

# Electricity Markets

Andrew Leach

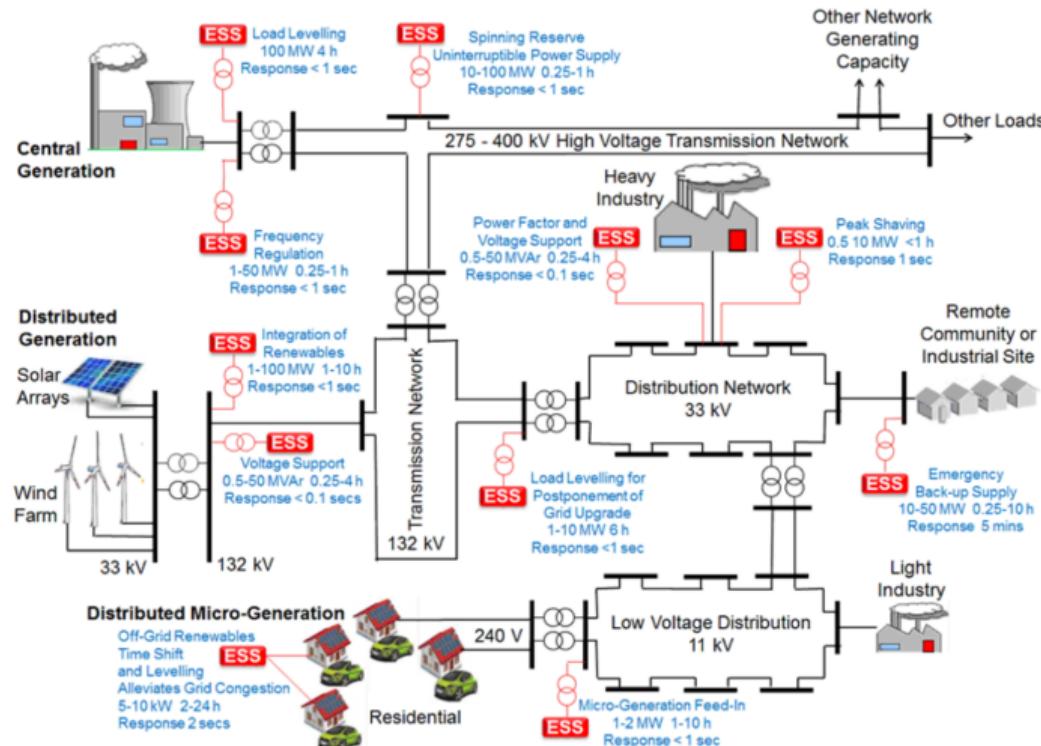
University of Alberta

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# Why aspiring lawyers should care about electricity and what you need to know

- Regulatory complexity:
  - Complex regulation, even in *deregulated* jurisdictions
  - Each part of the market has its own set of regulatory constructs (distribution, transmission, generation, retail)
- New technology means evolving market structures:
  - Electricity is, arguably, changing faster than any other energy market
  - Alberta's electricity market in the midst of a period of market- and regulatory-driven transition
- Economics 101 in action
  - Supply and demand curves determine prices every hour in Alberta's power market
- The next constitutional battleground?
  - Fed/prov issues, environmental policy, section 125 jurisprudence, the oddity that is section 92(10) including the declaratory power, and POGG all come into play!

## Grid Energy Storage Systems (ESS) and Applications



Source: [http://www.mpoweruk.com/grid\\_storage.htm](http://www.mpoweruk.com/grid_storage.htm)

# Market Participants

- Generation
- Transmission
- Distribution
- Ancillary Services
- Load
- Storage
- Microgeneration

# Market Regulation in Alberta

- Generation is a competitive market
- Transmission is regulated on a cost-of-service basis
- Distribution (local wires) is regulated on a cost-of-service basis, but retail (billing) is competitive.
- Ancillary Services is competitive
- Load (i.e. customers) may contract for electricity supply
- Storage (Still a lot TBD)

## Energy units - electricity

- Watts: measure of capacity (instantaneous production, installed capacity, or instantaneous demand)
  - Alberta system demand: 7,200-10,700 MW (megawatts or million watts)
  - Capital Power's Genessee 3 power plant has a nameplate capacity of 450 MW
- Watt hours: measure of energy (production or demand during a given period of time; i.e. flow through)
  - Production over a day, week, month, year
  - A 7.5W LED bulb on all day (24hr) uses 180Wh of electricity (.18kWh)
- Volts: measure of the electrical potential or the ability to convert charge to power (Watts=amps x volts)
  - Transmission lines: 150-765 kV
  - Distribution lines: 13,800 Volts
  - Household wiring: 120-240 Volts

# Energy Prices

- Electricity prices: expressed in power delivered over time
  - Cents/kilowatt-hour (c/kWh)
  - Dollars per megawatt-hour (\$/MWh)
  - Levelized costs of electricity (supply costs) in \$/MWh
- Capacity costs are expressed in a cost per megawatt or cost of capacity
  - Genessee 3 cost approximately \$1.5 million/MW or \$1.50 per watt to build
  - Solar panel prices have declined to now lie under \$1/W of capacity
  - Balance of system costs imply that a solar system costs \$2-3/W of installed capacity
- Other prices matter for electricity markets as well
  - Renewable energy credits (usually prices in \$/MWh)
  - Emissions credits or permits (\$/tonne)
  - Capacity payments (\$/MW)
  - GHG or other emissions permits or credits (\$/tonne)

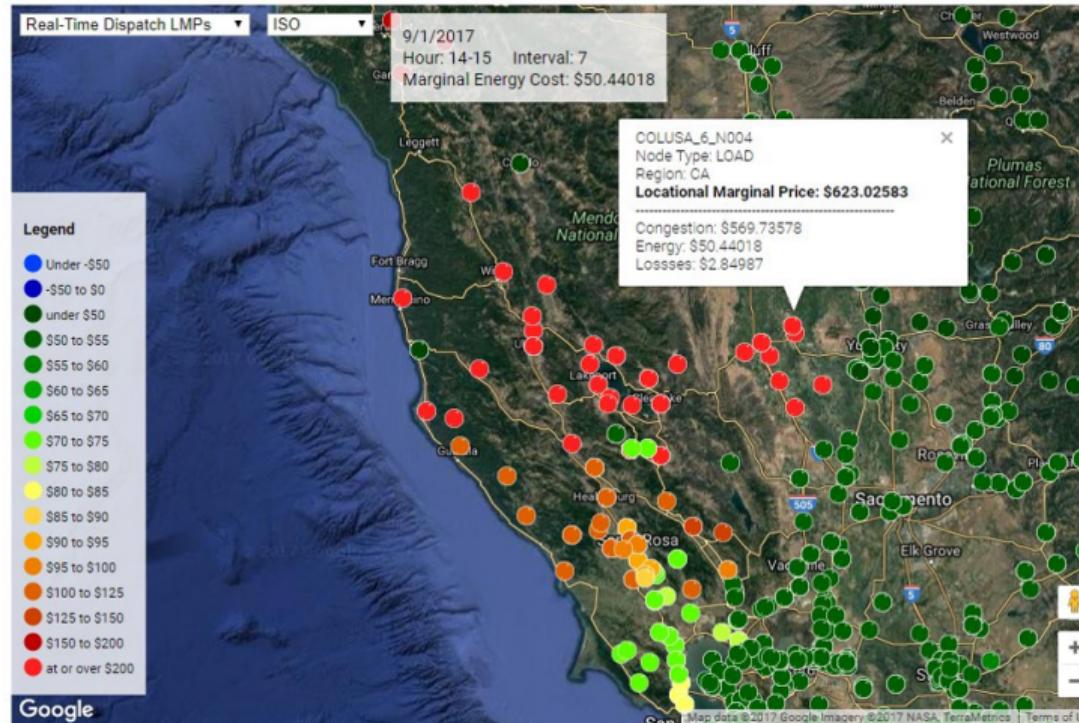
# Regulatory characteristics

- Rate-regulated or state-owned utilities
  - EPCOR (legacy) or BC Hydro
  - PG & E in California
- Competitive markets
  - Energy only markets: ERCOT and Alberta
  - Energy and capacity markets: MISO, PJM
  - Real-time vs day-ahead prices: PJM and others have day-ahead market and then a real-time differences market
  - Many other design characteristic differences between restructured or competitive markets

# Alberta Wholesale Energy Market Design

- Energy-only market
- Real time, spot pricing, no day-ahead market
- Single node
- Capacity market was contemplated, but not pursued
- Transmission
  - Regulated monopoly
  - Congestion free (no nodal pricing)
  - No transmission rights
  - Paid for (mostly) by load (consumers)
- Ancillary services: separate, competitive market for operating reserves, transmission-must-run, load-shed and black start

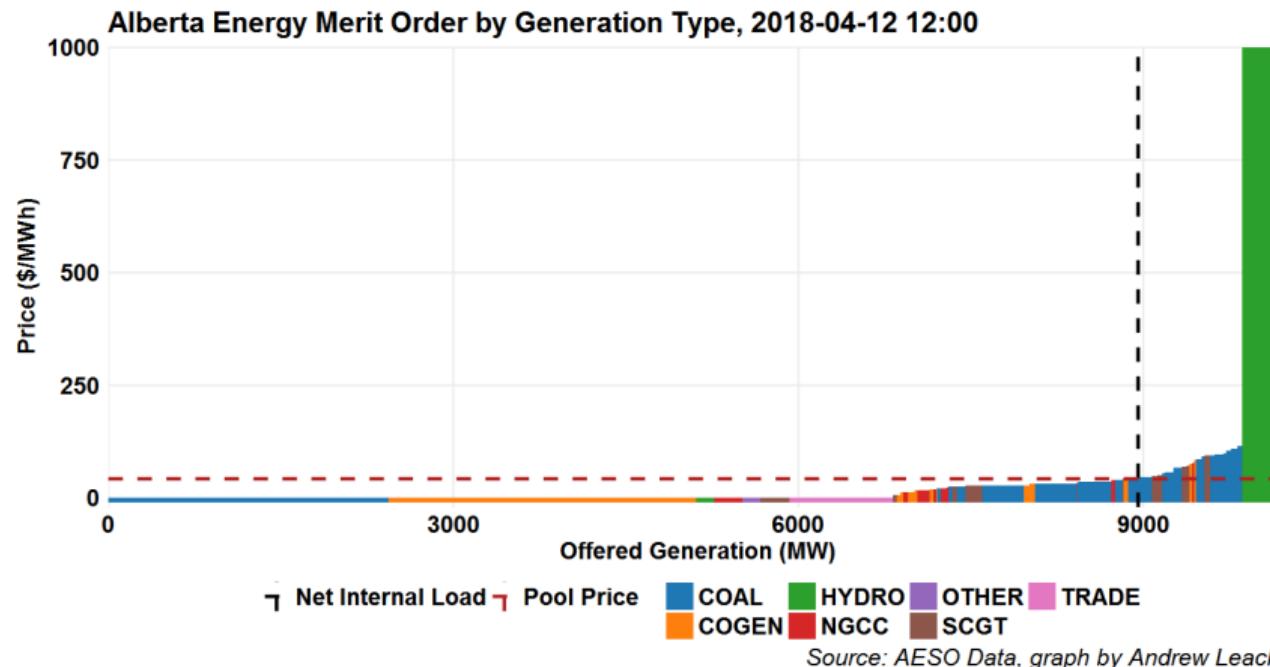
# Nodal Pricing Example



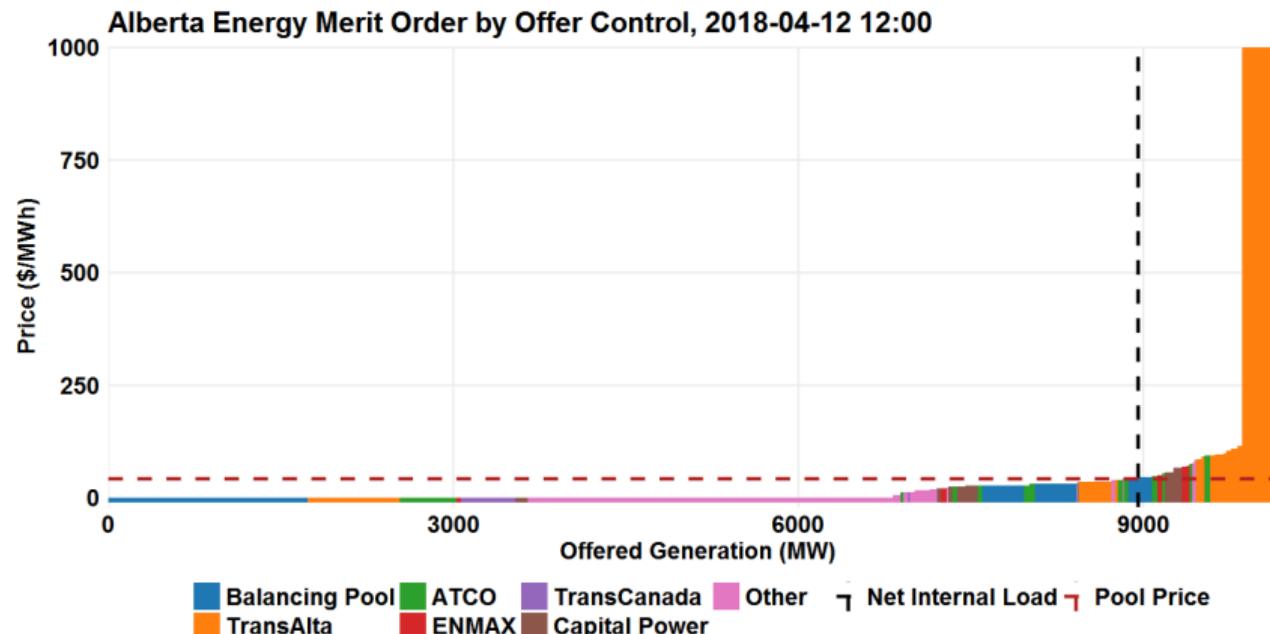
# The Alberta Wholesale Market

- Suppliers place offers of power at particular price[-5em]
- Demand-side bids placed for power with a maximum price
- Supply offers are sorted from low to high
- Demand offers are sorted from high to low
- Marginal price is set at the price which equates supply and demand - economics 101 at work!
- Import and renewable supply is bid-in at \$0, but everyone receives the market price
- Export demand is bid-in at \$999, so they do not set the price directly but pay the marginal price
- Consumer default bid allows AESO to go up merit order to meet observed demand

# The Merit Order

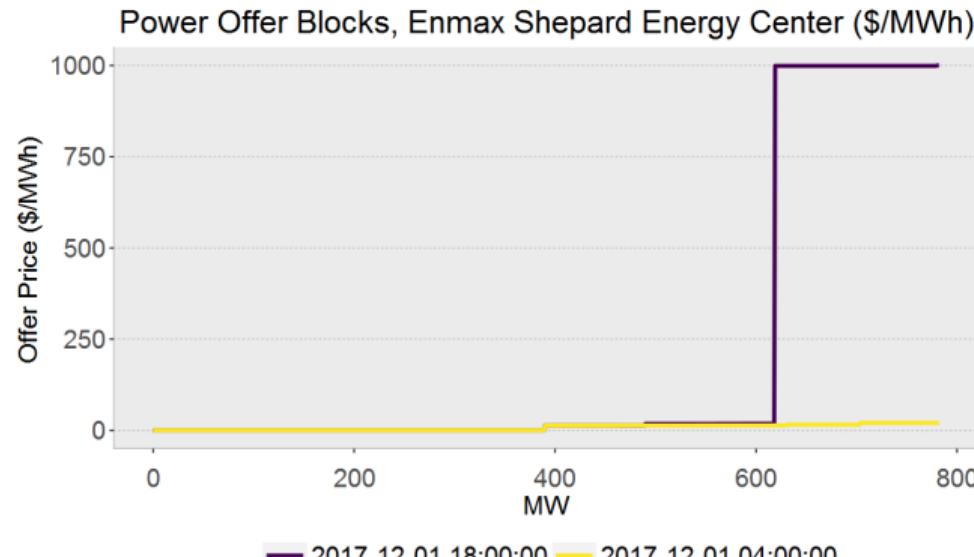


# The Merit Order



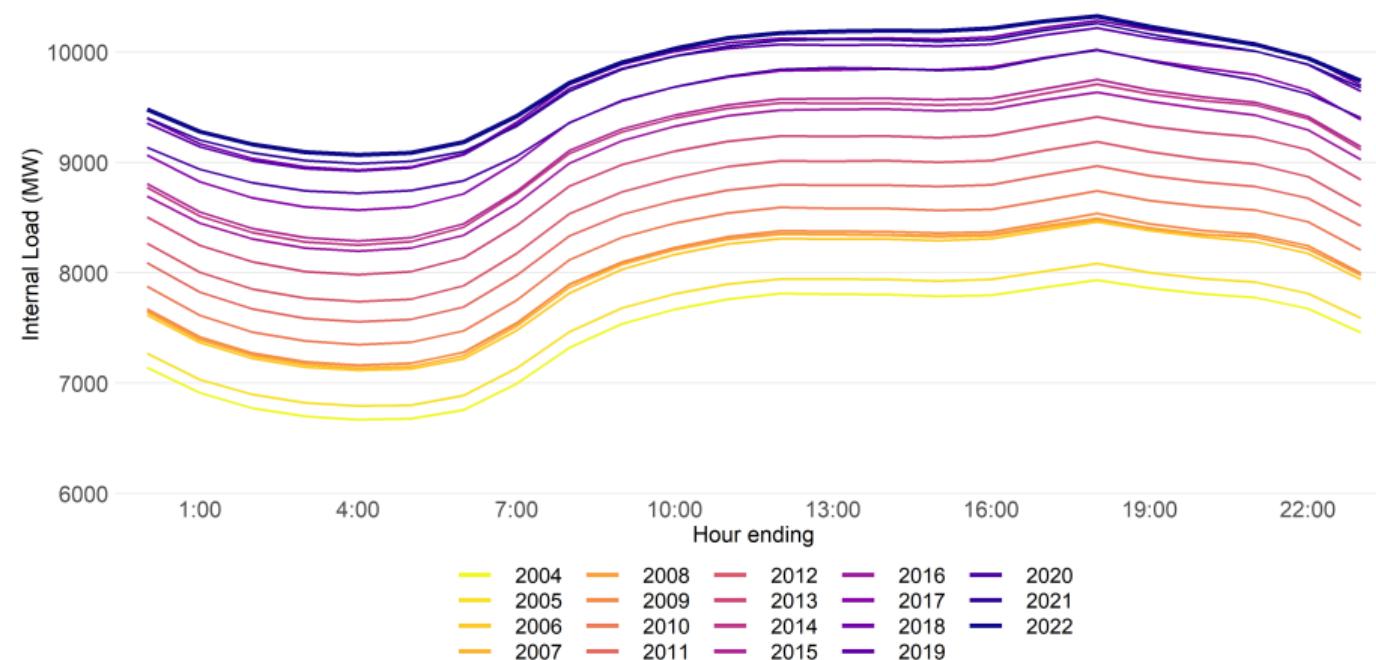
Source: AESO Data, graph by Andrew Leach.

# Offers

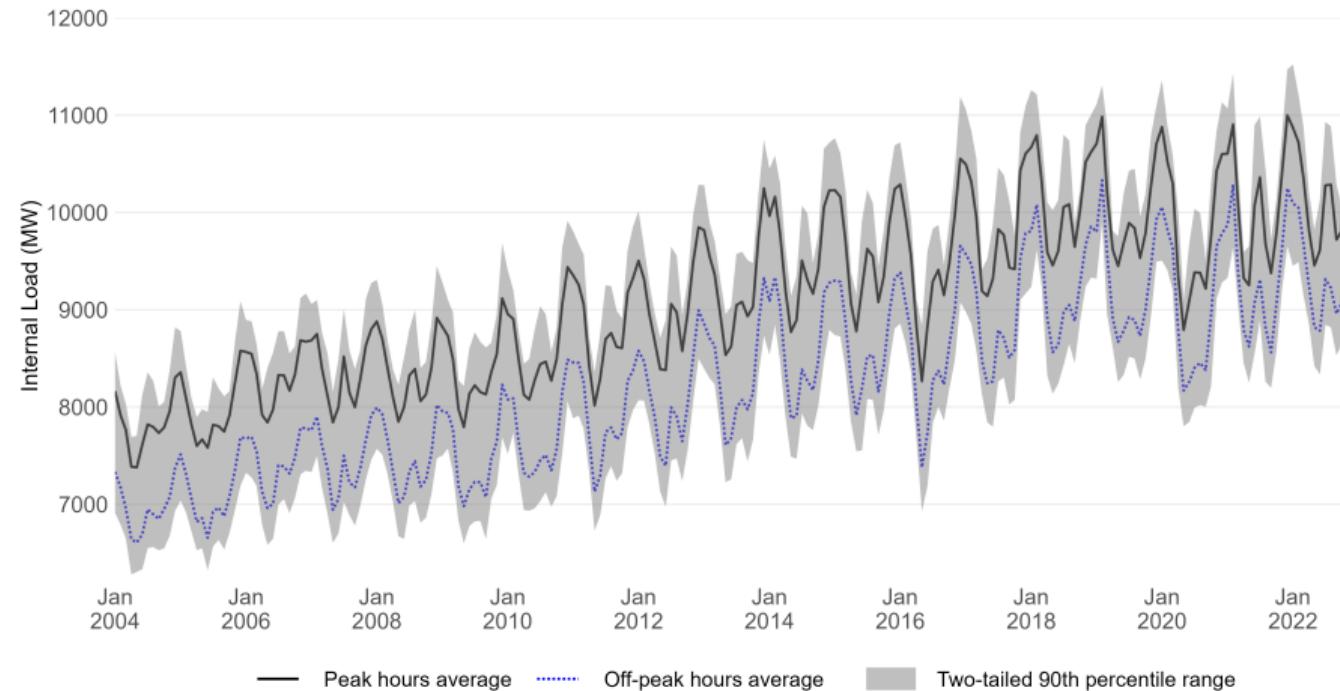


Source: AESO Data, Graph by Andrew Leach

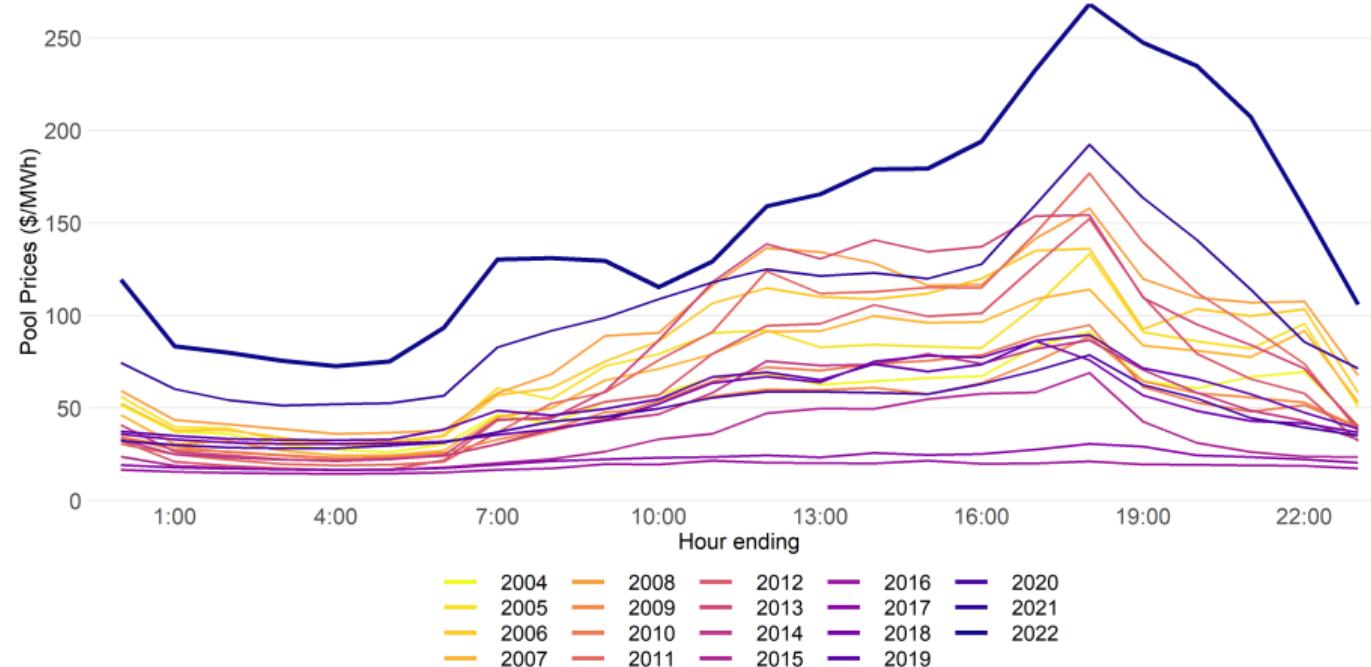
# Hourly Loads



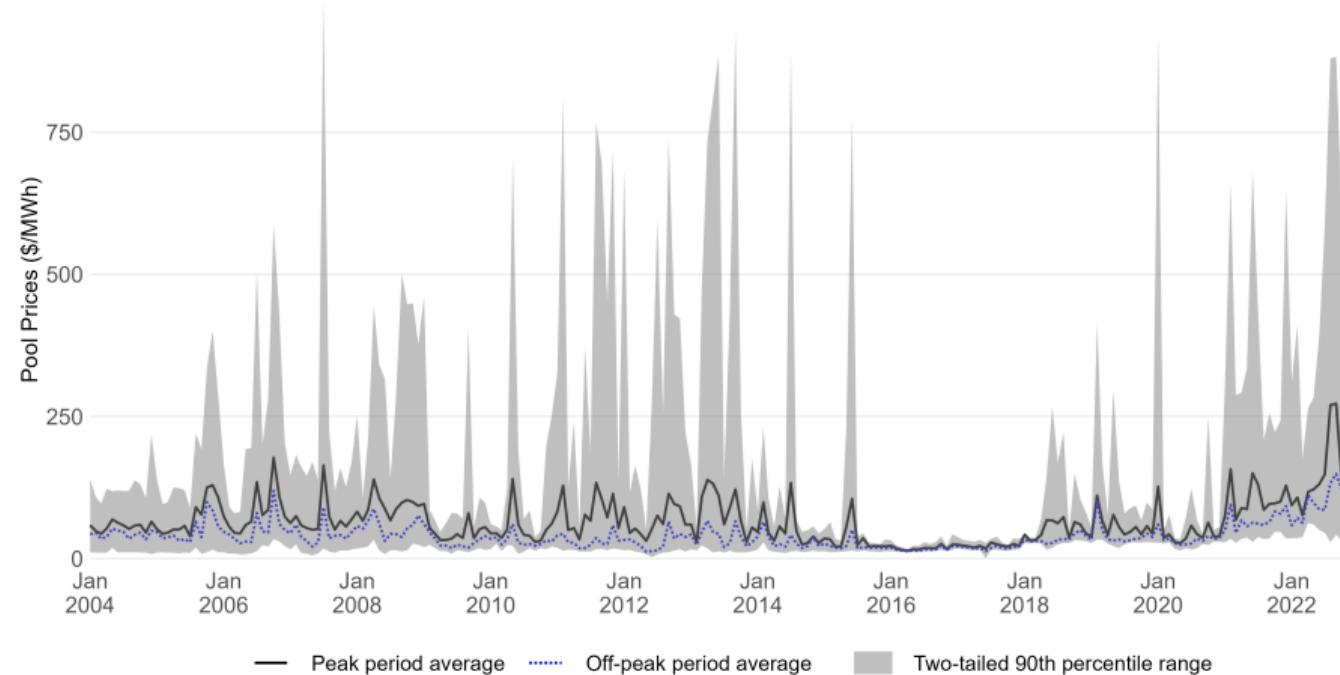
# Peak and Average Loads



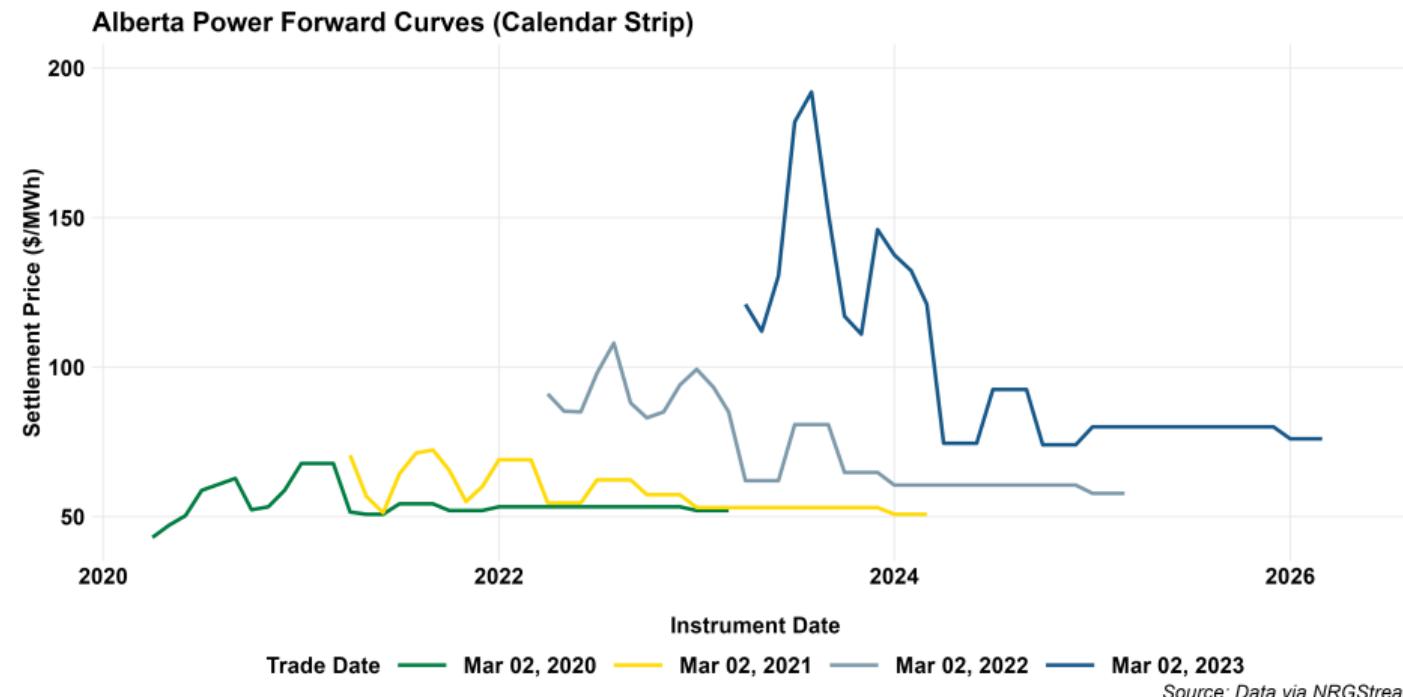
# Hourly Prices



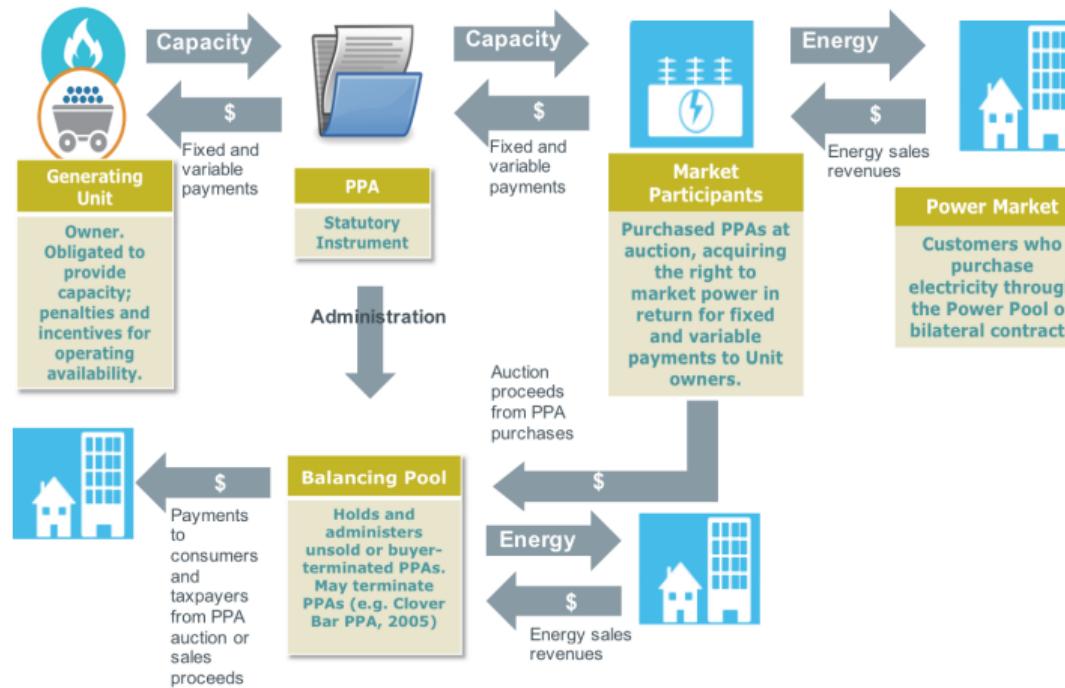
## Prices over time



# Forward Markets



# The Balancing Pool: What on earth does/did it do?



Source: Capital Power

# Alberta's Evolving Electricity Market

- Capacity Market False Start
- Coal Phase Out
- Renewables (the REP Program and now commercial PPAs)
- Carbon Pricing (TIER and the federal GGPPA)

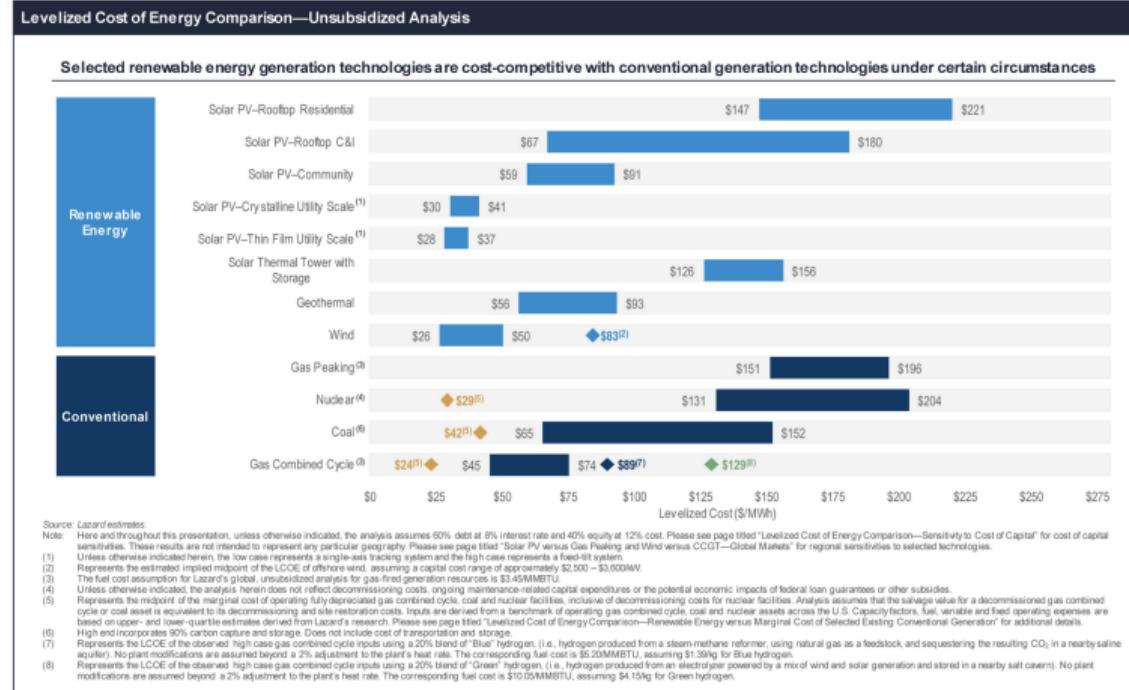
# Costs of New Capacity Additions

**Table 1a. Estimated capacity-weighted<sup>a</sup> levelized cost of electricity (LCOE) and levelized cost of storage (LCOS) for new resources entering service in 2027 (2021 dollars per megawatthour)**

Plant type	Capacity factor (percent)	Levelized capital cost	Levelized fixed O&M <sup>b</sup>	Levelized variable cost	Levelized transmission cost	Total system LCOE or LCOS	Levelized tax credit <sup>c</sup>	Total LCOE or LCOS including tax credit
<b>Dispatchable technologies</b>								
Ultra-supercritical coal	NB	NB	NB	NB	NB	NB	NB	NB
Combined cycle	87%	\$8.56	\$1.68	\$25.80	\$1.01	\$37.05	NA	\$37.05
Advanced nuclear	NB	NB	NB	NB	NB	NB	NB	NB
Geothermal	90%	\$21.80	\$15.20	\$1.21	\$1.40	\$39.61	-\$2.18	\$37.43
Biomass	NB	NB	NB	NB	NB	NB	NB	NB
<b>Resource-constrained technologies</b>								
Wind, onshore	43%	\$27.45	\$7.44	\$0.00	\$2.91	\$37.80	NA	\$37.80
Wind, offshore	NB	NB	NB	NB	NB	NB	NB	NB
Solar, standalone <sup>d</sup>	29%	\$26.35	\$6.34	\$0.00	\$3.41	\$36.09	-\$2.64	\$33.46
Solar, hybrid <sup>d,e</sup>	26%	\$39.12	\$15.00	\$0.00	\$4.51	\$58.62	-\$3.91	\$54.71
Hydroelectric <sup>e</sup>	NB	NB	NB	NB	NB	NB	NB	NB
<b>Capacity resource technologies</b>								
Combustion turbine	10%	\$55.55	\$8.37	\$49.93	\$10.00	\$123.84	NA	\$123.84
Battery storage	10%	\$64.74	\$29.64	\$18.92	\$11.54	\$124.84	\$0.00	\$124.84

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2022*

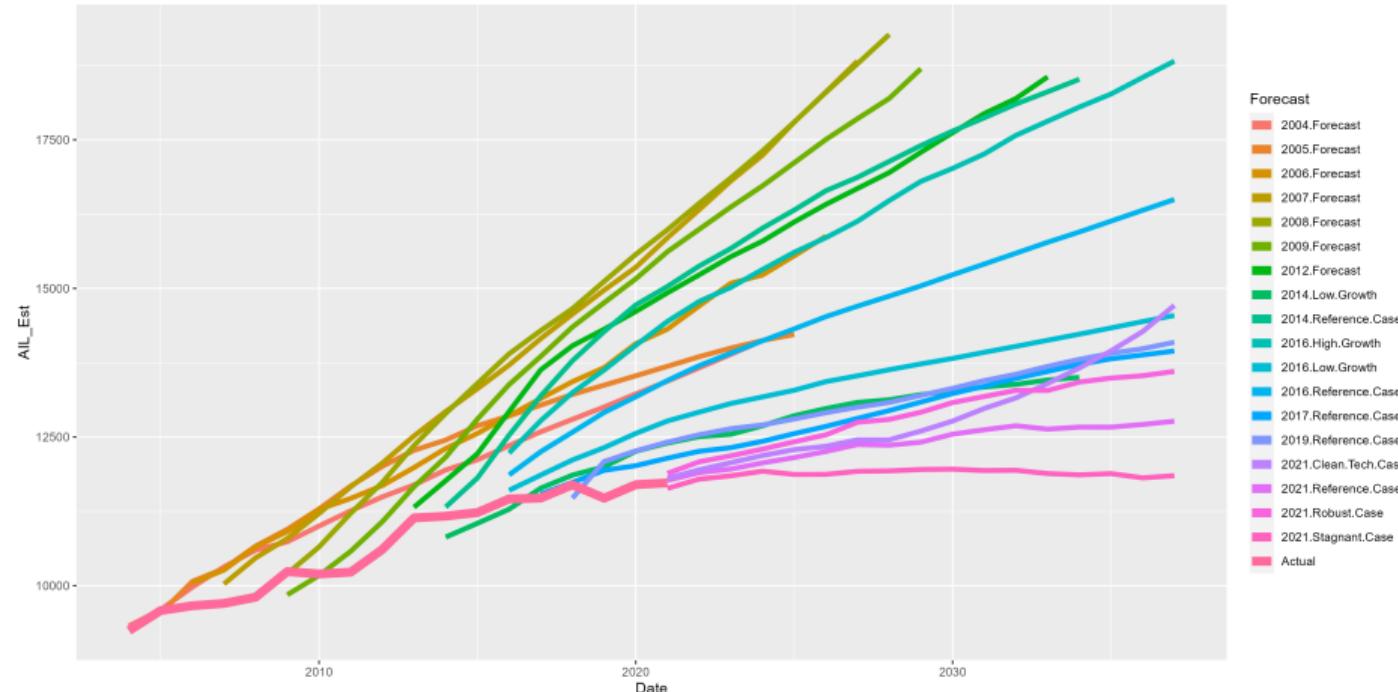
# Costs of New Capacity Additions



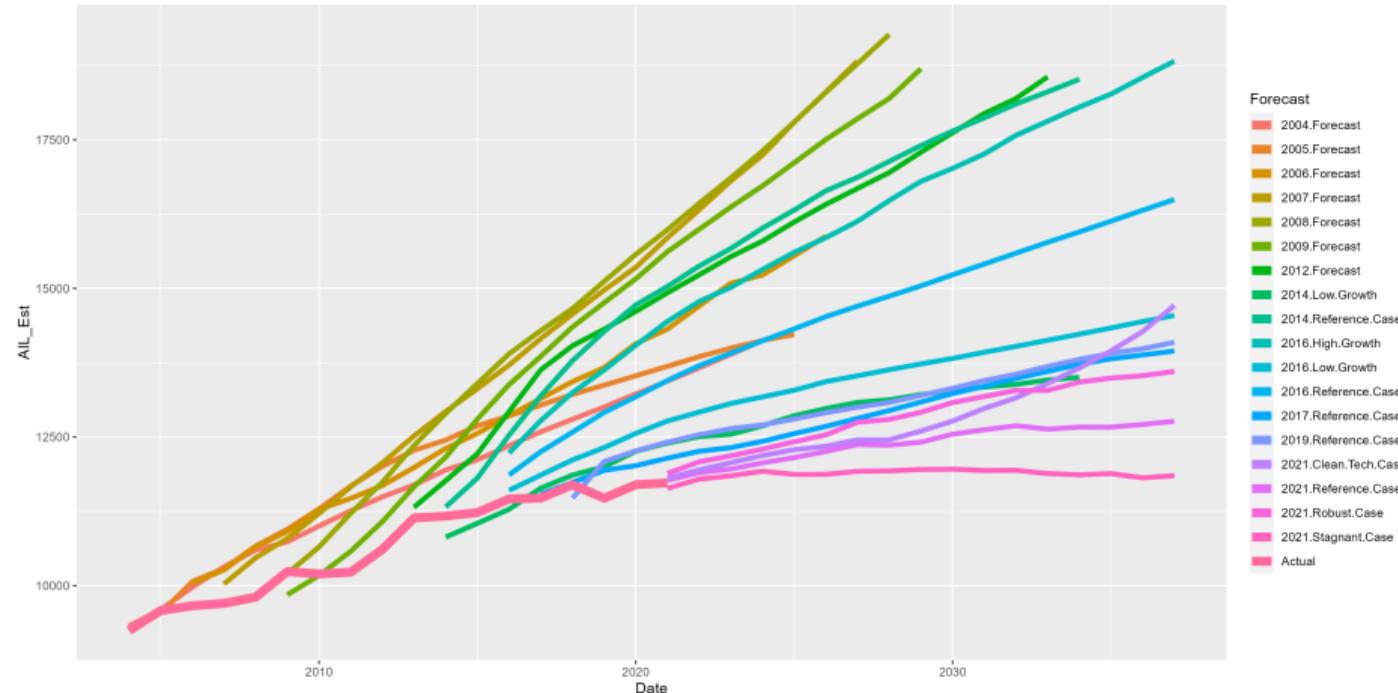
# New Technology

SOLAR			
ASSET	MC	TNG	DCR
BRD1 Burdett (BRD1)	11	8	0
BUR1 Burdett (BUR1)	20	15	0
Brooks Solar (BSC1)	15	7	0
Brooks Solar 1 (BRK1)	13	10	0
Brooks Solar 2 (BRK2)	14	11	0
COL1 Coaldale (COL1)	23	19	0
Claresholm 1 (CLR1)	58	45	0
Claresholm 2 (CLR2)	75	58	0
Conrad 1 (CRD1)	23	11	0
Conrad 2 (CRD2)	18	9	0
East Strathmore Namaka (NMK1)	20	16	0
Hays (HYS1)	23	21	0
Hull (HUL1)	25	0	0
Innisfail (INF1)	22	12	0
Jenner (JER1)	23	20	0
Monarch (MON1)	24	0	0
Strathmore 1 (STR1)	18	14	0
Strathmore 2 (STR2)	23	18	0
Suffield (SUF1)	23	20	0
Travers (TVS1)	465	400	0
Vauxhall (VXH1)	22	17	0
Vulcan (VCN1)	22	1	0
Westfield Yellow Lake (WEF1)	19	15	0
kisikaw-pisim 1 (KKP1)*	7	0	0
kisikaw-pisim 2 (KKP2)*	7	0	0

# New Technology



# New Technology

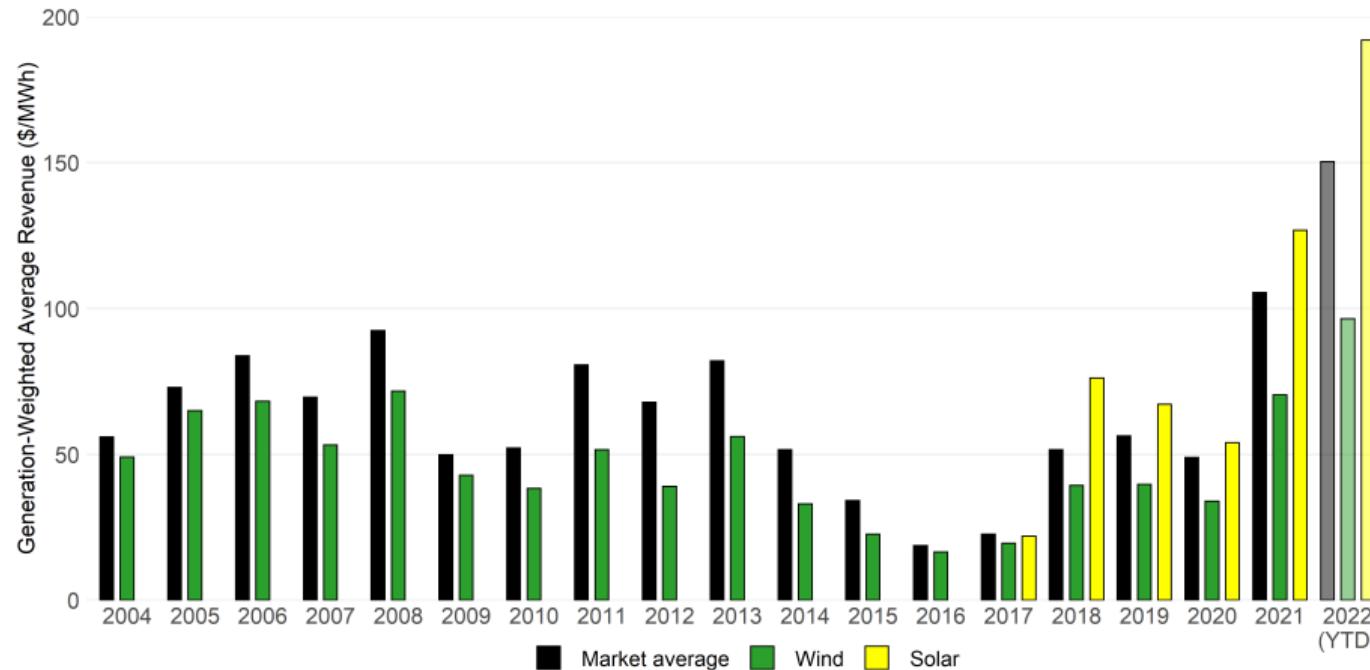


# New Technology

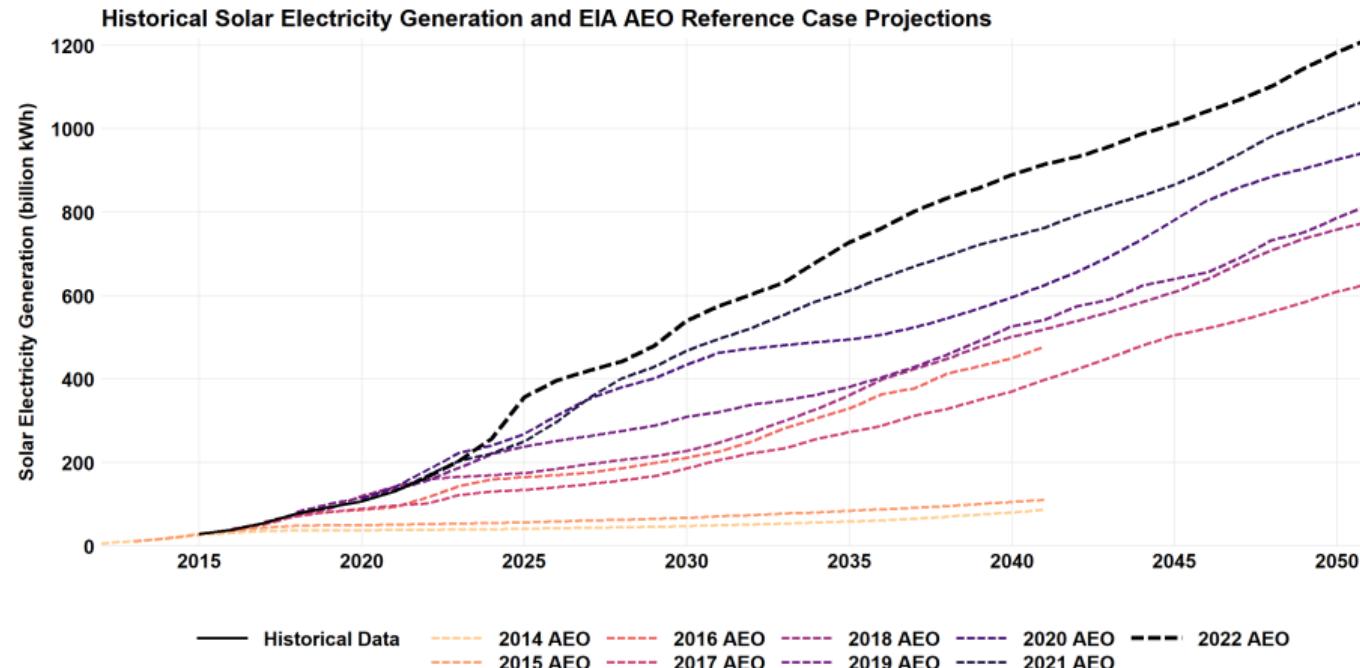
*Table 1: Micro-generation and Small Distributed Generation by Energy Source*

August-2022	Micro-generation		Distributed Generation		Total	
	Number of Sites	Installed Capacity (kW)	Number of Sites	Installed Capacity (kW)	Number of Sites	Installed Capacity (kW)
Biomass	1	1,692	6	13,453	7	15,145
Co-gen/Solar	1	227	0	0	1	227
Gas	5	753	26	72,430	31	73,183
Gas Cogen	6	1,098	5	14,280	11	15,378
Hydro	1	73	4	8,900	5	8,973
Other	21	3,853	2	2,065	23	5,918
Solar	9,302	132,627	3	10,450	9,305	143,077
Solar/Wind	34	284	0	0	34	284
Wind	56	2,065	21	25,375	77	27,440
Total	9,427	142,672	67	146,953	9,494	289,625

# Price Capture by Technology

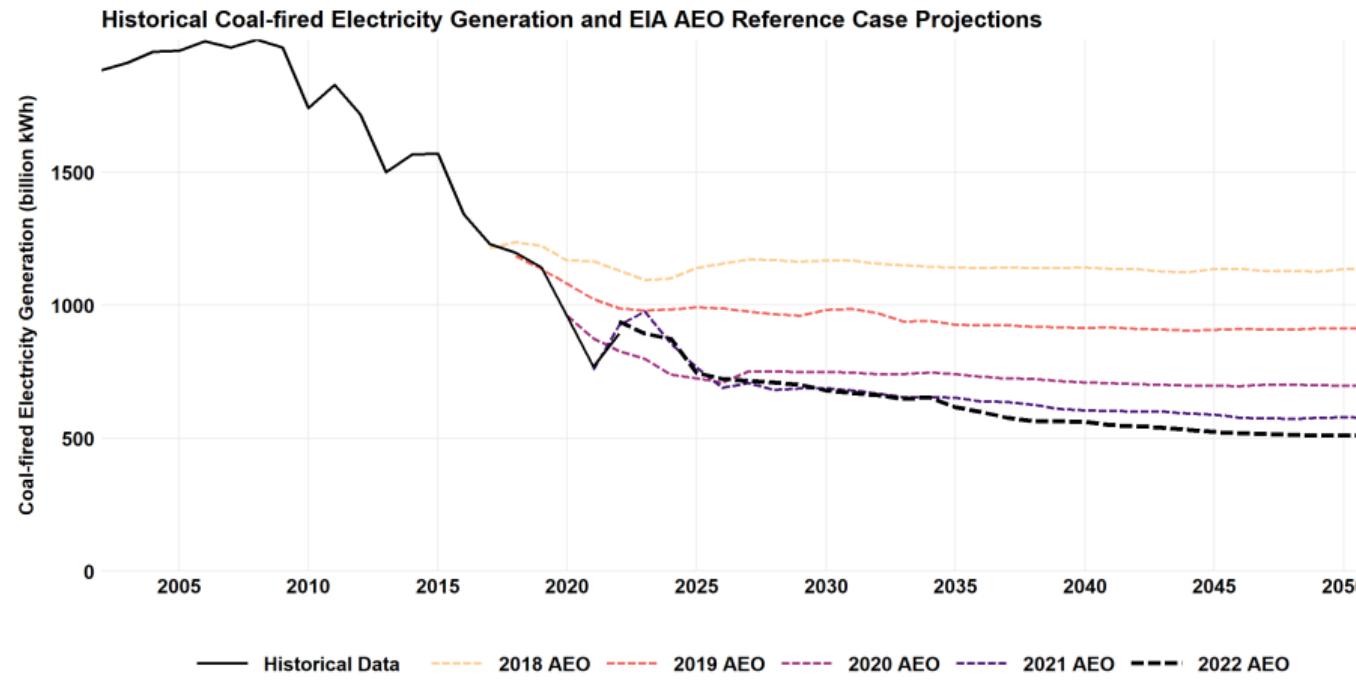


# Evolution of Technology



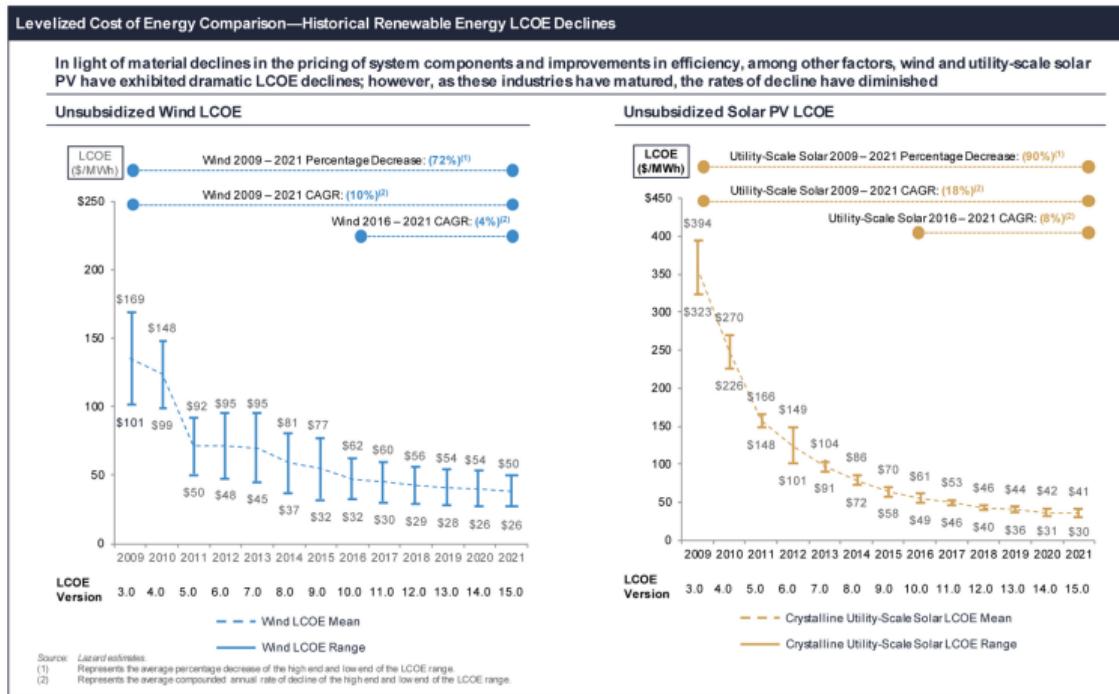
Source: Data via EIA AEO, graph by Andrew Leach.

# Evolution of Technology



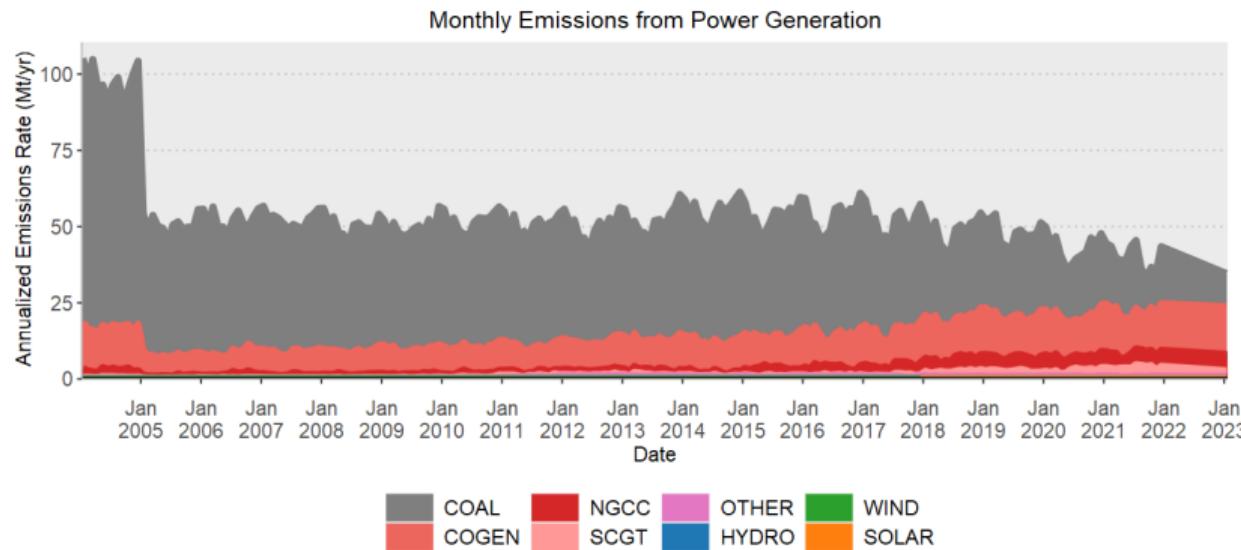
Source: Data via EIA AEO, graph by Andrew Leach.

# Evolution of Technology



Source: Lazard

# GHG Policy and Electricity Supply



## Deeper cuts: the roles of storage and transmission

- Renewables now offer some of the cheapest electricity we have ever seen
- Renewables are not (generally) dispatchable
- Renewables seasonal and/or daily generation patterns don't always match load
- The sun is always shining / the wind is always blowing somewhere

## Deeper cuts: the roles of storage and transmission

- How do we overcome the need for more transmission or storage?
- Who will pay for the assets? How will the assets be paid for the services they provide?
- Renewables, storage, and even transmission can erode their own value proposition - with a lot of storage or transmission in place, it's harder to see the value for storage
- The value of transmission and storage assets may not be captured by the jurisdiction or the regulatory sector in which they are built

## Readings and guest speaker

- Rivers and Dolter paper on decarbonizing Canada's supply
- van de Biezenbos paper on transmission
- Clean Electricity Standard discussion paper