

Role of Hydropower in a Low Carbon Future

ESIG 2021 Spring Technical Workshop

Session 7: Energy Storage Developments

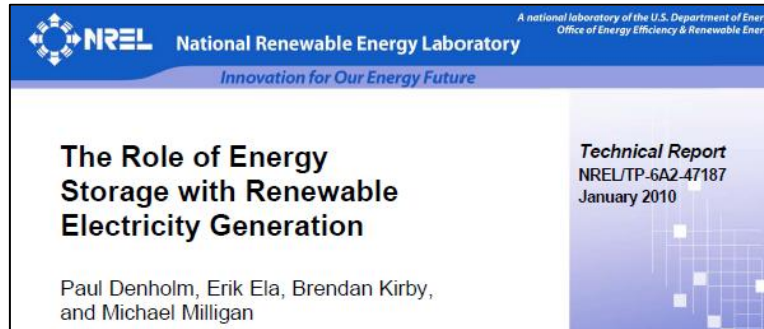
Pierre-Olivier Pineau

HEC Montréal, Canada

March 23, 2021 – 3-4.30 pm

Storyline

1. **Storage is key for RE integration** – but often discussed independently from transmission and hydropower reservoirs
2. **Dams and their reservoirs store water**: potential energy is stored. Usually not considered a storage system... although it stores energy!
3. **Energy storage in dams represent huge storage options** that can be used – to some extent – to integrate RE
4. **Northeast case study**: RE integration & Hydro-Quebec's 176 TWh of storage (equivalent to about 2 billions EVs; there's 276 million cars in the US)



Global Operational + Announced Energy Storage, Rated Capacity and Energy (2020)

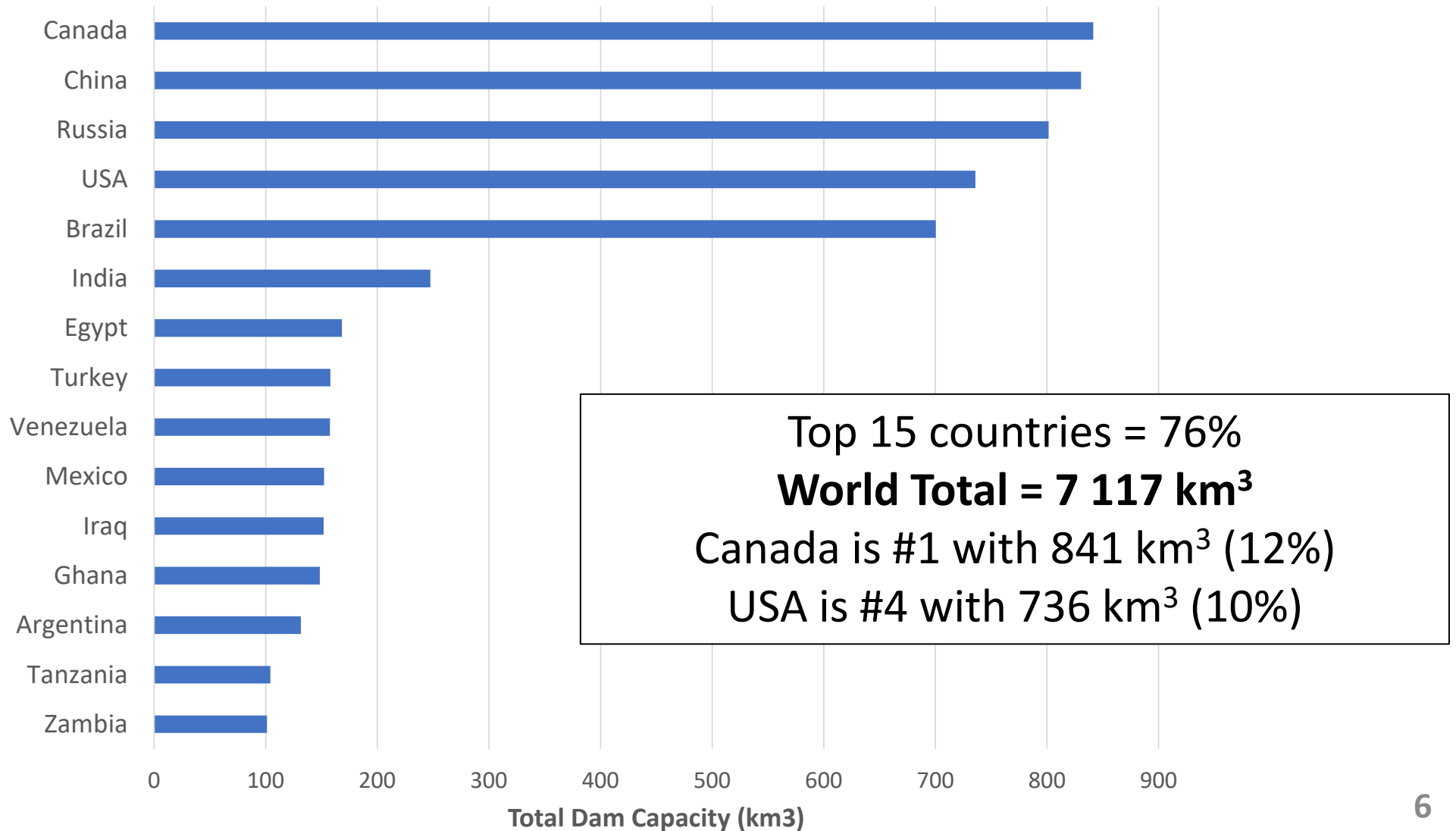
	Operational (MW)	Announced (MW)		Operational (GWh)	Announced (GWh)	
Electro-chemical	1 781,9	524	1,2%	3,8	1,5	0,3%
Electro-mechanical (flywheel, comp. air)	1 655,1	521	1,2%	33,8	4,0	2,1%
Hydrogen Storage	17,3	0	0,0%	0,1	0,0	0,0%
Lead-Carbon	0,4	0	0,0%	0,0	0,0	0,0%
Liquid Air Energy Storage	0,0	0	0,0%	0,0	0,0	0,0%
Lithium Ion Battery	3,4	751	0,4%	0,0	0,0	0,0%
Pumped Hydro Storage	167 790,0	11 455	95,8%	1 556,9	157,6	96,6%
Thermal Storage	2 443,9	111	1,4%	15,8	0,5	0,9%
Total	173 692,8	13 363		1 610,5	163,7	

Electric Storage Resources - Definition

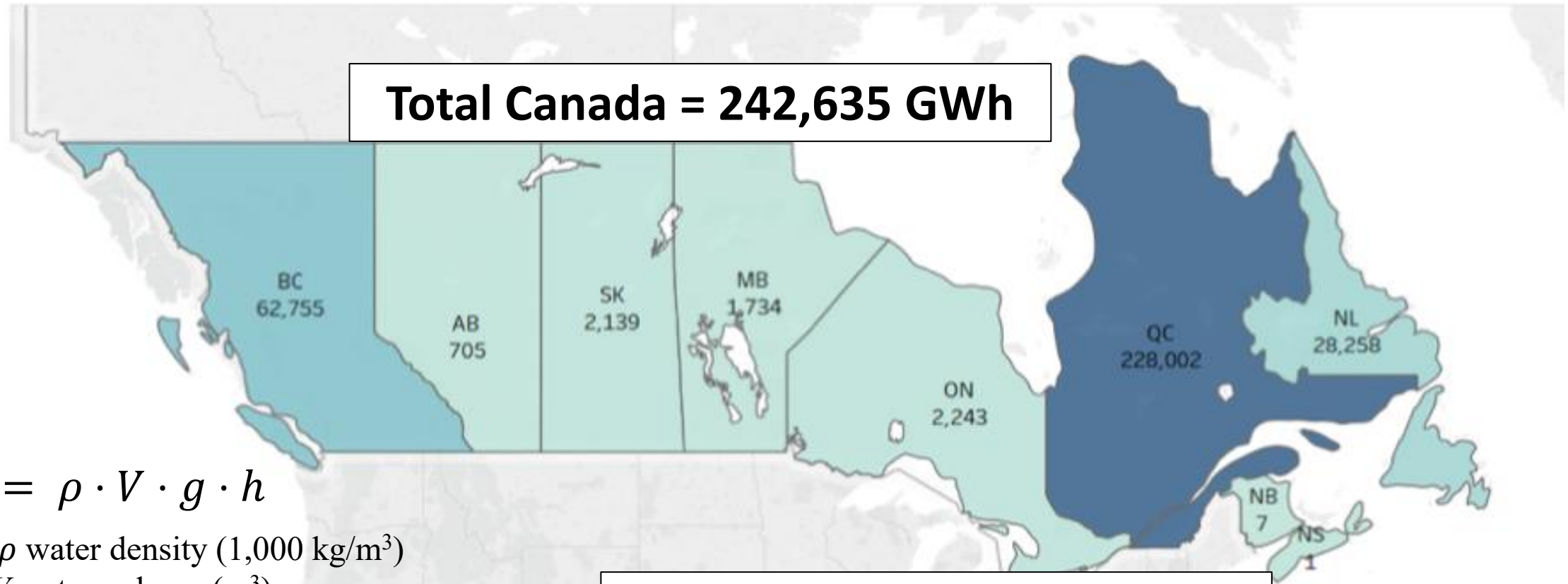
“a resource capable of **receiving electric energy** from the grid and storing it for later **injection of electricity back to the grid** regardless of where the resource is located on the electrical system.”

FERC Order 841 *Electric Storage Participation in Markets Operated by RTOs and ISOs* (2018)

Global Dam Capacity, 2017 (km³ of water)



Estimated Energy Storage Capacity in Canadian Powered Dams by Province, in GWh



$$E = \rho \cdot V \cdot g \cdot h$$

ρ water density (1,000 kg/m³)

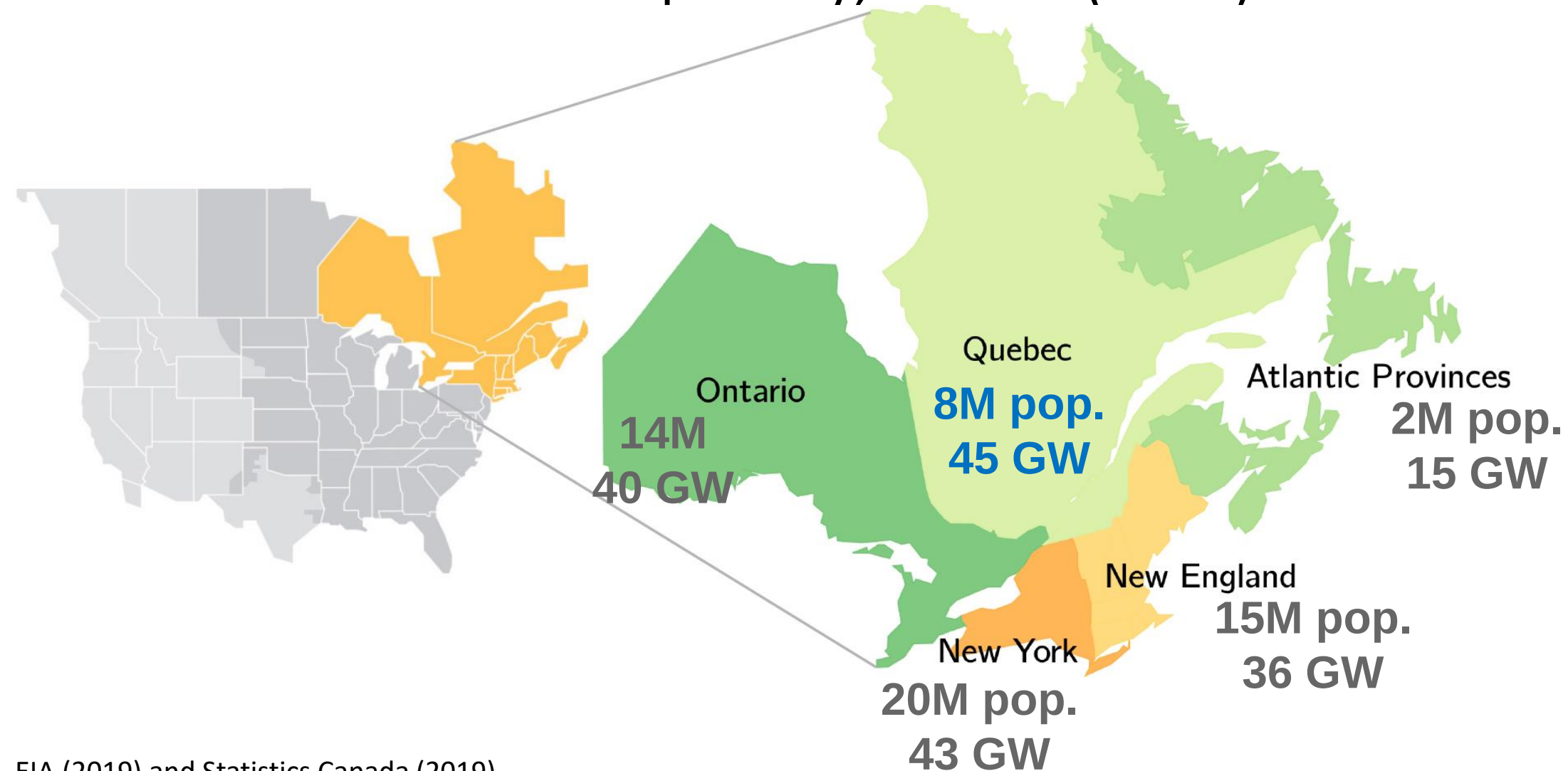
V water volume (m³)

g gravitational acceleration (9,81 m/s²)

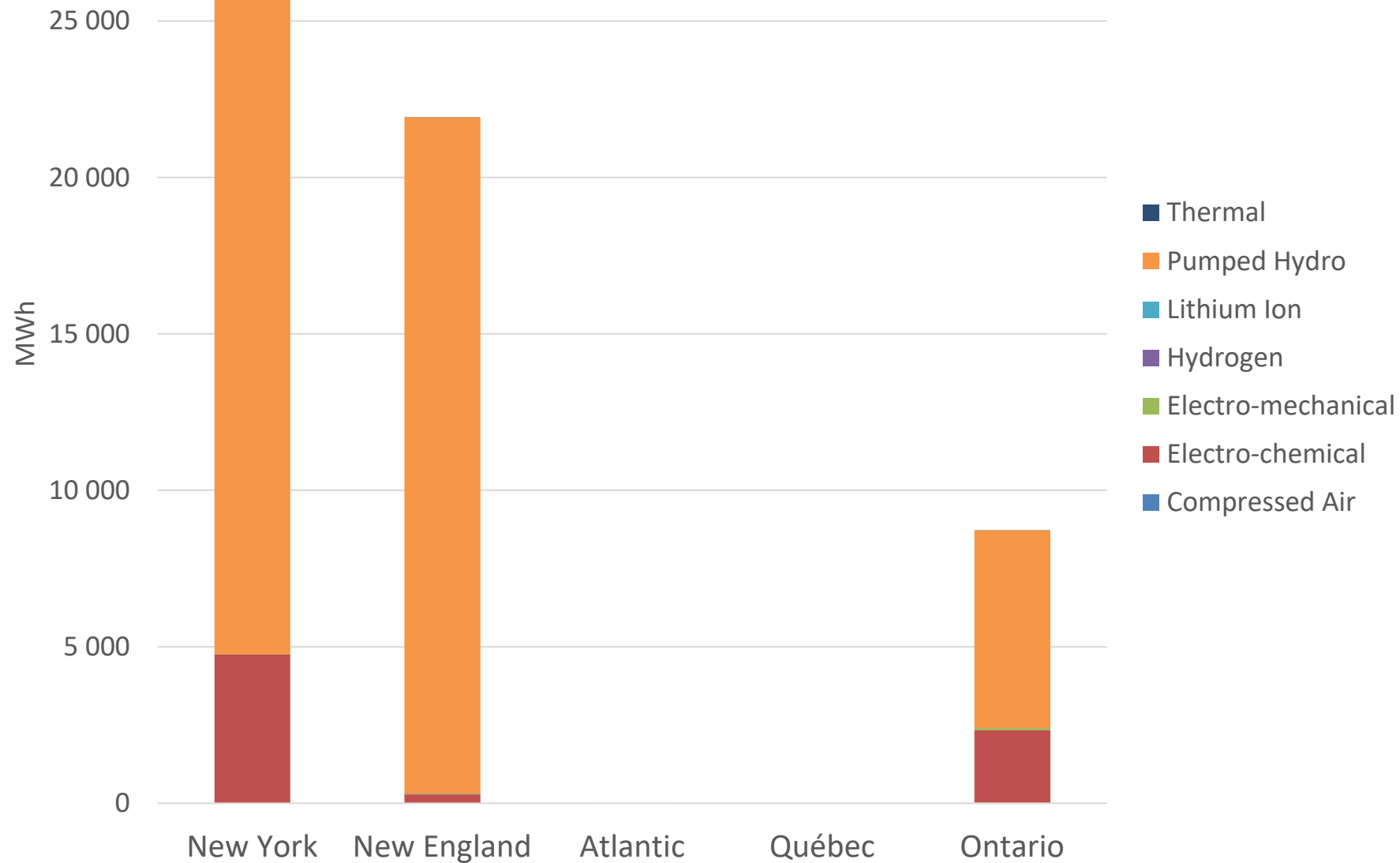
h hydraulic head (m)

**Global Energy Storage Capacity
= 1,610 GWh (0.7%)**

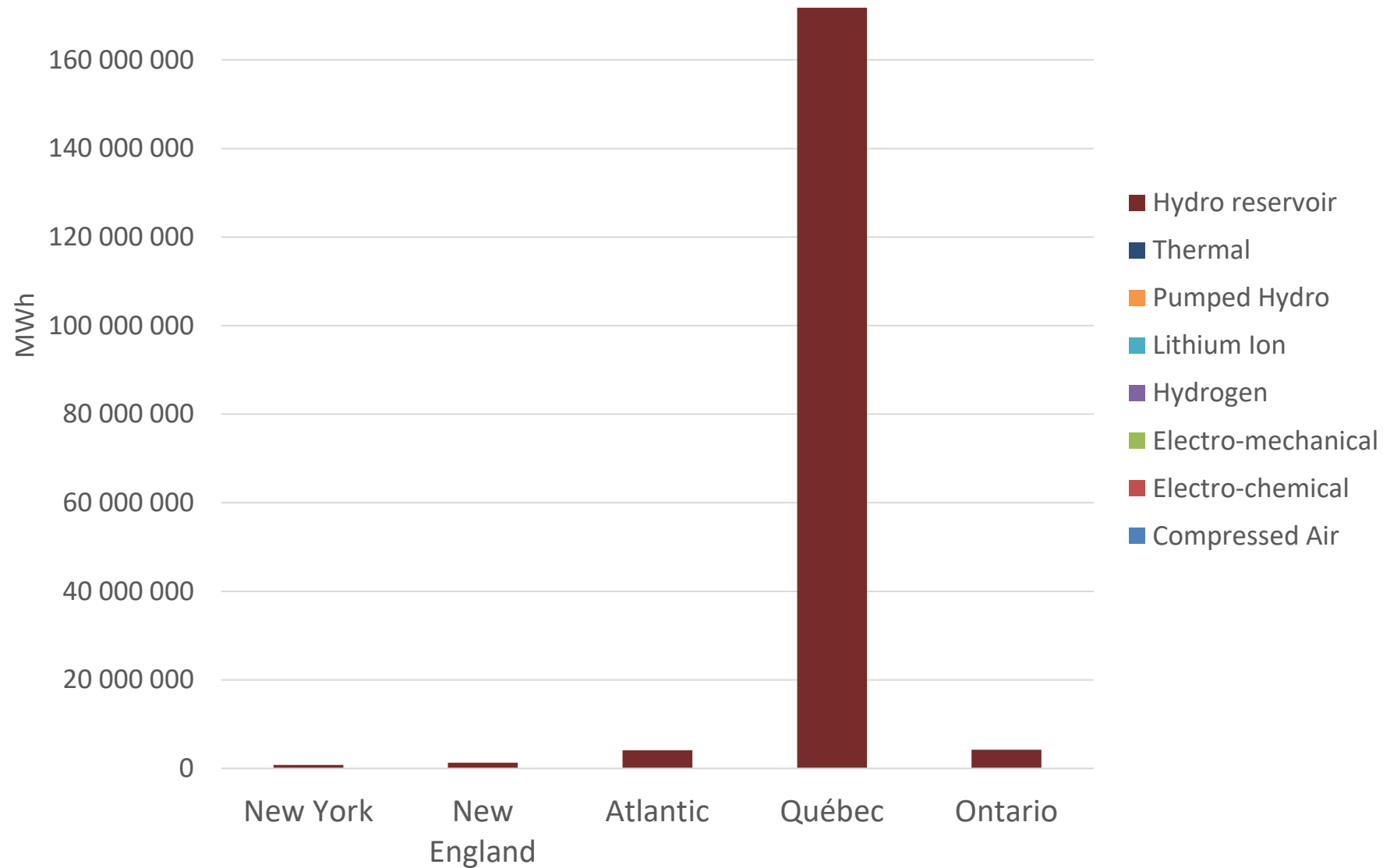
Northeast: Population and installed capacity, 2017 (GW)



Energy Storage, 2020

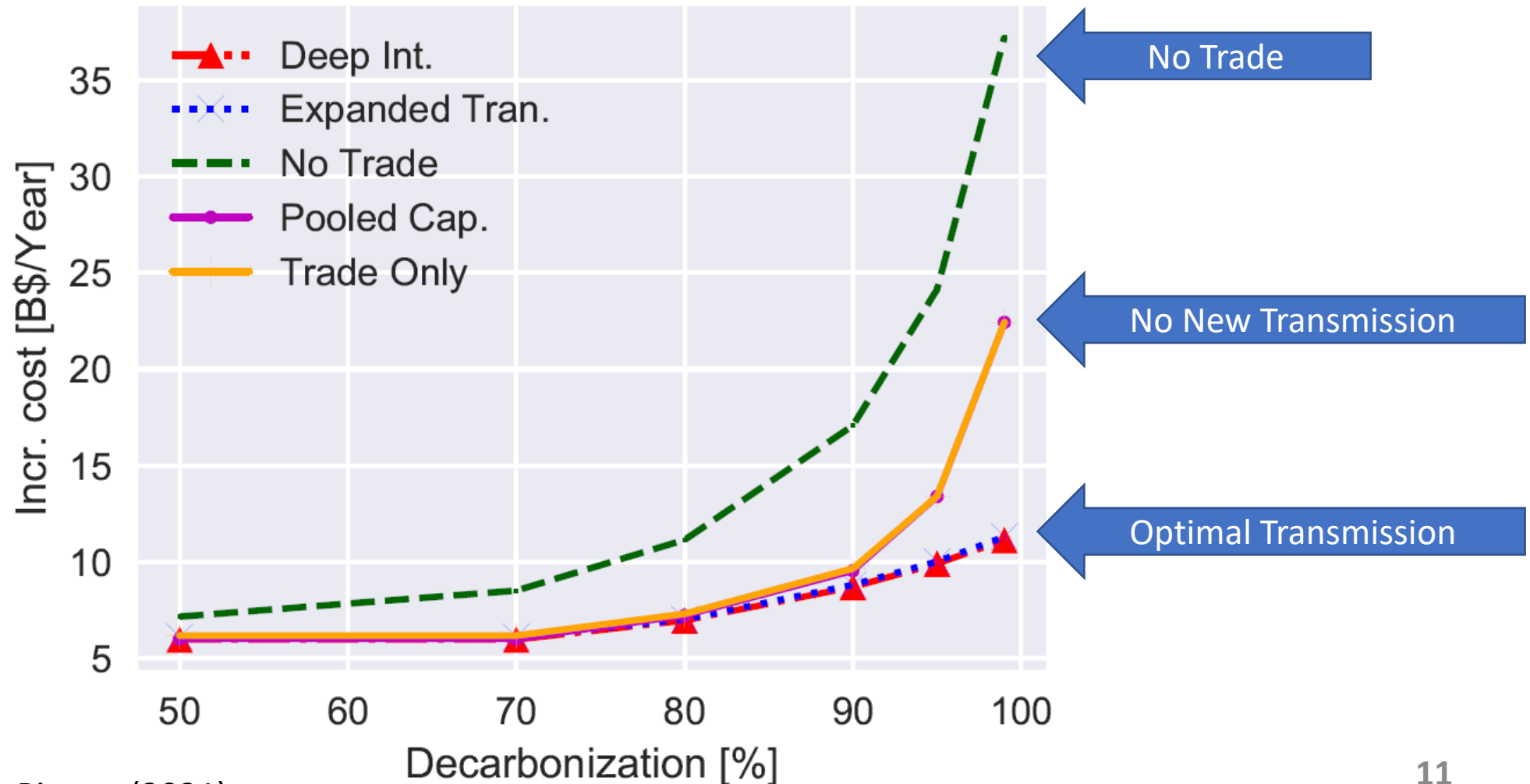


Energy Storage, 2020



Decarbonization Cost in the Northeast

No Trade / No New Transmission / Optimal Transmission



More Regional Integration = More Wind

With Optimal Transmission :

- Hydro-Wind correlation: from -0,06 to **-0,28**
- Wind generation: from 102 to **120 TWh**
- Wind curtailment: from 1,5 % to **0,1 %**

Hydro Dams + Transmission = 100% decarbonization and more PV & Wind

No Additional
Transmission
with Quebec

<i>New MW</i>	QC	ON	AT	NY	NE	Total
Solar PV	0	5 607	4 625	14 247	6 635	31 114
Wind	0	5 000	13 834	8 911	15 877	43 622
New hydro	0			456		456
Storage	0	1 101	160	915		2 177
	0	11 708	18 619	24 529	22 512	77 368

**Yearly cost:
\$19.8G**

Optimal
Transmission
with Quebec
(+ 16 GW)

<i>New MW</i>	QC	ON	AT	NY	NE	Total
Solar PV	0	1 416	3 461	21 021	7 556	33 454
Wind	0	5 000	13 834	8 014	17 728	44 576
New hydro	0			456		456
Storage	0					0
	0	6 416	17 295	29 491	25 284	78 486

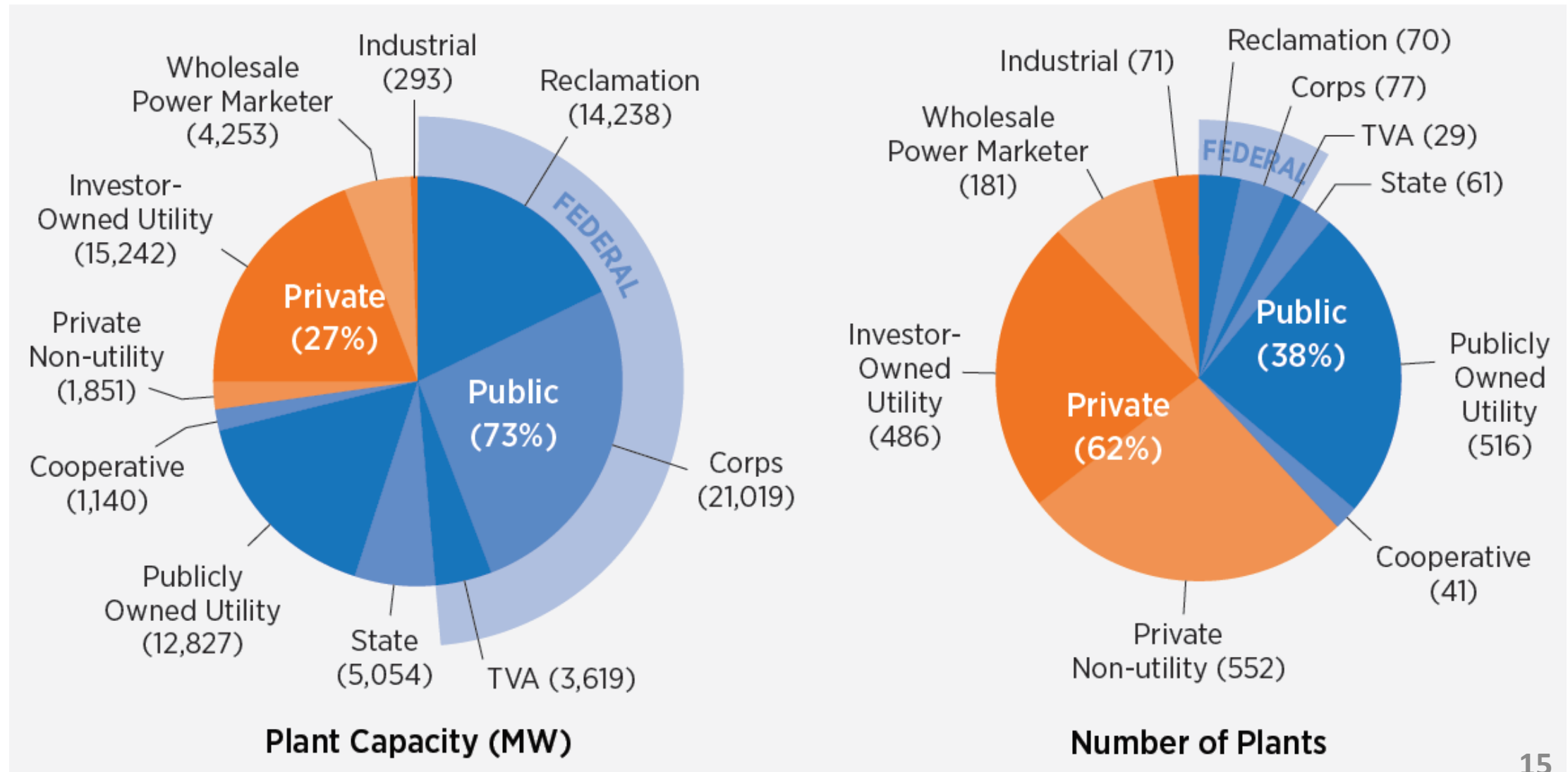
\$17.1G

In these scenarios, Quebec cannot invest in new wind & solar PV.

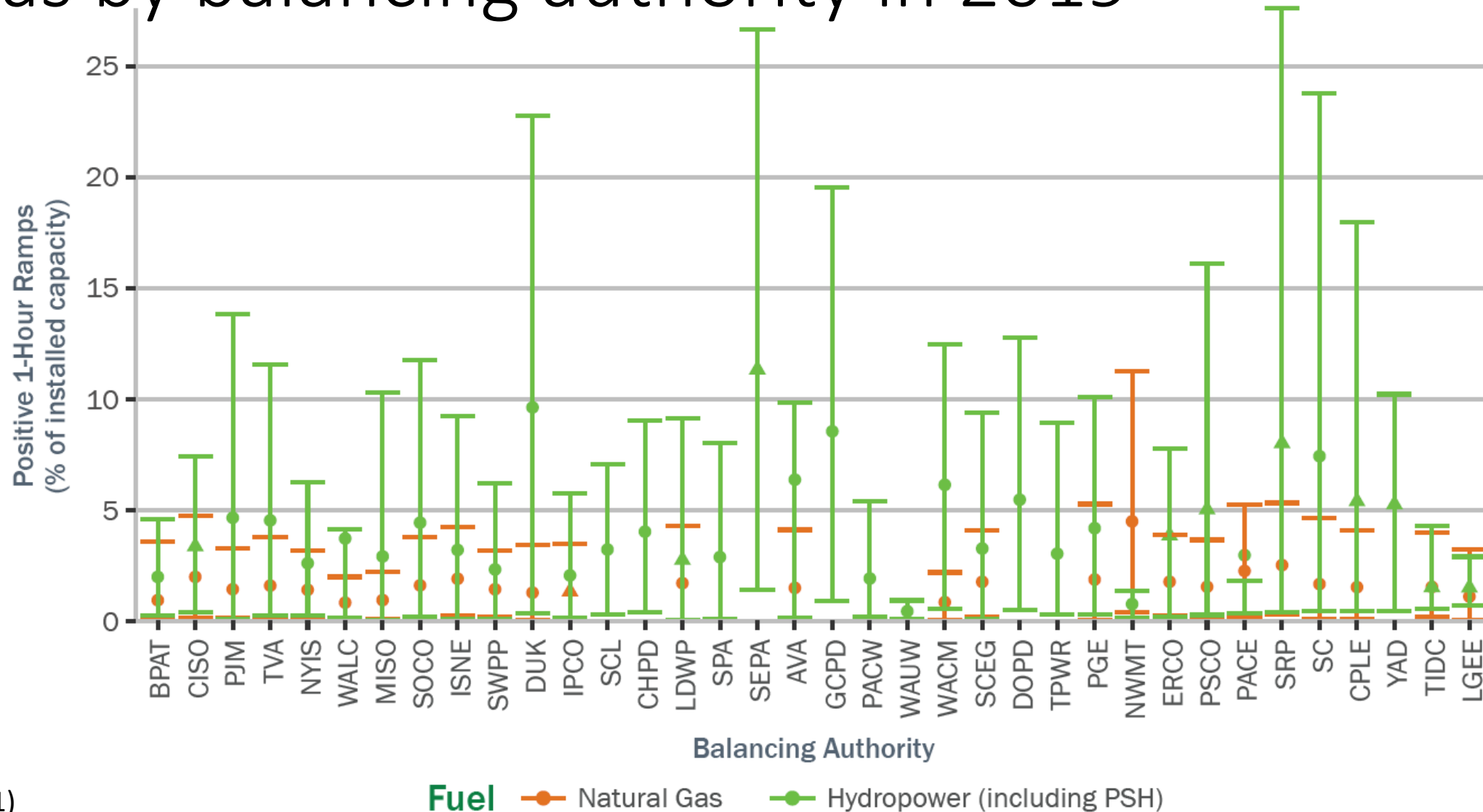
Challenges to overcome

- Joint/regional planning
- Shared market rules
- Cooperation:
 - Shared capacity constraints
 - *Energy imbalance market*
 - Transmission investments

Hydropower in the US (79.6 GW + 21.6 GW PSH)



One-hour ramps for hydropower and natural gas by balancing authority in 2019



Thank You

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