INSTITUT DE L'ÉNERGIE TROTTIER

Chair in Energy Sector Management
HEC MONTRÉAL

Modelling the Northeast Region: Hydropower, Capacity Constraints and Transmission

Workshop on the Development of an Open Modelling Platform for Electrification and Deep Decarbonisation Studies

Grande Bibliothèque – Room M.450 475, boulevard De Maisonneuve Est, Montréal, Canada

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Contributors

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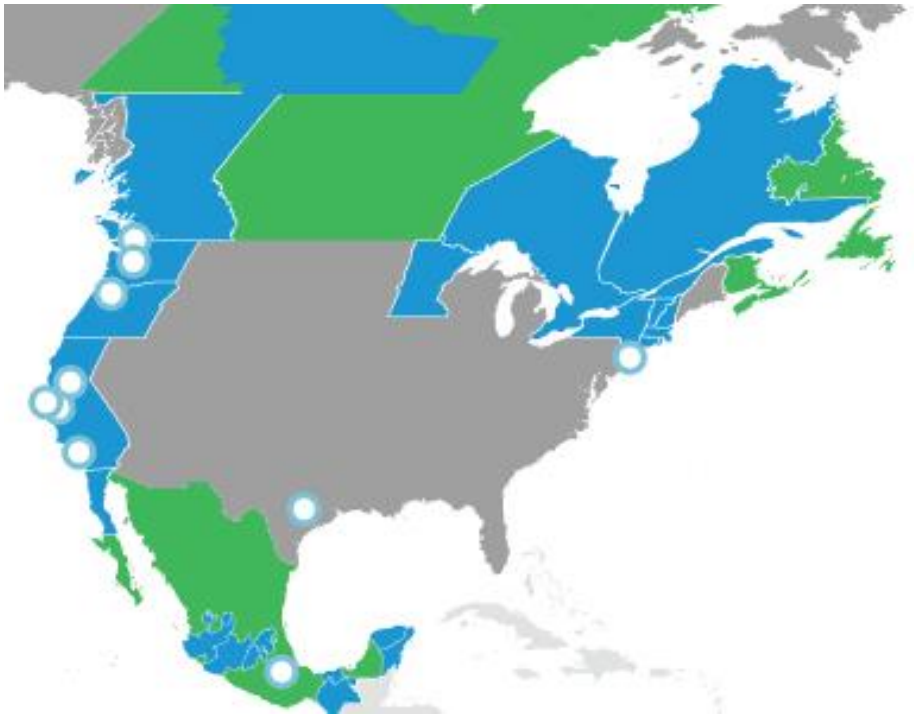
- Financial support from the Institut de l’énergie Trottier (IET)

Agenda

1. Objectives
2. Approach
3. Methods
4. Outputs

1. Objectives

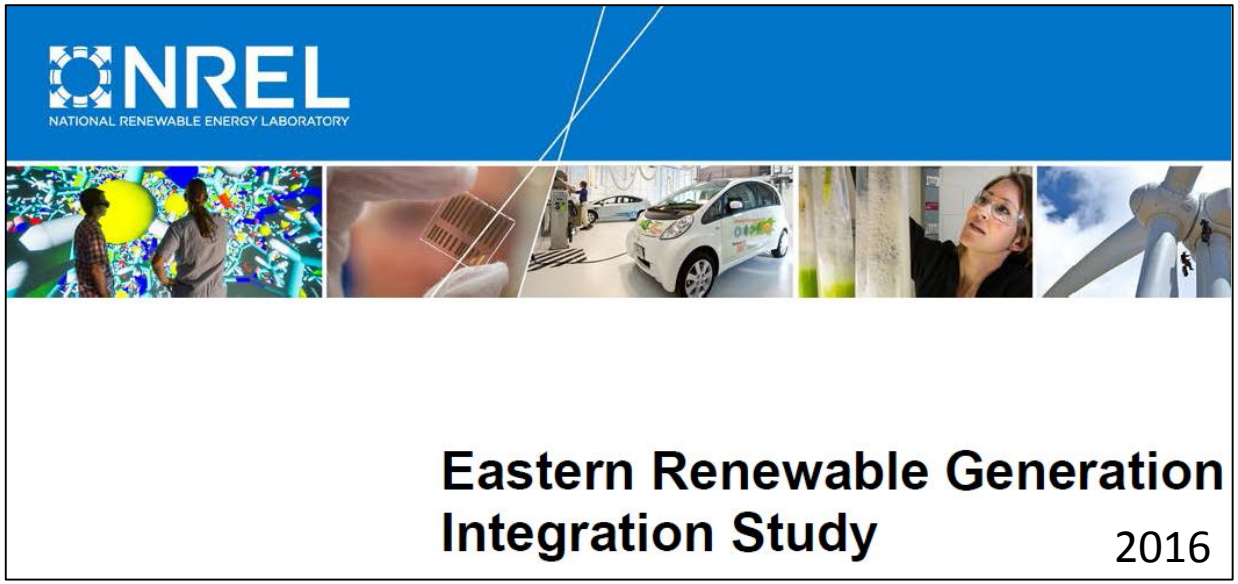
Paris Agreement, state and provincial climate goals, Under 2° Coalition



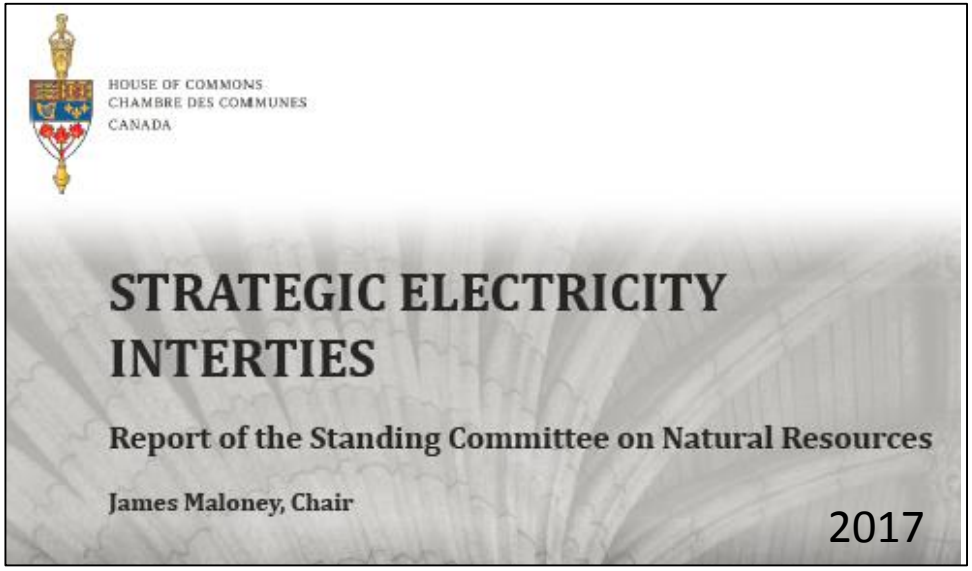
- 177 jurisdictions (37 countries)
- 1.2 billion people (16% of the world)
- $28.8 trillion in GDP (39% of the global economy)

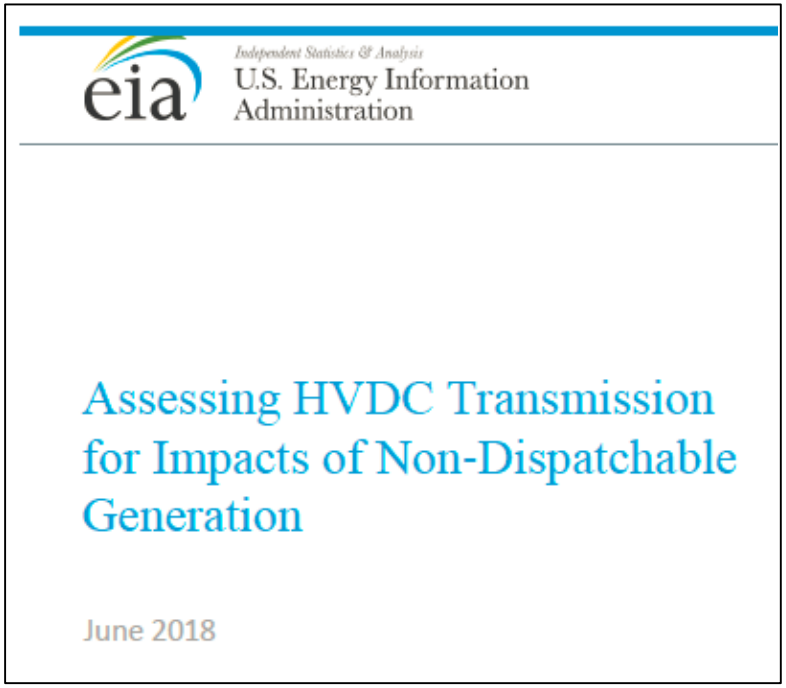
Under2 Coalition's shared goal: limiting GHG emissions to **2 tons per capita, or 80-95% below 1990 level** by 2050.

Under2mou (2017)

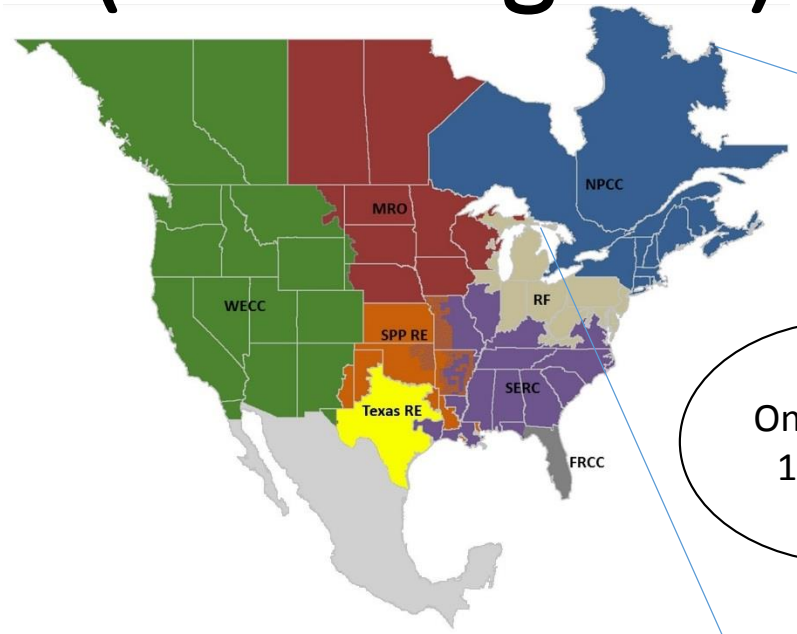


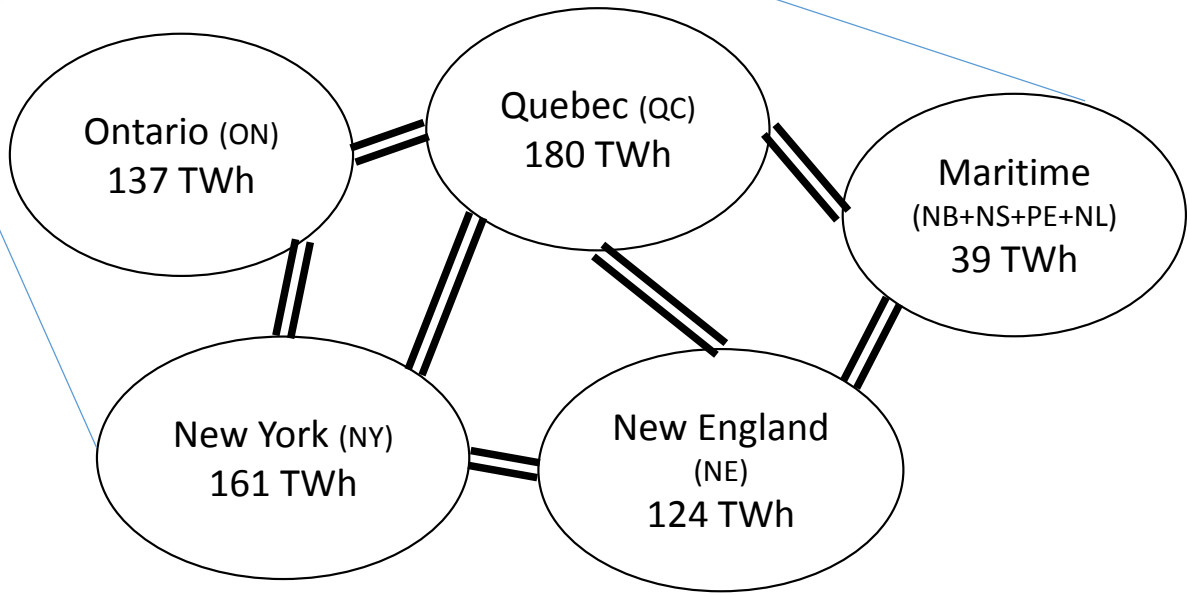
2019: North American Renewable Integration Study



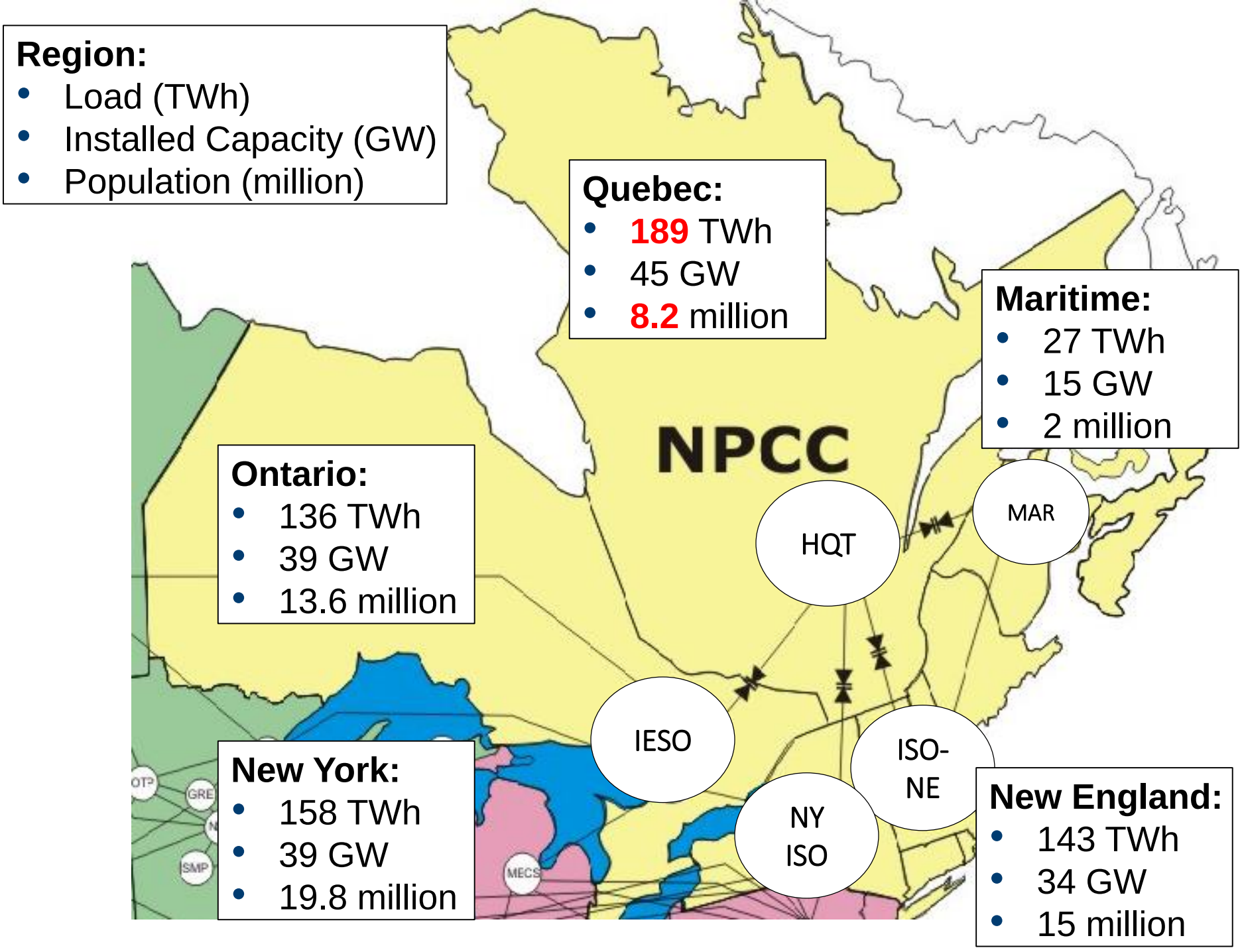


Region of Interest: NPCC (5 sub-regions)





Northeast Power Coordinating Council (NPCC) is one of nine regional electric reliability councils under North American Electric Reliability Corporation authority.


Region:
• Load (TWh)
• Installed Capacity (GW)
• Population (million)
Quebec:
• 189 TWh
• 45 GW
• 8.2 million
Maritime:
• 27 TWh
• 15 GW
• 2 million
NPCC
Ontario:
• 136 TWh
• 39 GW
• 13.6 million
HQT
MAR
IESO
ISO-NE
NY ISO
New York:
• 158 TWh
• 39 GW
• 19.8 million
New England:
• 143 TWh
• 34 GW
• 15 million
OTP
GRE
SMP
MECS

Objectives

1. Study the gains from greater **power system integration**
2. Assess various power system **decarbonization strategies**
3. Better understand the potential regional role of **hydropower reservoirs**
4. Foster interest and **policy discussions** on regional power system integration

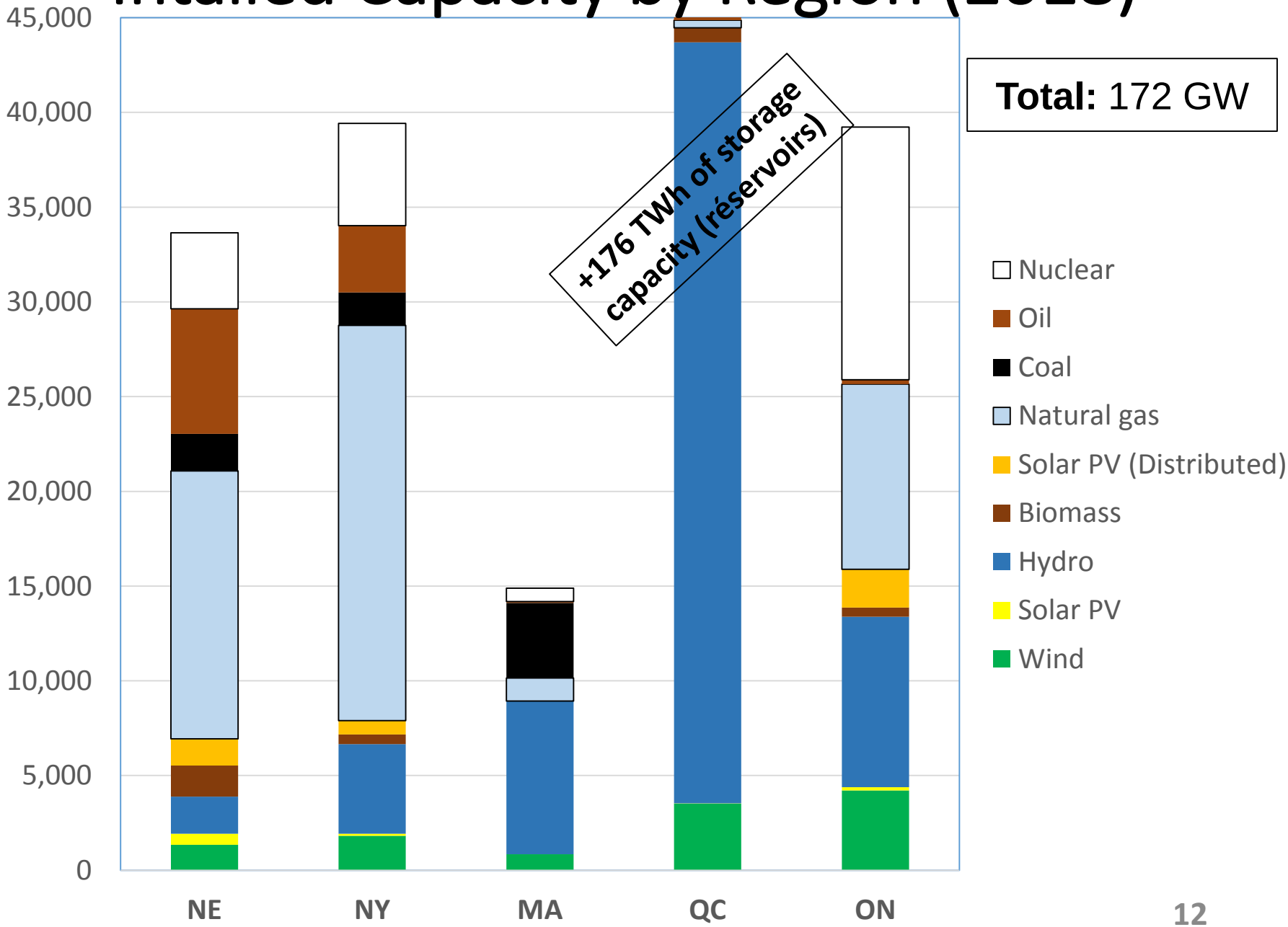
2. Approach

Overall Approach

What investments would be required to meet the power sector decarbonization goals in Northeastern North America?

- Start from nothing
- … except for long-lived assets: existing hydropower and interconnections

Intalled Capacity by Region (2018)



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

Meanings of Power System *Integration*

- **Physical integration**: level of interconnections (electricity transmission constraints between sub-regions)
- **Institutional integration**: local or regional capacity constraints

Decarbonization

- Reduction of GHG emissions from the power sector from 1990 levels: 50% to 99%
- Hourly load data from 2016 (various load level scenarios will be investigated)

3. Methods

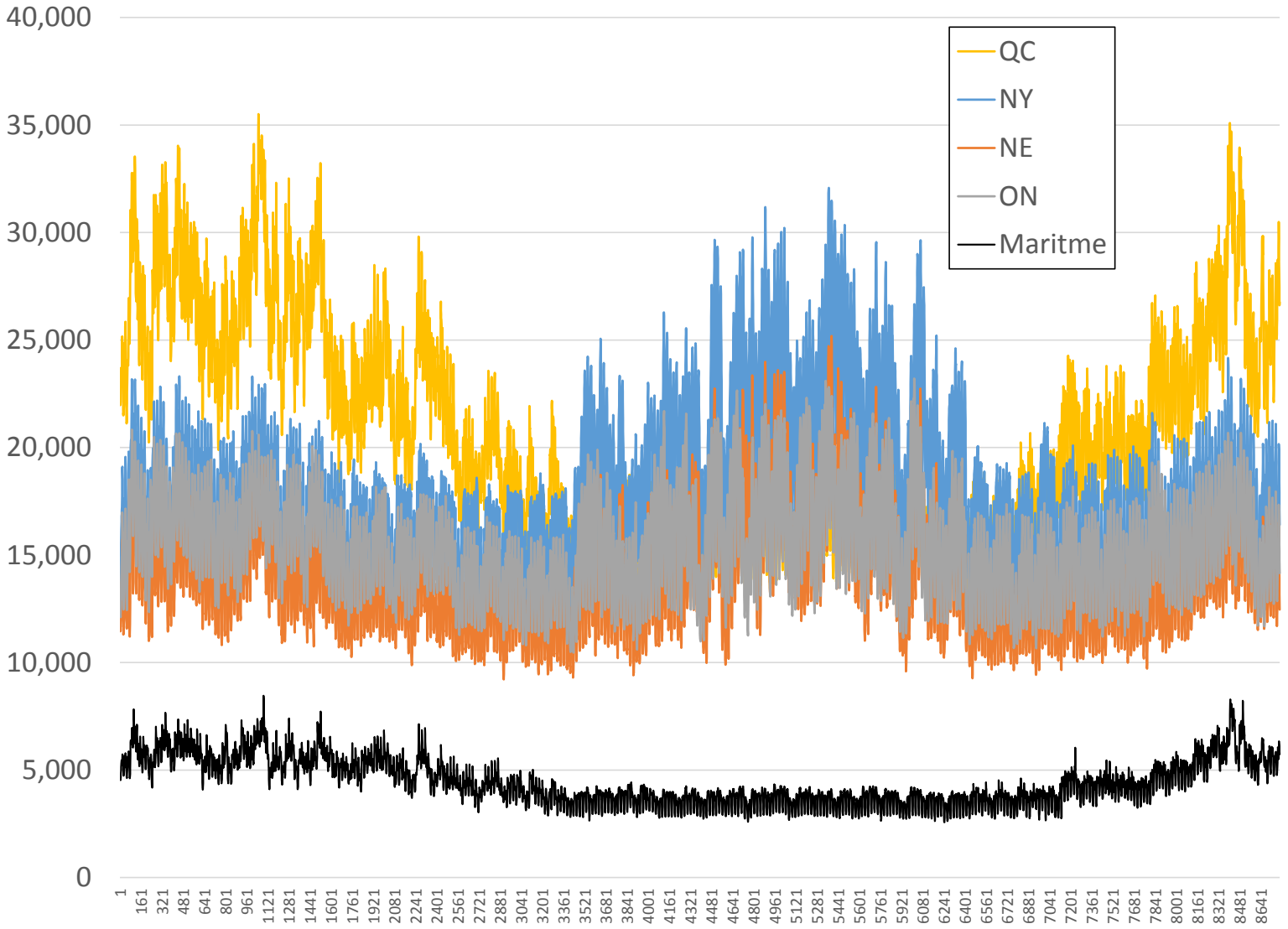
Method: Capacity Expansion Model

Linear Optimization Model

Minimize the annualized investment (generating and transmission capacity) and operation costs, subject to:

- *Hourly load constraints in each region*
- *Capacity constraints*
- *GHG emissions constraints*

Hourly Load data for 2016



Business as Usual vs. Shared Capacity

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

Nameplate Capacity per region (Thermal+Nuclear) ≥

$\mathbf{max}_{\mathbf{hours}}$ {Demand – DR
– Production(Wind+Solar+Hydro)
– Battery(Discharge - Charge)}

- **Shared Capacity**: interconnections count

Nameplate Capacity per region (Thermal+Nuclear) ≥

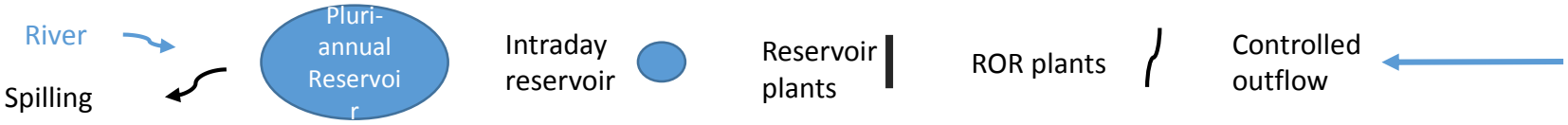
$\mathbf{max}_{\mathbf{hours}}$ {Demand – DR
– Production(Wind+Solar+Hydro)
– Battery(Discharge - Charge)
– Transmission(Imports - Exports)}

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

Technologies

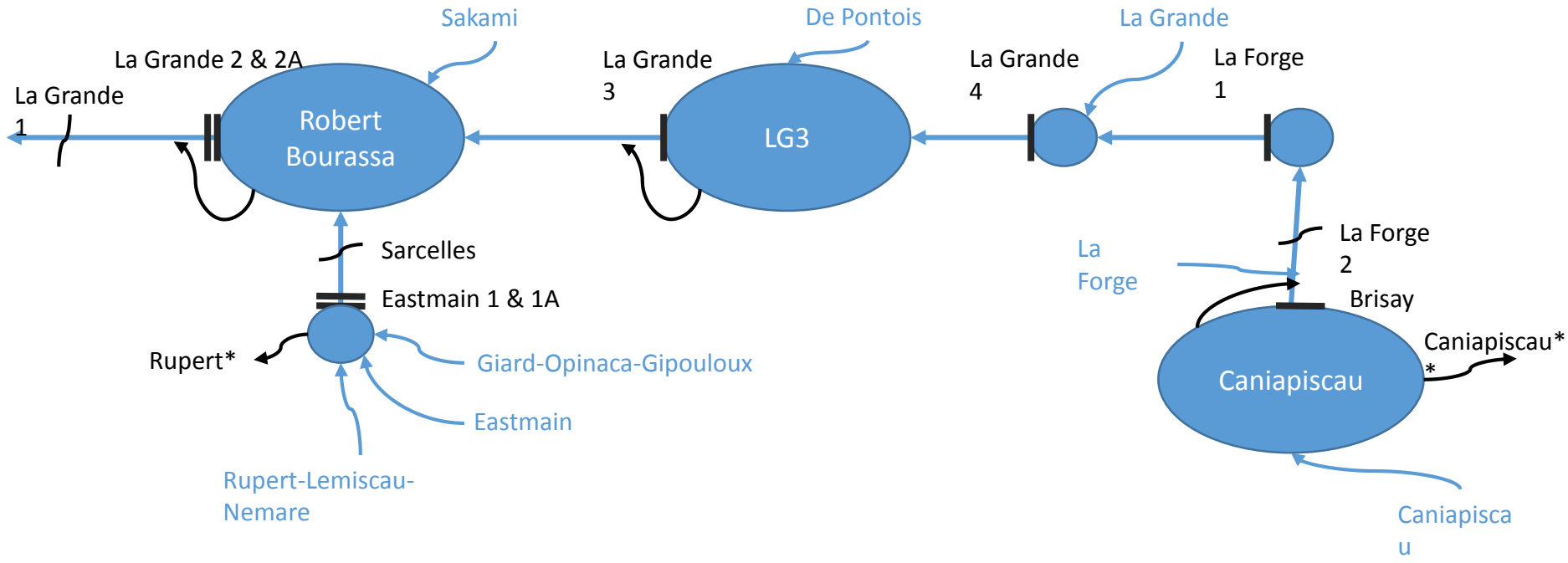
- All legacy hydro from all sub-regions is used
  - Run-of-river (ROR) in all 5 sub-regions
  - Reservoir (RES) in Quebec
  - Pumped hydro in New York
- Additional investment is required:
  - Increamental hydro
  - Thermal: natural gas combusion turbine (CT) and combined-cycle gas turbine (CCGT)
  -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

Hydropower Modelling: Notation and Assumptions



- We model the hydropower generation as “valleys”, where upstream plants’ outflow is an inflow to downstream plants.
- Rivers are exogenous inflows
- Pluri-annual reservoirs are the five biggest reservoirs in Quebec, for which public data on maximum and minimum volume is available.
- All other reservoir, for which no public data on the minimum volume is available, are considered for intraday arbitrage only
- ROR plants are all other plants. To avoid some difficult operational constraints, we would assume no bound on their spilling.

La Grande

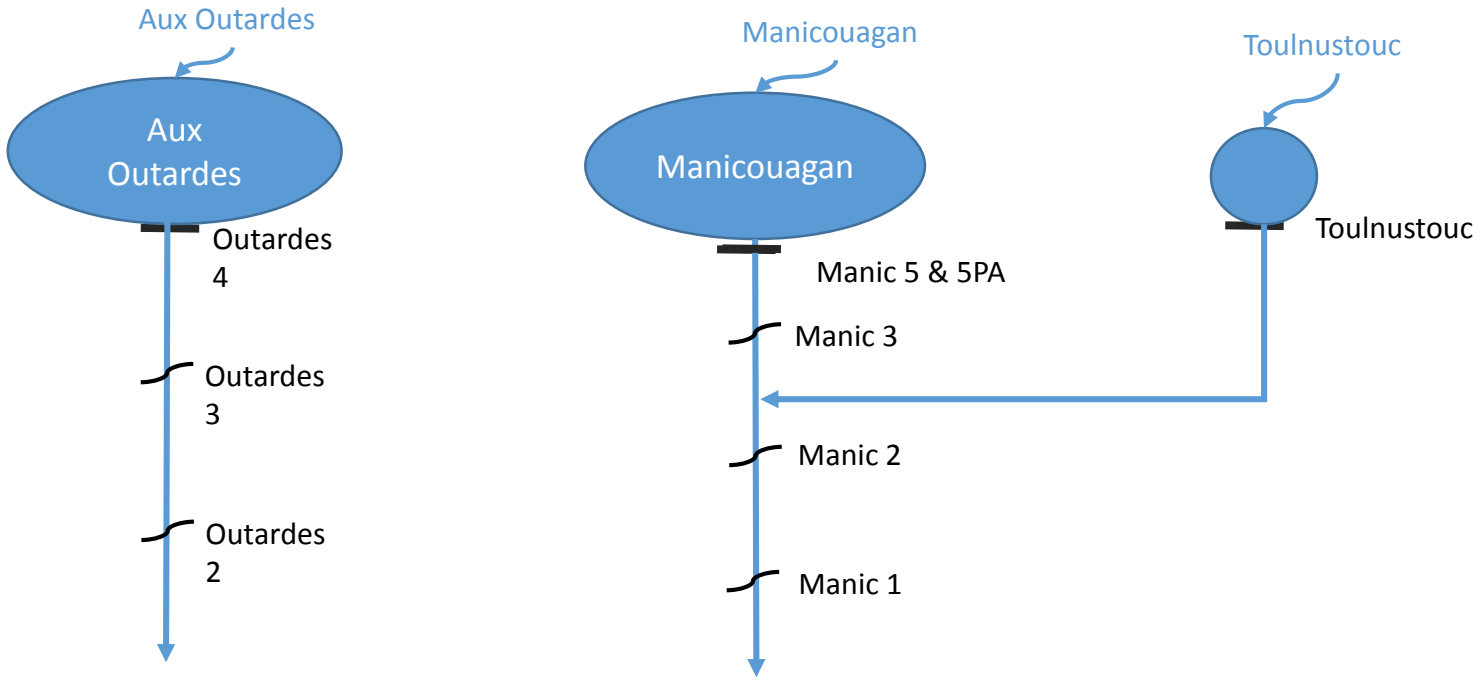


All river inflows are public data. They have been measured in natural state, that is, before the installation of the La Grande Complex.

* There are strong environmental constraints on the management of the Rupert river

**This spilling mechanism (Duplanter) has never been used since the Brisay plant is in service.

Manicouagan and Outardes

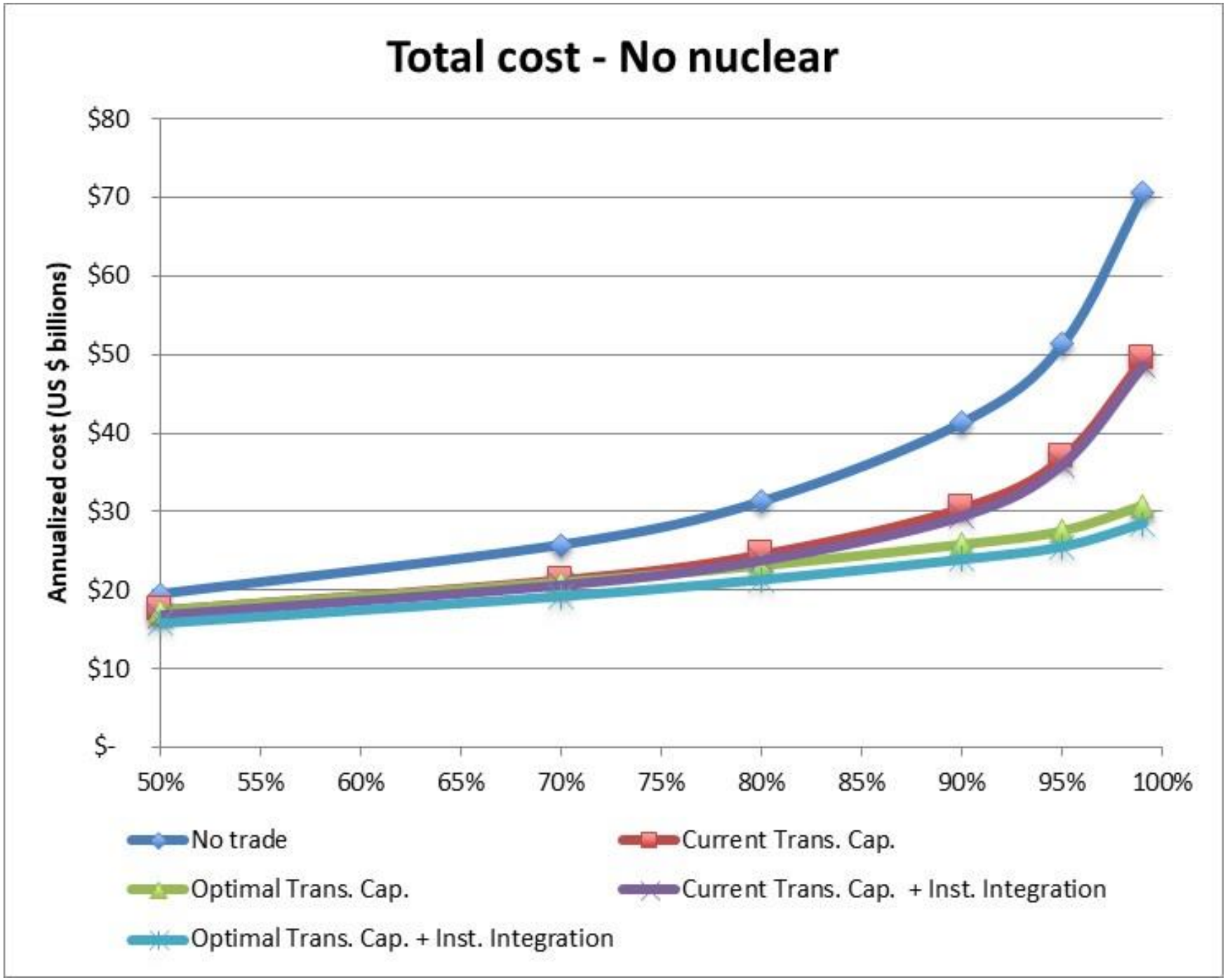


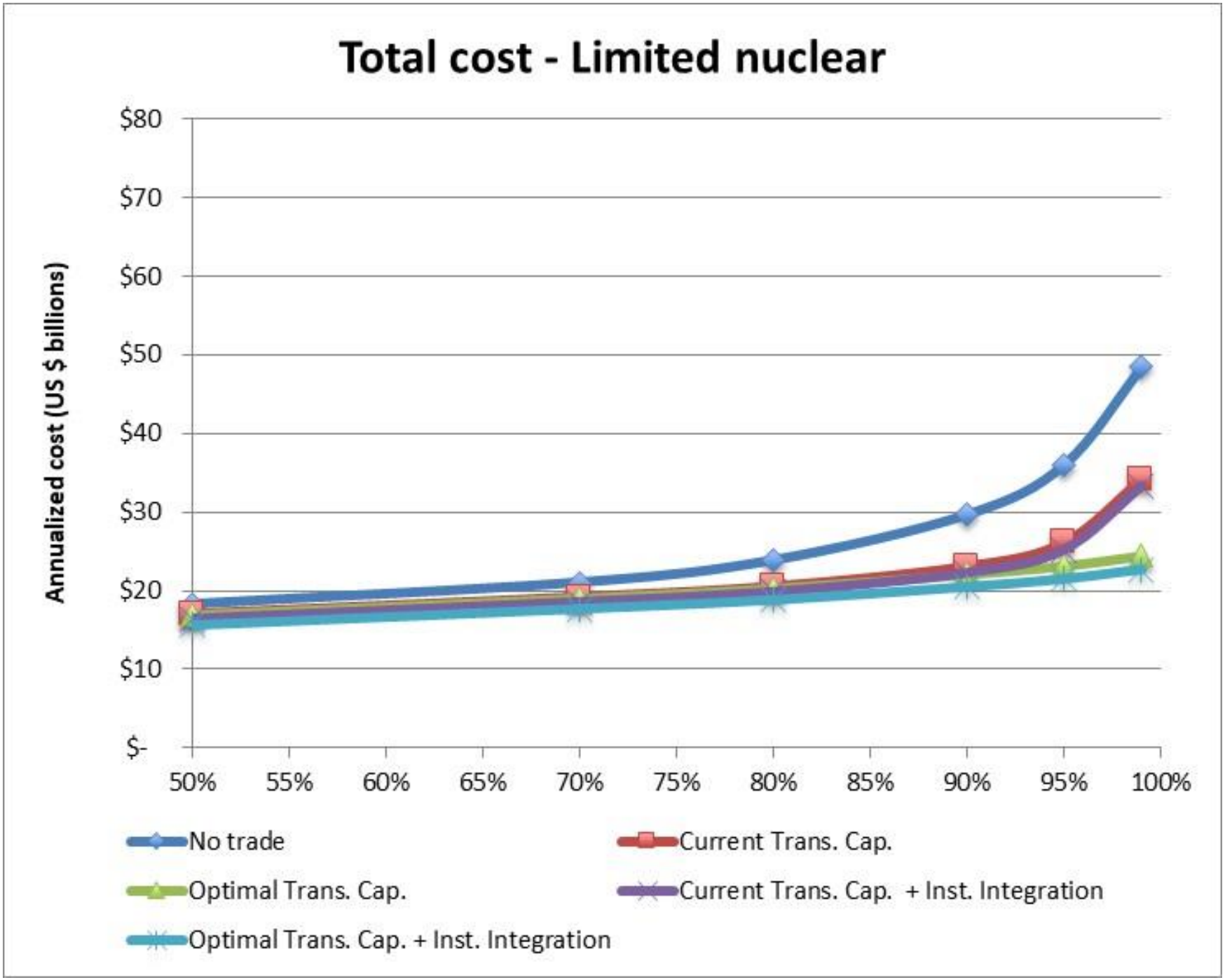
All river inflows are public data. However, they have been measured during the operation of the plants. These flows are thus following power generation pattern, and not the natural pattern. How to deal with that? (For these reservoir, data on the flows and the water level are available)

4. Outputs

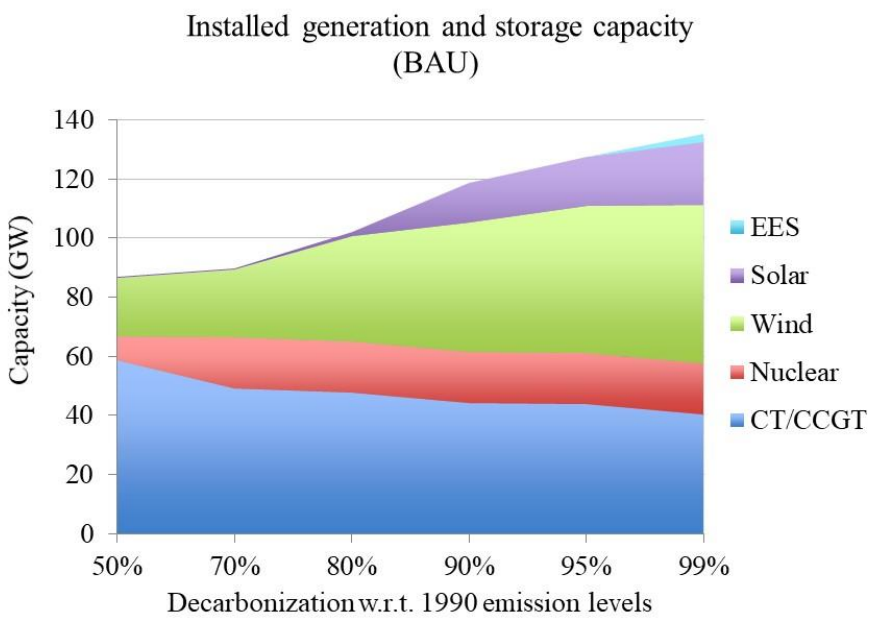
Outputs

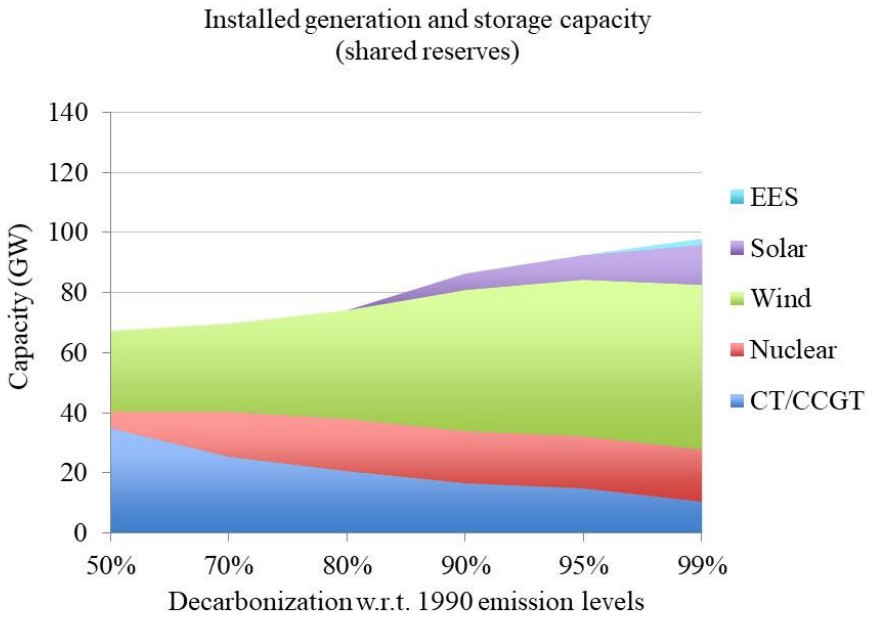
- Overall yearly cost (global and by sub-region)
- Required generation capacity
- Generation from installed capacity & daily reservoir levels
- Exports and imports
- Price levels and variability
- Carbon price


Total cost - No nuclear
Annualized cost (US $ billions)
$80
$70
$60
$50
$40
$30
$20
$10
$-
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
No trade
Current Trans. Cap.
Optimal Trans. Cap.
Current Trans. Cap. + Inst. Integration
Optimal Trans. Cap. + Inst. Integration


Total cost - Limited nuclear
Annualized cost (US $ billions)
$80
$70
$60
$50
$40
$30
$20
$10
$-
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
No trade
Current Trans. Cap.
Optimal Trans. Cap.
Current Trans. Cap. + Inst. Integration
Optimal Trans. Cap. + Inst. Integration

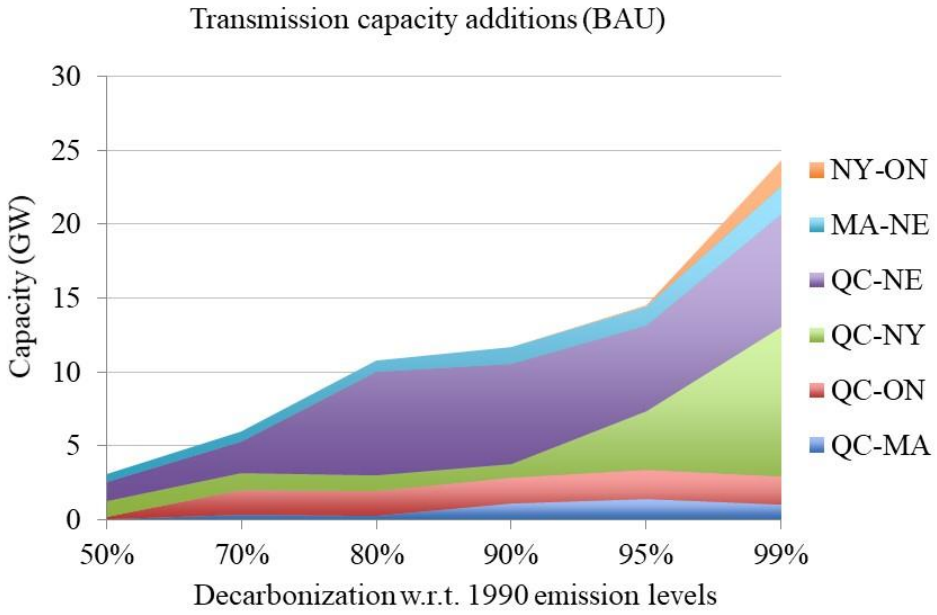
Installed Capacity *without* and *with* Institutional Integration

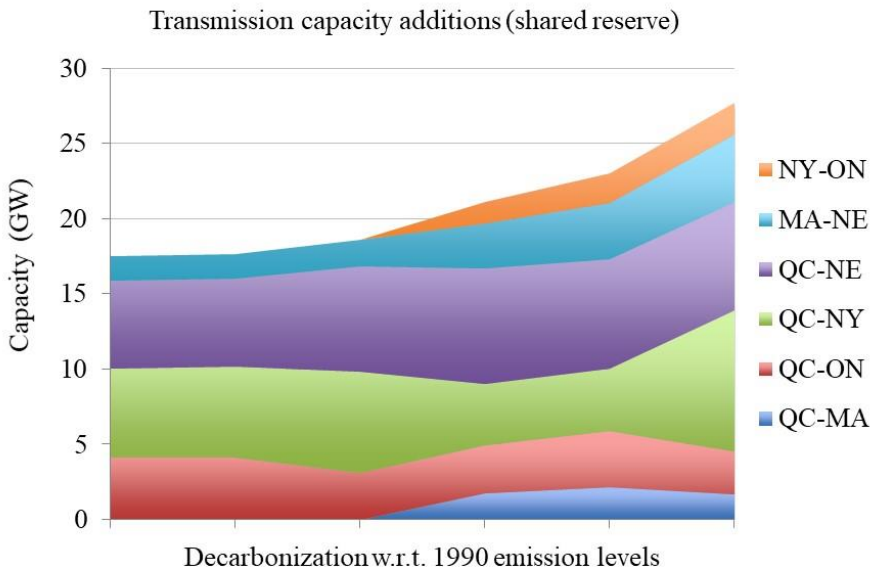


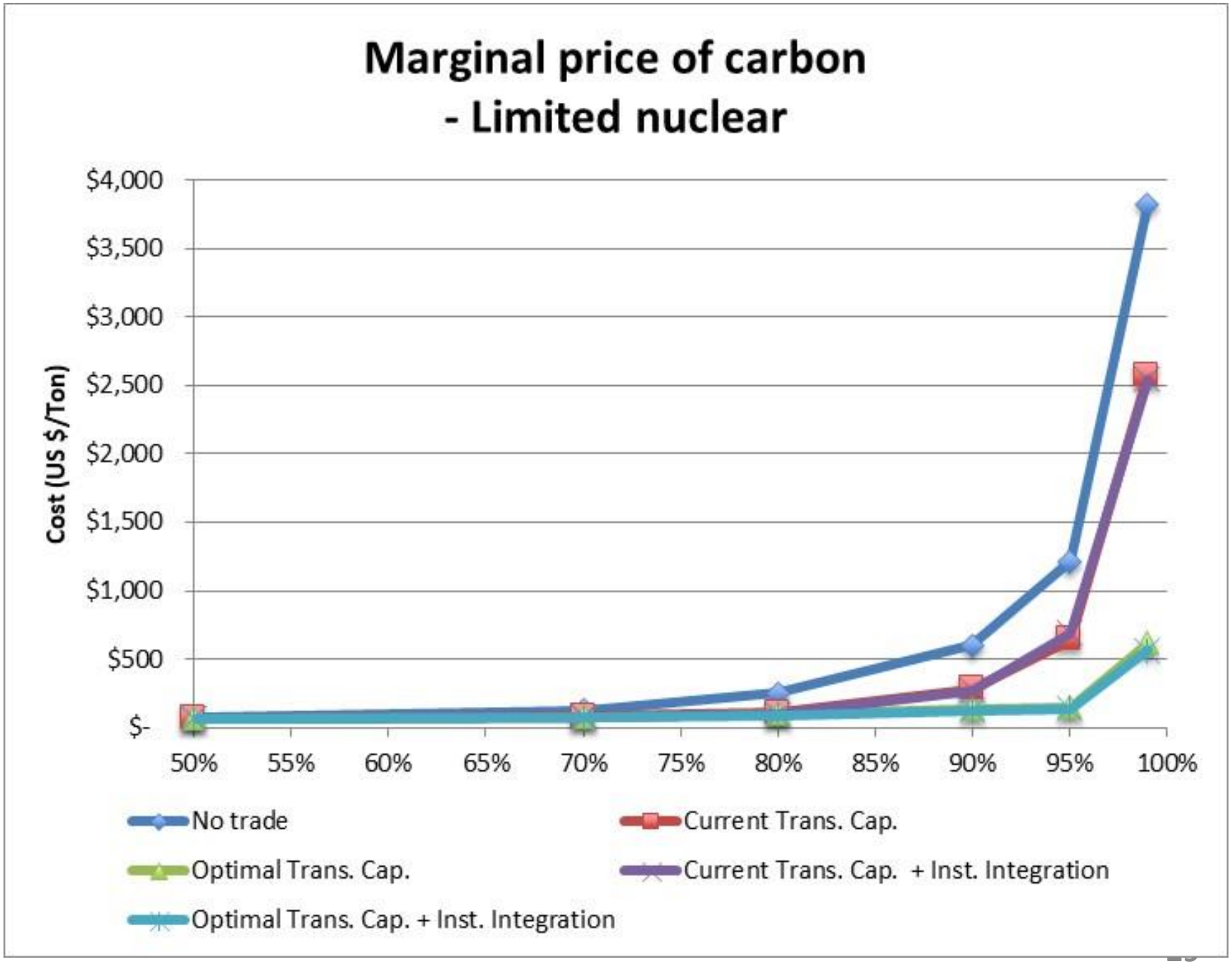


With optimal transmission investment

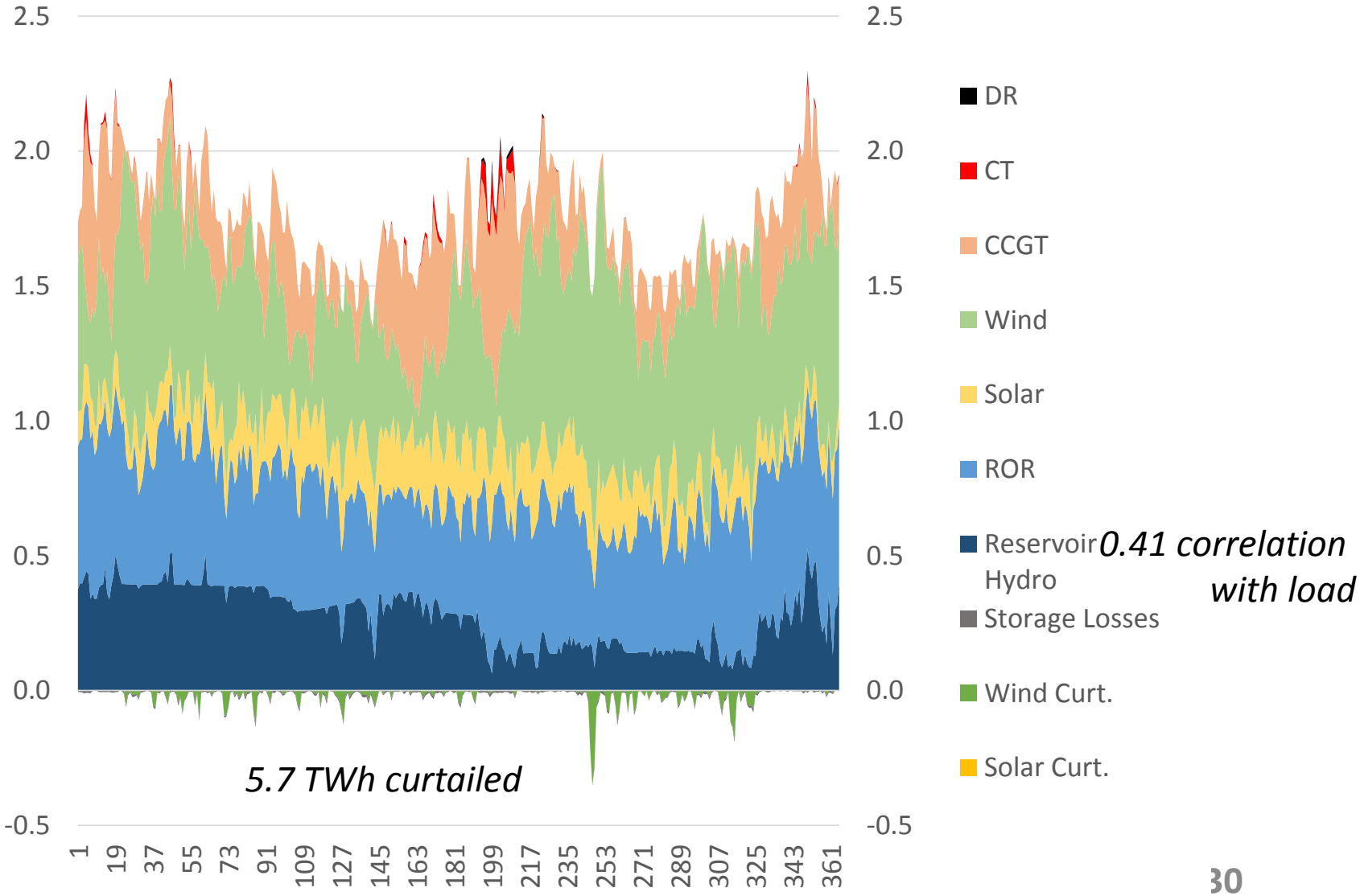
Transmission Capacity Additions *without* and *with* Institutional Integration



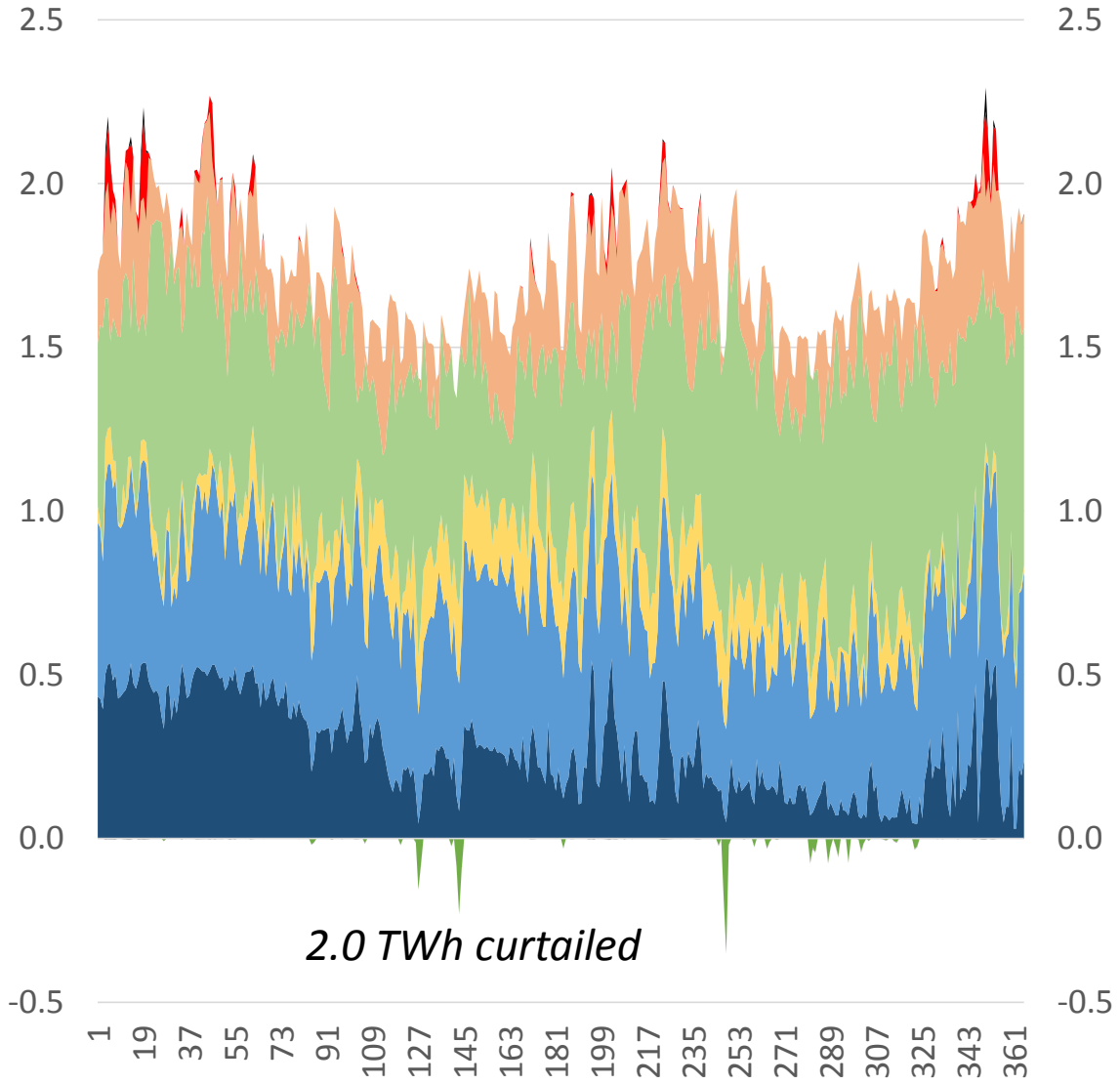



Marginal price of carbon
- Limited nuclear
Cost (US $/Ton)
$4,000
$3,500
$3,000
$2,500
$2,000
$1,500
$1,000
$500
$-
50%
55%
60%
65%
70%
75%
80%
85%
90%
95%
100%
No trade
Current Trans. Cap.
Optimal Trans. Cap.
Current Trans. Cap. + Inst. Integration
Optimal Trans. Cap. + Inst. Integration

Production Profile BAU-Limited T



Production Profile Shared-Uncons. T



Conclusion

- Regional integration gains are significant, especially under deep decarbonization
- Political economy issues will be far more complex than technical ones:
  - Cost sharing
  - Electricity price increase
  - Carbon price
  - “Energy independence”
  - Sub-regional coalitions
  - …