Choices and uncertainties: shaping demand through energy efficiency to lower system costs

Florian Mitjana
Michel Denault
Pierre-Olivier Pineau

Chair in Energy Sector Management
HEC MONTRÉAL

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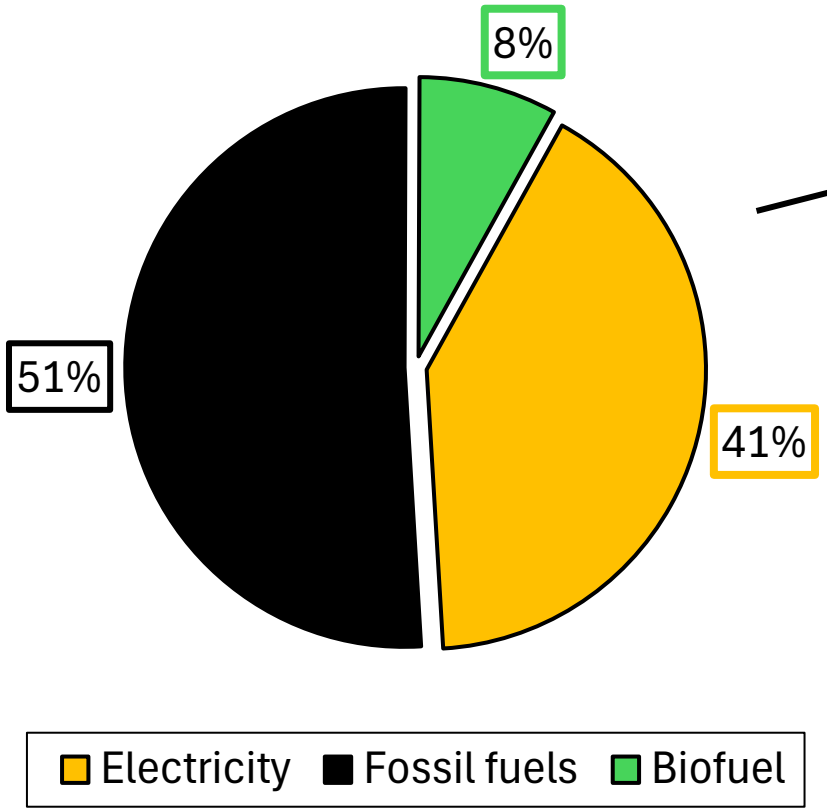
Québec's decarbonization challenges

Total consumption by energy form in Québec, 2022



Source: Whitmore, J. et Pineau, P.-O., 2025. État de l'énergie au Québec, édition 2025, Chaire de gestion du secteur de l'énergie, HEC Montréal.

- Thousand of buildings still heated with gas or oil
- Some industries still use coal
- Most cars use gasoline

Main research objective

Compare two cases of electrification

Using:

- Load profile generator
- Capacity expansion and dispatch optimization model

Load profile generator: Description

Inputs

Residential & Commercial sector

- Space heating (Baseboard, Heat pump, Dual-energy)
- Cooling
- Hot water
- Residual

- Population
- Surface (m^2)
- Intensity (GJ/m^2 ou GJ/p)
- Temperatures

Industrial sector

- Constant part

- Consumption (TWh)

Transportation sector

- Car
- SUV
- Truck

- Number of vehicles
- Consumption (kWh/km)
- Annual distance (km)

Hourly breakdown of daily consumption:

- Weekday
- Weekend day

Validation against historical data (2019 to 2023)

Output

Hourly load profile over 8760 hours

Load profile generator: 2050 scenarios

Two cases for 2050

1. Business As Usual (BAU) case

Trends since 2000

- Low building insulation and low heat pump penetration
- Constant increase in surface area per capita
- Significant growth of the vehicle fleet

2. Energy Efficiency (EE) case

Strong political actions

- Passive buildings + High heat pump penetration
- More public transport or freight transport by rail

And for both cases

- Industry sector:
  - Electrification of some fossil fuels
  - New industries

Temperatures

(National Research Council of Canada)

Climate datasets for 564 reference locations in Canada

- Temperature profiles for:

Typical year | Extreme Cold year | Extreme Warm year

- Four global warming scenarios for 2050

+1.5 °C | +2.0 °C | +2.5 °C | +3.0 °C

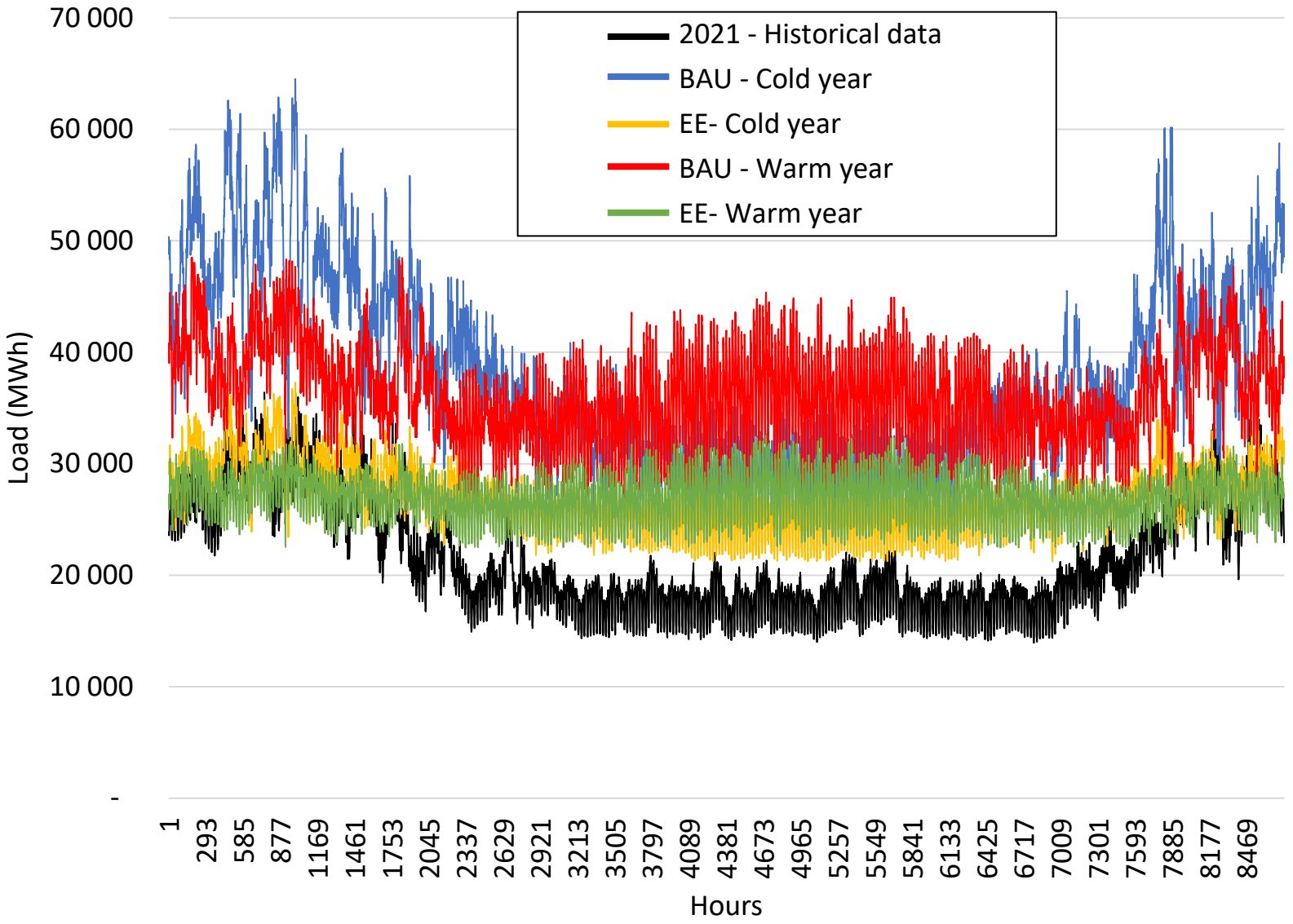
Focus here :

- Extreme cold year with +1.5°C
- Extreme warm year with +3.0°C

Assumptions of BAU and EE cases

Sectors		2021	2050 BAU	2050 EE
Building	Population	8.8 M	9.9 M	9.9 M
	Heating space intensity	130 kWh/m²	***80 kWh/m²***	***30 kWh/m²***
	Heat pump penetration	6%	***50%***	***90%***
	Surface area	58 m²/p	***75m²/p***	***60m²/p***
Transport	Cars	0.05 M	***4 M***	***3 M***
	SUV	0.02 M	***5.8 M***	***1.5 M***
	Trucks	0 M	***0.1 M***	***0.08 M***

Results : Load profiles of BAU and EE cases



	Total load (TWh)	Peak load (MW)
2021	189	36 400
BAU Cold year	329	64 522
BAU Warm year	317	48 512
EE Cold year	235	37 294
EE Warm year	236	32 554

Capacity expansion and dispatch optimization model

One load profile → **MODEL**

Capacity expansion decisions for:
- Generation
- Battery storage

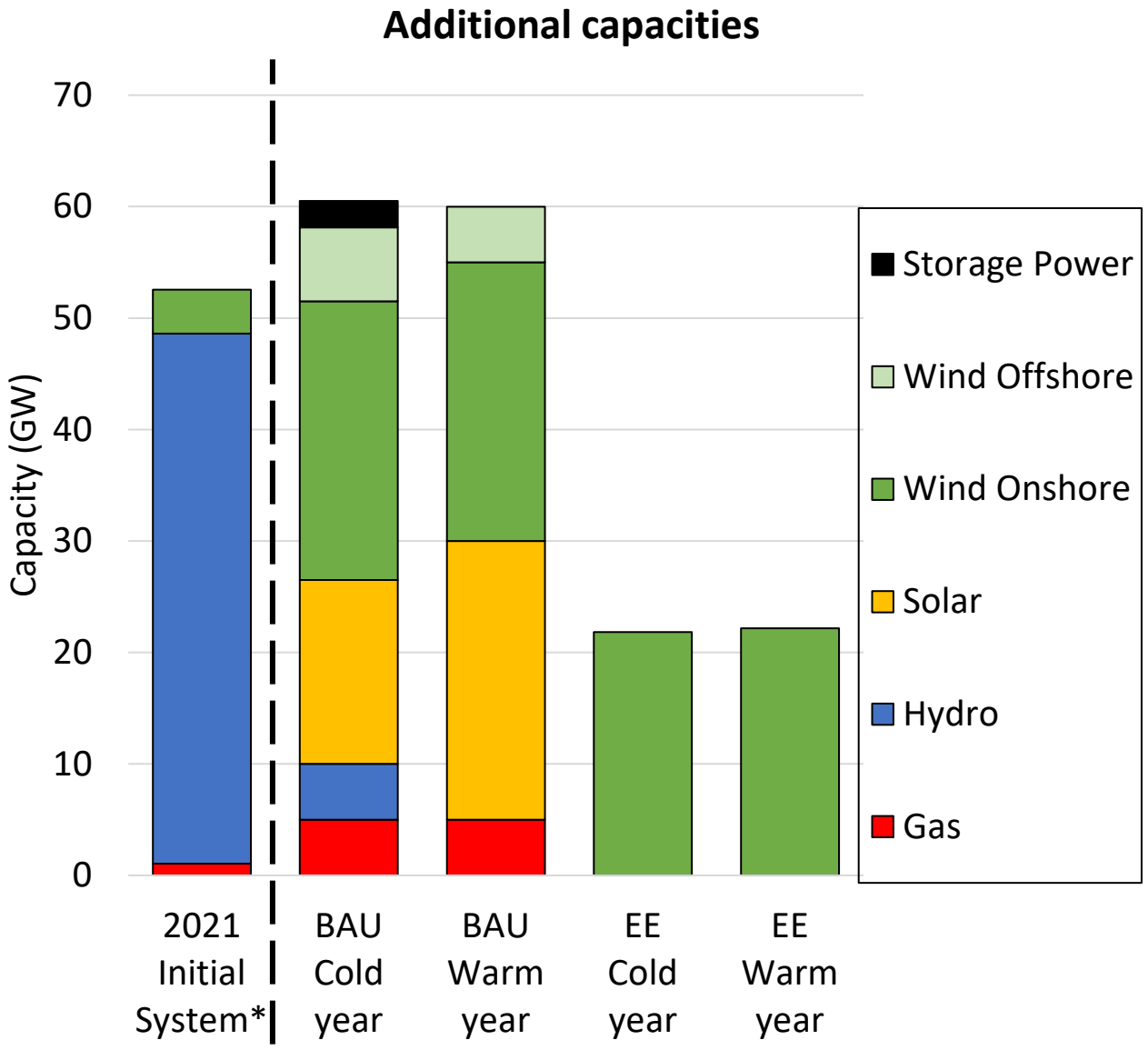
Manage system operations over a representative year:
- Hourly load balance
- Demand-side management

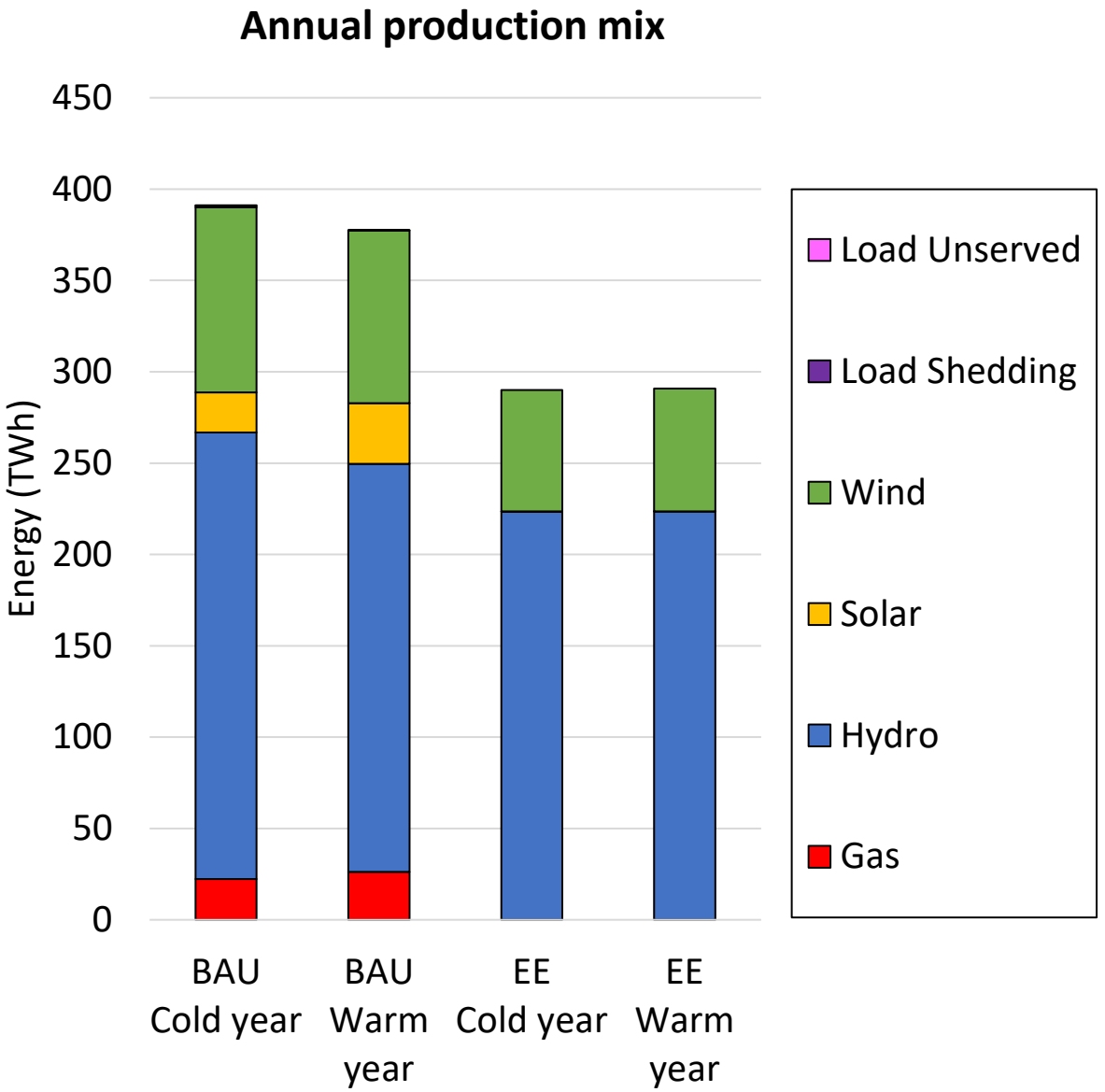
→ **Minimize the costs** of **capacity expansion** and **system operations**

Generation technologies	Limits on capacity expansion
Solar | Wind onshore | Wind offshore	25 GW each
Hydro	5 GW
Natural gas	5 GW
Nuclear	0 GW
Storage Power	10 GW

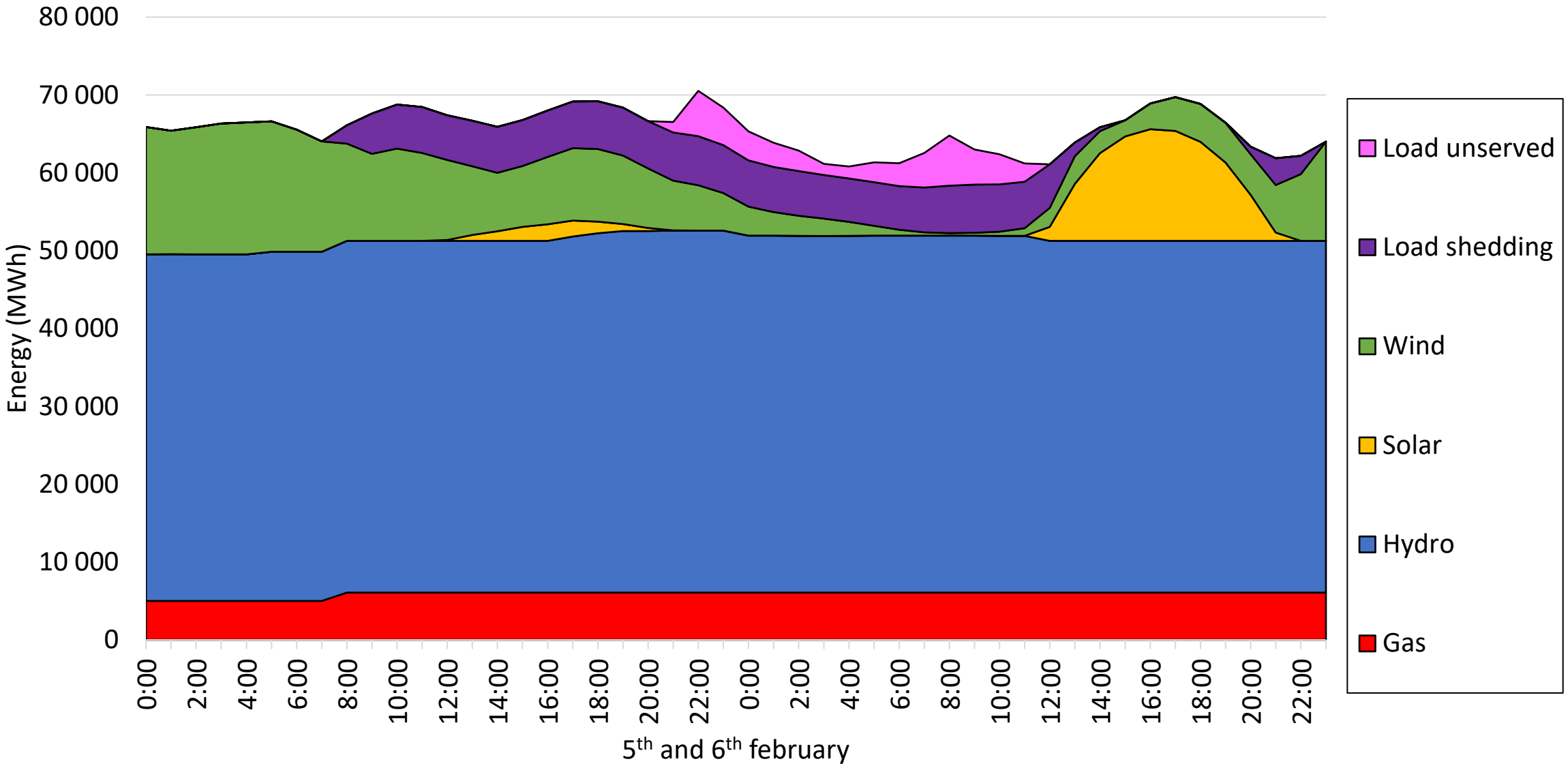
Exchanges with CA provinces and US states are fixed (~35 TWh of net exports)

Results : capacity expansion and production mix

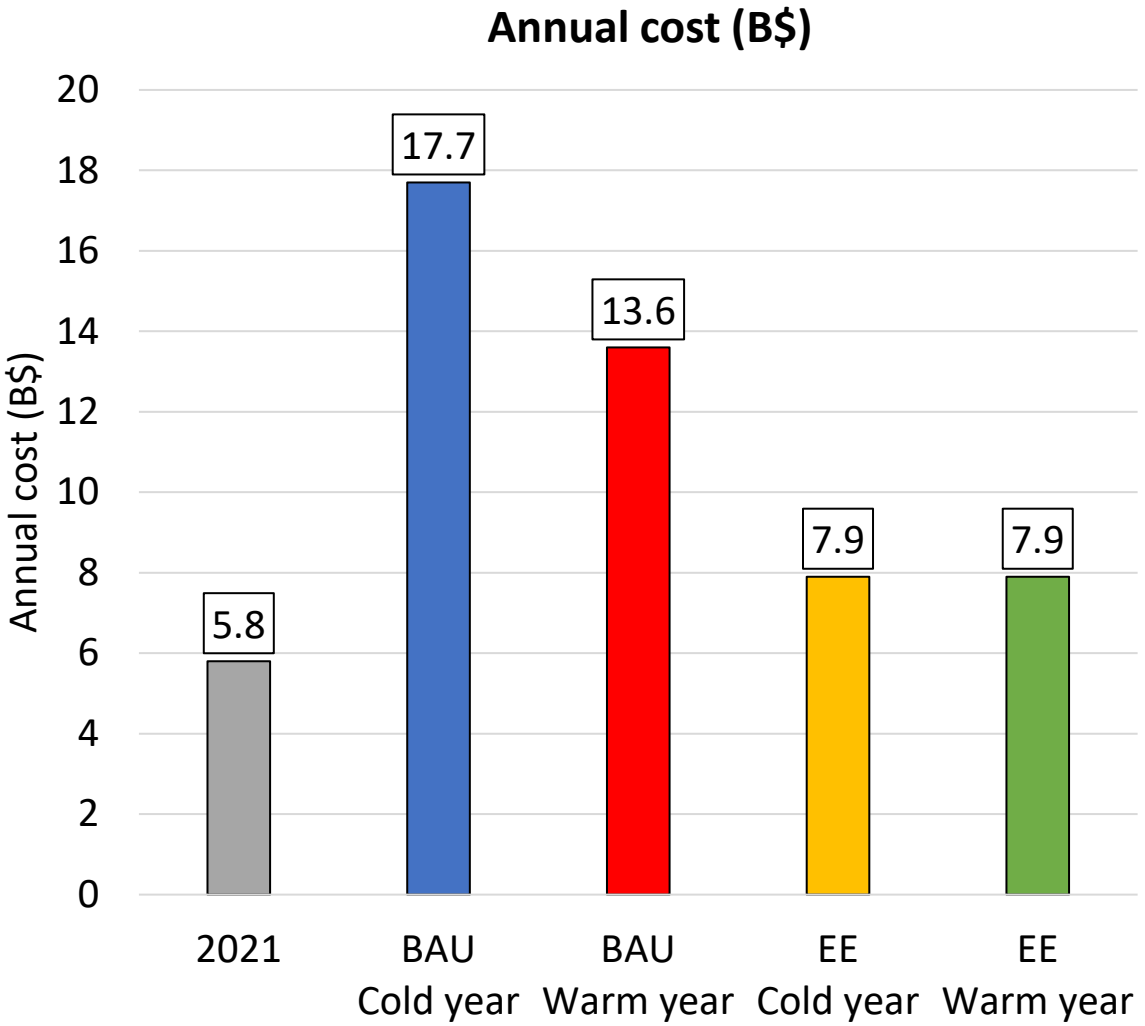




BAU - Cold year case: Production mix for the two consecutive days with the highest load



Power system costs



Summary

BAU and EE cases

Which way to go ?

- BAU: A power system size multiplied by two, with high costs, and subject to be more often jeopardized by weather events ?
- EE: With investment in buildings and transports to mitigate expansion needs, leading to a system more reliable, flexible and affordable

Thanks for your attention

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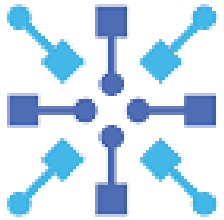

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