Decarbonizing the North American Northeast Power Sector: BAU or Integration?

Pierre-Olivier Pineau, HEC Montreal

Session 1: The implications of emerging technologies on electricity markets design and pricing

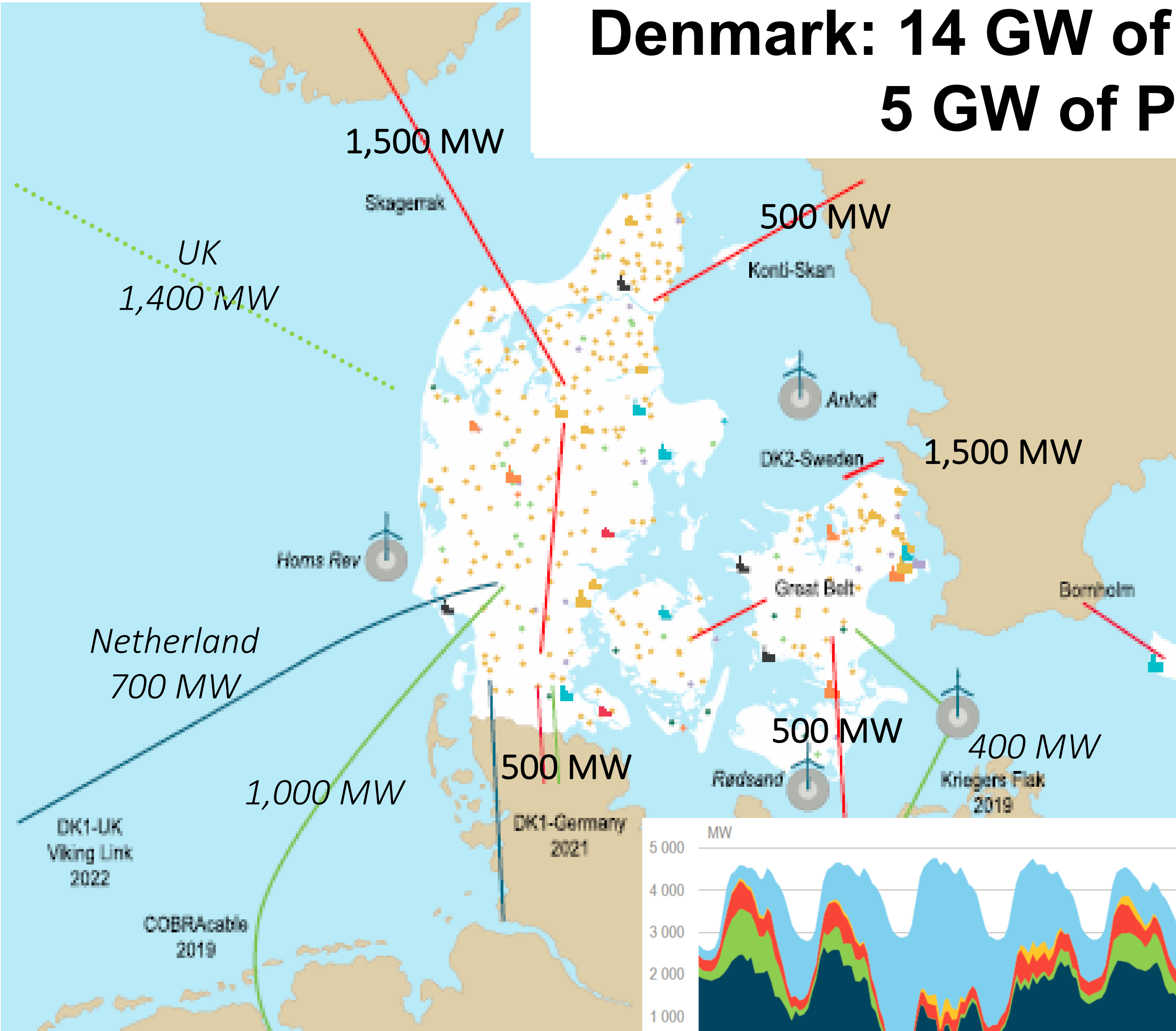
Electricity Market Design in Transition
Annual Workshop on the Economics of Electricity Policy and Markets
Ivey Energy Policy and Management Centre

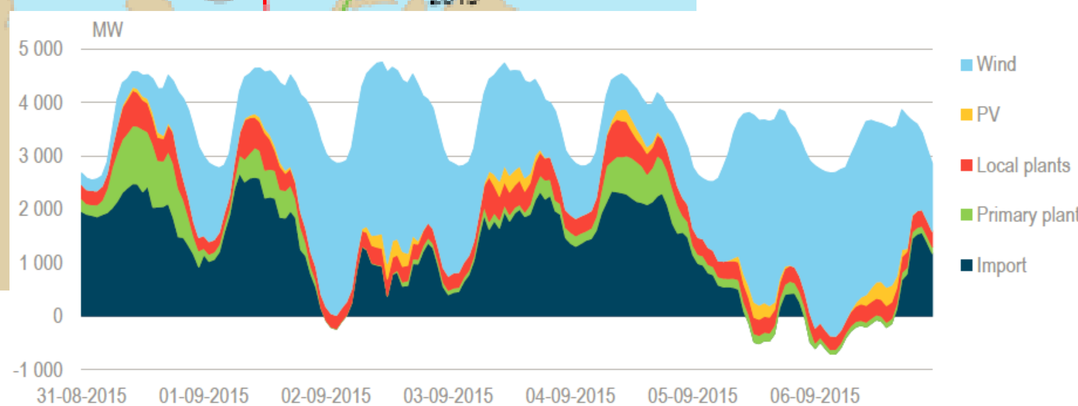
October 18th 2018 – 8h45am-5h30pm

Ivey Tangerine Leadership Centre
130 King Street West, Toronto

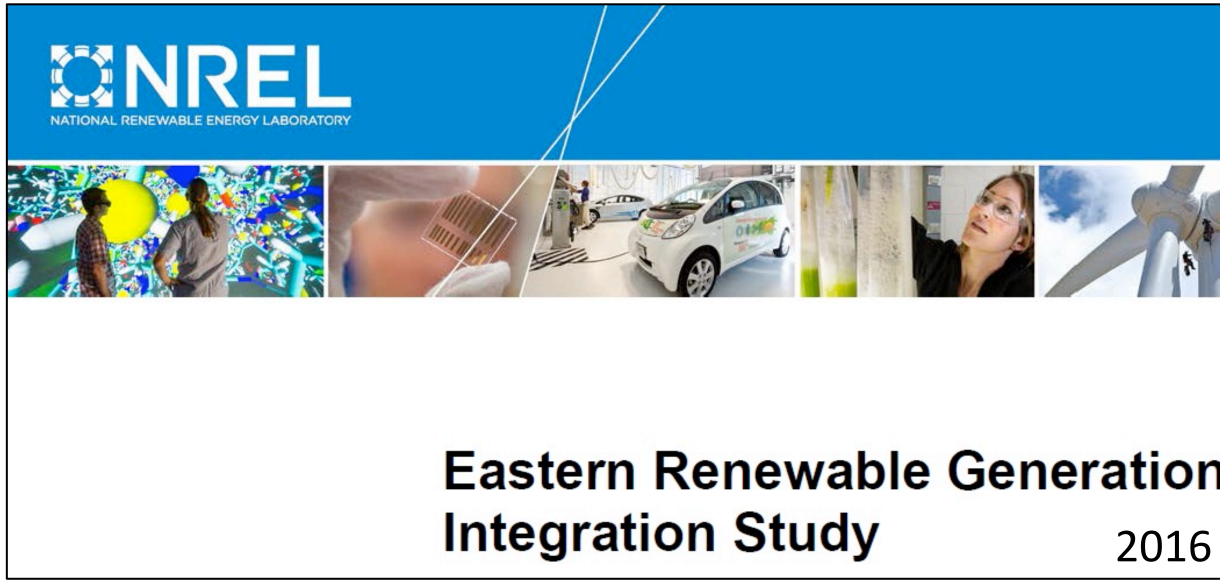
Denmark: 14 GW of Capacity
5 GW of Peak Load

30 TWh
42.5% wind
18% biofuels
2.5% solar
28.8% coal
7.3% gas
1% oil

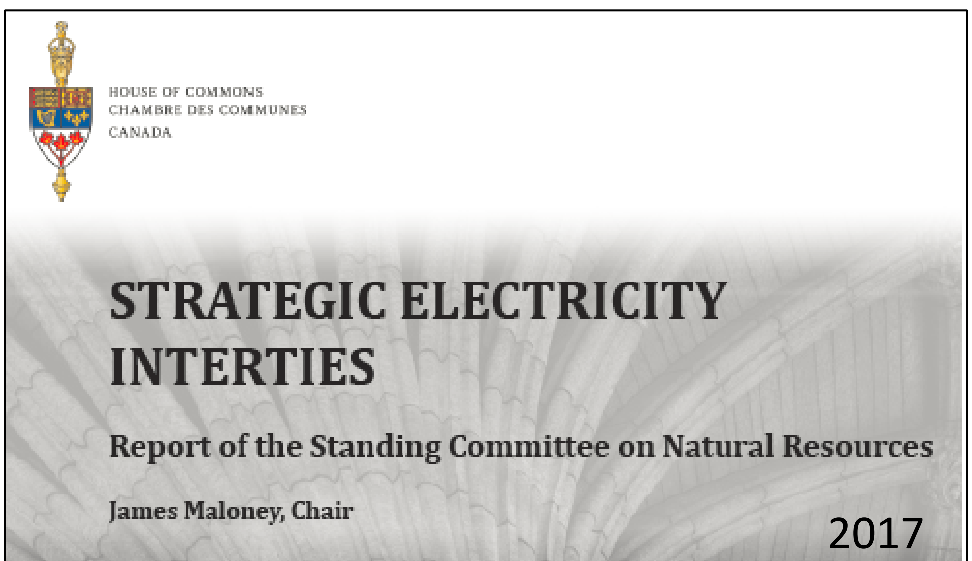


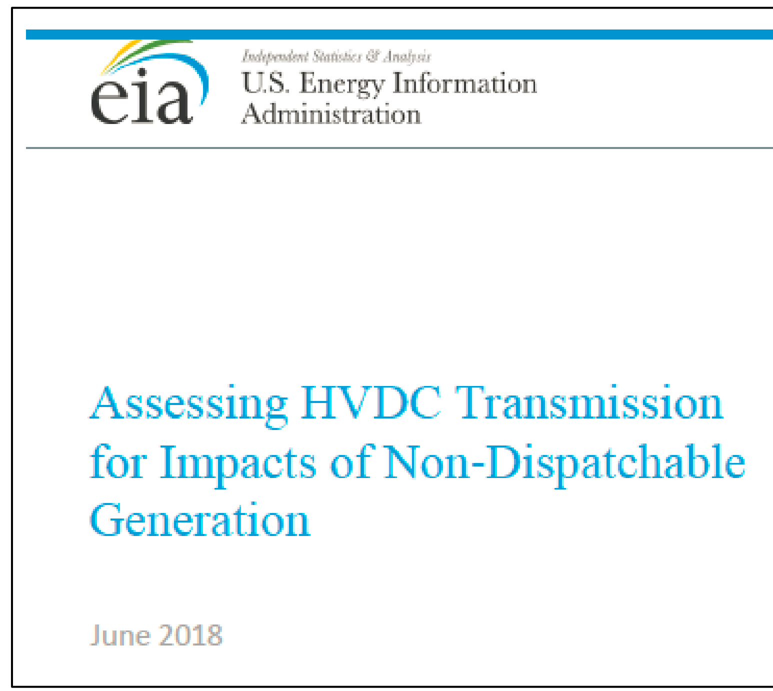


IEA (2017)

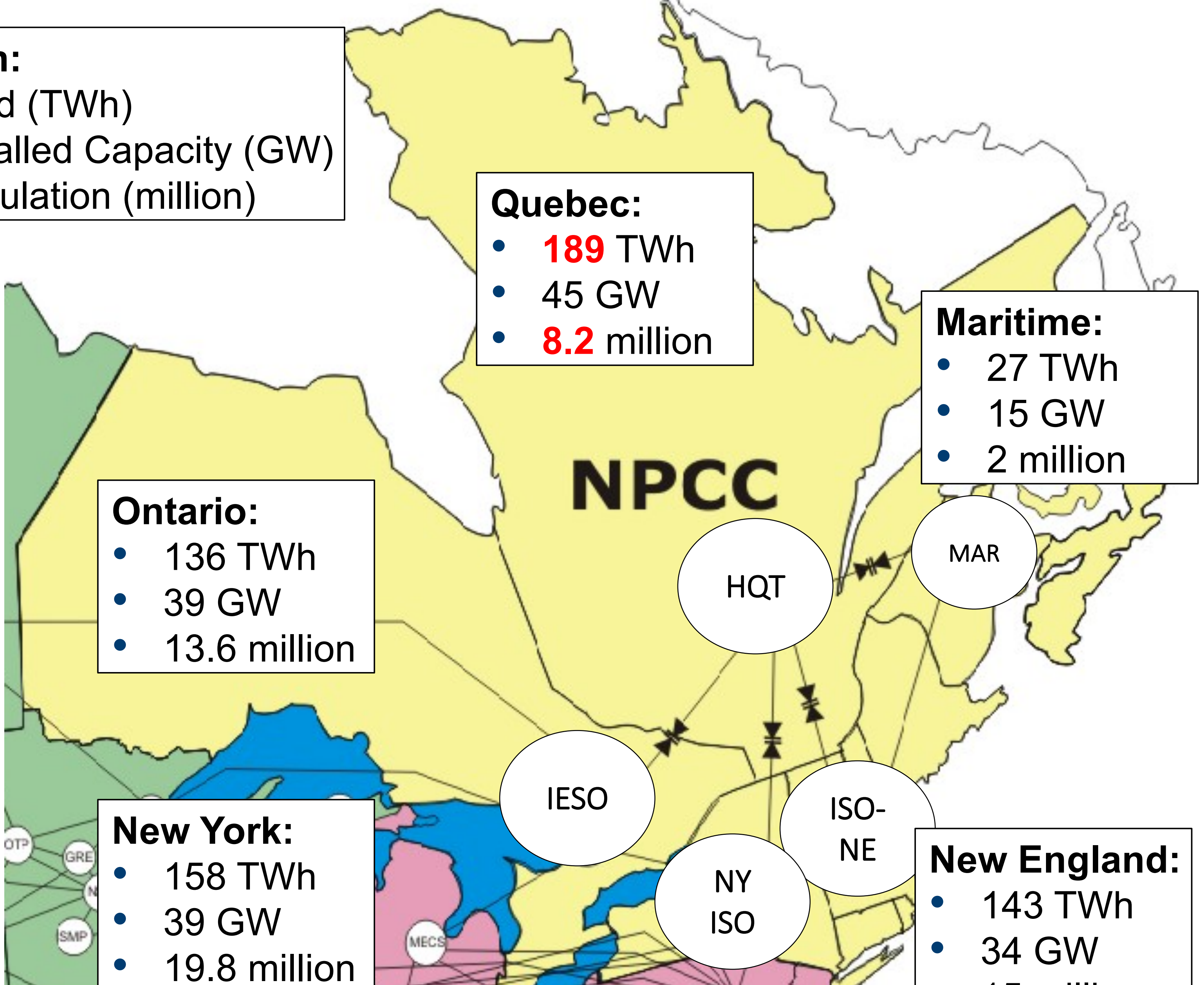


2019: North American Renewable Integration Study





Region:
- Load (TWh)
- Installed Capacity (GW)
- Population (million)



Quebec:
- 189 TWh
- 45 GW
- 8.2 million

Maritime:
- 27 TWh
- 15 GW
- 2 million

Ontario:
- 136 TWh
- 39 GW
- 13.6 million

New York:
- 158 TWh
- 39 GW
- 19.8 million

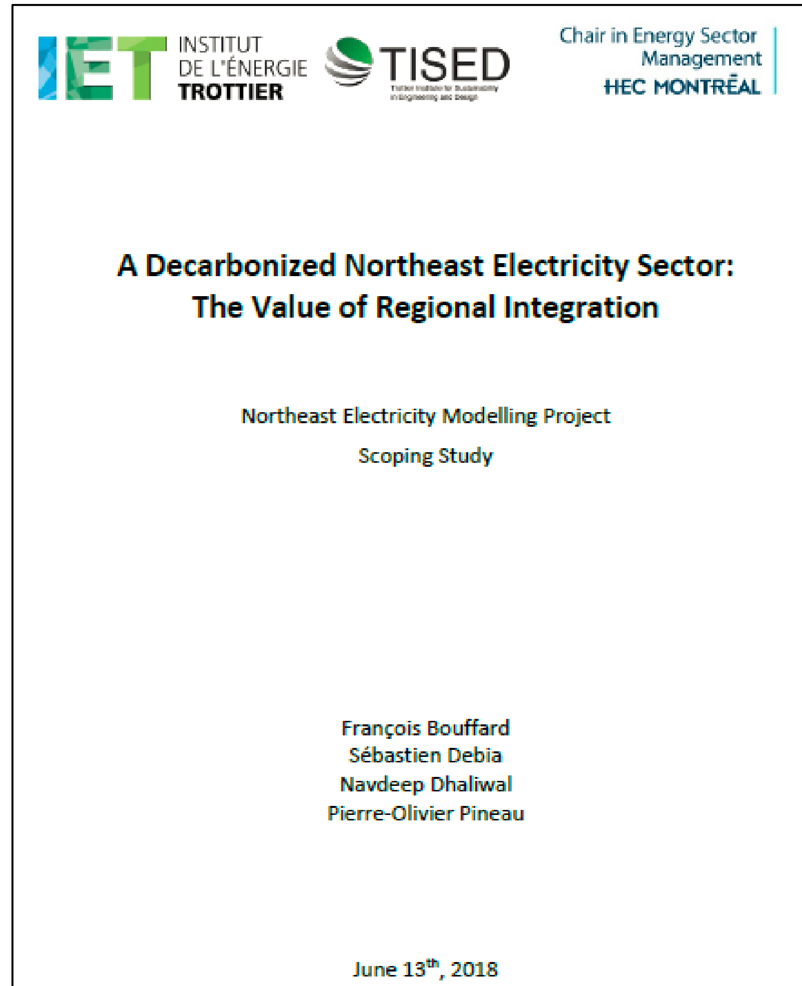
New England:
- 143 TWh
- 34 GW
- 15 million

NERC (2017)

Agenda

1. Motivation
2. Results
3. Model
4. Further Studies

http://energie.hec.ca/npcc/



INSTITUT DE L'ÉNERGIE TROTTIER

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Chair in Energy Sector Management
HEC MONTRÉAL

A Decarbonized Northeast Electricity Sector: The Value of Regional Integration

Northeast Electricity Modelling Project

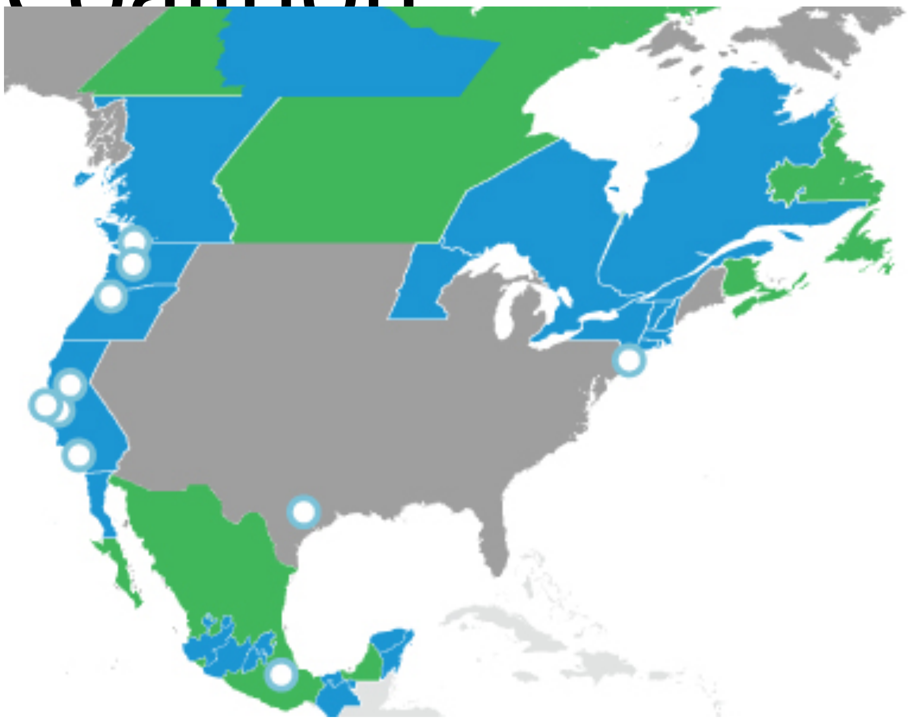
Scoping Study

François Bouffard
Sébastien Debia
Navdeep Dhaliwal
Pierre-Olivier Pineau

June 13th, 2018

1. Motivation

Paris Agreement, state and provincial climate goals, Under 2° Coalition

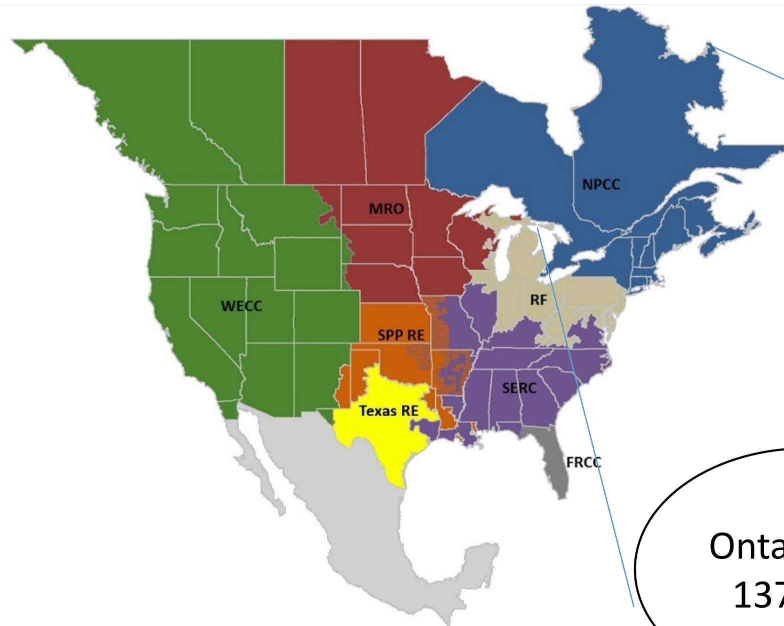


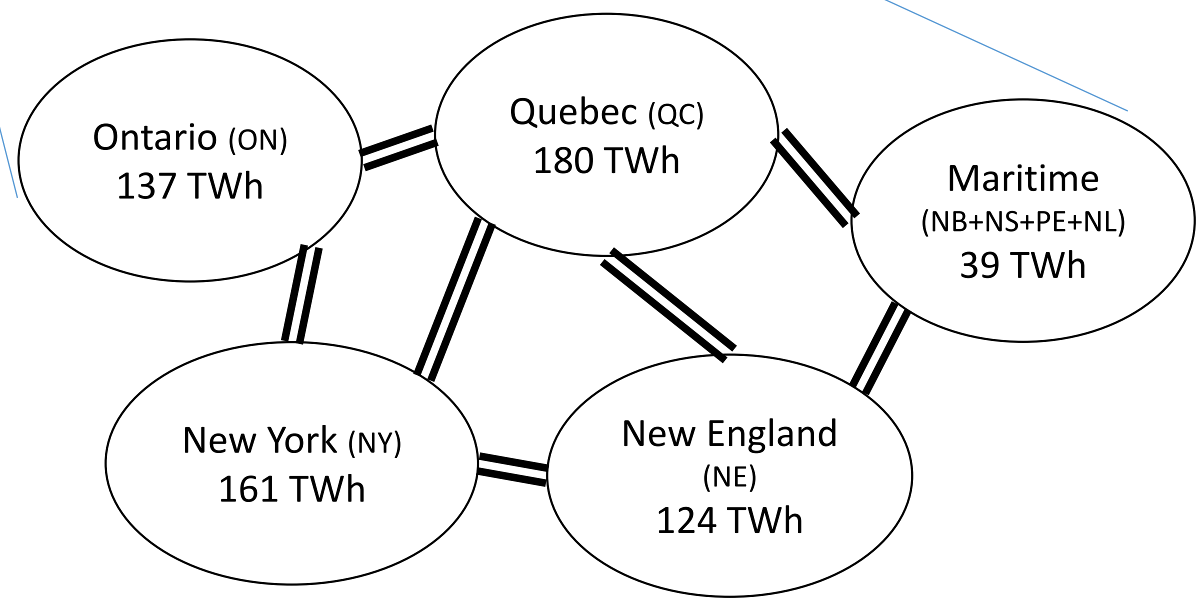
- 177 jurisdictions (37 countries)
- 1.2 billion people (16% of the world)
- $28.8 trillion in GDP (39% of the global economy)

Under2 Coalition's shared goal: limiting GHG emissions to **2 tons per capita, or 80-95% below 1990 level** by 2050.

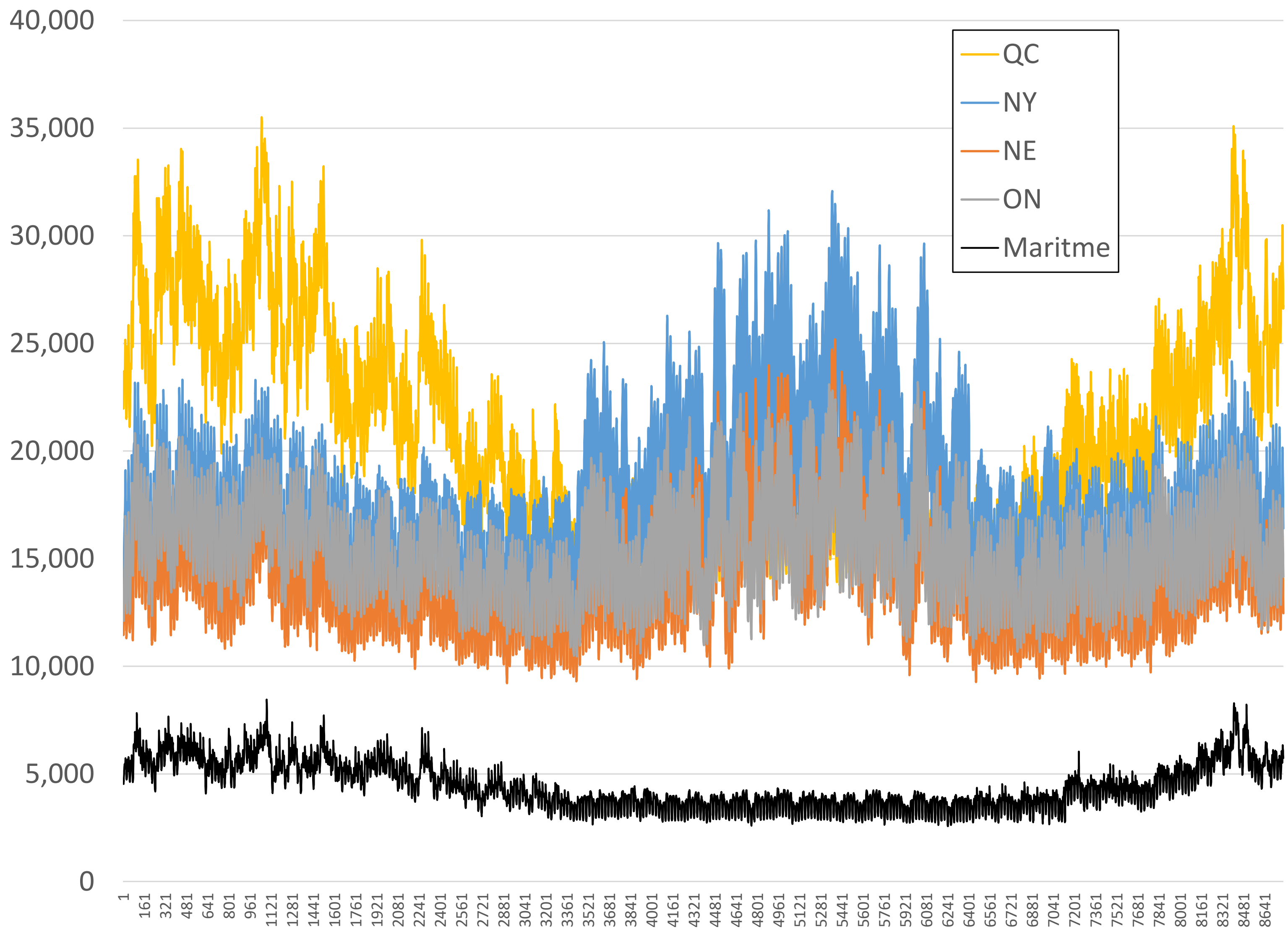
Under2mou (2017)

Region of Interest: Northeast Power Coordinating Council (NPCC) (5 sub-regions)

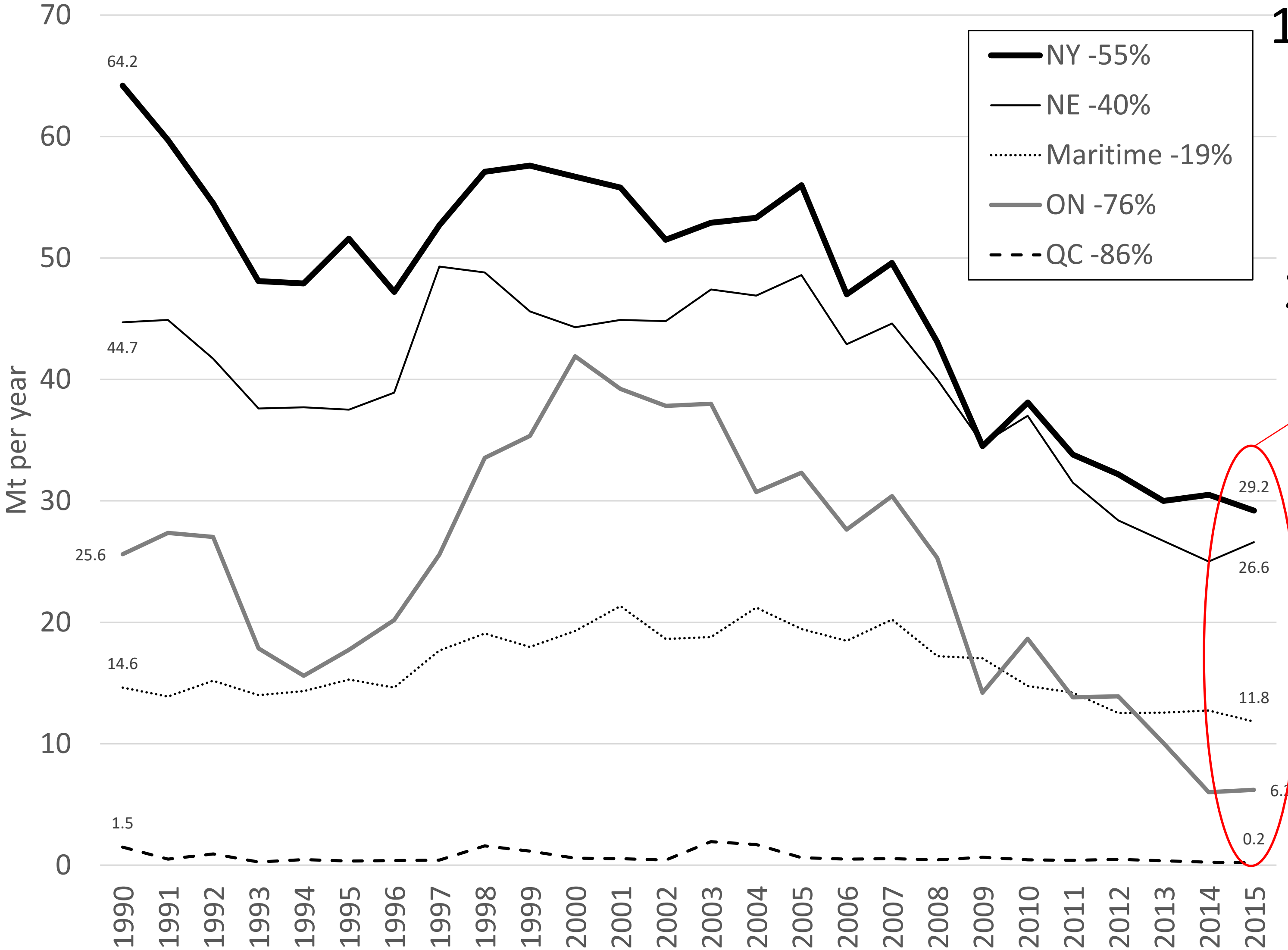




Hourly Load data for 2016



NPCC GHG Emissions 1990-2015

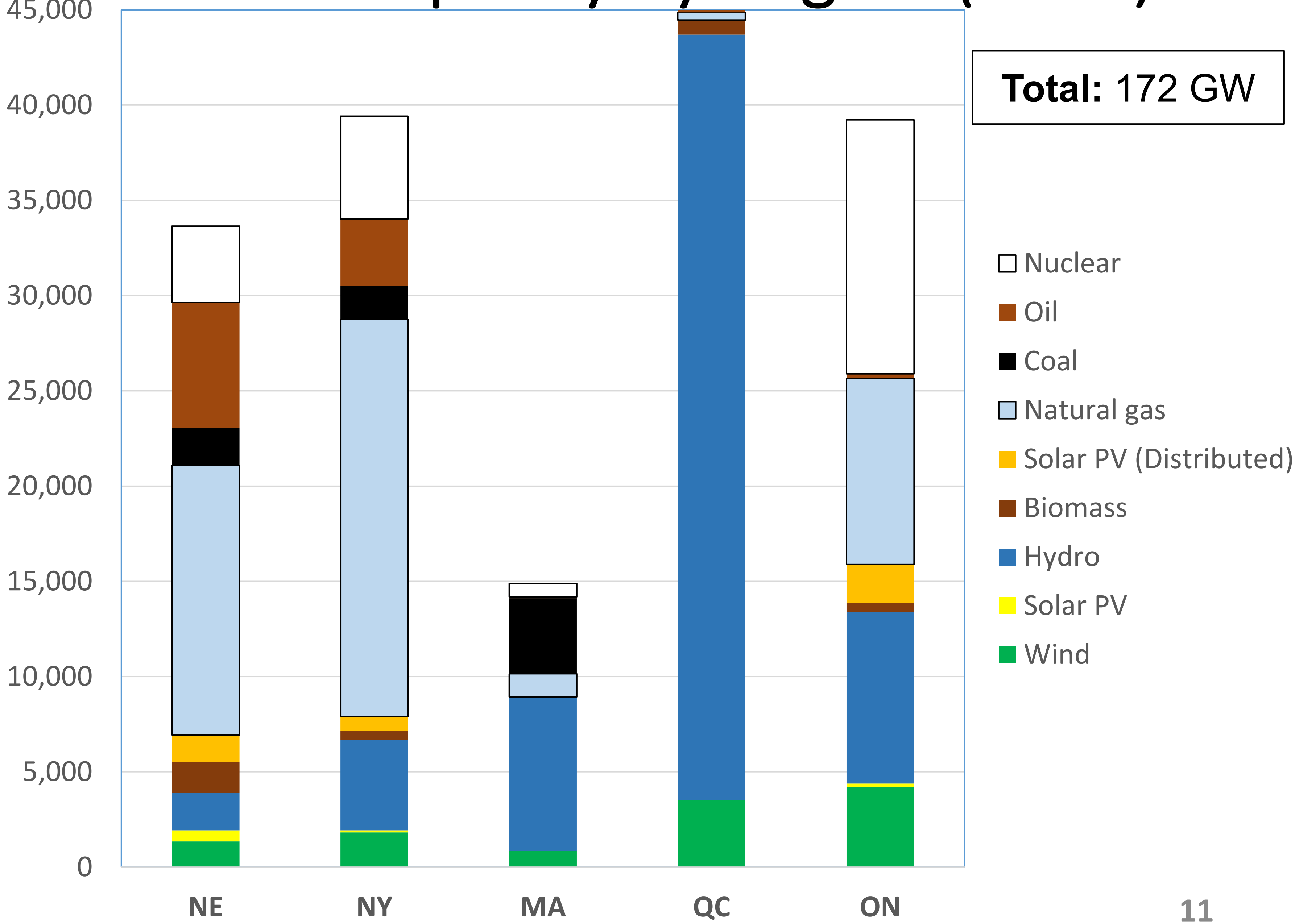


1990: 151 Mt

2015: 74 Mt

80% below 1990: **30 Mt**

Intalled Capacity by Region (2018)



EIA (2018), Statistics Canada (2018), IESO (2018) and HQ (2018)

What are the Gains from “Integration”?

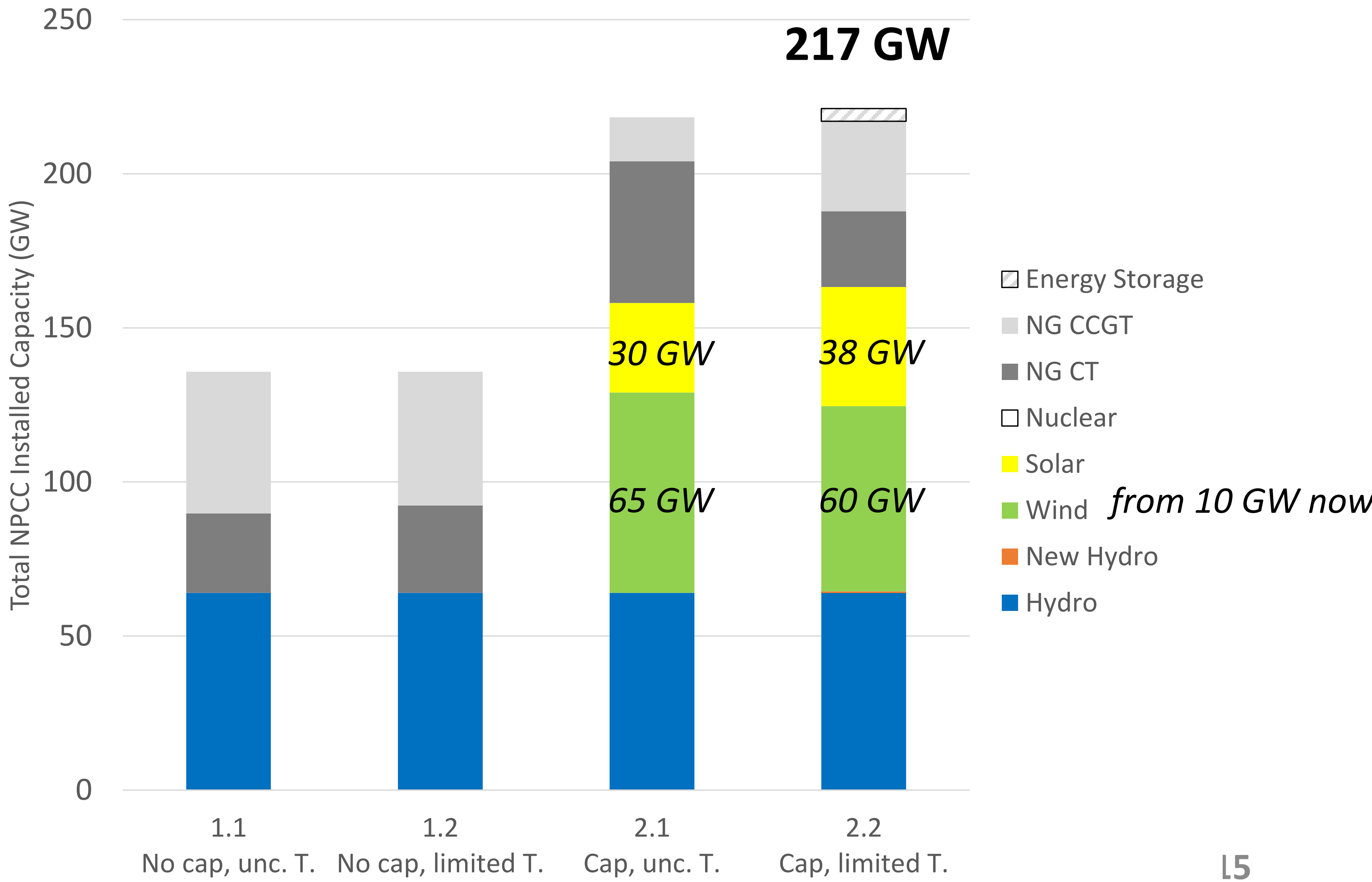
- **Physical integration**: no transmission constraints between sub-regions
- **Institutional integration**: no local capacity constraint (NPCC only capacity requirement)

2. Results

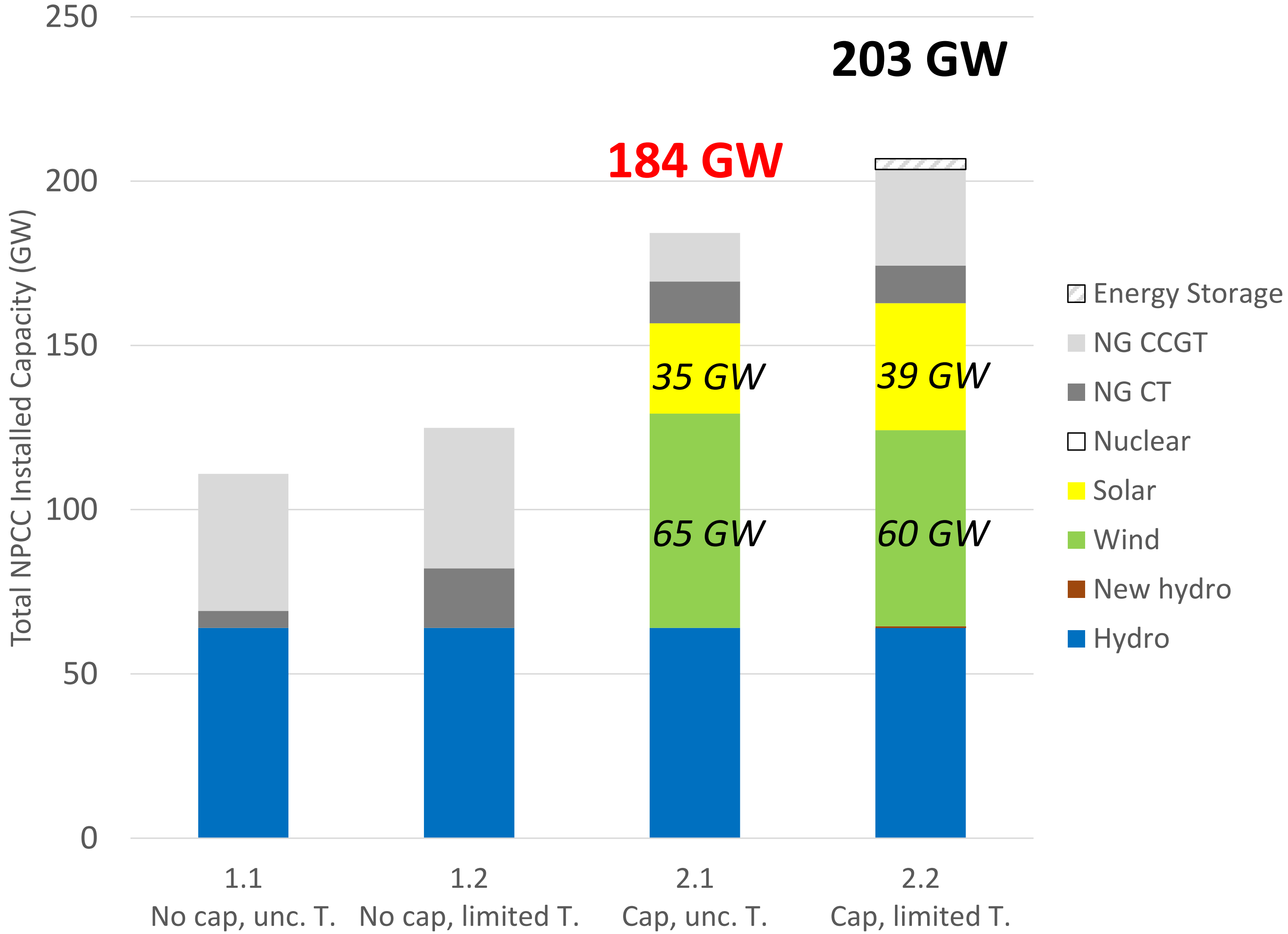
Results: Annual Power System Cost ($Billion per year)

	No carbon cap			Carbon cap		
	1.1	1.2		2.1	2.2	
	Transmission			Transmission		
	Unlimited	Limited	*Gain*	Unlimited	Limited	*Gain*
BAU	$14.1	$14.2	*$0.1* *0.7%*	$21.9	**$24.1**	*$2.2* *9.3%*
Shared capacity	$12.5	$13.6	*$1.1* *8.1%*	**$20.0**	$23.3	*$3.3* *14.2%*
Gain	*$1.5* *11.0%*	*$0.6* *4.2%*		*$1.9* *8.8%*	*$0.8* *3.5%*	

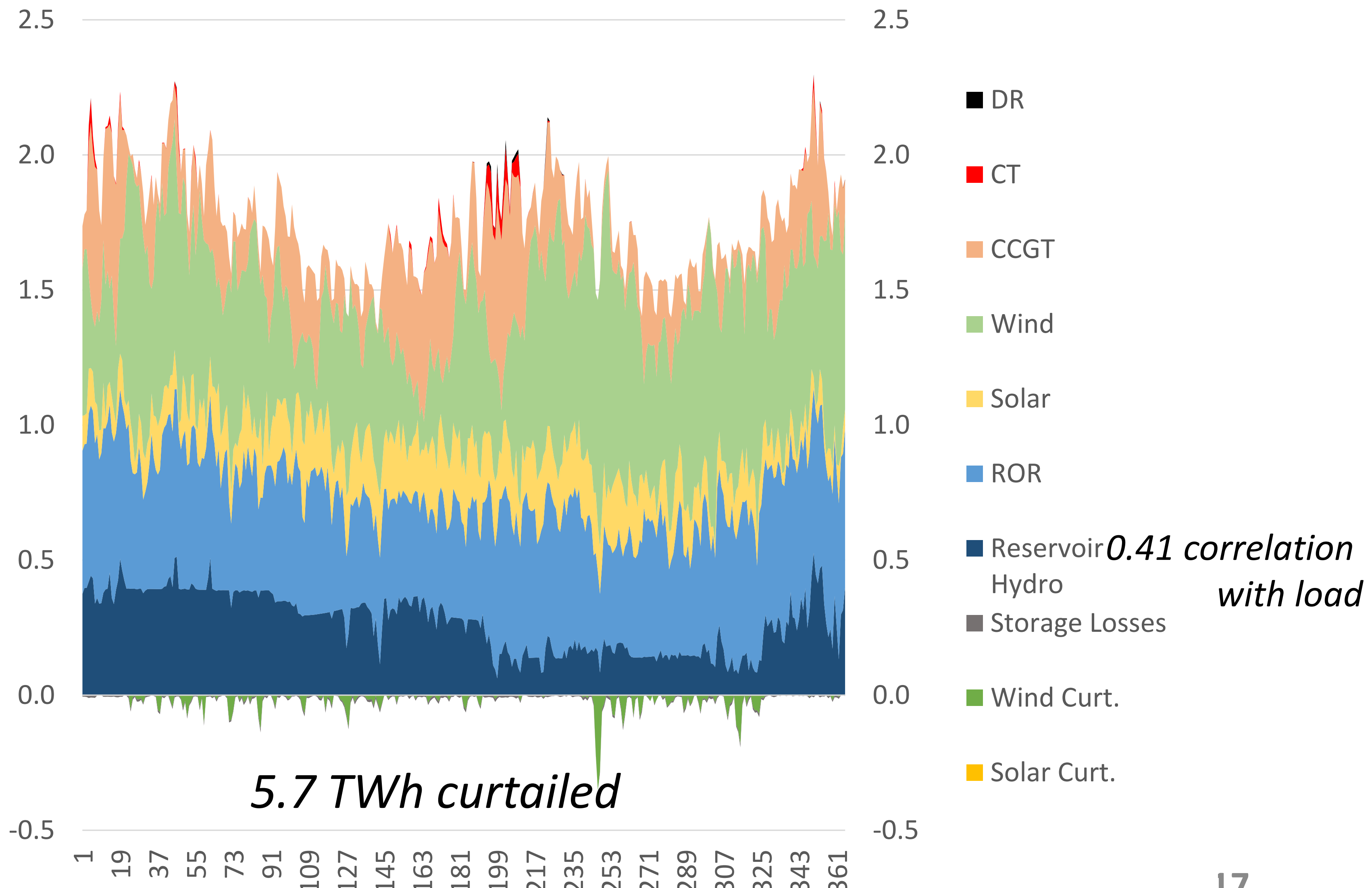
Total Capacity in the BAU Scenarios (GW)



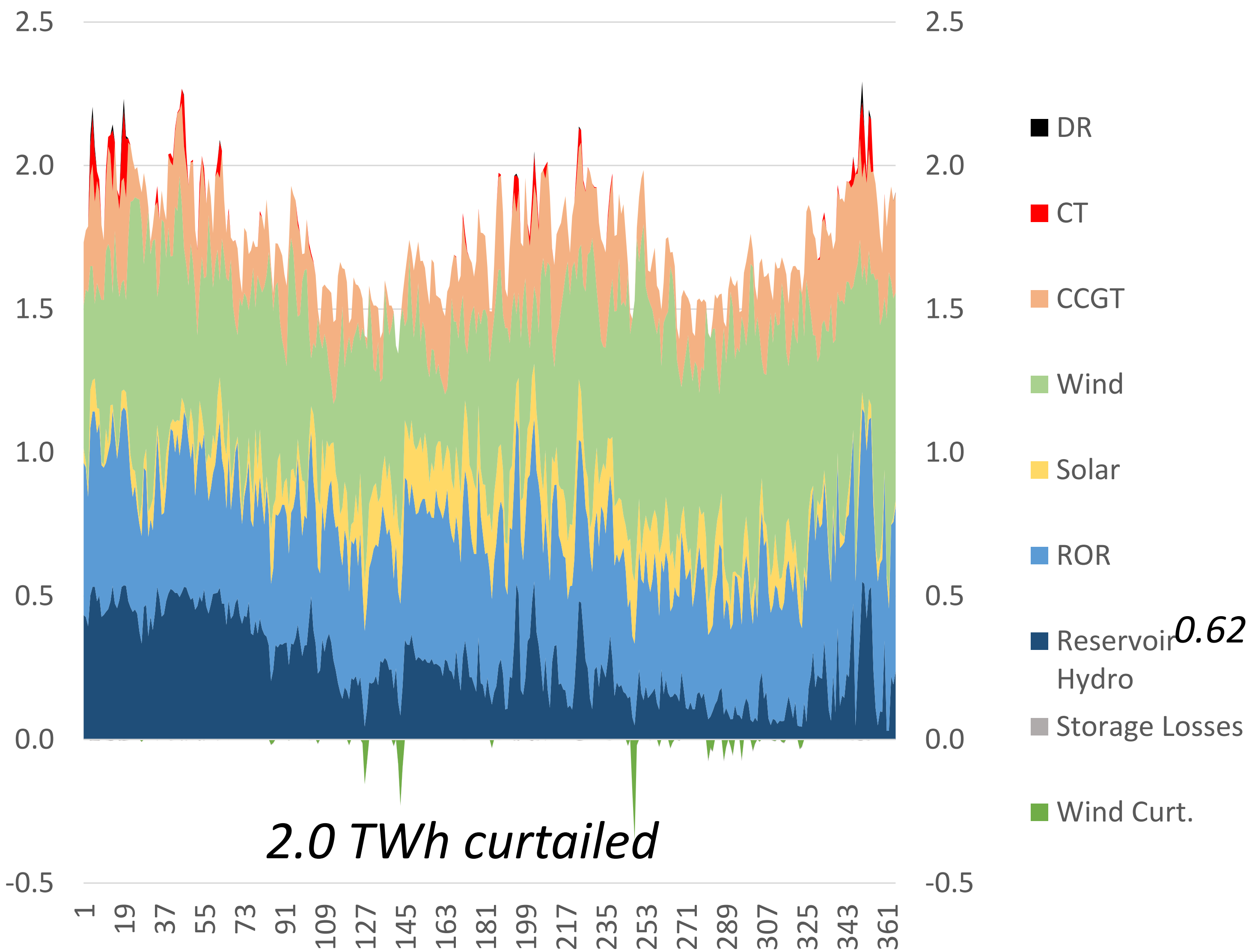
Total Capacity in the Shared Capacity Scenarios (GW)



Daily Production Profile BAU-Limited T



Daily Production Profile Shared Capacity-Unlimited T.



0.62 correlation with load

3. Model

Objective

Model: Capacity Expansion

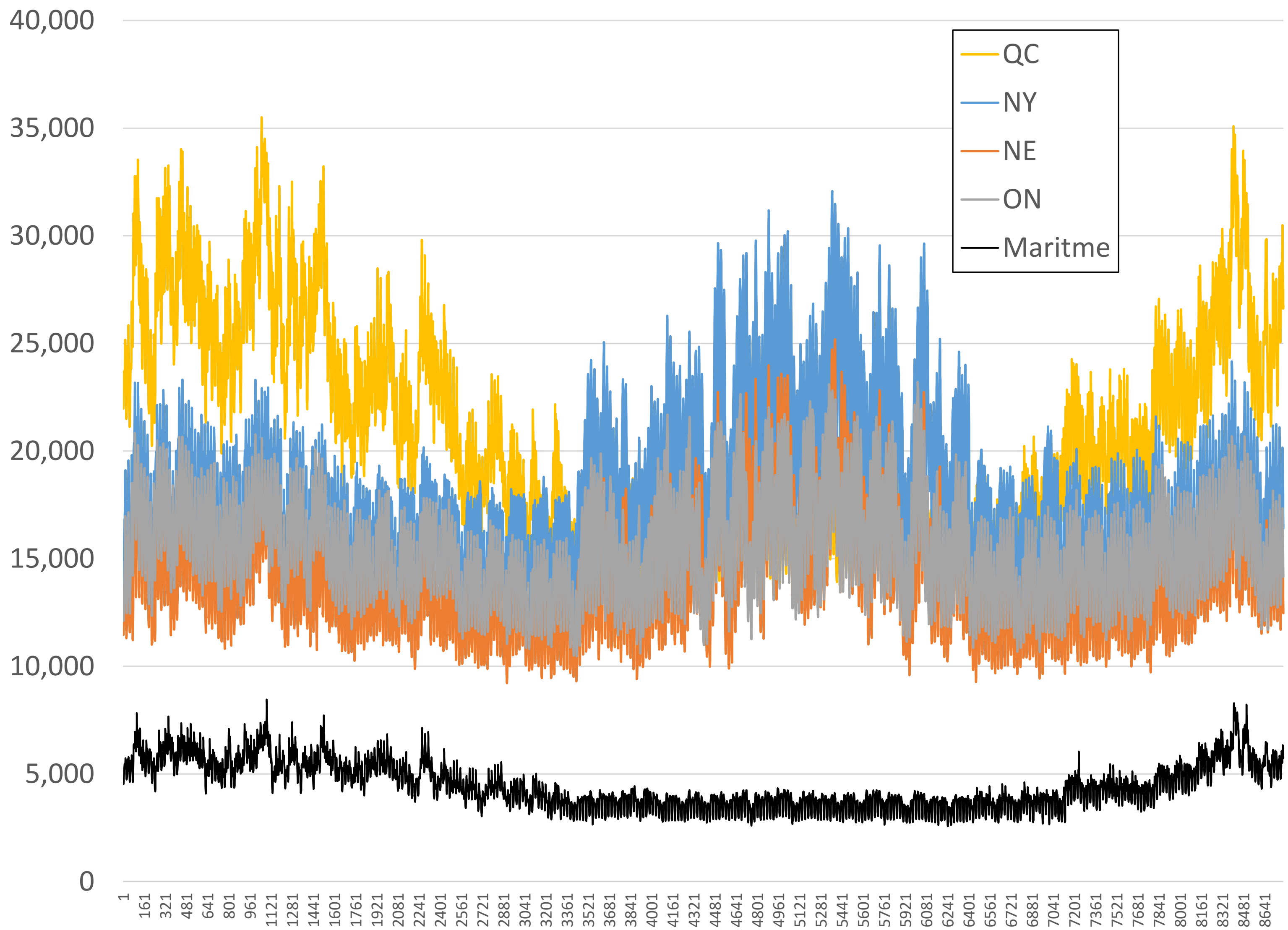
Minimize the annualized investment and operation costs, subject to:

- *Meeting hourly load in each region*
- *Capacity constraints*

Linear programming model

“Transportation” Model (no real power flows)

Hourly Load data for 2016



8 Main Scenarios

1. No cap on emissions		2. Carbon cap	
1.1 Unconstrained Transmission	**1.2 Limited Transmission**	**2.1 Unconstrained Transmission**	**2.2 Limited Transmission**
BAU	BAU	BAU	BAU
Shared Capacity	Shared Capacity	Shared Capacity	Shared Capacity

Institutional integration

Physical integration

Business as Usual vs. Shared Capacity

- **BAU**: each sub-region is under its own capacity constraint

$$\text{Nameplate Capacity per region (Thermal+Nuclear)} \geq$$
$$\mathbf{max}_{\mathbf{hours}}\ \{\text{Demand} - \text{DR} - \text{Production(Wind+Solar+Hydro)} - \text{Battery(Discharge - Charge)}\}$$

- **Shared Capacity**: interconnections count

$$\text{Nameplate Capacity per region (Thermal+Nuclear)} \geq$$
$$\mathbf{max}_{\mathbf{hours}}\ \{\text{Demand} - \text{DR} - \text{Production(Wind+Solar+Hydro)} - \text{Battery(Discharge - Charge)} - \text{Transmission(Imports - Exports)}\}$$

(only 1 global capacity NPCC constraint in the unconstrainted transmission case)

Technologies

- All legacy hydro from all sub-regions is used
  - Run-of-river (ROR) in all 5 sub-regions
  - Reservoir (RES) in Quebec
  - Pumped hydro in New York
- Additional investment is required:
  - Increamental hydro
  - Thermal: natural gas combustion turbine (CT) and combined-cycle gas turbine (CCGT)
  - Nuclear
  - Wind
  - Solar
  - Storage
  - Demand response / load shedding ($10,000/MWh)

4. Further Studies

Identified Options

- Optimal investment in transmission capacity
- Impact of load profile changes: increased electricity demand and higher peak
- Energy efficiency
- Sensitivity to technology costs
- Tighter emission cap (90% reduction, 95% reduction)
- Hydropower:
  - Analysis of the system’s value of reservoir storage
  - Sensitivity to the amount of water storage availability
  - Sensitivity to the amount of water available in a given year
- Representation of intra-region transmission bottlenecks and higher fidelity transmission system modeling (dc power flow)
- Climate change impacts
- Demand-side flexibility and endogenous investment in demand-side technologies
- Modeling of the energy transition over the years to capture the effects of policy decisions

Next Steps

- Links with ongoing initiatives:
  - NARIS
  - Pan-Canadian grid development initiatives
- Outreach:
  - Canada-US
  - Ontario & Maritimes

Conclusion and Take Aways

- Both physical and institutional integration have value
- With the current loads, yearly gains are about $4B
- Higher loads would be much more expensive to serve (new wind, solar + storage needed)

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