

Décarboniser l'électricité du Nord-Est américain : un modèle pour analyser les gains d'une approche régionale

Transition énergétique et croissance de l'électricité verte

AIEQ

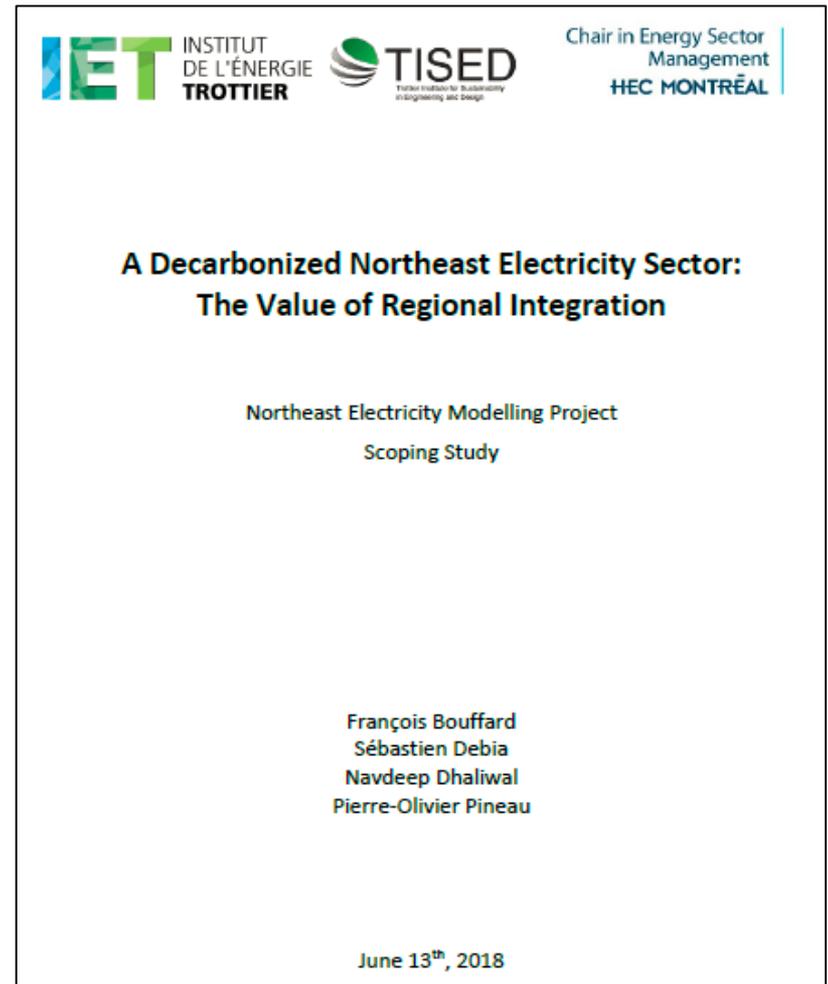
10 octobre 2018 – 8h30-8h50

Hôtel Intercontinental - Salle Sarah Bernhardt

Agenda

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

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



The image shows the cover page of a report. At the top, there are logos for IET (Institut de l'Énergie Trottier), TISED (Tutor Industrie/Sustainability in Engineering and Design), and the Chair in Energy Sector Management at HEC Montréal. The title of the report is 'A Decarbonized Northeast Electricity Sector: The Value of Regional Integration'. Below the title, it specifies 'Northeast Electricity Modelling Project' and 'Scoping Study'. The authors listed are François Bouffard, Sébastien Debia, Navdeep Dhaliwal, and Pierre-Olivier Pineau. The date 'June 13th, 2018' is at the bottom right.

IET INSTITUT DE L'ÉNERGIE TROTTIER

TISED Tutor Industrie/Sustainability in Engineering and Design

Chair in Energy Sector Management
HEC MONTRÉAL

**A Decarbonized Northeast Electricity Sector:
The Value of Regional Integration**

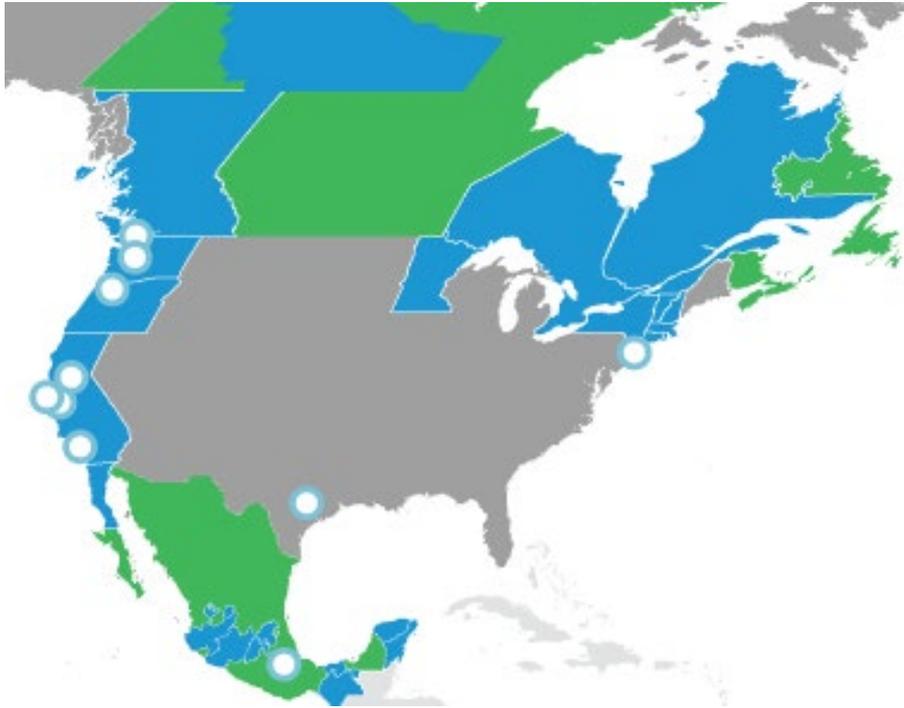
Northeast Electricity Modelling Project
Scoping Study

François Bouffard
Sébastien Debia
Navdeep Dhaliwal
Pierre-Olivier Pineau

June 13th, 2018

1. Motivation

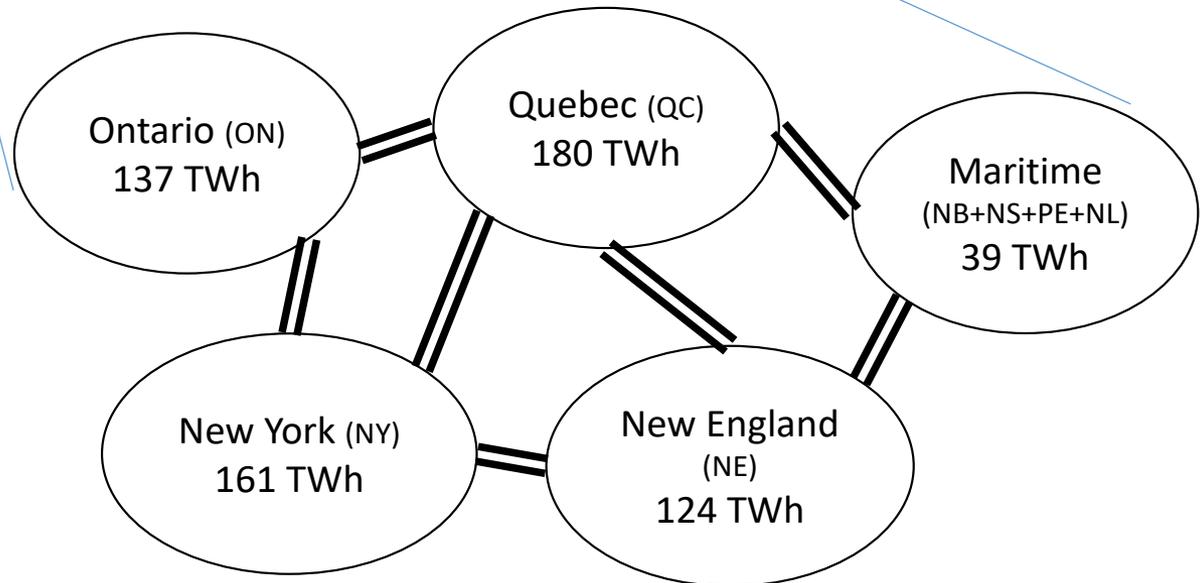
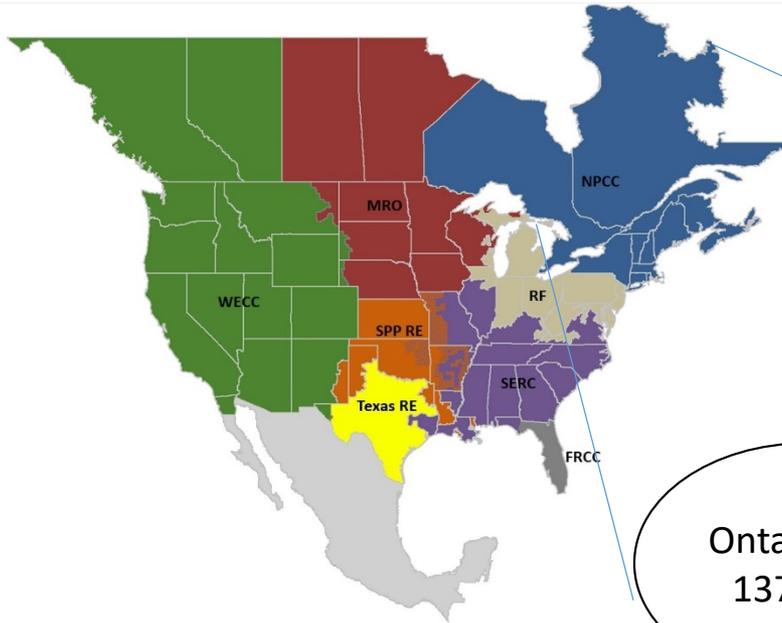
Paris Agreement, state and provincial climate goals, Under 2° Coalition



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

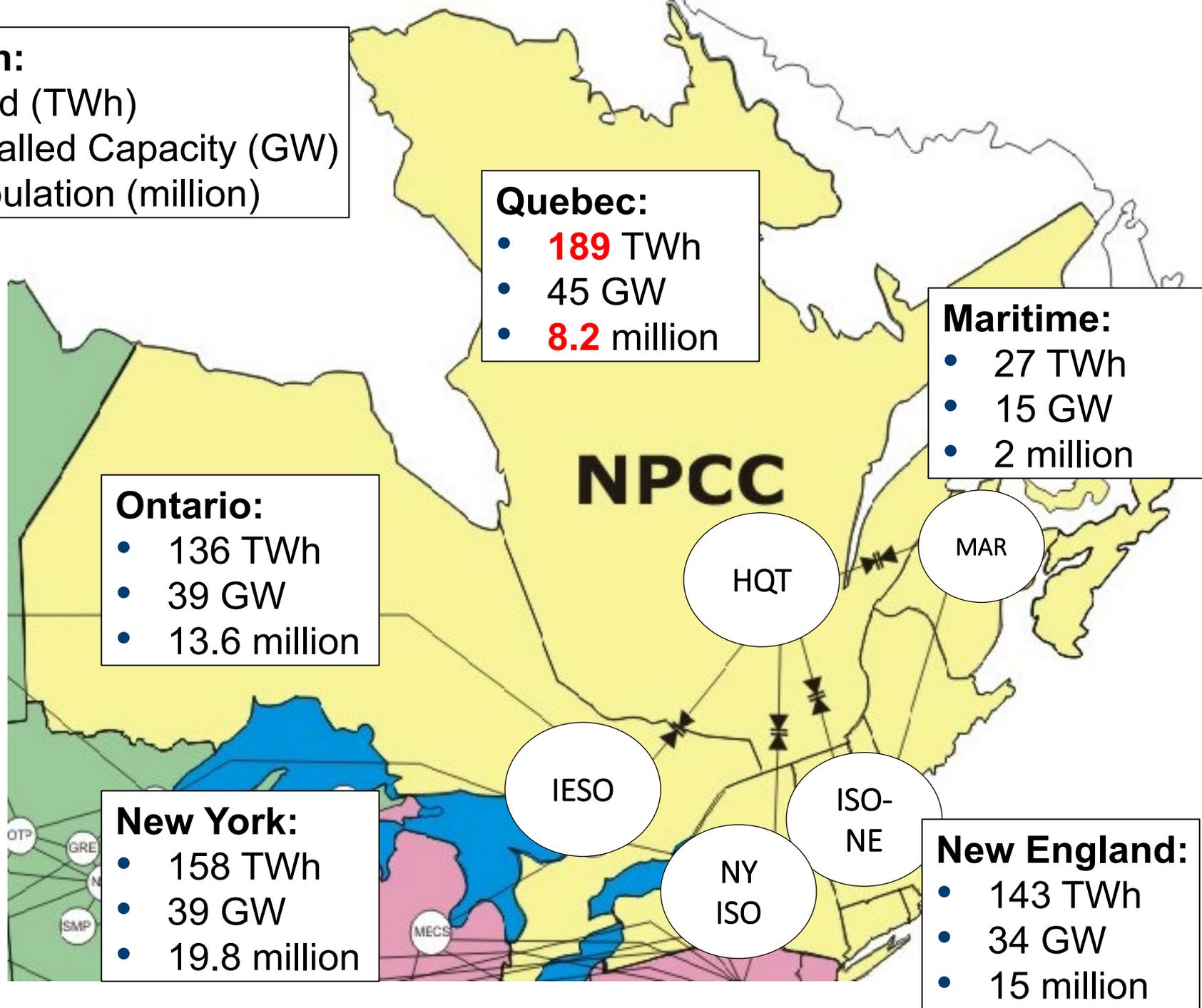
Under2 Coalition's shared goal: limiting GHG emissions to **2 tons per capita, or 80-95% below 1990 level** by 2050.

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



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

NPCC

HQT

MAR

IESO

NY ISO

ISO-NE

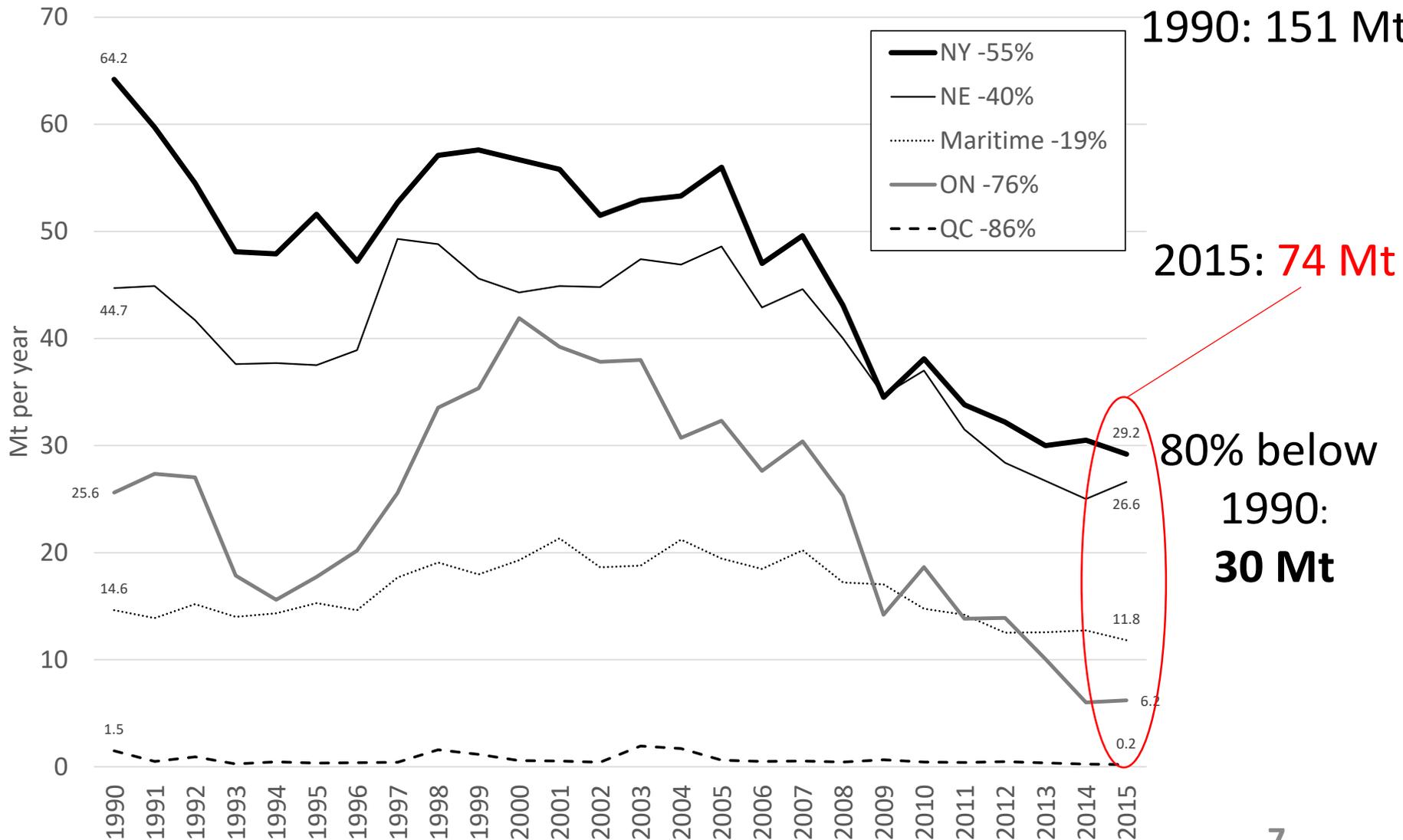
OTP

GRE

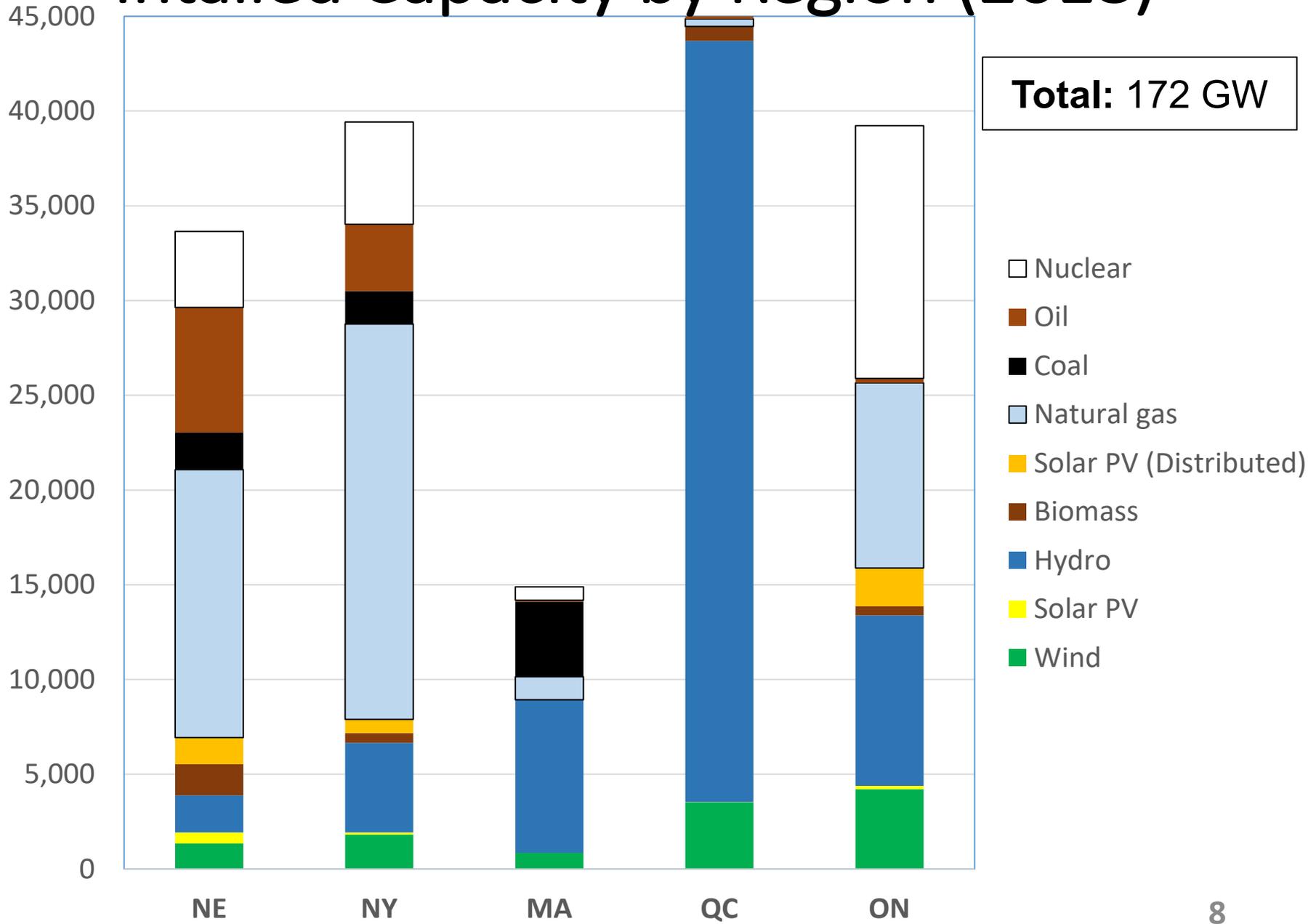
SMP

MECS

NPCC GHG Emissions 1990-2015



Intalled Capacity by Region (2018)



What are the Gains from “Integration”?

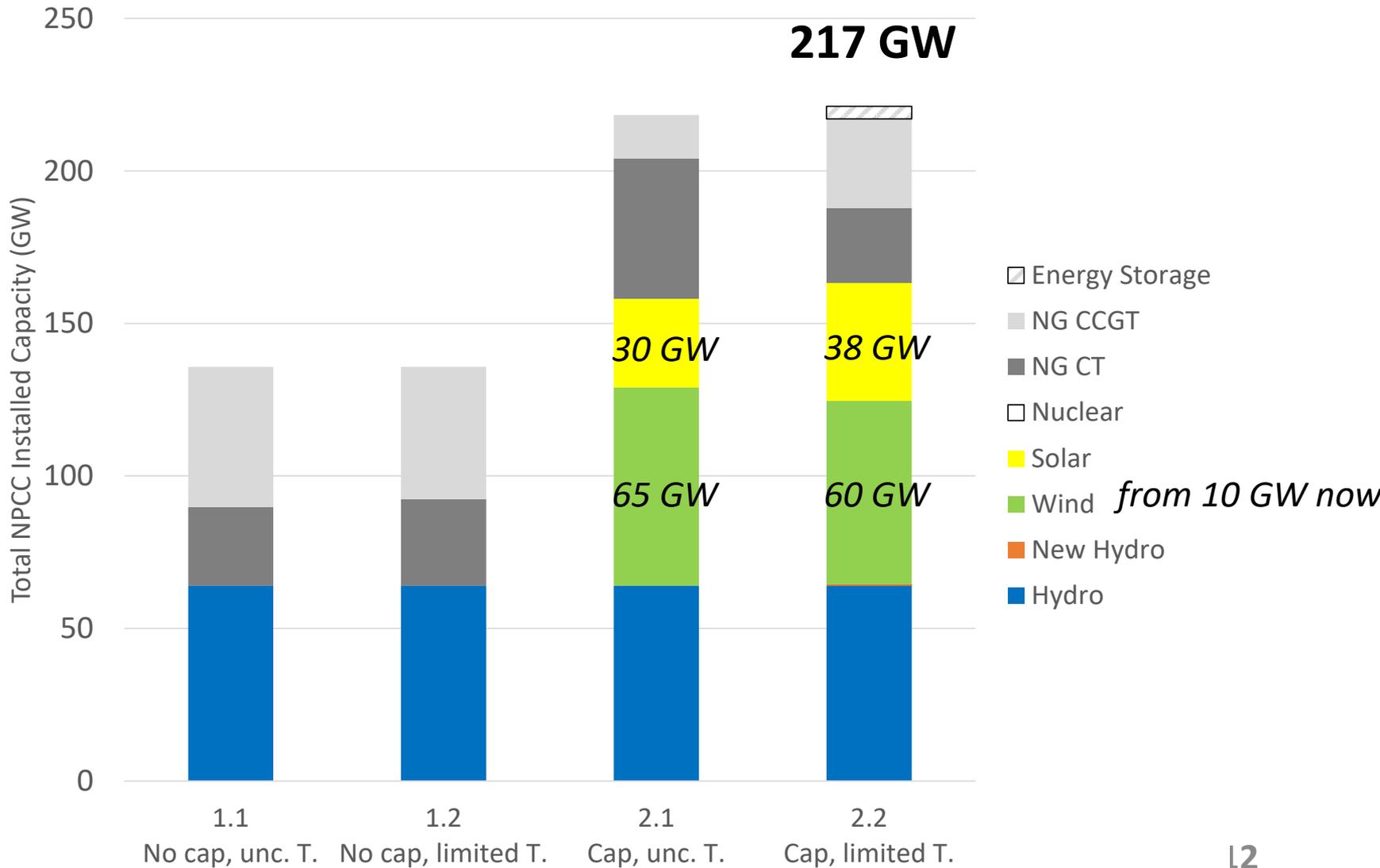
- **Physical integration:** no transmission constraints between sub-regions
- **Institutional integration:** no local capacity constraint (NPCC only capacity requirement)

2. Results

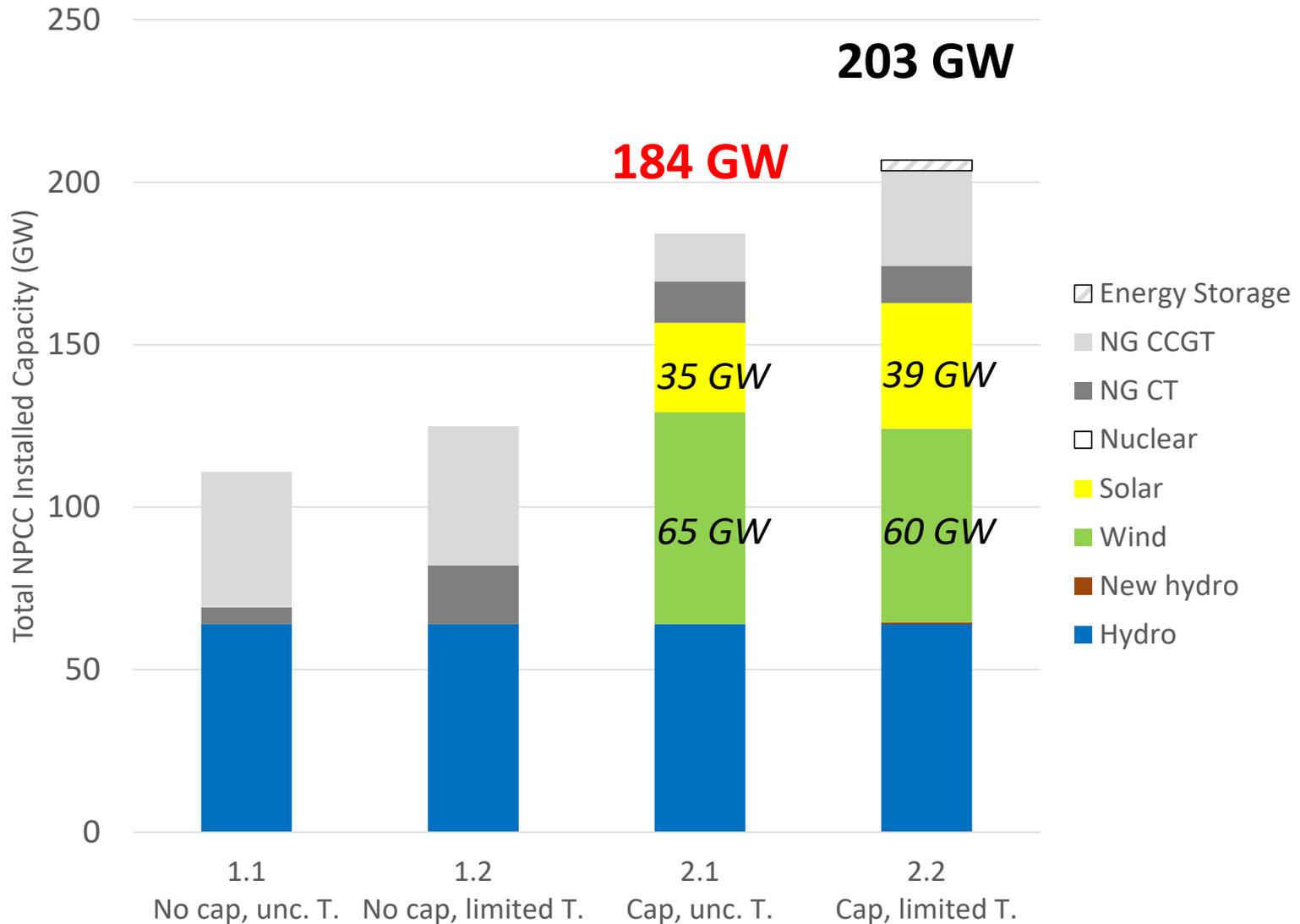
Results: Annual Power System Cost (\$Billion per year)

	No carbon cap			Carbon cap		
	1.1	1.2		2.1	2.2	
	Transmission			Transmission		
	Unlimited	Limited	<i>Gain</i>	Unlimited	Limited	<i>Gain</i>
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%
<i>Gain</i>	\$1.5	\$0.6		\$1.9	\$0.8	
	11.0%	4.2%		8.8%	3.5%	

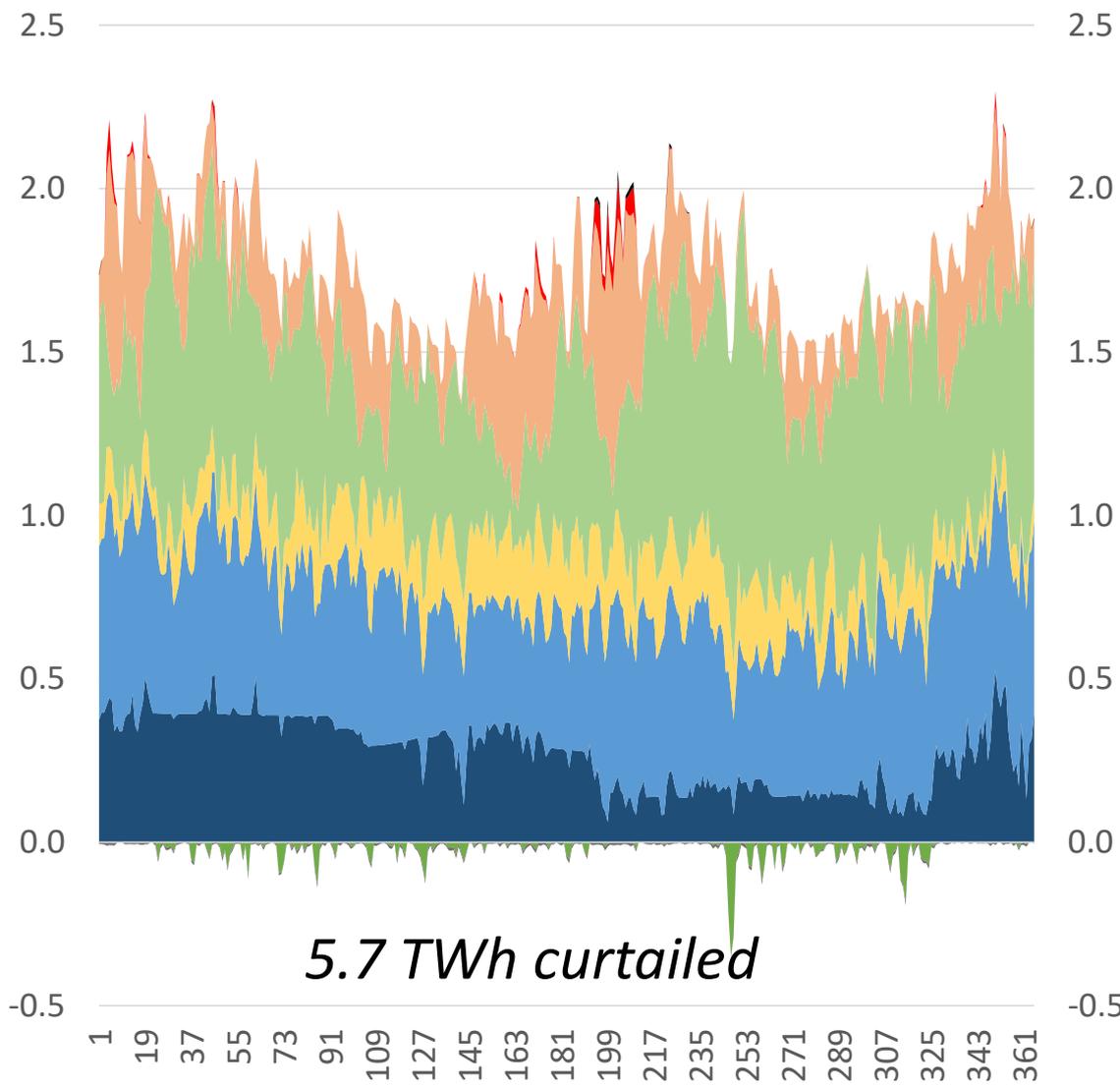
Total Capacity in the BAU Scenarios (GW)



Total Capacity in the Shared Capacity Scenarios (GW)



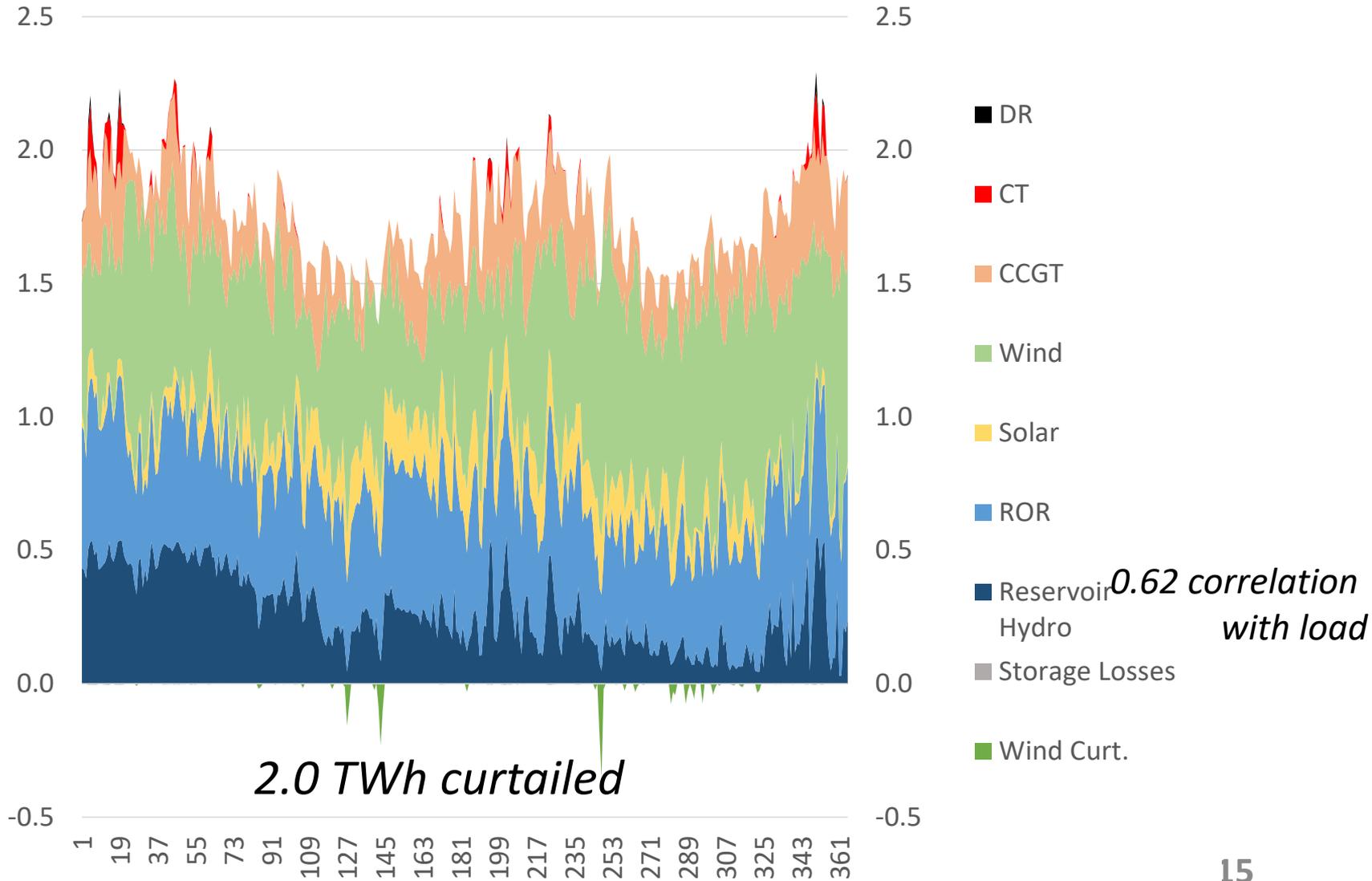
Daily Production Profile BAU-Limited T



- DR
- CT
- CCGT
- Wind
- Solar
- ROR
- Reservoir Hydro
- Storage Losses
- Wind Curt.
- Solar Curt.

0.41 correlation with load

Daily Production Profile Shared Capacity-Unlimited T.



3. Model

Objective

Model: Capacity Expansion

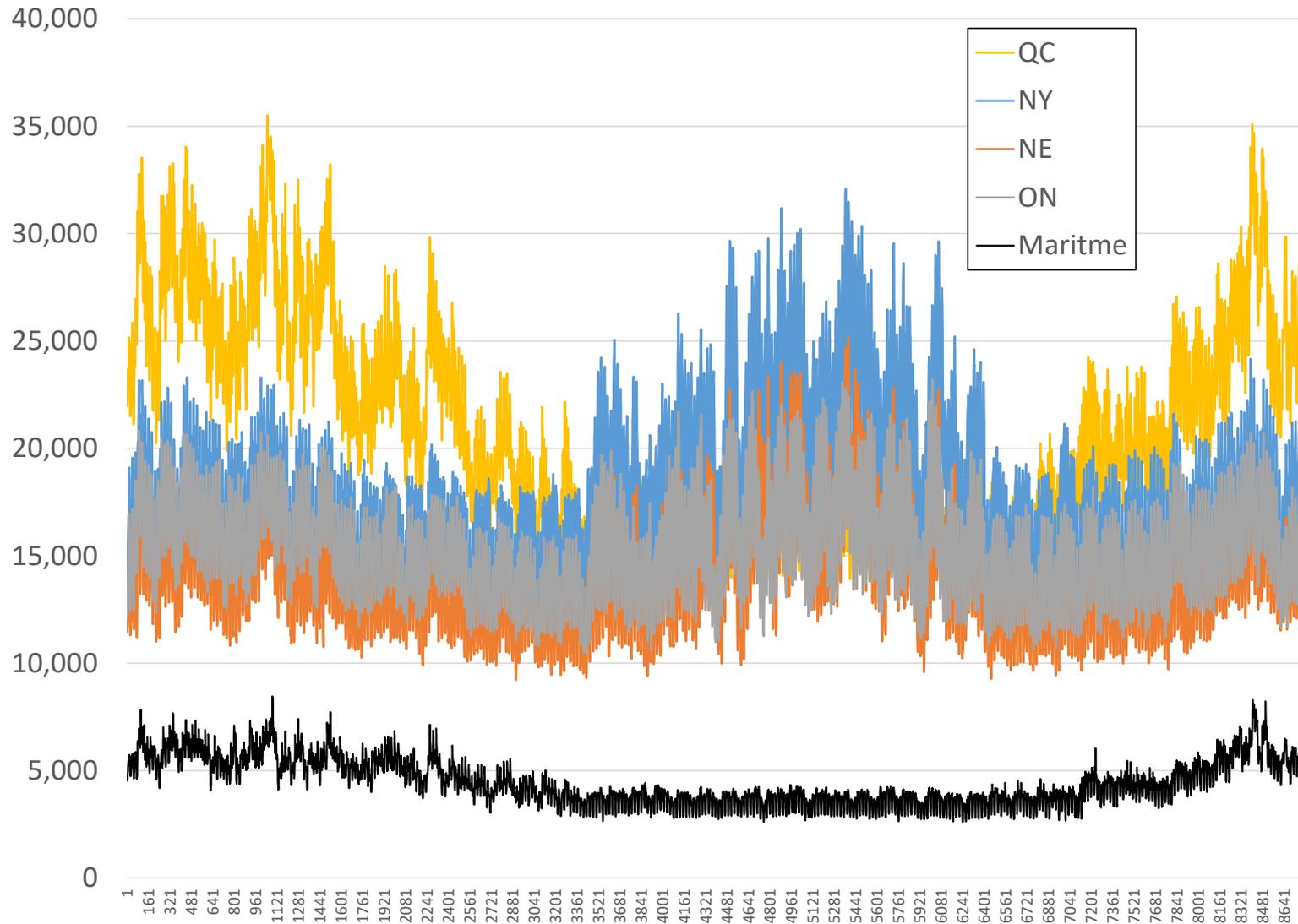
Minimize the annualized investment and operation costs, subject to:

- *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

Nameplate Capacity per region (Thermal+Nuclear) \geq

$$\begin{aligned} & \max_{\text{hours}} \{ \text{Demand} - \text{DR} \\ & - \text{Production}(\text{Wind} + \text{Solar} + \text{Hydro}) \\ & - \text{Battery}(\text{Discharge} - \text{Charge}) \} \end{aligned}$$

- **Shared Capacity:** interconnections count

Nameplate Capacity per region (Thermal+Nuclear) \geq

$$\begin{aligned} & \max_{\text{hours}} \{ \text{Demand} - \text{DR} \\ & - \text{Production}(\text{Wind} + \text{Solar} + \text{Hydro}) \\ & - \text{Battery}(\text{Discharge} - \text{Charge}) \\ & - \text{Transmission}(\text{Imports} - \text{Exports}) \} \end{aligned}$$

(only 1 global capacity NPCC constraint in the unconstrained 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:
 - Incremental 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)

Chaire de gestion
du secteur de l'énergie
HEC MONTRÉAL

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VALERO

5. Additionnal Results

Marginal energy cost (“Price”)

		No carbon cap						Carbon cap					
		Limited Transmission					Un. T	Limited Transmission					Un. T
		QC	ON	MA	NY	NE	NPCC	QC	ON	MA	NY	NE	NPCC
BAU	Energy Price	21.2	24.8	24.8	24.8	24.8	24.8	43.4	93.1	79.3	93.3	87.4	69.4
	Std. Dev.	1.7	7.23	7.32	7.21	7.24	5.0	10.4	36.7	45.1	37.8	40.9	17.9
Shared	Energy Price	20.8	28.9	29.0	28.9	27.7	29.3	46.6	92.8	81.9	96.9	91.2	74.0
	Std. Dev.	1.9	56.8	118.2	55.7	48.5	54.7	3.4	44.8	122	127.4	126.0	55.6

CO2 and Trade

BAU	No carbon cap		Carbon cap	
	1.1	1.2	2.1	2.2
	Un T	Limited T	Un T	Limited T
CO₂ (Mt)	122.0	123.9	30.1	30.1
Net export (TWh)				
QC	21.48	23.58	102.10	53.06
ON	42.24	-9.38	-36.12	-17.06
MA	-65.36	-4.84	49.09	-4.21
NY	-50.15	3.08	-72.57	-17.55
NE	-112.55	-12.44	-39.93	-14.25

Shared	No carbon cap		Carbon cap	
	1.1	1.2	2.1	2.2
	Un T	Limited T	Un T	Limited T
CO₂ (Mt)	122.4	124.1	30.1	30.1
Net export (TWh)				
QC	23.46	23.57	137.14	50.49
ON	-101.79	-10.08	-67.42	-16.82
MA	-34.52	-5.18	19.27	-3.84
NY	232.71	3.49	-8.33	-16.22
NE	-118.21	-11.81	-78.20	-13.61

Levelized Cost of Electricity (\$/MWh)

		No carbon cap		Carbon cap	
		1.1	1.2	2.1	2.2
		Un T	Limited T	Un T	Limited T
BAU	CT	\$4,988.48	\$199.66	\$624.85	\$703.22
	CCGT	\$32.32	\$31.96	\$36.49	\$51.42
	Wind1			\$44.06	\$43.87
	Wind2			\$61.49	\$61.22
	Wind3			\$102.88	\$102.40
	Solar			\$67.06	\$69.21
Shared	CT	\$242.33	\$133.67	\$216.28	\$328.50
	CCGT	\$31.29	\$31.85	\$36.92	\$51.52
	Wind1			\$44.06	\$43.59
	Wind2			\$61.49	\$60.81
	Wind3			\$102.88	\$101.69
	Solar			\$64.71	\$69.21

Capacity Value (\$/MW)

		No carbon cap		Carbon cap	
		1.1	1.2	2.1	2.2
		Un T	Limited T	Un T	Limited T
BAU	QC	\$50,275	\$3,725	\$4,344	\$25,739
	ON	\$56,427	\$56,427	\$56,427	\$56,427
	MA	\$56,500	\$56,500	\$56,500	\$56,500
	NY	\$56,353	\$56,353	\$56,353	\$56,353
	NE	\$56,574	\$56,574	\$56,574	\$56,574
Shared	QC		\$2,117		\$0
	ON		\$20,890		\$48,189
	MA	\$17,365	\$19,901	\$24,057	\$26,547
	NY		\$20,814		\$11,531
	NE		\$30,803		\$16,057

GHG Value (\$/t)

	No carbon cap		Carbon cap	
	1.1	1.2	2.1	2.2
	Unconstrained T	Limited T	Unconstrained T	Limited T
BAU	\$0	\$0	\$141	\$258
Shared	\$0	\$0	\$144	\$250

Additional Scenarios

- Nuclear
- Energy Only (no capacity constraint)
- 30% load decrease in QC
- 30 TWh net trade limit in QC

Results

(\$Billion per year)

	Carbon cap with nuclear		Energy Only		30% load decrease		30TWh
	Un T	Limited T	Un T	Limited T	Un T	Limited T	Limited T
BAU	\$19.6	\$20.0			\$18.3	\$22.6	\$25.1
Shared	\$18.0	\$19.3	\$20.0	\$23.3	\$15.9	\$21.8	\$24.0
BAU-Shared Difference	\$1.6	\$0.7			\$2.3	\$0.8	\$1.1
%	8.3%	3.4%			12.8%	3.4%	4.3%