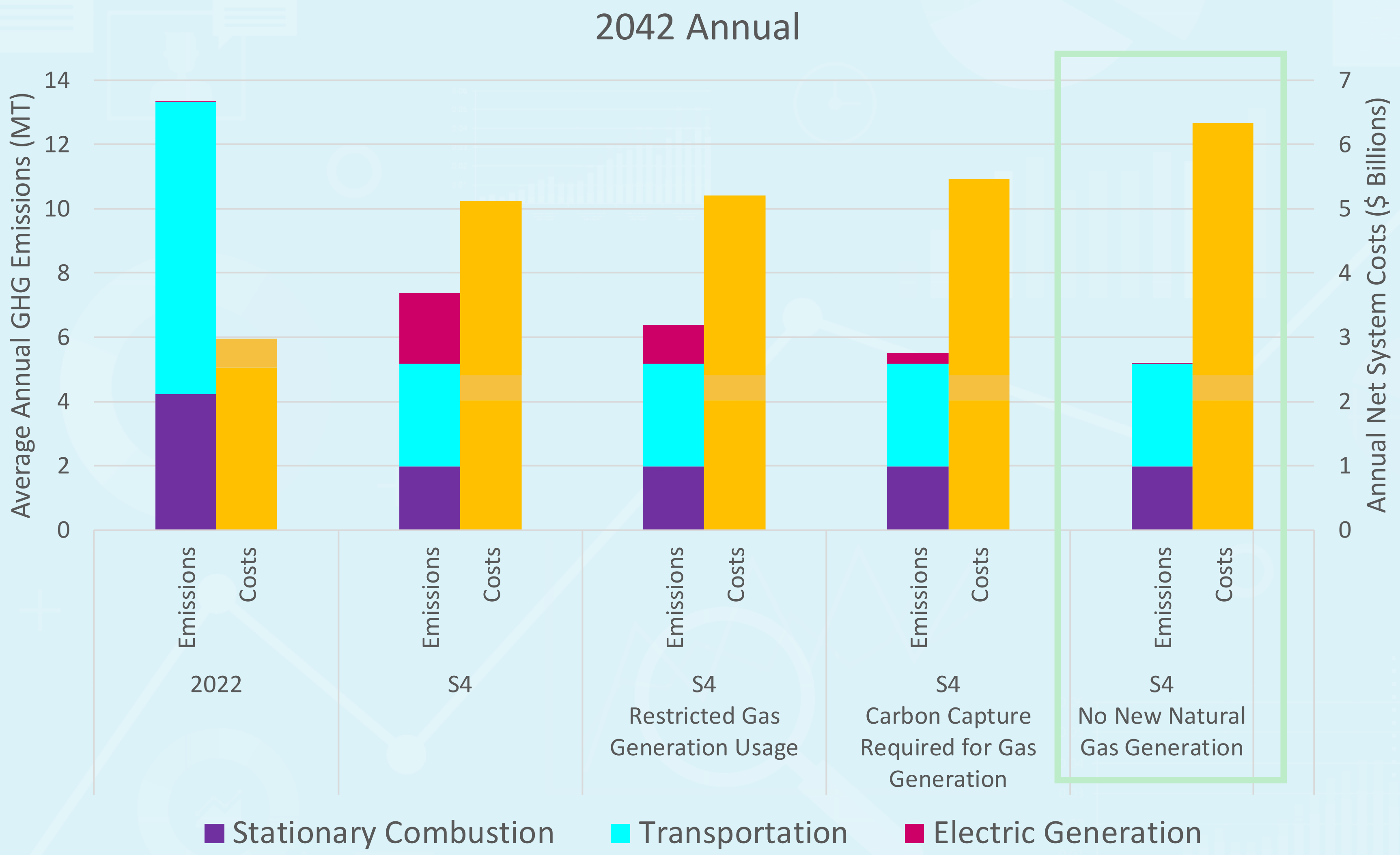
Thermal capacity is replaced by a mixture of resources including:

- hydrogen fueled combustion turbines used for winter capacity
- substantially more new wind generation
- more energy efficiency (DSM)
- biomass, small modular reactors (SMR), and major new hydropower; this is the only sensitivity where these resources were found to be cost-effective.

There is no utility scale solar generation. More surplus energy would be result due to the amount and type of new generation.

Gas Generation Grouping
Cost and GHG Emissions

New observations since initial modelling results



S4 sensitivity: No New Natural Gas Generation
Compared to scenario 4 (S4), there is a substantial cost increase, with some GHG emissions decrease.

* Manitoba GHG emissions shown do not include non-energy dependent sources, like agricultural based emissions.

Observations
Gas Generation Grouping

New observations since initial modelling results

Limiting thermal generation reduces emissions but increases costs

Carbon capture increases use of thermal generation and net system costs

Not allowing new natural gas generation significantly increases cost and reliance on less mature technologies

MODELLING & ANALYSIS RESULTS

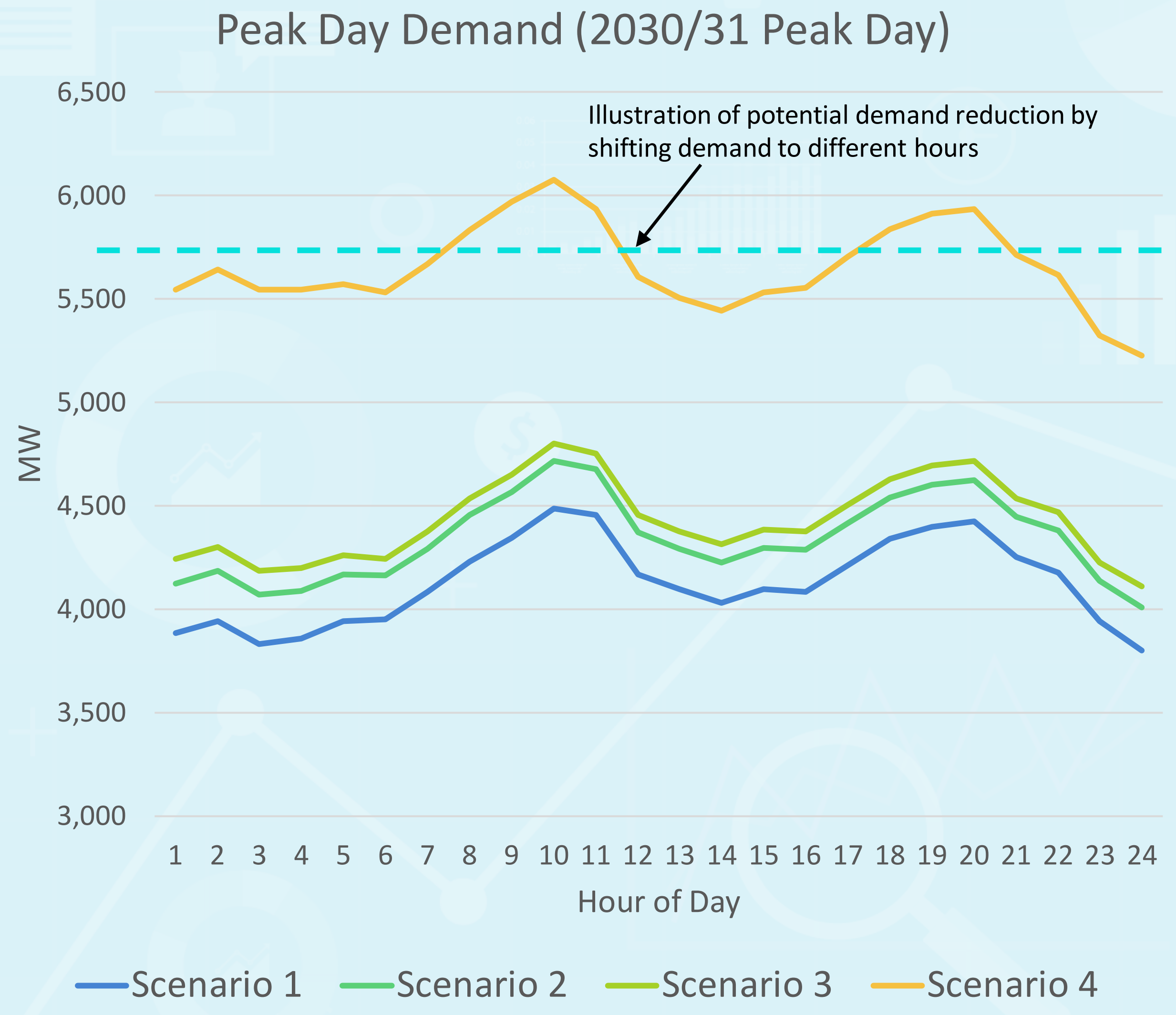
CUSTOMER GROUPING

Customer Grouping
Summary of Sensitivities

Sensitivity	What was changed from the scenarios?	Why was this sensitivity done?
Demand Response	Demand response programs were added to reduce peak demand.	Understand the potential value of new demand response programs.
Solar	Amount of solar customer self-generation was varied. The cost of utility scale solar cost was reduced as a sensitivity.	Understand the value of solar relative to other resources.
Dual fuel for heating	Assume natural gas heating customers replace air conditioners with air-source heat pumps instead of converting to electric resistance heating.	Understand the impact to cost and GHG emissions associated with using air-source heat pumps with natural gas for heating instead of electric resistance heat.
Ground source heat pump	Ground source heat pumps for heating and cooling were added as a resource option.	Understand how the cost and attributes of ground source heat pumps compare to other resources.
Energy Efficiency	Energy efficiency assumptions were updated.	Understand the value of energy efficiency relative to other resources.

Customer Grouping
Demand Response (DR)

New observations since initial modelling results



Demand response measures are cost-effective for delaying or reducing the need for new capacity resources, including gas turbines and batteries.

Delaying new capacity resources, results in a need for new resources that provide energy to meet the growing need for energy.

The goal of demand response programs are to reduce peak electric demand. This sensitivity assumed total electrical energy use did not change and the energy was shifted to different hours.

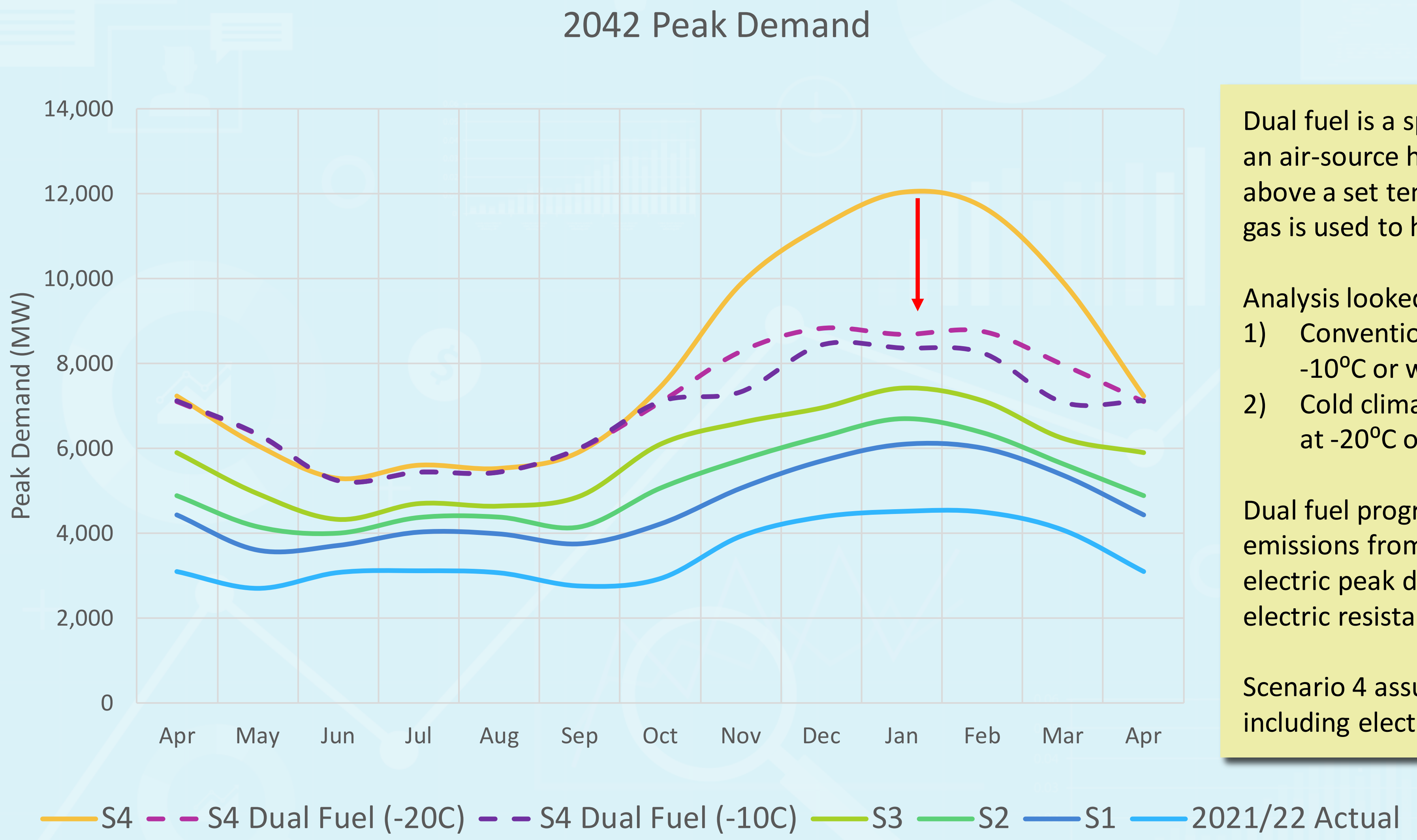
Demand Response may be achieved through:

- Residential Direct Load Control (e.g. EV Smart Charger Control, WiFi thermostat)
- Commercial or Industrial Interruptible Rates and Manual Curtailment.

Time Varying Rates may be able to provide similar peak reductions as other demand response programs.

Customer Grouping
Dual Fuel for Heating

No material changes since initial modelling results



Dual fuel is a space heating technology using an air-source heat pump to heat and cool above a set temperature, and then natural gas is used to heat below that temperature.

Analysis looked at two technologies:

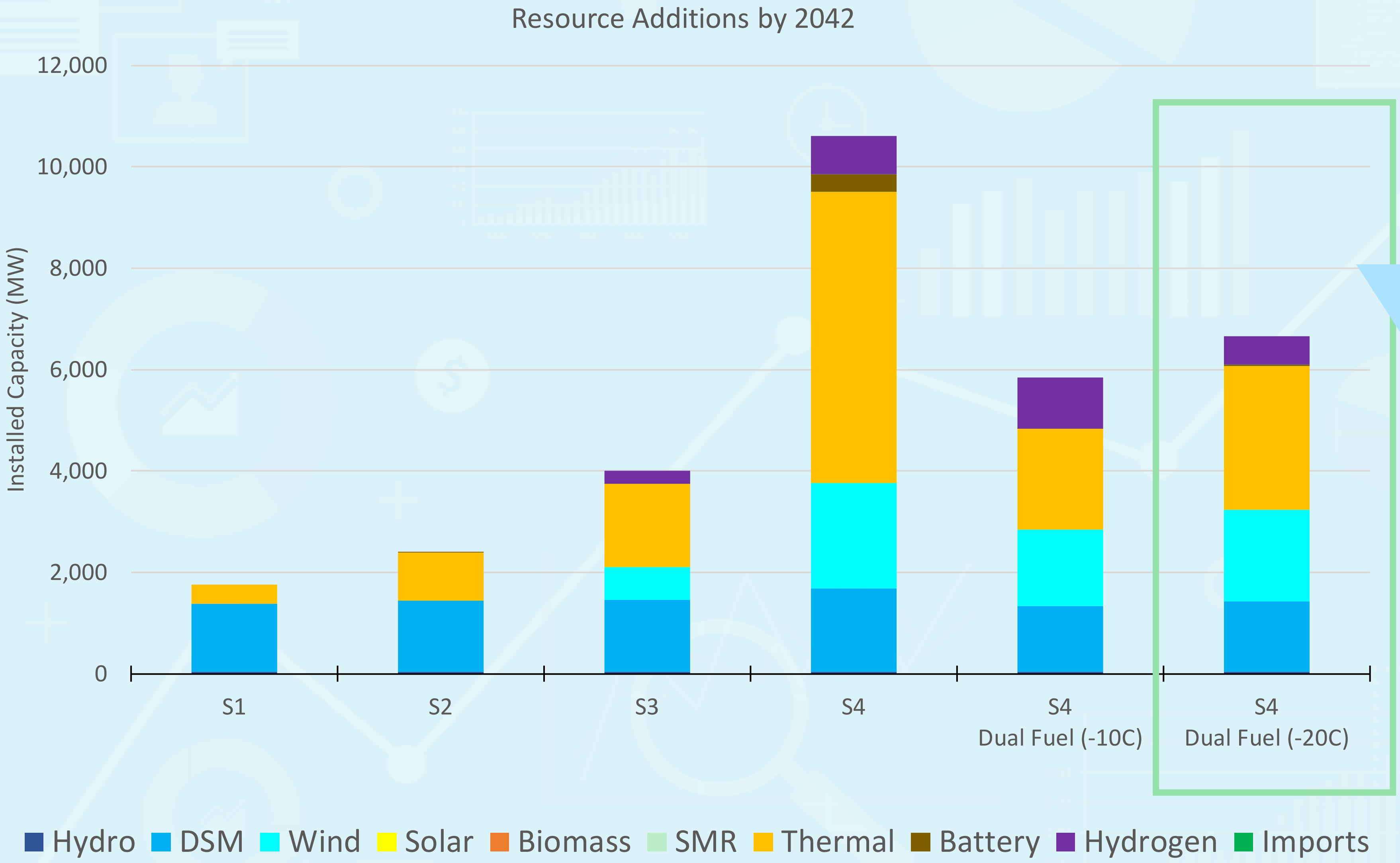
1) Conventional air-source heat pump that operate at -10^{o}C or warmer
2) Cold climate air-source heat pumps that operate at -20^{o}C or warmer.

Dual fuel programs have the potential to reduced GHG emissions from natural gas usage, while avoiding electric peak demand impacts of converting to full electric resistance heating.

Scenario 4 assumed accelerated decarbonization including electric resistance space heating.

Dual Fuel for Heating
Energy and Capacity Supply Mix

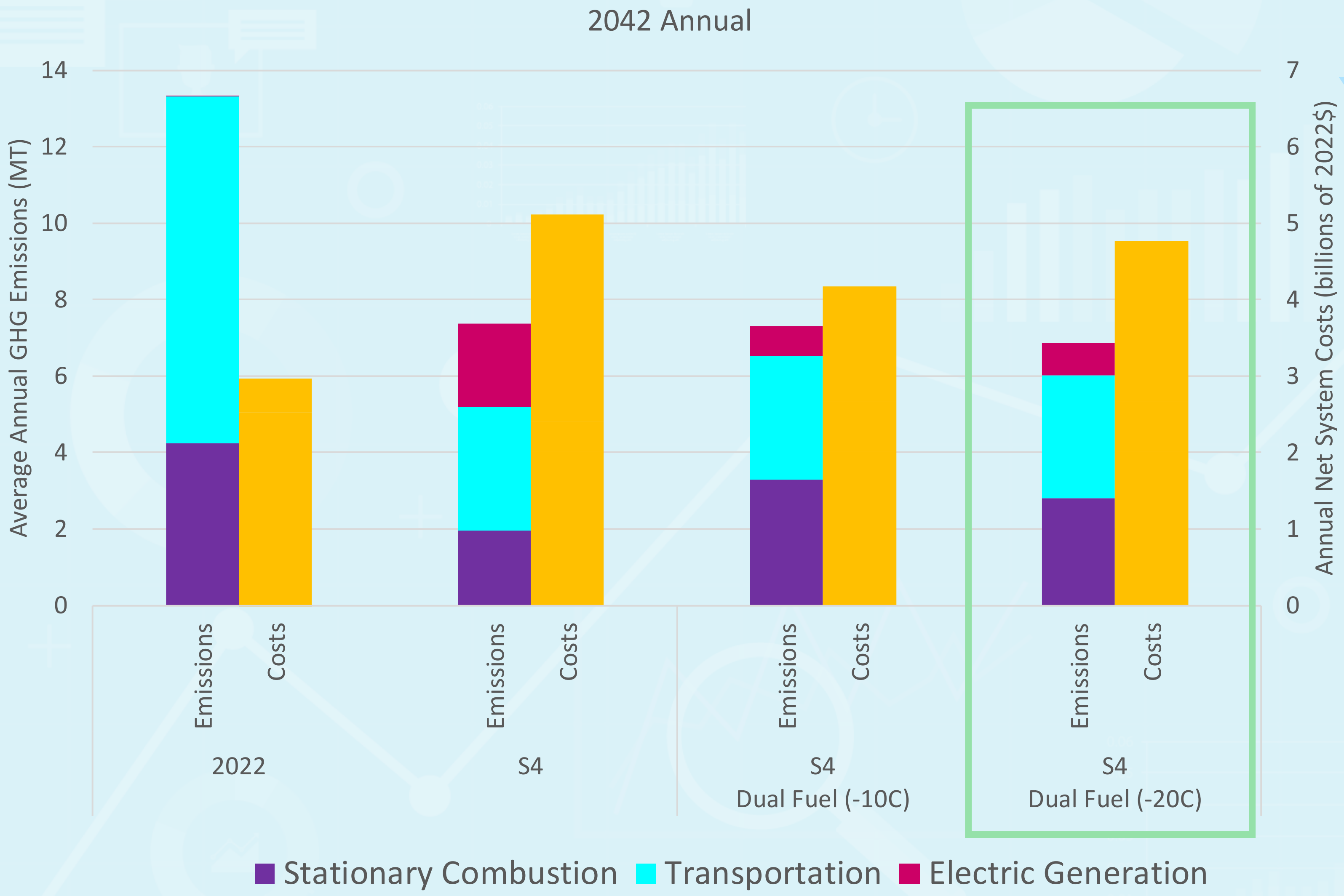
No material changes since initial modelling results



<u>S4 sensitivities: Dual Fuel</u>
Total resource additions are much lower than in scenario 4 (S4). The existing natural gas system continues to be leveraged to meet peak energy needs and mitigate cost impacts.

Dual Fuel for Heating
Cost and GHG Emissions

New observations since initial modelling results



Dual fuel programs have the potential to reduce GHG emissions at a lower overall cost.

Cold climate (-20C) air-source heat pumps appear to offer limited advantage over conventional heat pumps for GHG emission reductions due to higher cost.

Costs shown include an estimate for costs to purchase and install air-source heat pumps in dual fuel cases (this cost was not included in dual fuel sensitivity initial results).

Alternative fuels may present an opportunity to support further decarbonization while leveraging existing gas infrastructure.

* Manitoba GHG emissions shown do not include non-energy dependent sources like agricultural based emissions.

Customer Grouping
Ground source heat pump (GSHP)

New observations since initial modelling results

Ground source heat-pumps (GSHP) can be effective in cold climates because their performance does not reduce in very cold weather. There can be barriers to adoption, like upfront costs.

While results do not support the widespread adoption of GSHPs, these are sensitive to assumptions about long-term performance. Further study is required to refine GSHP modelling assumptions.

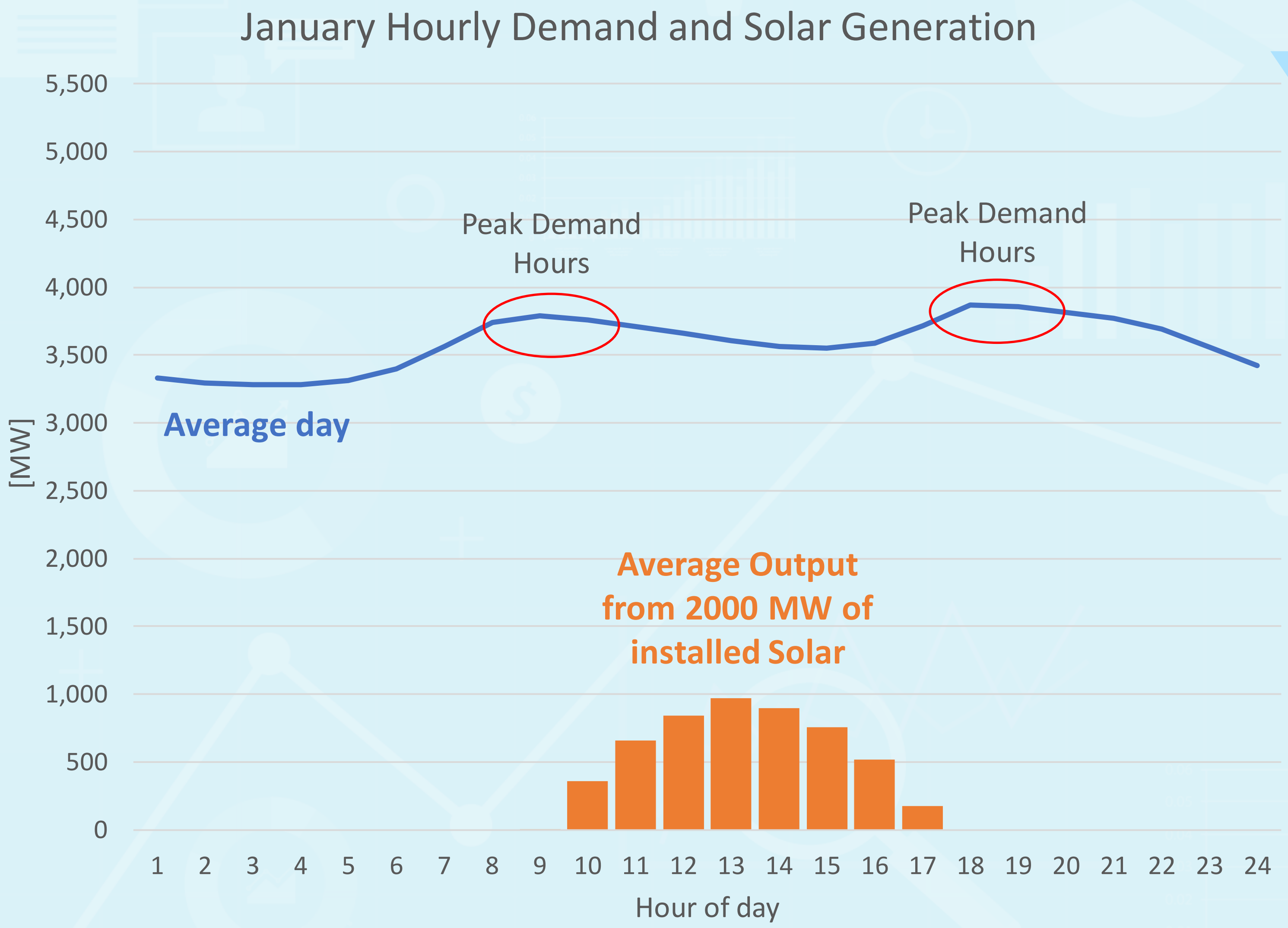
GSHPs may be valuable due to their ability to be deployed in shorter timeframes than other utility scale options can be.

Ground source heat-pumps (GSHP), as an alternative to using natural gas for space heating, have the potential to reduce GHG emissions.

While GSHPs can be more efficient than traditional heating and cooling systems, their performance is affected by many factors including: soil type, system sizing, installation quality, relative heating and cooling needs, maintenance, and building design. The performance of individual GSHP systems can vary significantly from installation and can degrade over time.

Customer Grouping
Solar Power

New observations since initial modelling results



Utility scale solar generation is not as cost-effective as other resources available in Manitoba, even with assumptions it is less expensive than new wind generation.

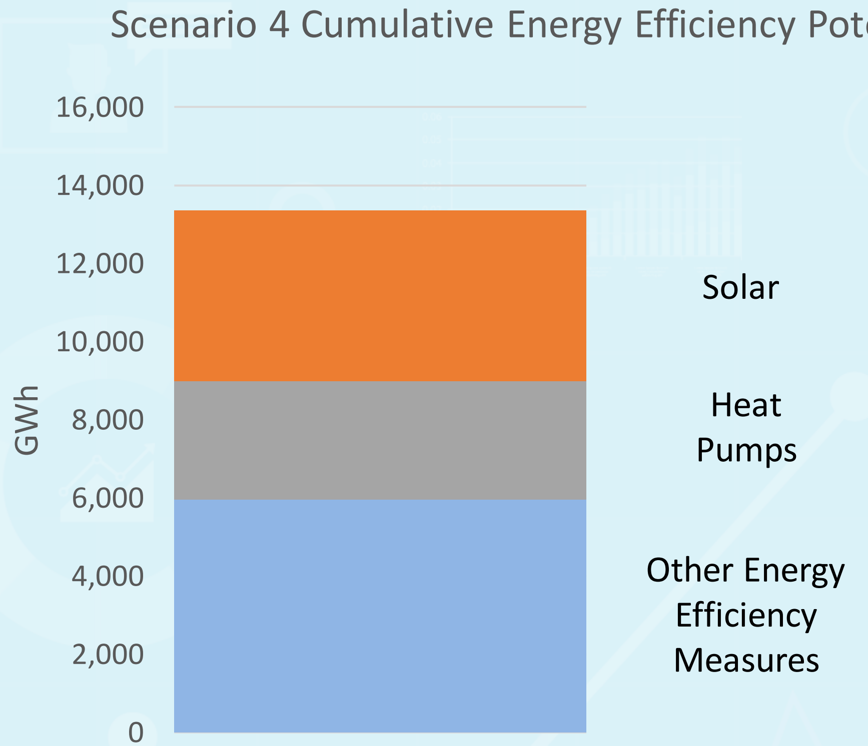
Solar options were available for the model to select in all scenarios and sensitivities. Solar was never found to be cost-effective compared to other resource options, including when reducing the cost of solar generation.

Solar may be utility scale or customer owned.

Solar generation does not provide electricity that can be relied on to help meet Manitoba's high winter demand. Solar energy generation aligns well to support peak demand in some jurisdictions, like those with high summer demand.

Customer Sensitivities
Energy Efficiency (EE)

New observations since initial modelling results



Potential electrical energy savings based on what may be achieved in the marketplace

Energy efficiency measures were included as resources that could be selected by the model and evaluated along with other resource options. The set of efficiency measures included solar, heat pump, and other energy efficiency measures savings potential, as provided by a consultant.

Preliminary results show that varying amounts of other energy efficiency measures were selected. IRP analysis does not support solar as an economic option to meet demand relative to other resource options. Heat pump savings were only selected in Scenario 4 to meet rapid demand growth, before other more cost-effective resources could be put into service. Further discussions and study are underway with Efficiency Manitoba.

Observations Summary
Sensitivities

No New Natural Gas Generation
- significantly increases cost and reliance on technologies that are less mature

Dual Fuel
- programs have the potential to reduce GHG emissions at a lower overall cost

Demand Response
- cost-effective for delaying or reducing the need for new capacity resources

Ground Source Heat Pumps
- performance varies widely, not found to be cost-effective on average

Energy Efficiency
- cost-effectiveness dependent upon measure and requires closer analysis

Solar
- not as cost-effective as other resources available in Manitoba

MODELLING & ANALYSIS RESULTS

OTHER GROUPING

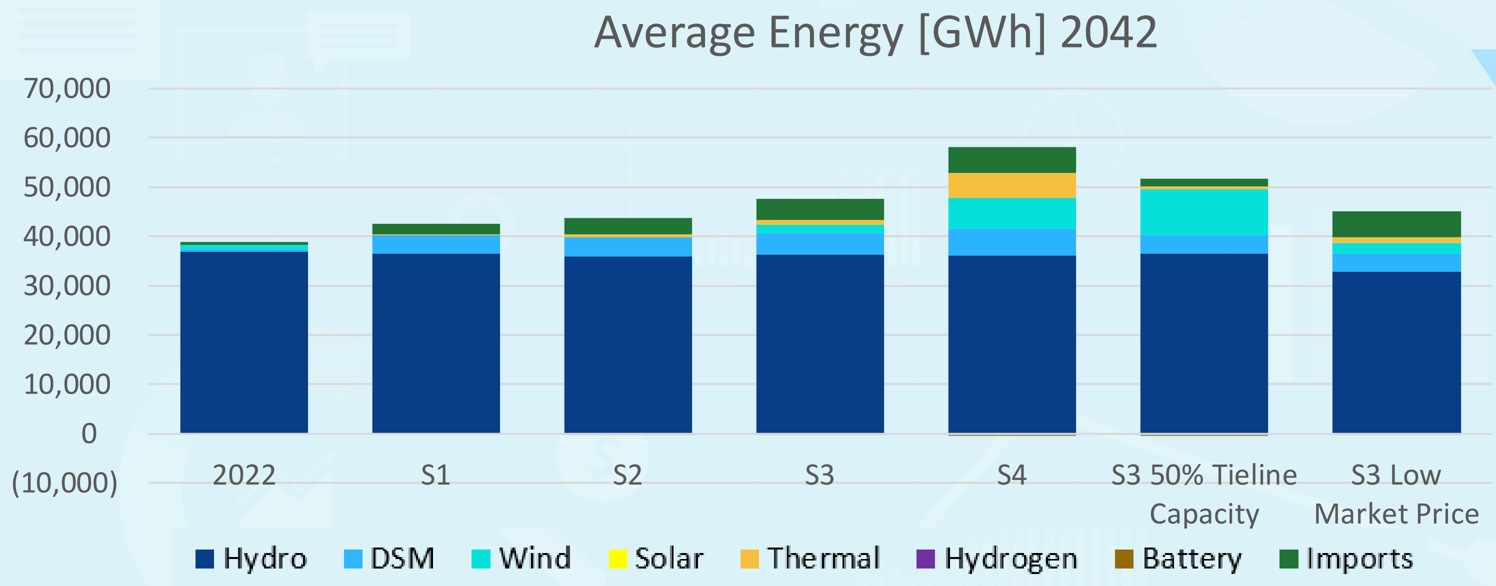
Other Grouping

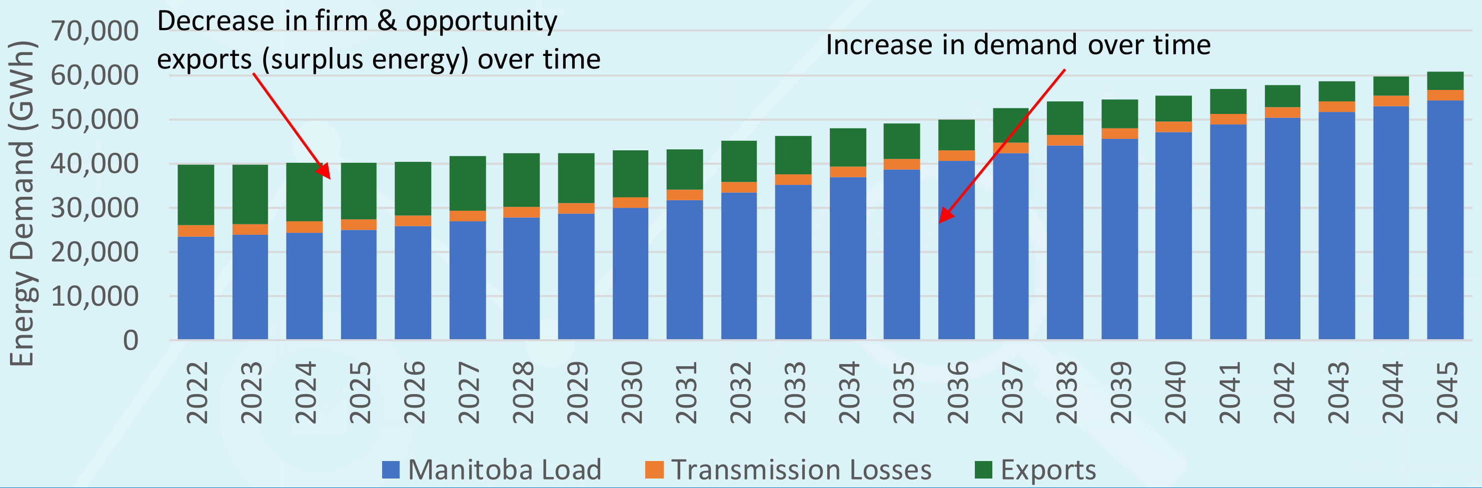
Summary of Sensitivities

Sensitivity	What was changed from the scenarios?	Why was this sensitivity done?
Energy Price & Market Interactions	Wholesale electricity prices were reduced. Imported energy was reduced.	Understand impact of changes in value of exported electricity. Understand impact of reducing imported electricity.
Climate Change	Amount of hydro-electric production as a result of changes in precipitation was varied. Changes to demand due to temperature changes.	Understand impact of changes in water flows to hydroelectric energy production.
New Hydropower Resources	A new hydro-electric generating station was assumed as a future new resource.	Understand the value of new hydro relative to other resources.

Other Grouping
Energy Price & Market Interactions

New observations since initial modelling results





Interconnections continue to provide value as they provide access to imports which are an economic source of energy.

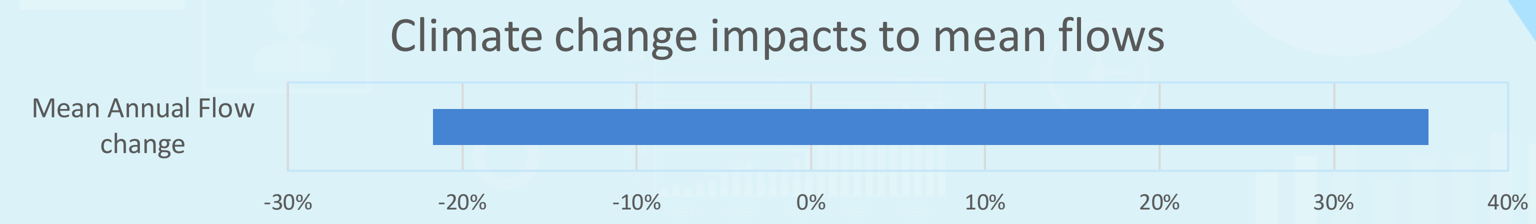
- Market price and import capability impacts the quantity, type, and need for new generation resources.
- Relying less on import capability generally increases new wind generation.
- Decreasing market prices generally decreases new wind generation.

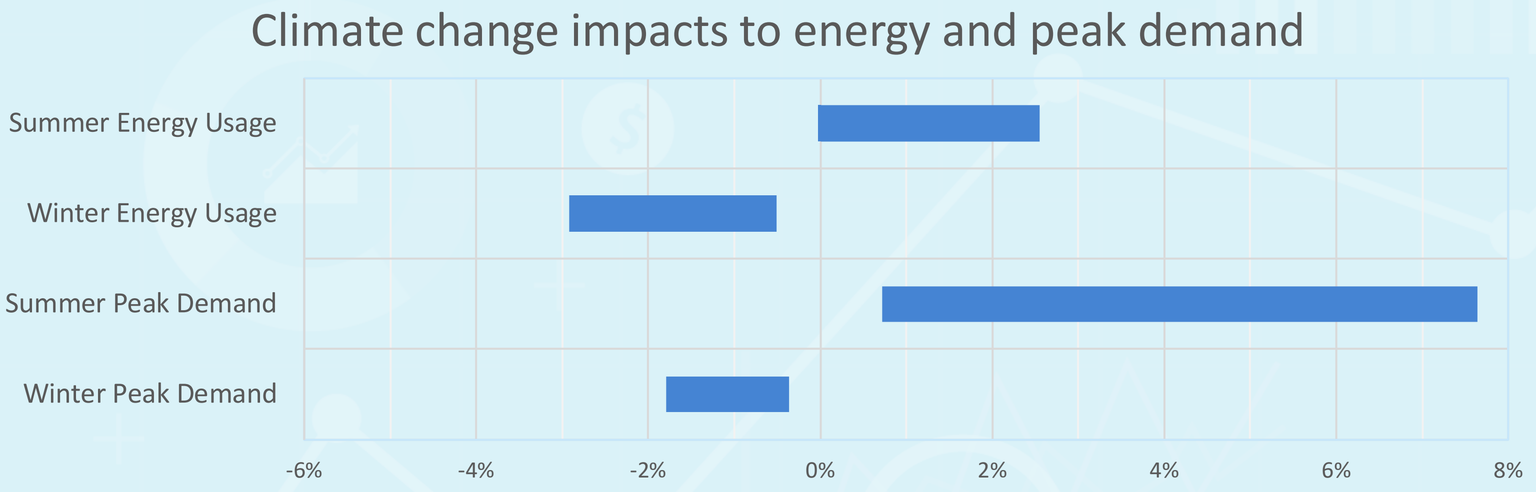
As demand grows within Manitoba, there will be less surplus energy to export, less exposure to export prices, and greater exposure to import price risks.

Manitoba Hydro has the ability to import energy and it may make sense do more of this in the future as energy needs within Manitoba grows. The cost of this energy is dependent upon wholesale market prices.

Other Grouping
Climate Change

New observations since initial modelling results





Climate Change sensitivities consider the impact of climate change on temperatures and precipitation. A warmer future is predicted but the impact on future mean annual water flows is uncertain.

While most climate scenarios point to a slightly wetter future on average, a drier future and more severe droughts is also possible.

Climate change impacts on flows are expected to be much more significant than temperature impacts. Increases in summer peak demand and reductions to winter energy need are predicted to be modest.

Climate change is anticipated to alter the hydrological cycle, impacting hydropower generation patterns. Climate change is also anticipated to impact energy usage and peak demand. The data in the chart depicts ranges based upon a representation of potential climate change modelling outcomes.

Other Grouping
New Hydropower Resources

New observations since initial modelling results

New hydropower is not cost-effective relative to other competing resource options.

Conawapa was only found to be economic in Scenario 4 if no new natural gas generation is permitted.

- Nine potential hydropower developments were included as resource options in the analysis.
- Conawapa is the most cost competitive new hydro project but it has an 18-year lead time and in-service date no earlier than 2041.
- Notigi is the second most cost competitive hydro project with a lead time of 10-years.

Observations
Other Grouping

Energy Price & Market Interactions

Reduced electricity imports generally increase need for new energy resources; decreased market prices generally decrease new energy resources.

Climate Change

Considerable uncertainty in mean annual flow projections, greater demand in summer, less energy needed in winter.

New Hydropower Resources

Not cost-effective relative to other resource options.

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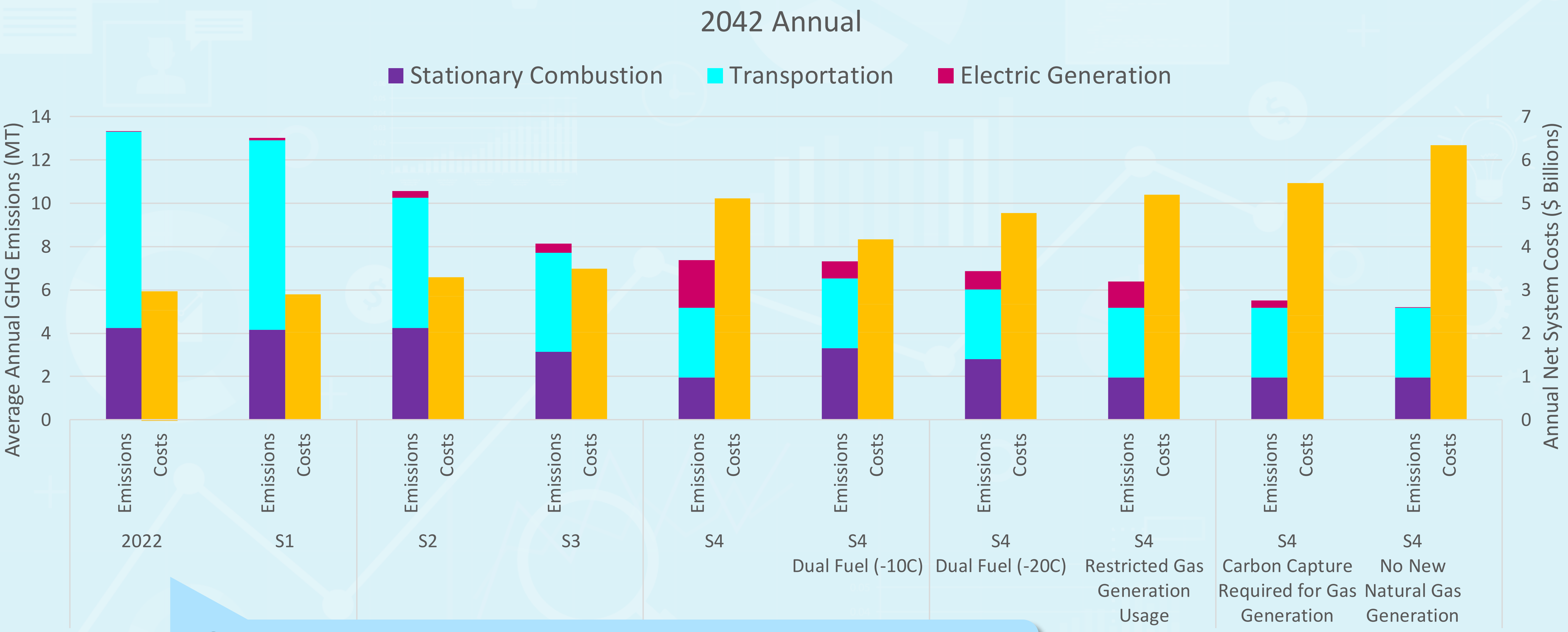
COMPARISON OF RESULTS

COST, CAPACITY, GHG EMISSIONS AND ENERGY

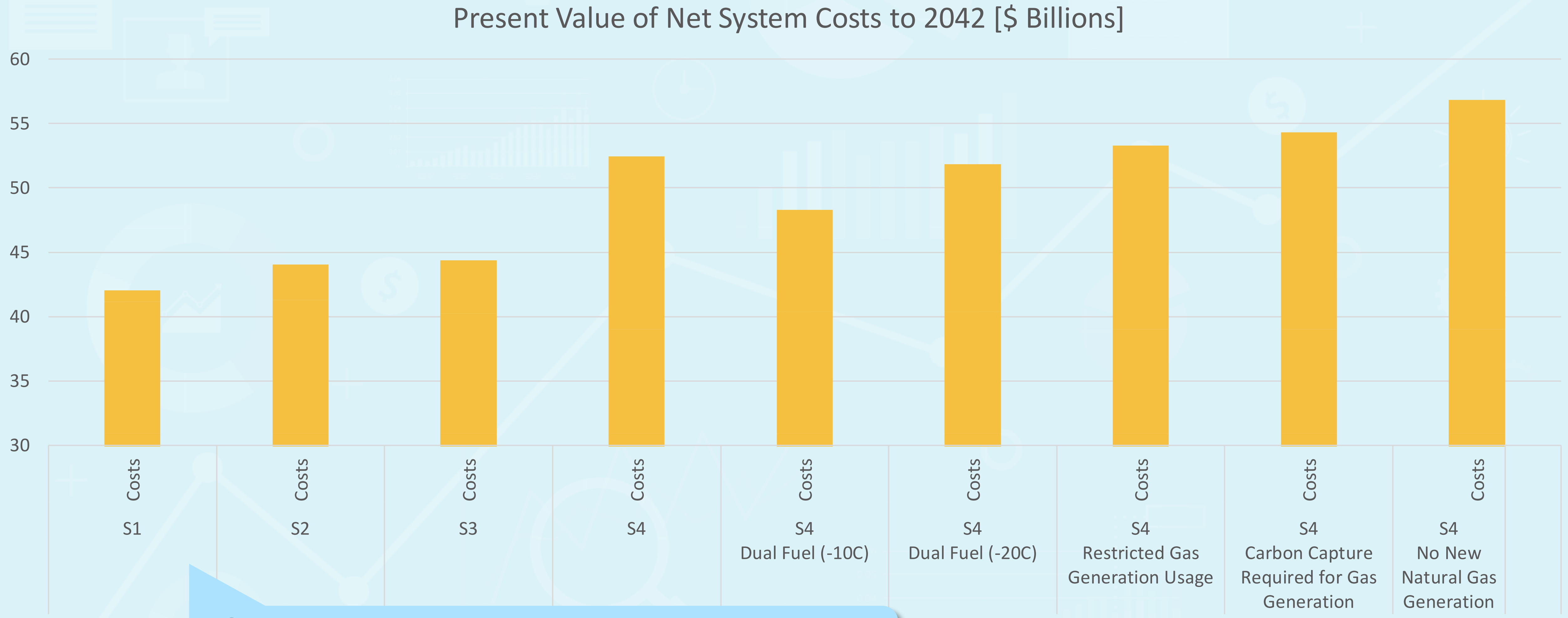
Comparison of Results
Cost and GHG Emissions

* Manitoba GHG emissions shown do not include non-energy dependent sources, like agricultural based emissions.



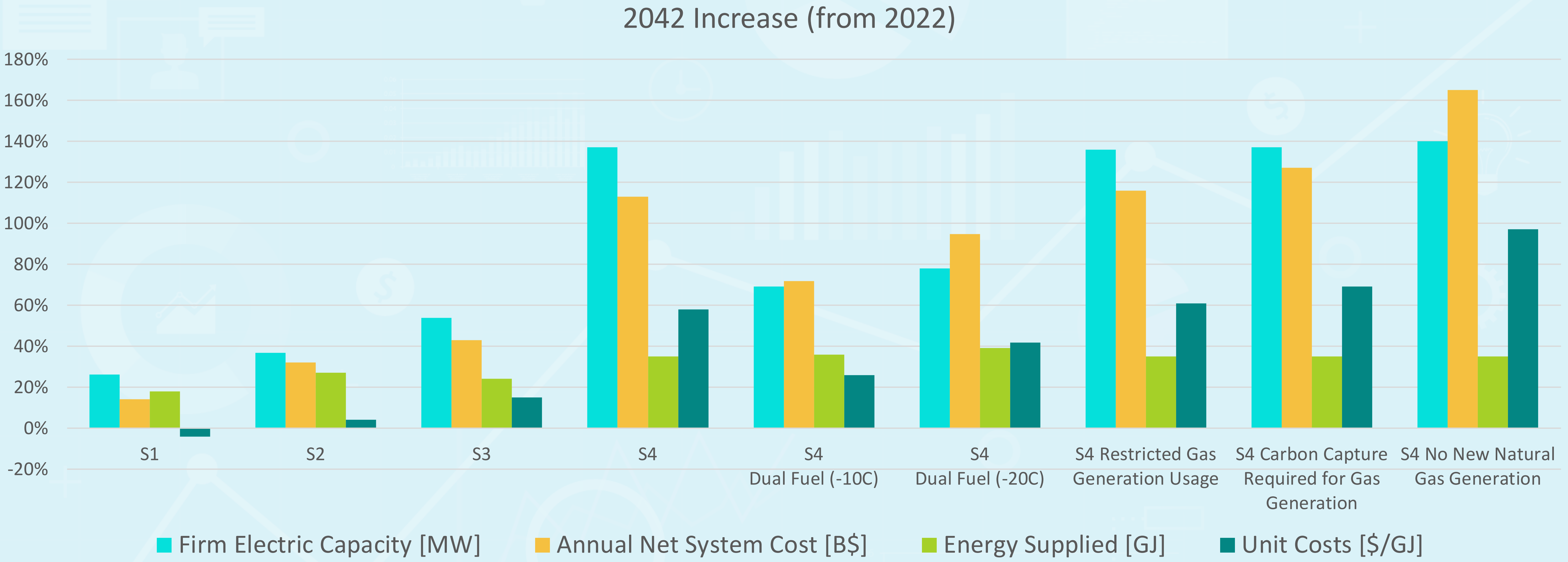
Cost and GHG emissions vary significantly across scenarios and sensitivities.

Comparison of Results
Present value of cost



Cost varies significantly across scenarios and sensitivities.

Comparison of Results
Cost, Capacity, and Energy Comparison



Cost is more closely correlated with electric capacity than energy demand.
Unit costs for energy (electric and natural gas) vary greatly across scenarios and sensitivities.

QUESTIONS?

email us at IRP@hydro.mb.ca

https://www.hydro.mb.ca/corporate/planning/

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