Modeling endogenous hydropower capacity expansion in GCAM-Canada

GCAM Community Modeling Meeting
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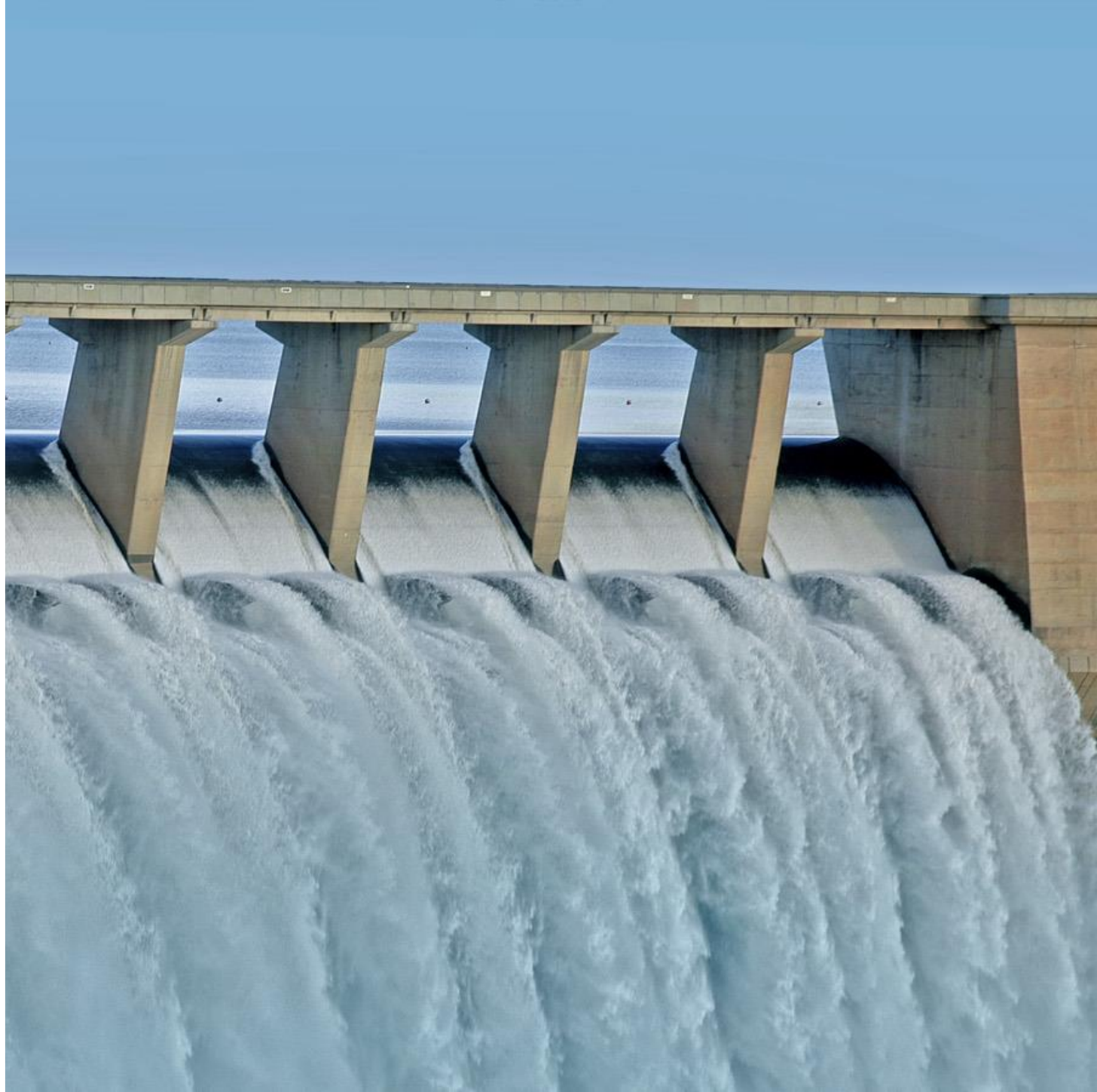
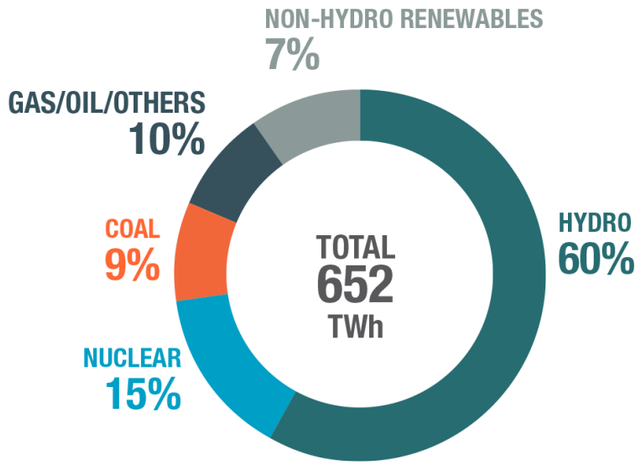


Hydropower in Canada

- Hydropower is the dominant source of electricity generation in Canada
- Hydropower capacity in Canada is expanding
- Several large hydropower projects under development in Canada have experienced significant cost overruns

Electricity Generation by Source, 2017



https://www.nrcan.gc.ca/electricity-facts/20068

Figure 1: Selected Large Hydro Projects

Site C	
Capacity	1,132 MW
Annual generation	5,268 GWh
% of utility ICAP when complete	9%
Commenced date	July 2015
% of current target budget	20%
Expected completion date	2024
Estimated cancellation costs	C$ 1.8 bn

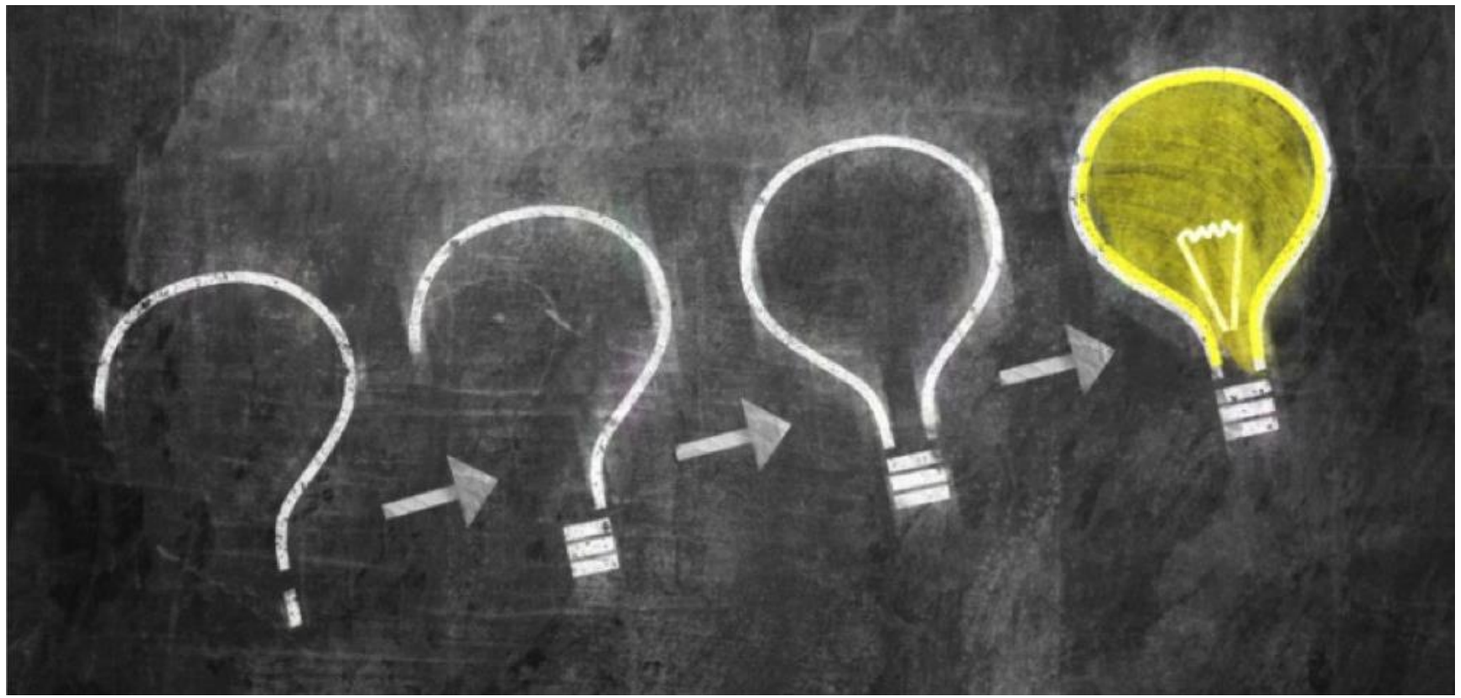
Keeyask	
Capacity	695 MW
Annual generation	4,400 GWh
% of utility ICAP when complete	12%
Commenced date	July 2014
% of current target budget	48%
Expected completion date	August 2021
Estimated cancellation costs	C$ 1.3 bn

Muskrat Falls	
Capacity	824 MW
Annual generation	4,900 GWh
% of utility ICAP when complete	11%
Commenced date	2013
% of current target budget	64%
Expected completion date	2019
Estimated cancellation costs	Not published

https://www.cdhowe.org/sites/default/files/attachments/research_papers/mixed/Commentary_528.pdf

Research Questions

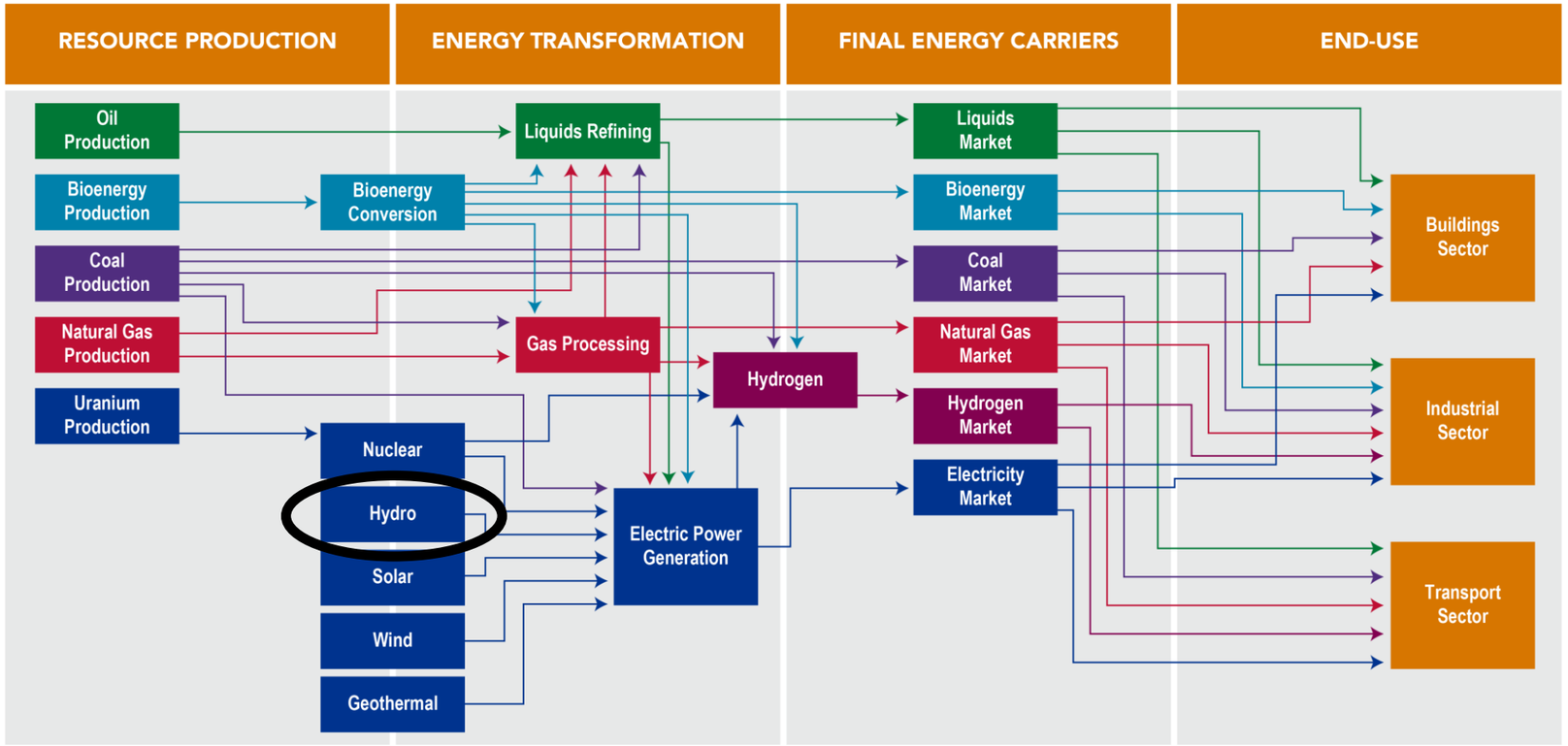
- How do the costs of hydropower impact its role in the evolution of Canada's power sector, including electrification of end-use sectors?
- How do these outcomes vary if hydropower cost-overruns are accounted for?



https://www.philpoteducation.com/mod/book/view.php?id=1274&chapterid=1768#/

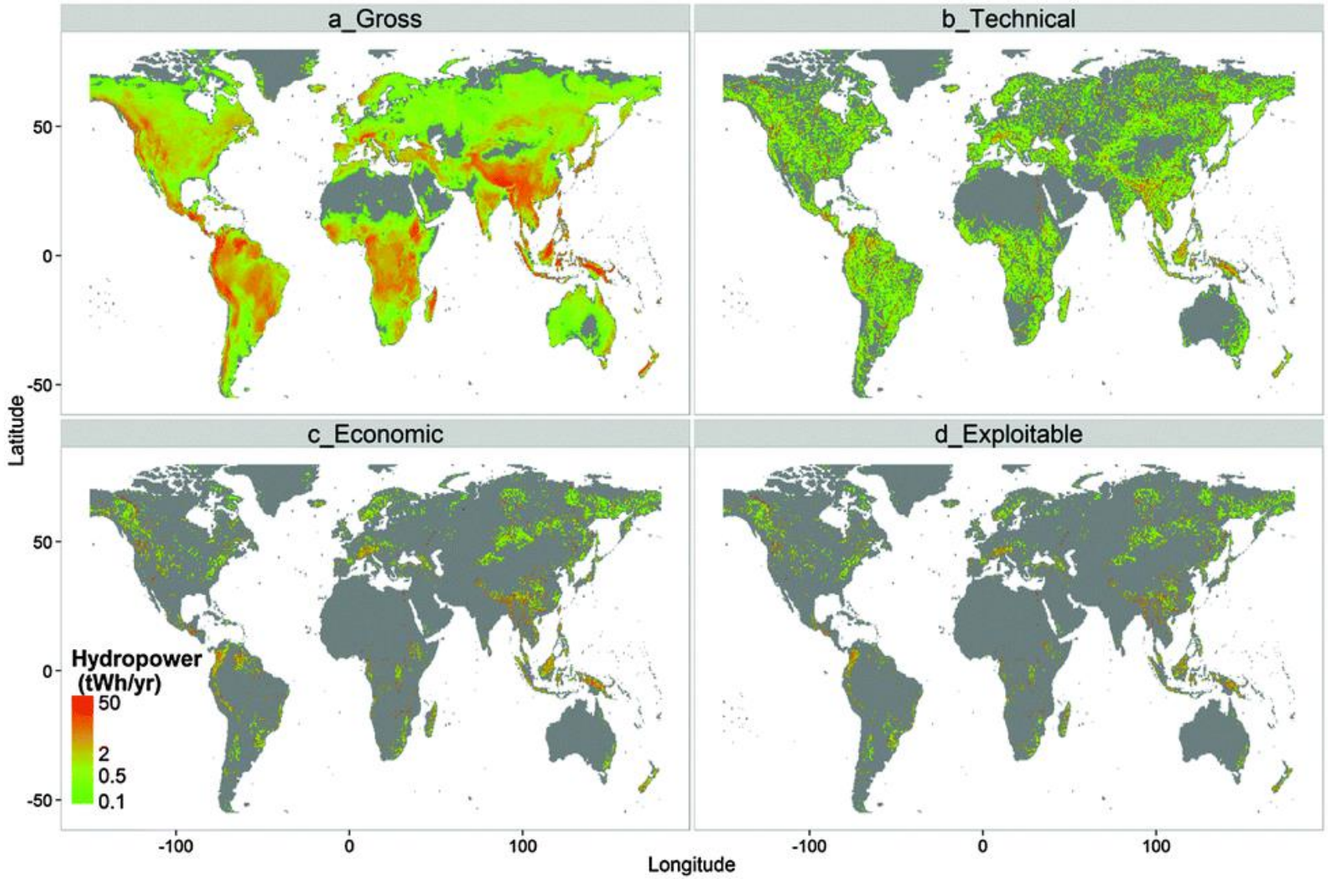
Current Hydropower Modeling Approach

- Hydropower in GCAM is modeled as a fixed output
- Hydropower electricity generation does not vary across scenarios
- Hydropower does not contribute to a region's modeled electricity price



Methodology

- Create hydropower resource and technology in GCAM
  - Hydropower supply curve information from Zhou et al. (2015)
  - Assumptions about technology characteristics (costs, capacity factors, etc.) from Environment and Climate Change Canada (ECCC)
- Increase capital costs based on literature of historical cost overruns



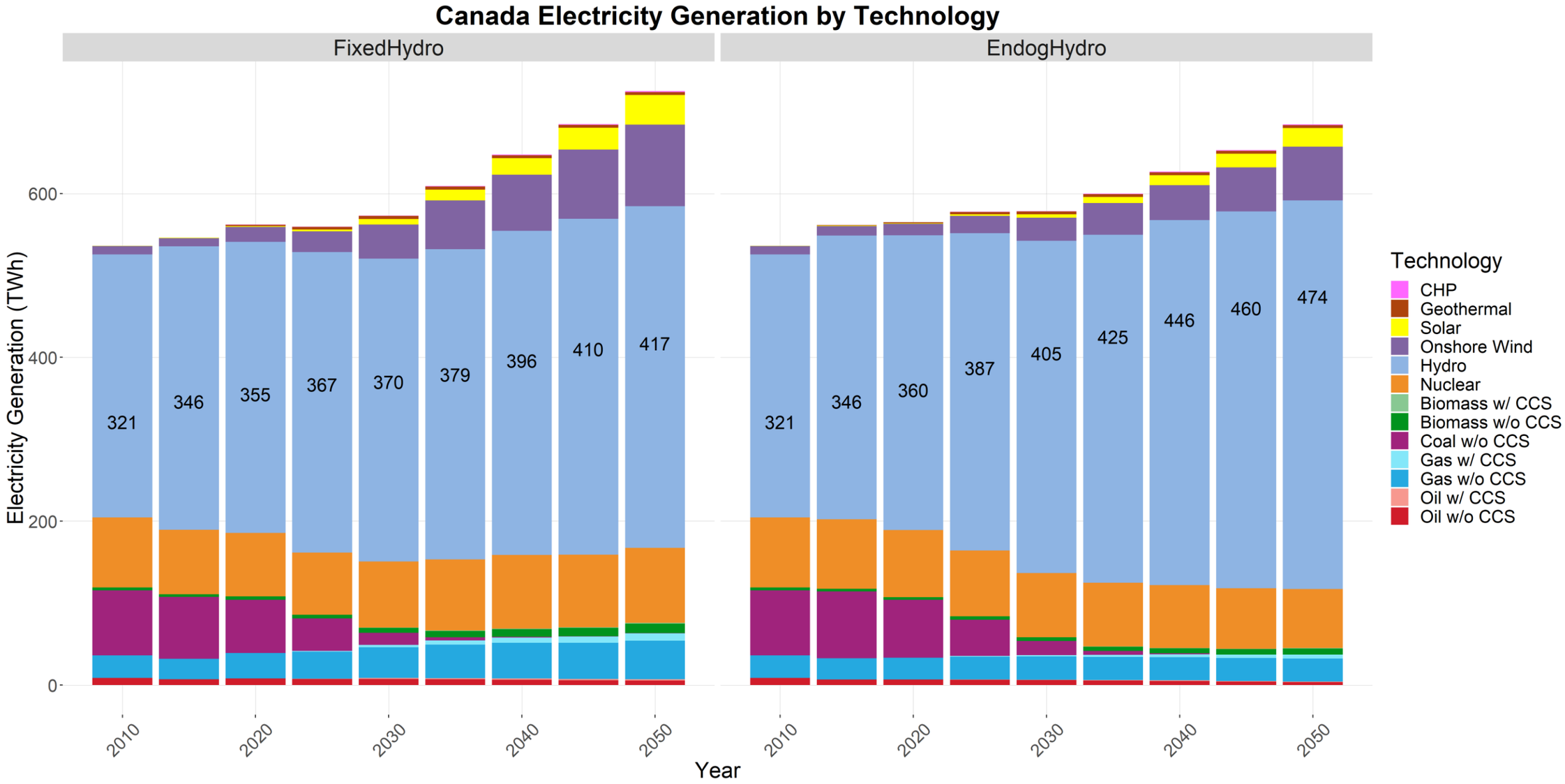
Source: Zhou et al. (2015)
https://pubs.rsc.org/en/content/articlelanding/2015/ee/c5ee00888c#!divAbstract

Cost Overrun Scenarios

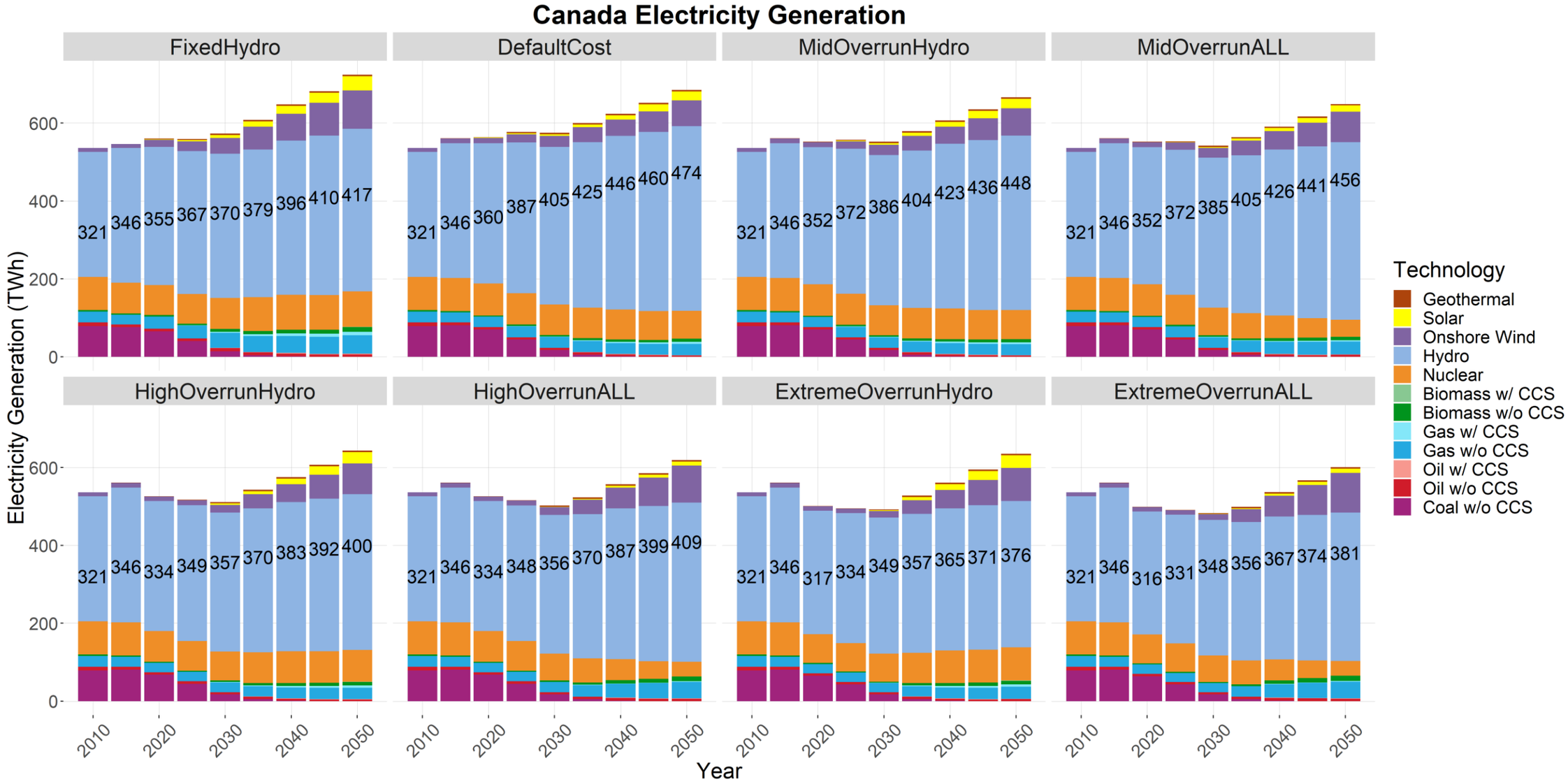
Technology	Mid Overrun	High Overrun	Extreme Overrun	Source
Hydropower	14%	53%	100%	Hollmann et al., 2014; CD Howe (2019) reports much higher values for recent projects in Canada (35%-105%)
Nuclear power	67%	117%	117%	Callegari 2017; Ansar et al., 2014
IGCC	20%	50%	50%	Ansar et al., 2014; within the median cost range for "Non-Standard Civil Engineering" overruns (6-66%)
CCS	20%	50%	50%	
CSP	20%	50%	50%	

- Two technology cases:
  - Only hydropower experiences cost overruns
  - All novel technologies (above) experience cost overruns
- Cost overruns phased in from 2020-2030

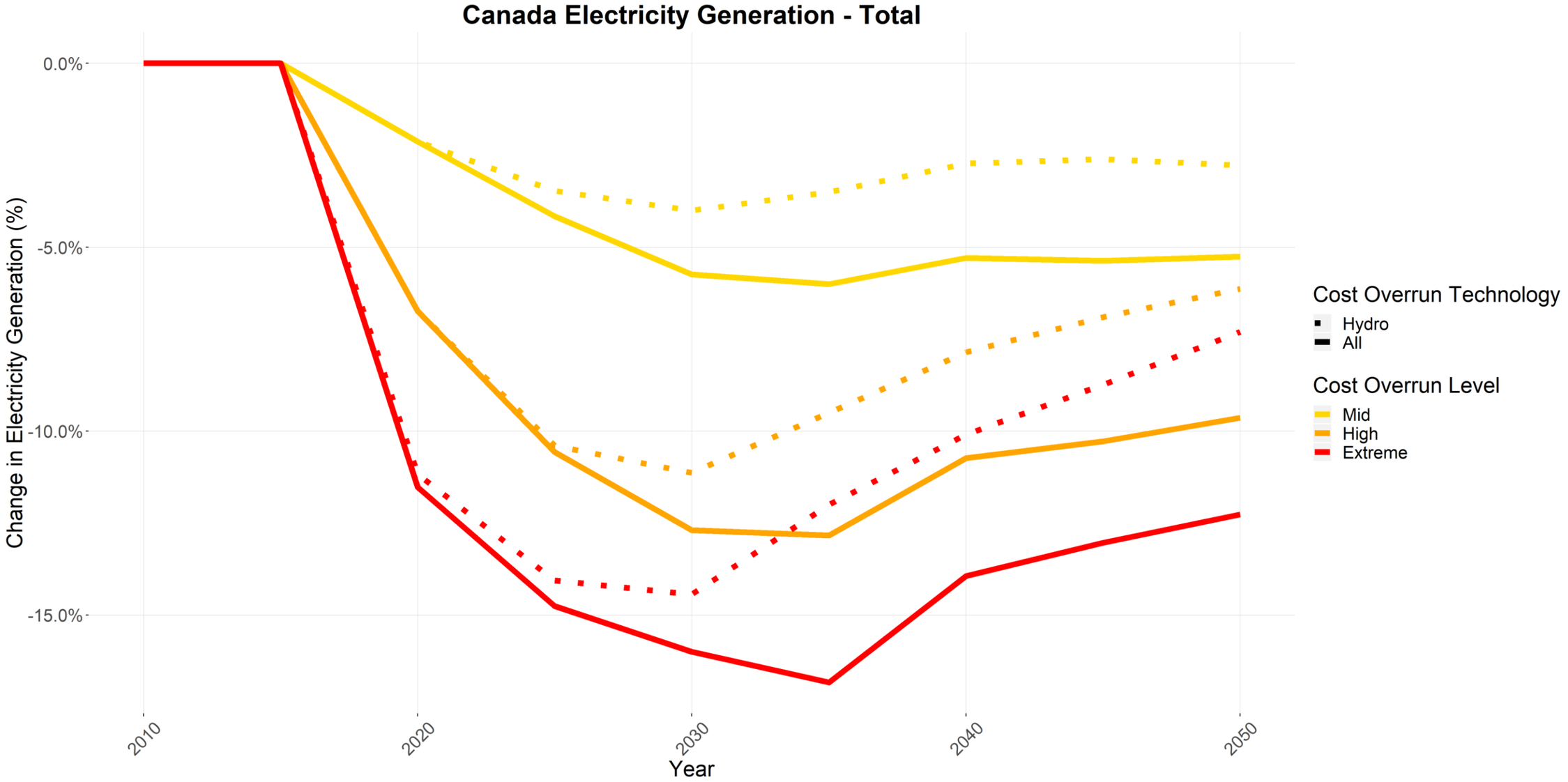
We Observe More Hydropower Expansion Under Baseline Case with Endogenous Hydropower



Cost Overruns Reduce Hydropower Expansion and Overall Electricity Demand



Change in Electricity Demand Ranges in Cost Overrun Cases Ranges from 3-12%



Conclusions

- Modeling hydropower deployment endogenously is necessary to answer key questions about the power sector in Canada
- We observe greater hydropower expansion in Canada under a baseline case with endogenous hydropower than with the previous fixed output approach
- Cost overruns could reduce hydropower expansion and overall electricity demand

Possibilities for Future Research

- Electricity trade dynamics with the USA
- Finer regional resource representation; interprovincial trade dynamics
- Greater technological detail (large hydro vs. small hydro vs. run of river)
- Endogenous climate impacts
  - emissions outcomes → climate → precipitation / runoff → hydropower production
- Complementary or competing uses of water
- Combine endogenous hydro with electricity investment & dispatch model

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Thank you