

Electricity Markets

Andrew Leach

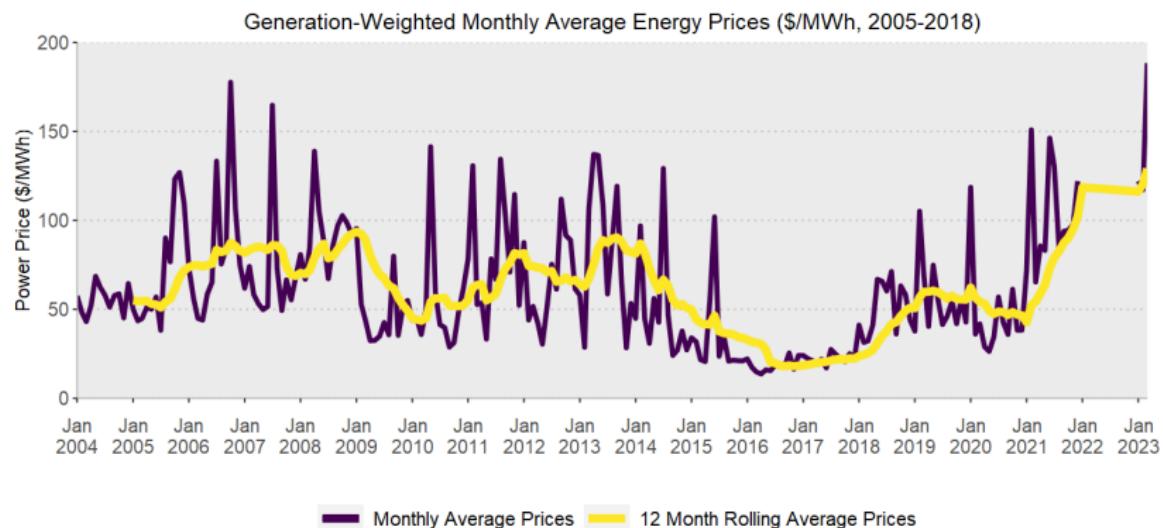
Department of Economics and Faculty of Law, University of Alberta

March 7, 2023

Why should you care about electricity?

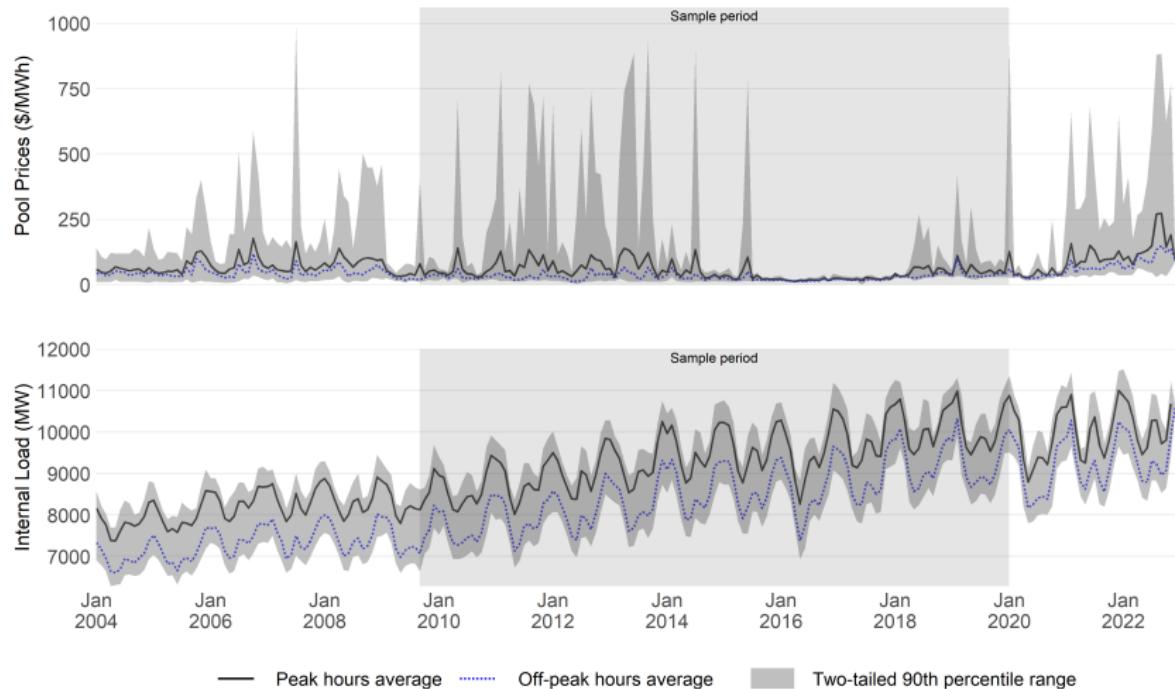
- Price volatility:
 - Electricity prices are an order of magnitude more volatile than oil or gas prices
 - Both supply and demand in Alberta affect us more than global or regional supplies and demands in oil and gas markets
- New technology:
 - Electricity is, arguably, changing faster than any other energy market
 - Alberta's electricity market is entering a period of market- and regulatory-driven transition
- Economics 101 in action
 - Nowhere else will you see supply and demand curves actually mapped out in real time determining prices as clearly as in Alberta's power market

Price Volatility



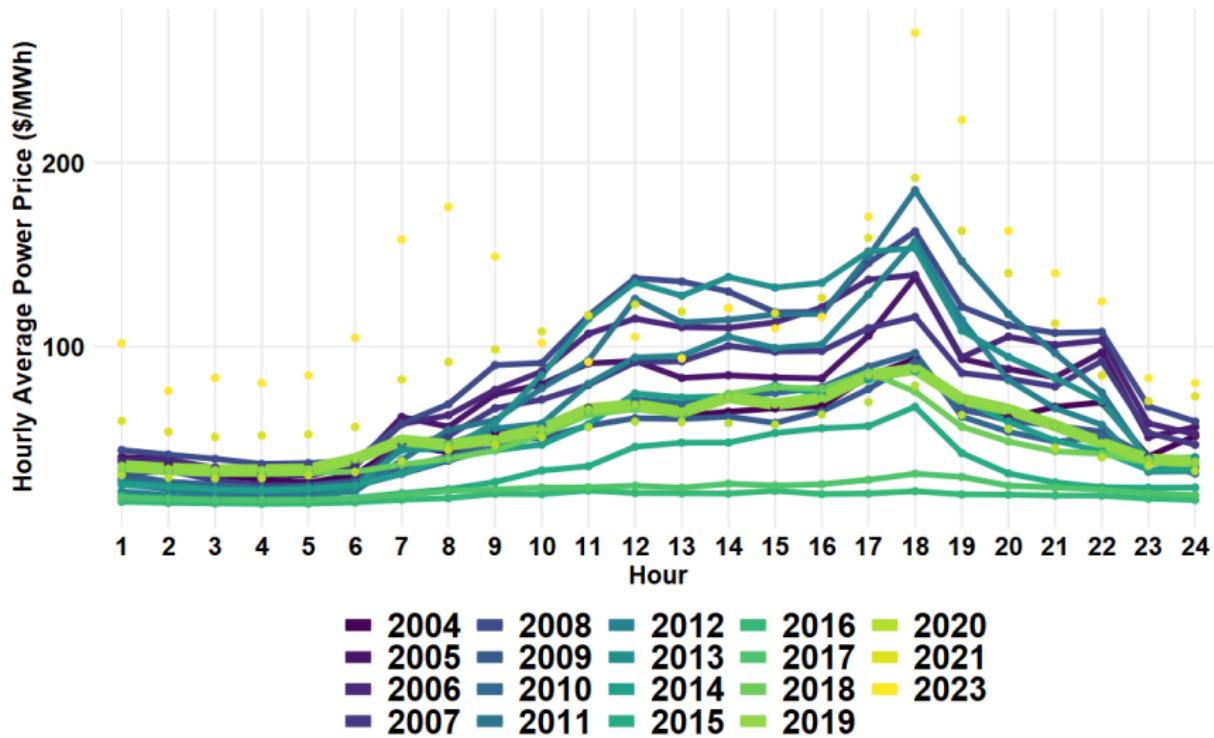
Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

Price Volatility



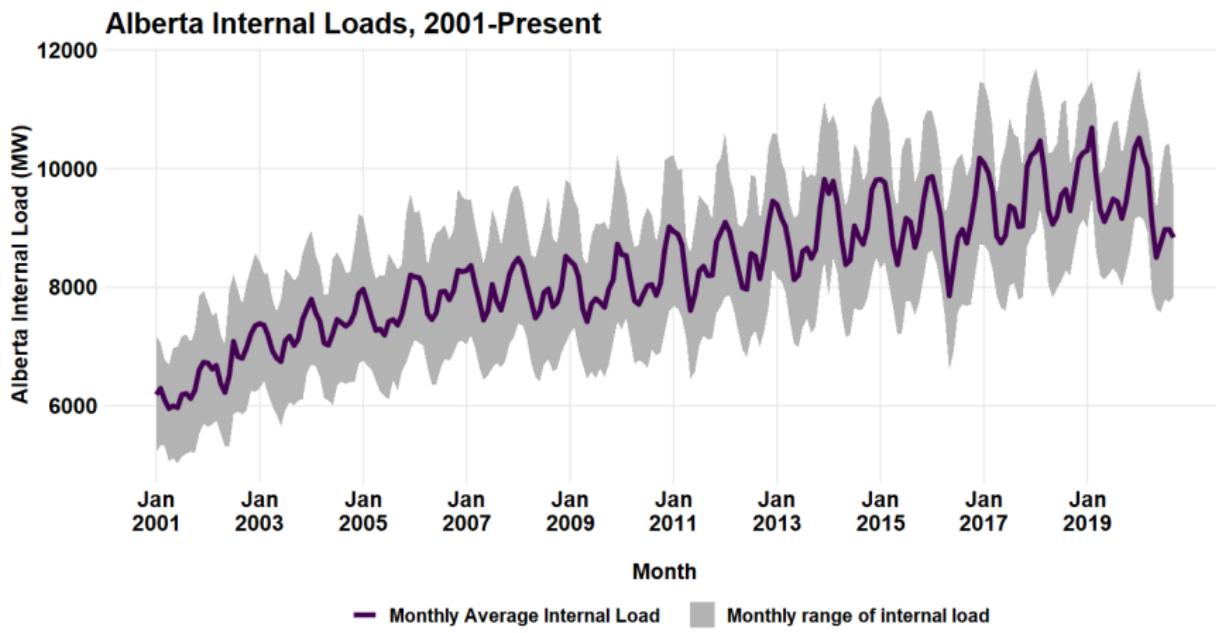
Price Volatility

Generation-Weighted Hourly Average Energy Prices



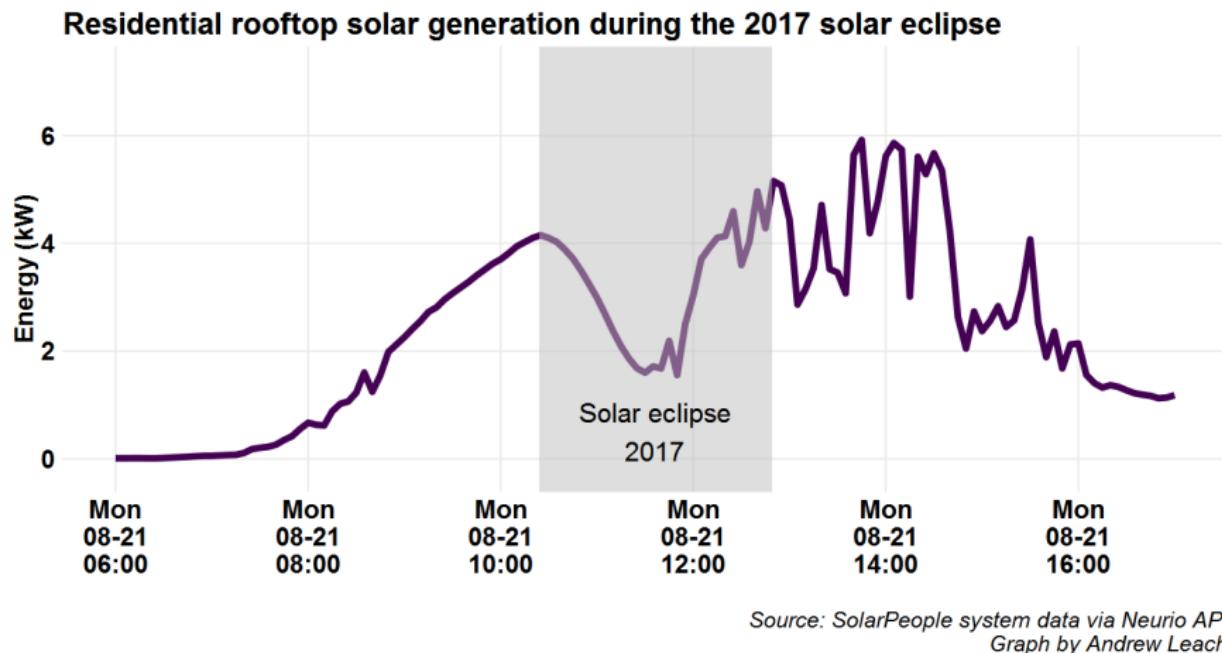
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Growth

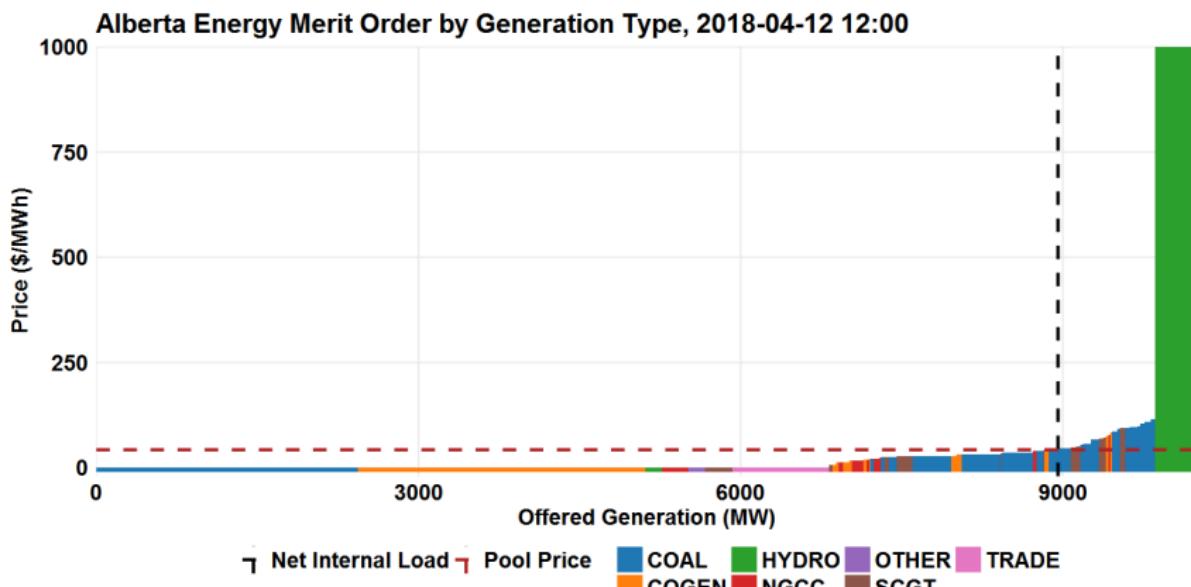


Source: AESO Data, Graph by Andrew Leach

New Technology

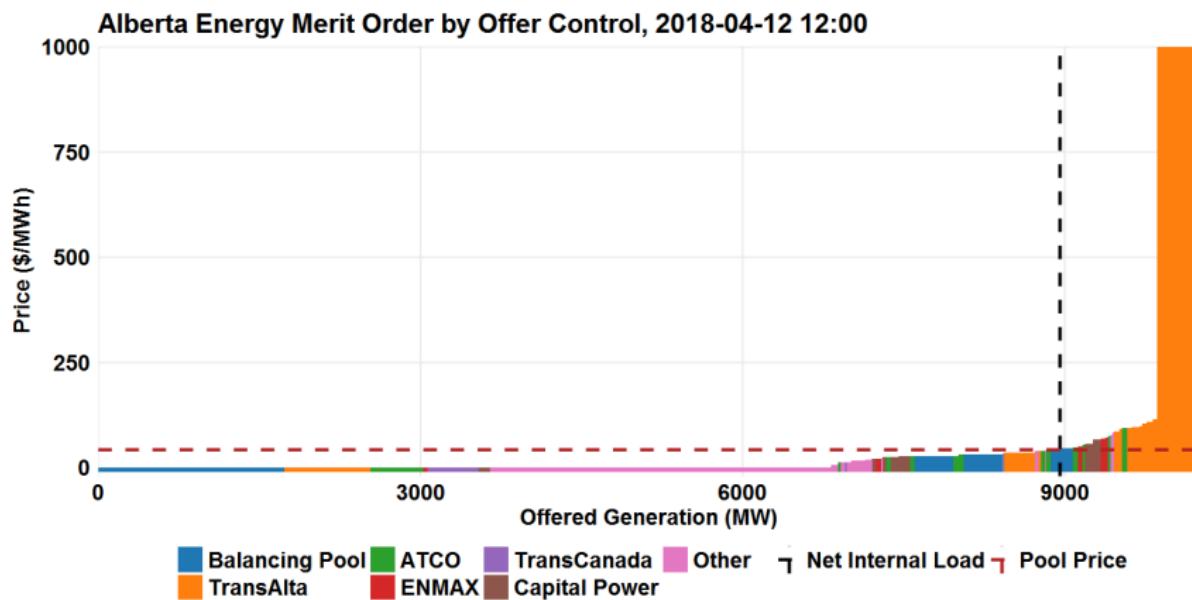


Economics 101



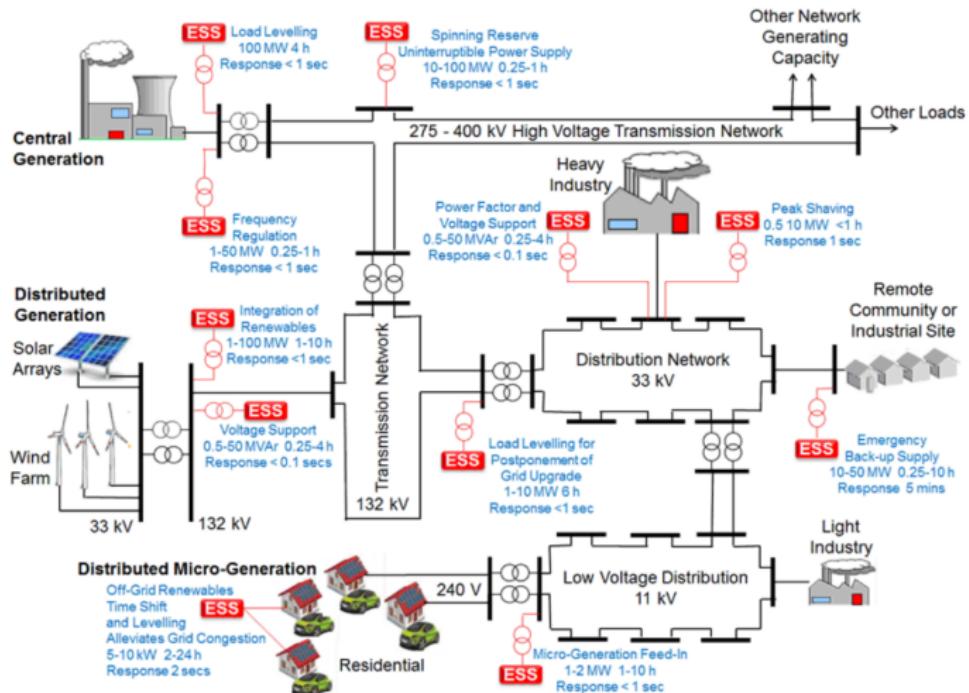
Source: AESO Data, graph by Andrew Leach.

Economics 101



Source: AESO Data, graph by Andrew Leach.

Grid Energy Storage Systems (ESS) and Applications



Source: http://www.mpoweruk.com/grid_storage.htm

Market Participants

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

Energy units - electricity

- Watts: measure of capacity (instantaneous production, installed capacity, or instantaneous demand)
 - Alberta system demand: 7,200-10,700 MW (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
- 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)
 - Air emissions permits or credits (\$/tonne)

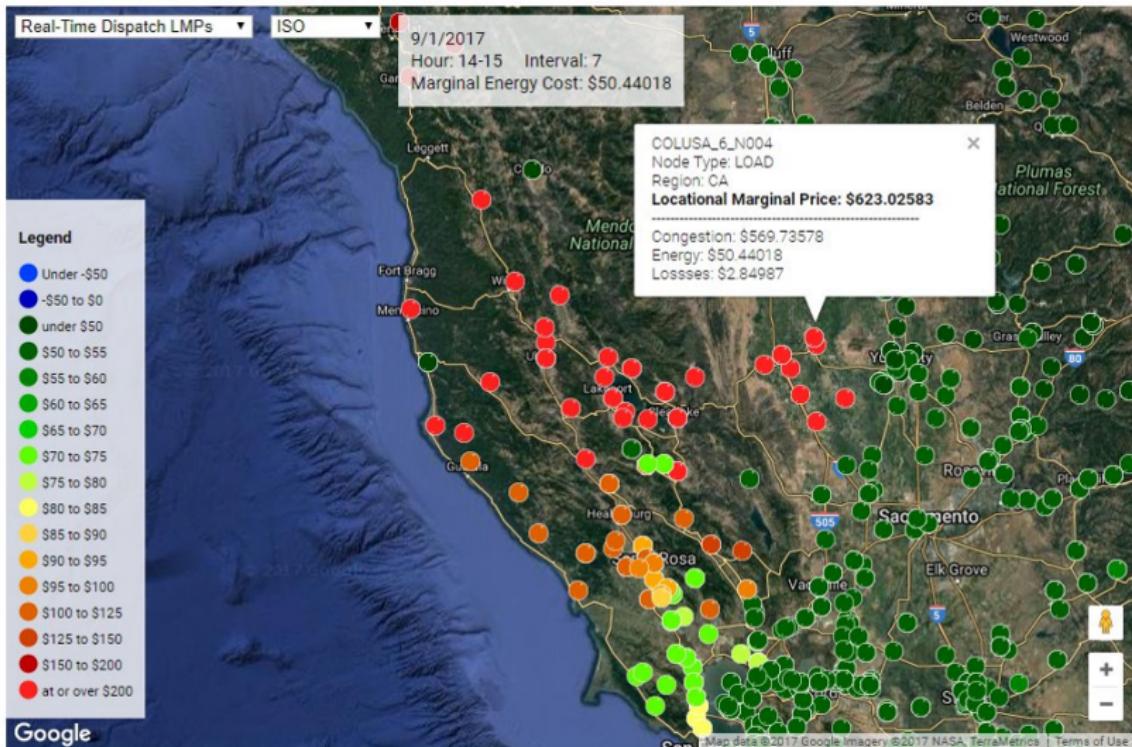
Regulatory characteristics

- Rate-regulated or state-owned utilities
- Competitive markets
 - Energy only markets: ERCOT and Alberta
 - Energy and capacity markets: MISO, PJM, soon-to-be Alberta
 - 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 Market Design

- Energy-only market
- Real time, spot pricing, no day-ahead market
- Single node
- Capacity market to be added in the near future
- Transmission
- Congestion free (no nodal pricing)
- No transmission rights
- Ancillary services: separate, competitive market for operating reserves, transmission-must-run, load-shed and black start

Nodal Pricing Example

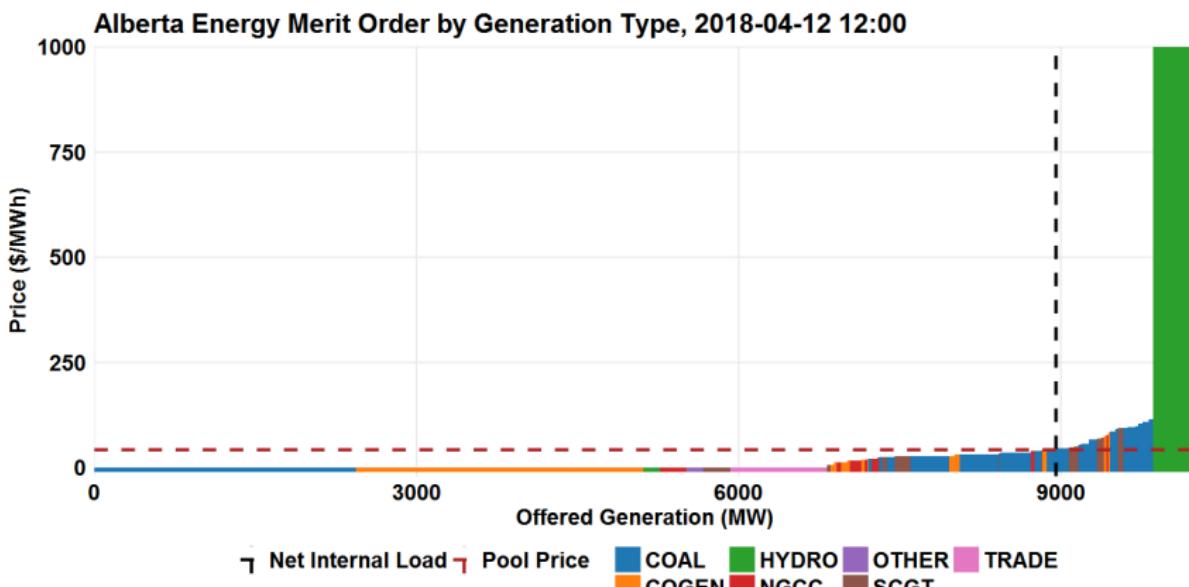


Source: CAISO

The Wholesale Market

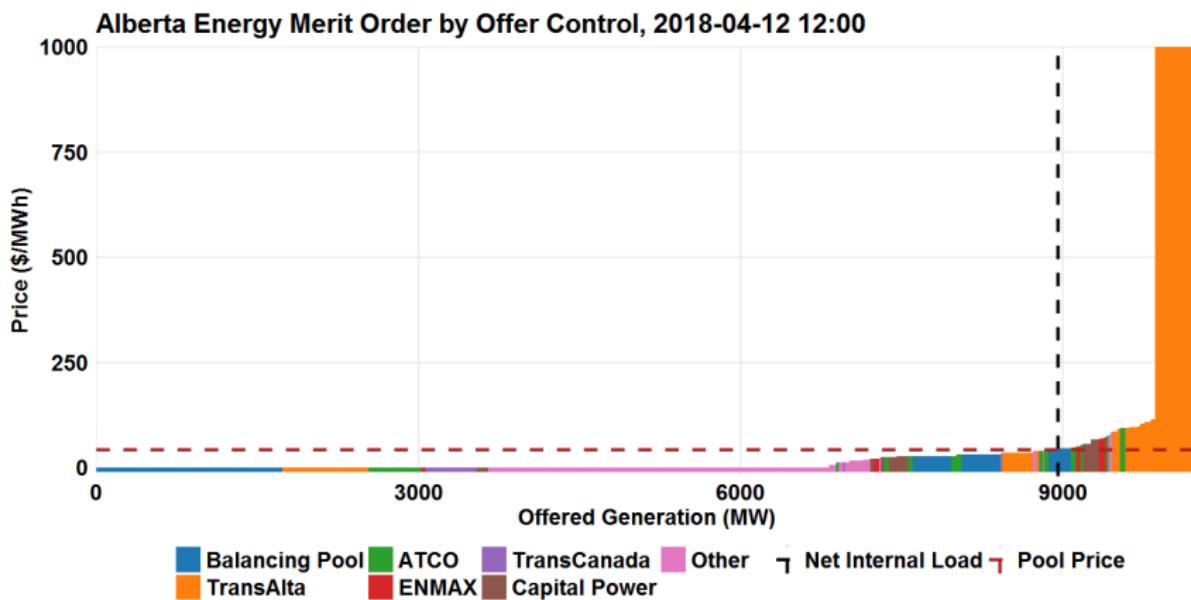
- Suppliers place offers of power at particular price
- Demand-side bids placed for power with a maximum price
- Supply offers are sorted from low to high
- Demand offers are sorted from high to low
- Marginal price is set at the price which equates supply and demand - economics 101 at work!
- Import supply is bid-in at \$0, but receive the marginal price

The Merit Order



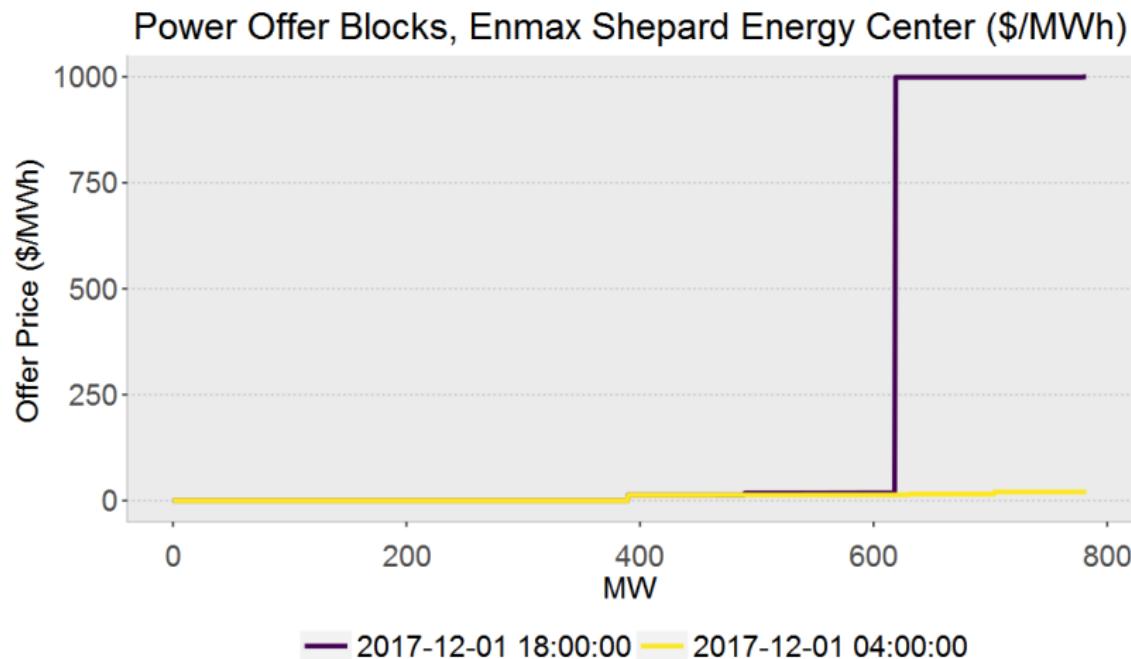
Source: AESO Data, graph by Andrew Leach.

The Merit Order



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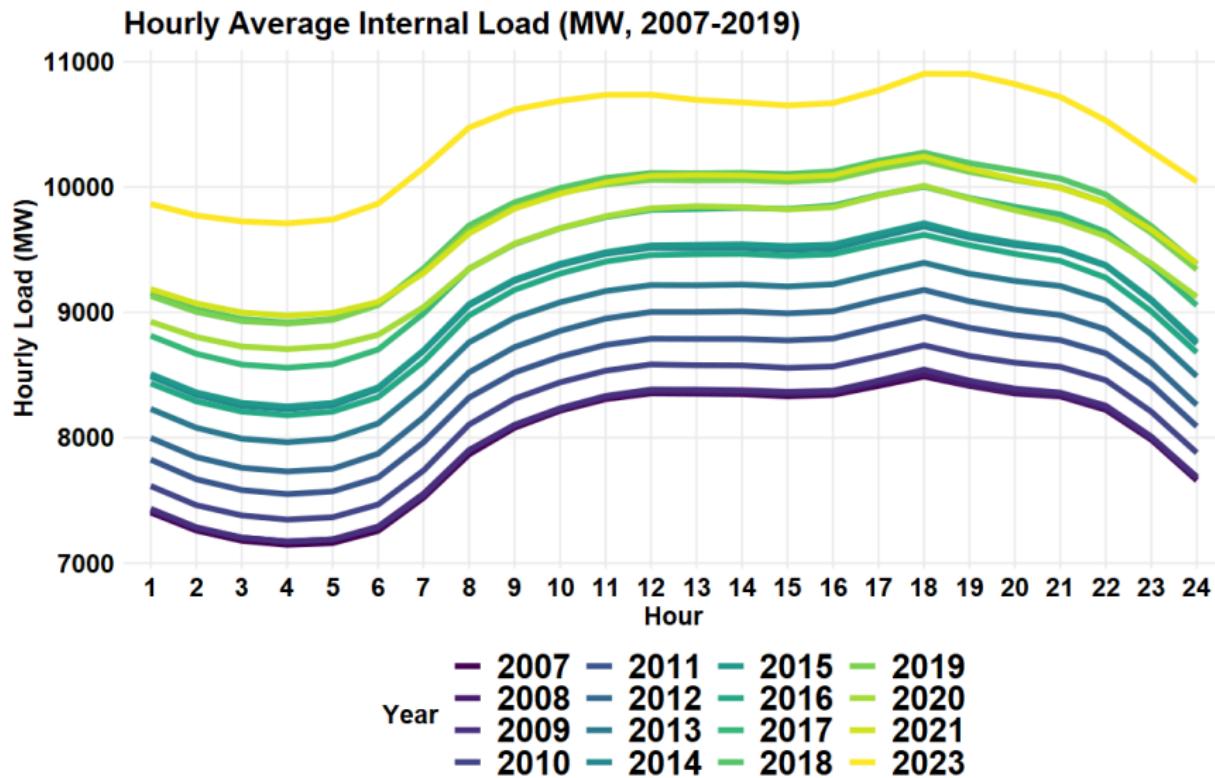
Offers



Source: AESO Data, Graph by Andrew Leach

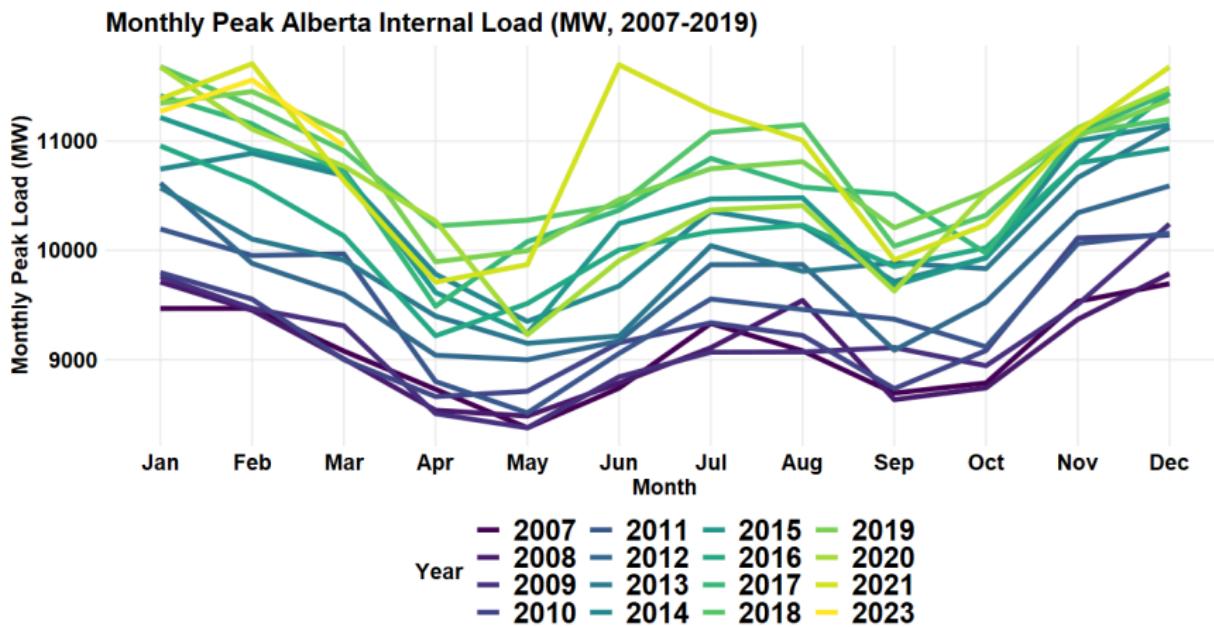
Offers

Hourly Loads



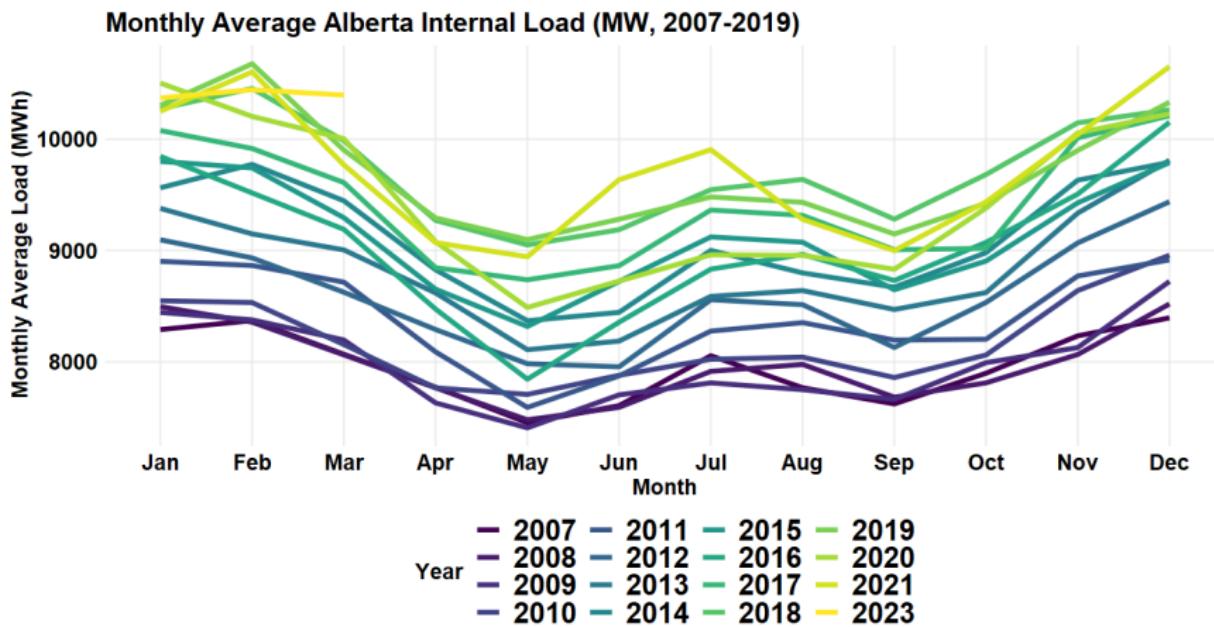
Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

Monthly Peak Loads



Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

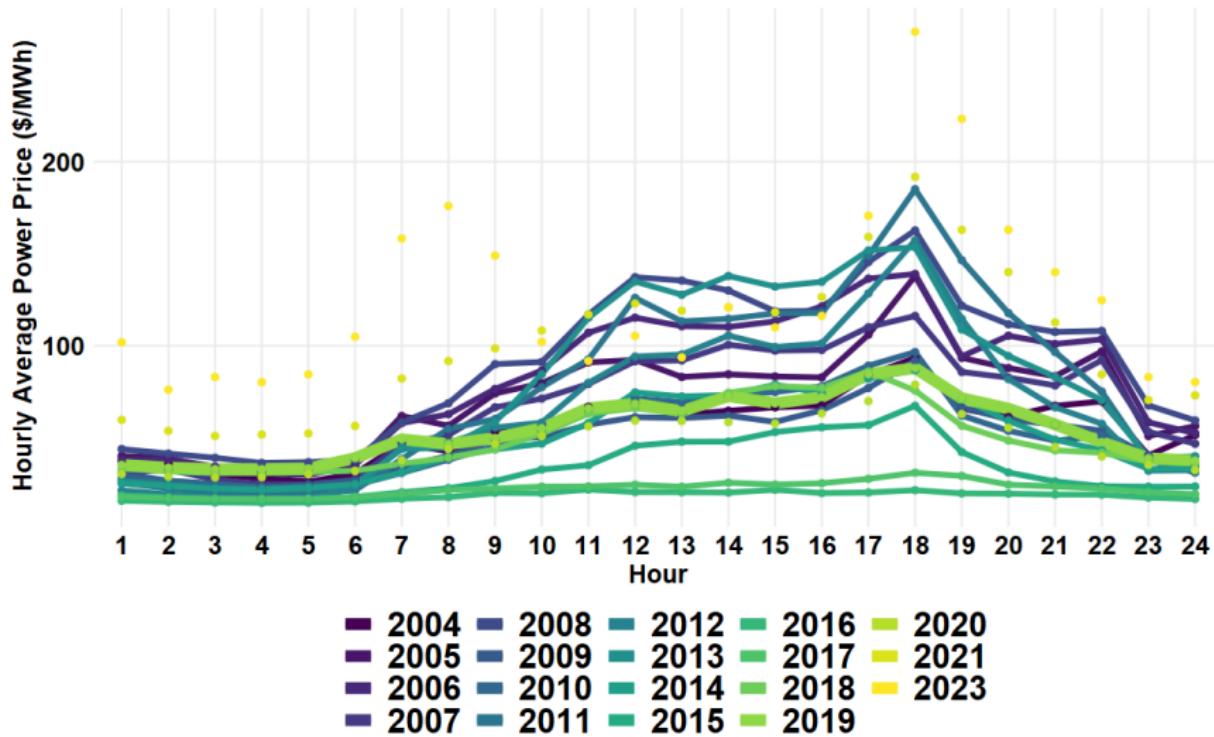
Monthly Average Loads



Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

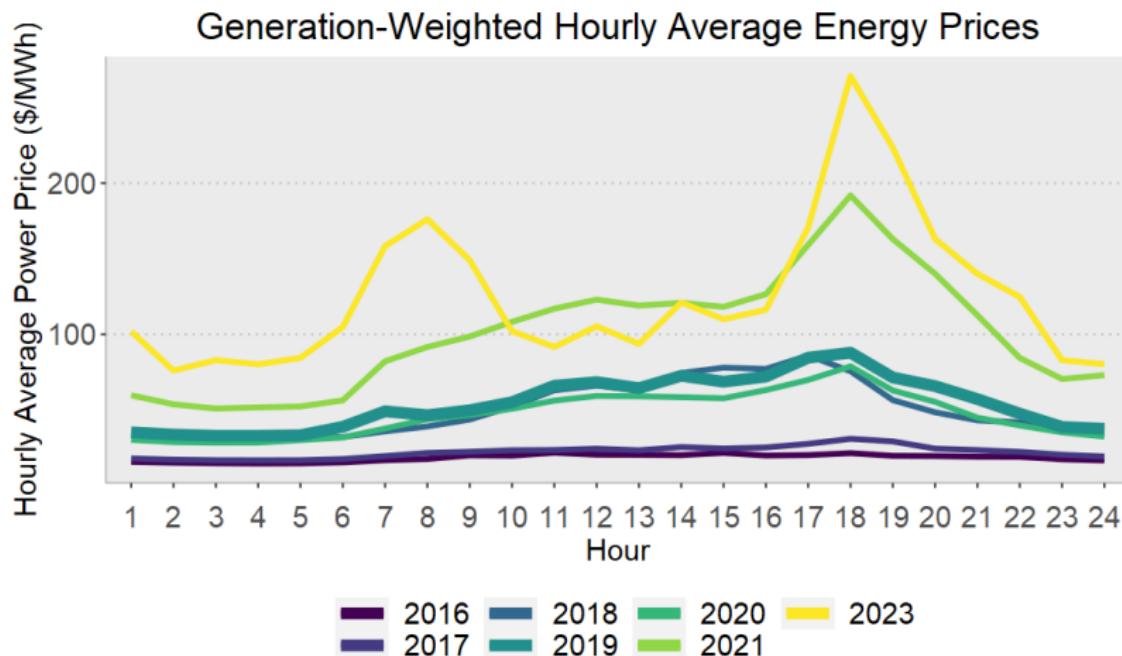
Hourly Prices

Generation-Weighted Hourly Average Energy Prices



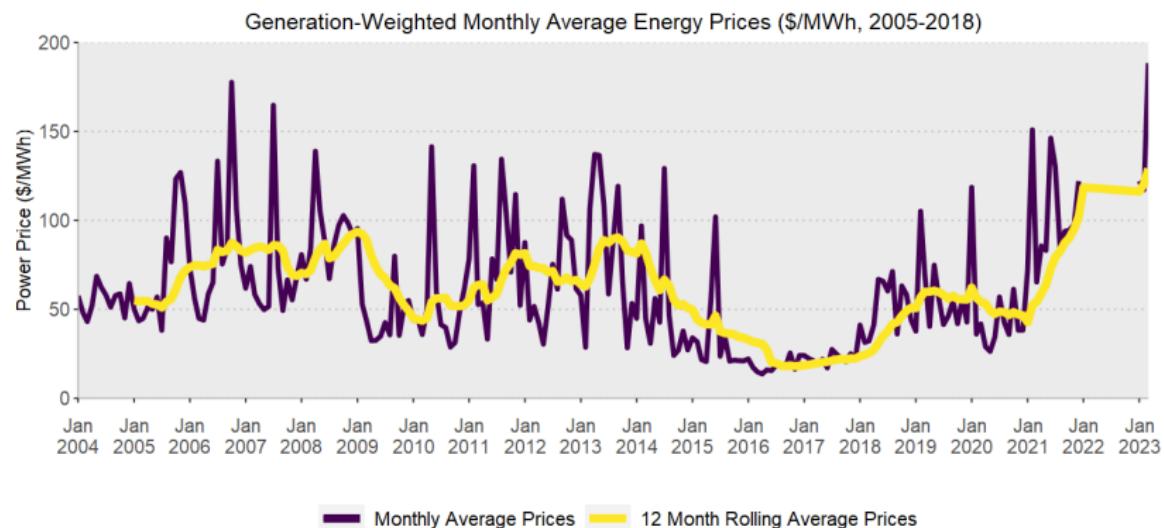
Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

Recent Hourly Prices



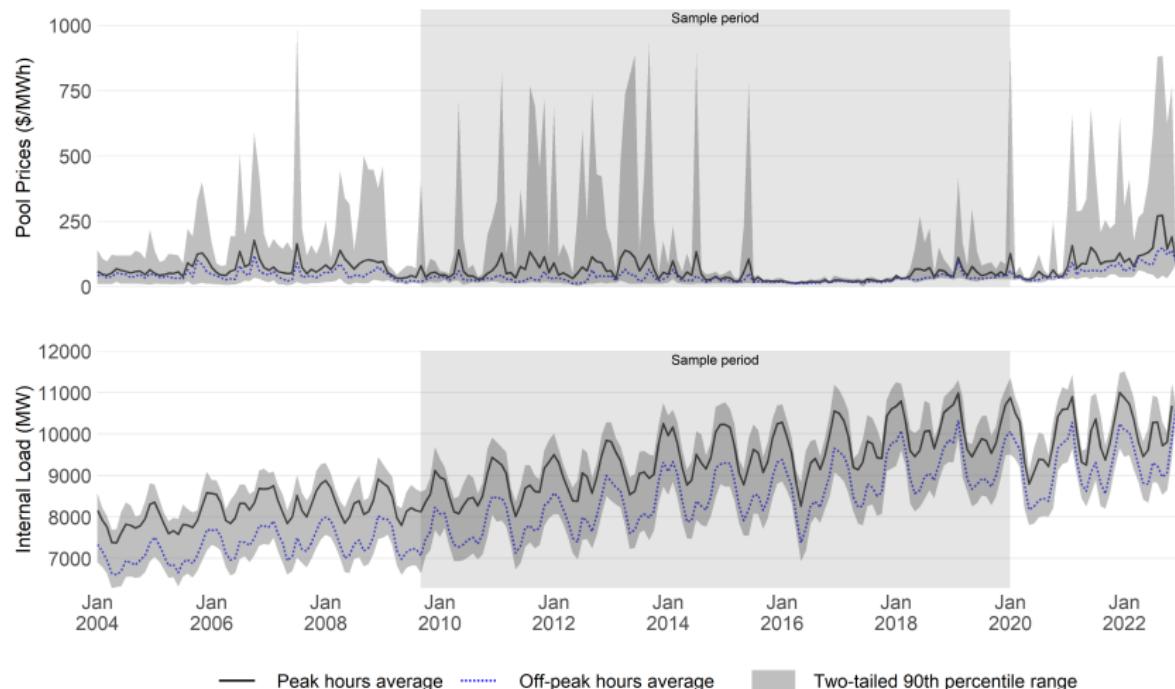
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Prices over time

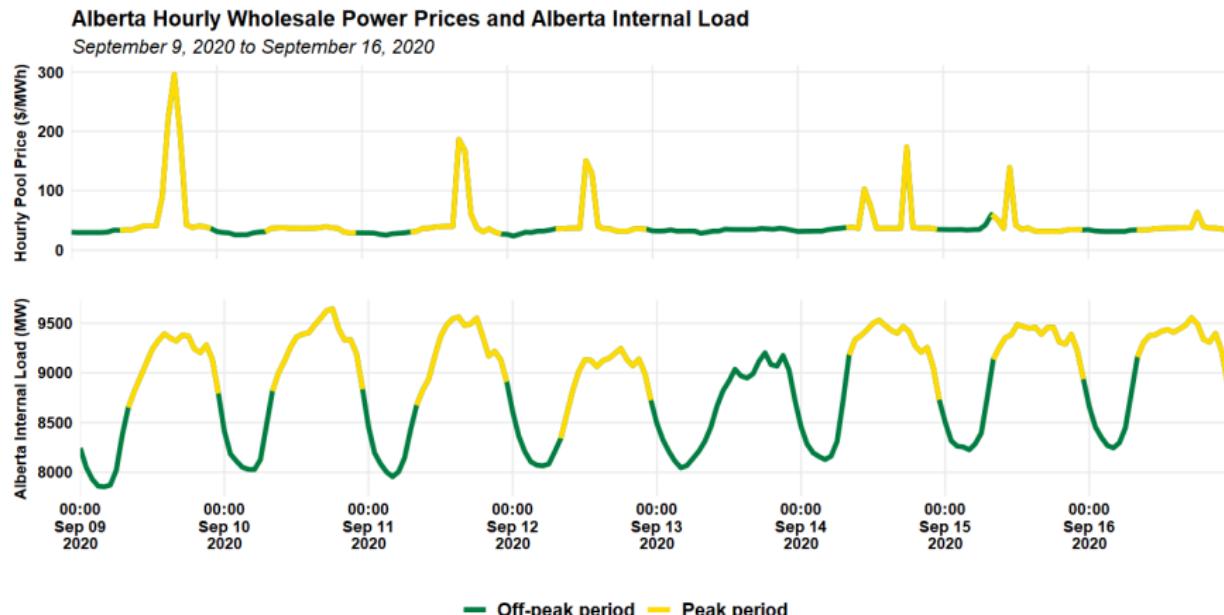


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Prices over time

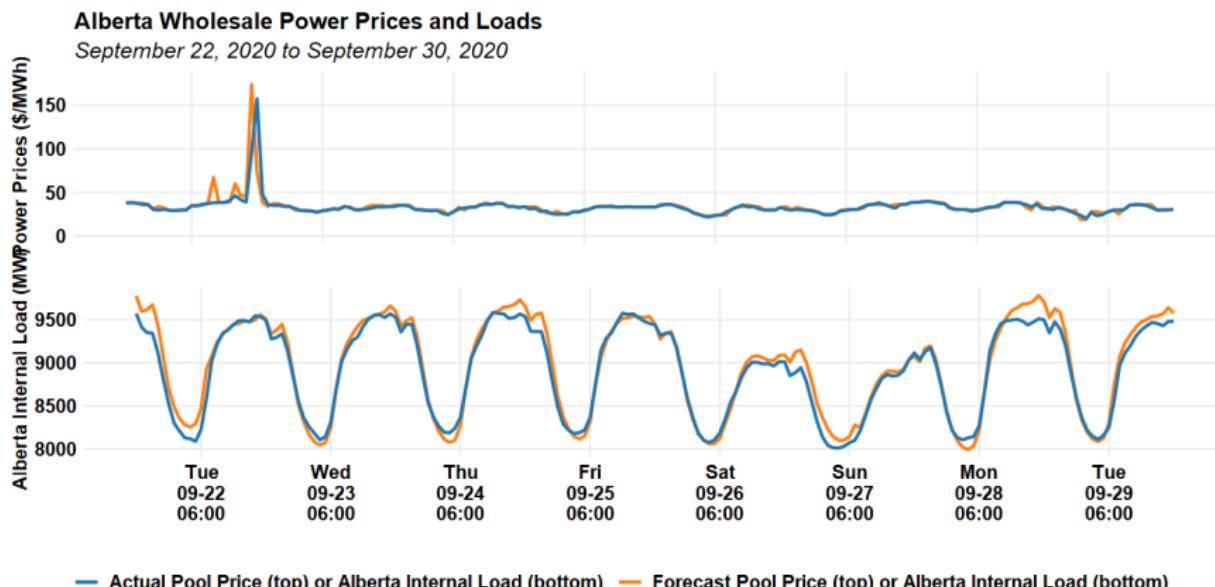


Prices over time



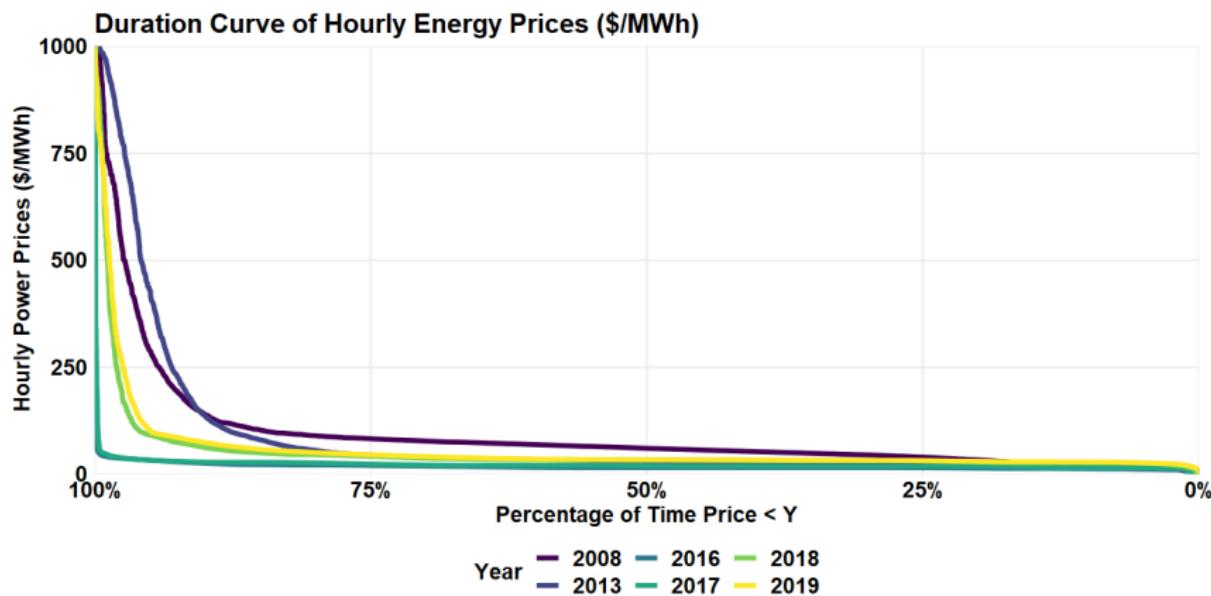
Source: AESO data, graph by Andrew Leach. Peak periods are between 7am and 11pm other than on statutory holidays or Sundays.

Forecasting Prices and Loads



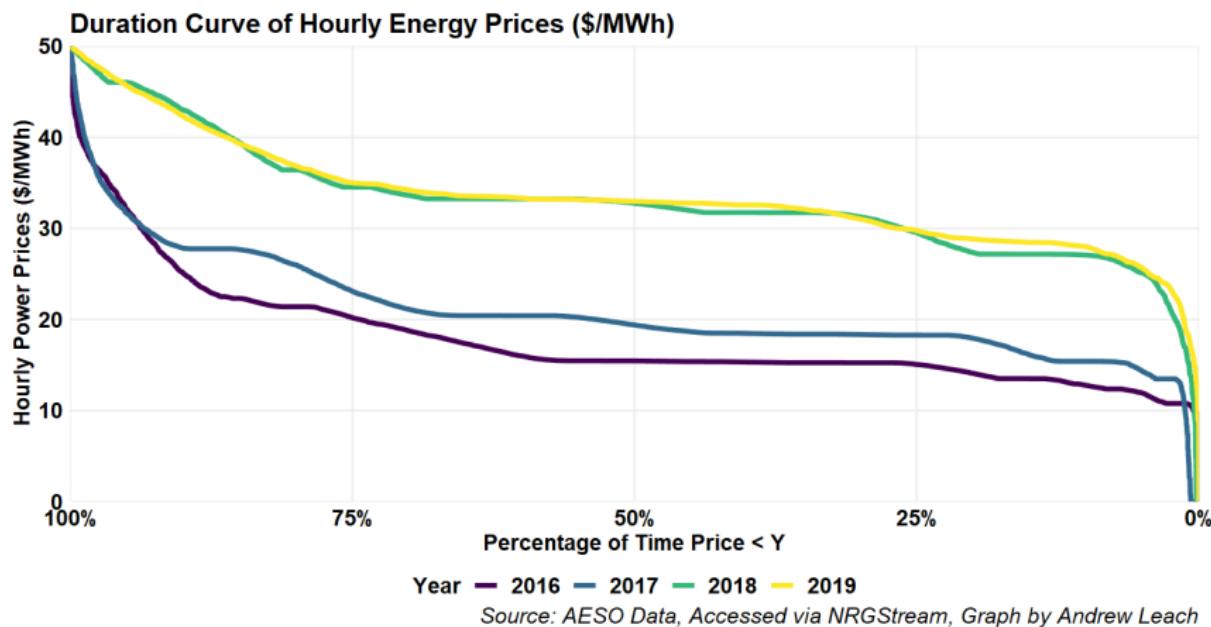
Source: AESO data, graph by Andrew Leach

Duration Curve of Prices

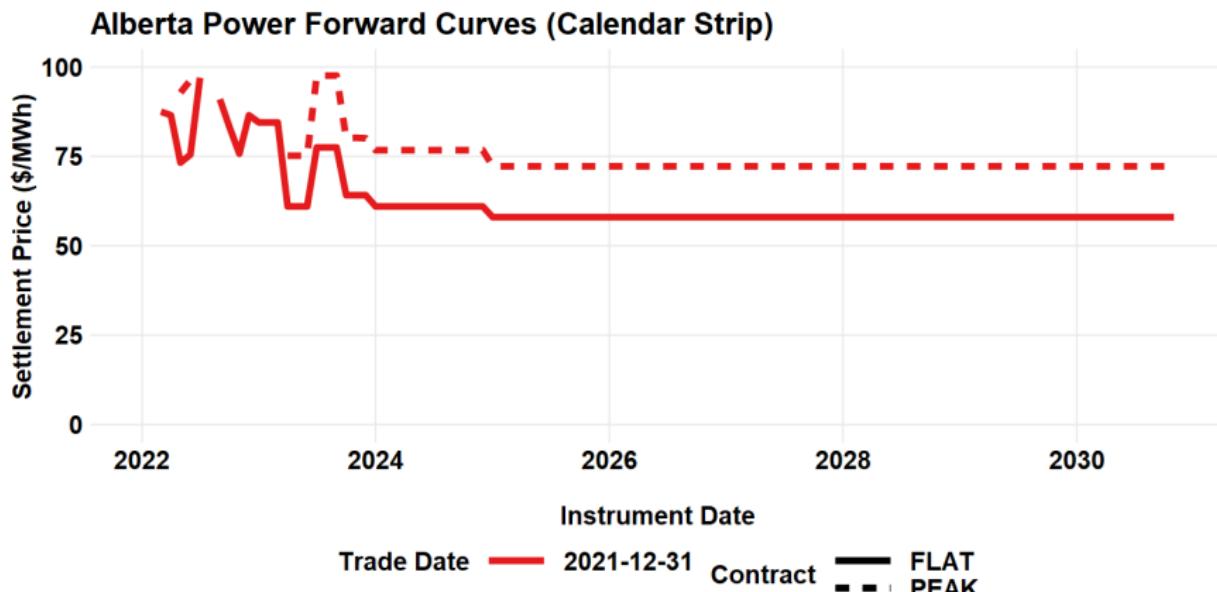


Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

Duration Curve of Prices

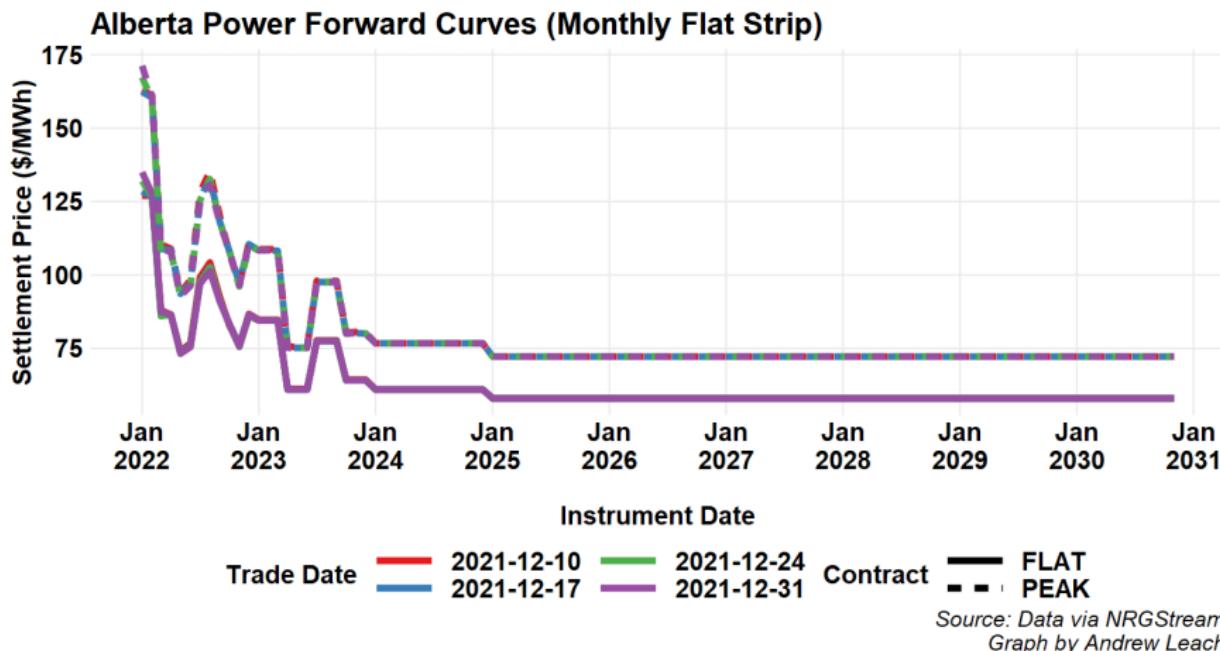


Forward Markets

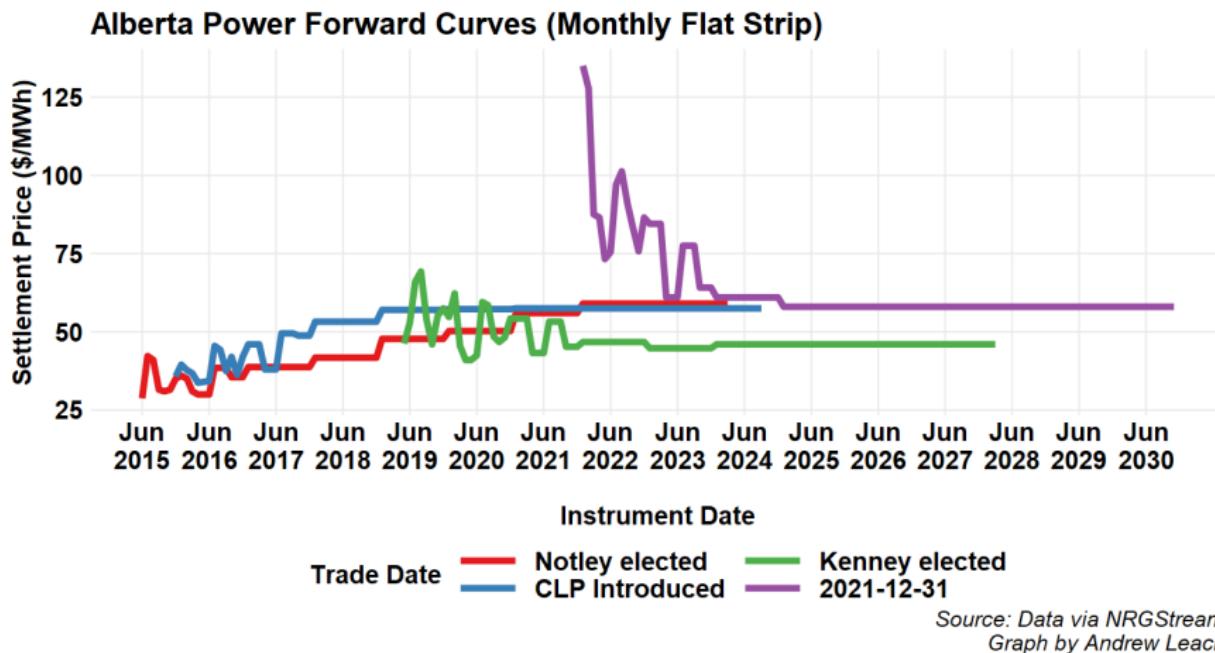


Source: Data via NRGStream
Graph by Andrew Leach

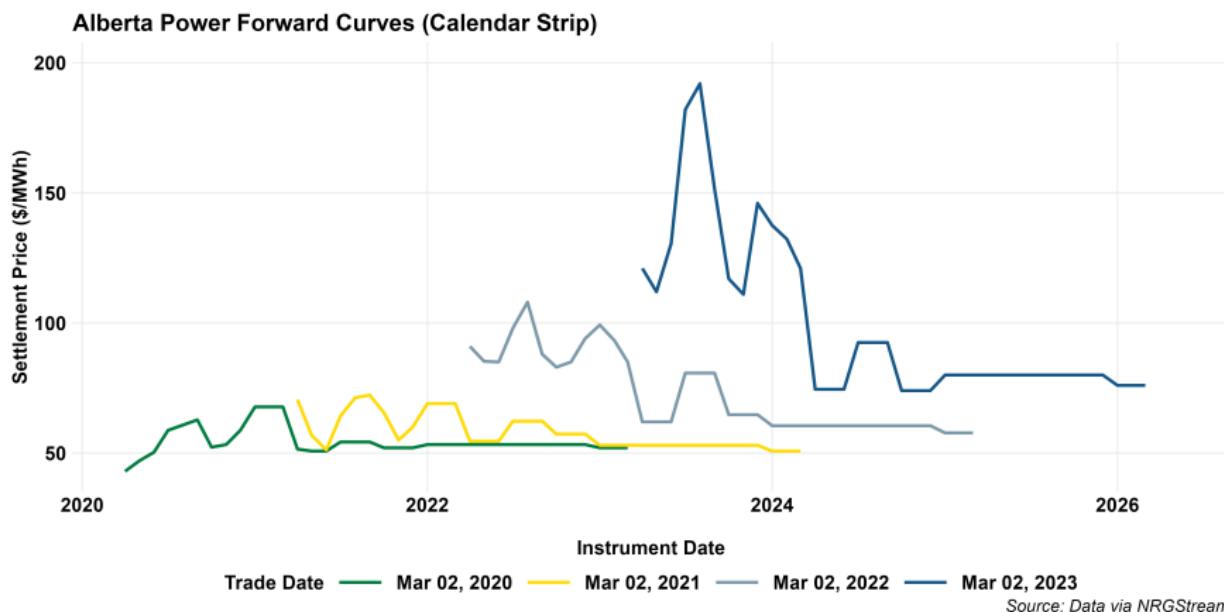
Forward Markets



Forward Markets

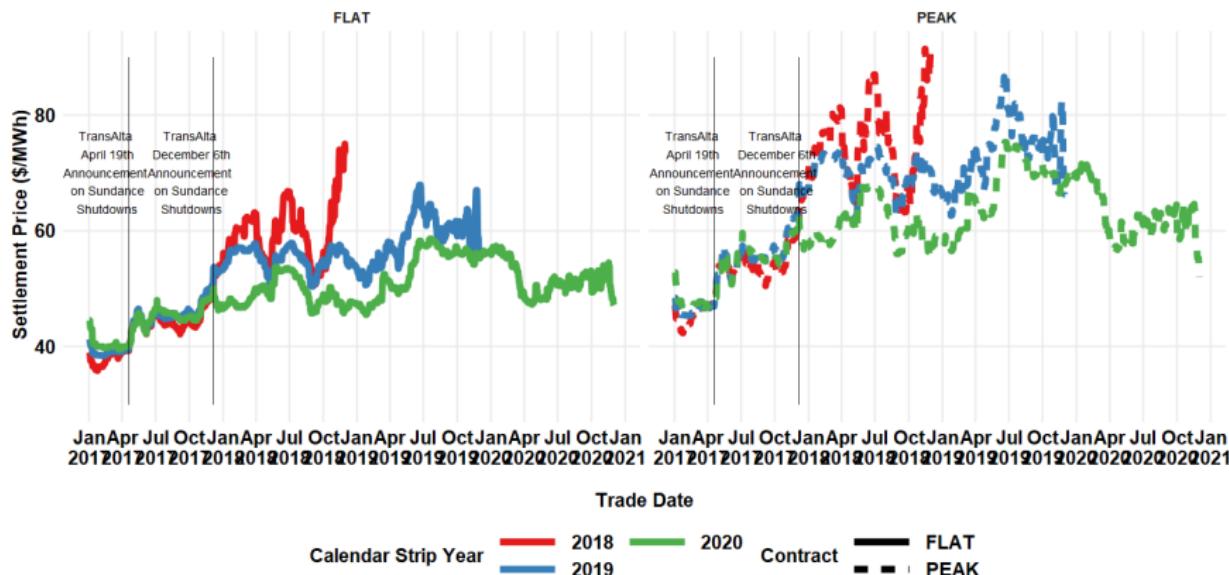


Forward Markets



Forward Markets

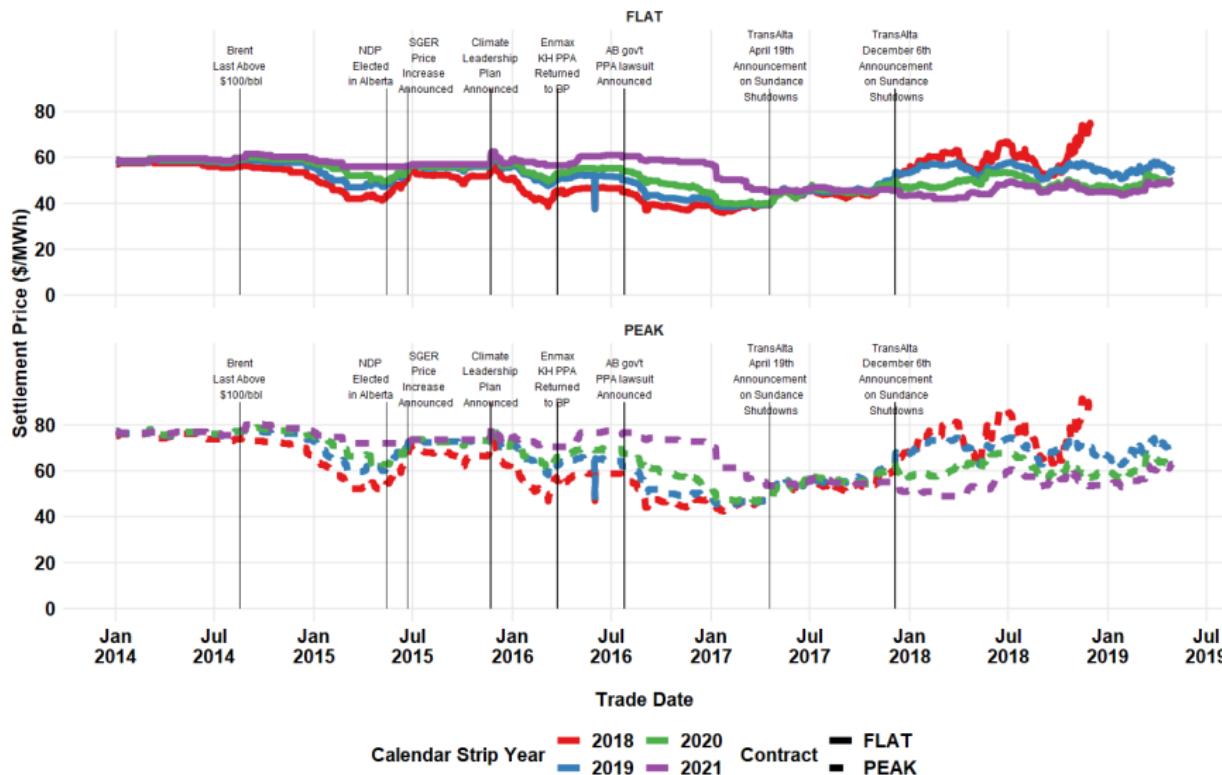
Alberta Power Forward Contract Values (Calendar Strip)



Source: Data via NRGStream
Graph by Andrew L each

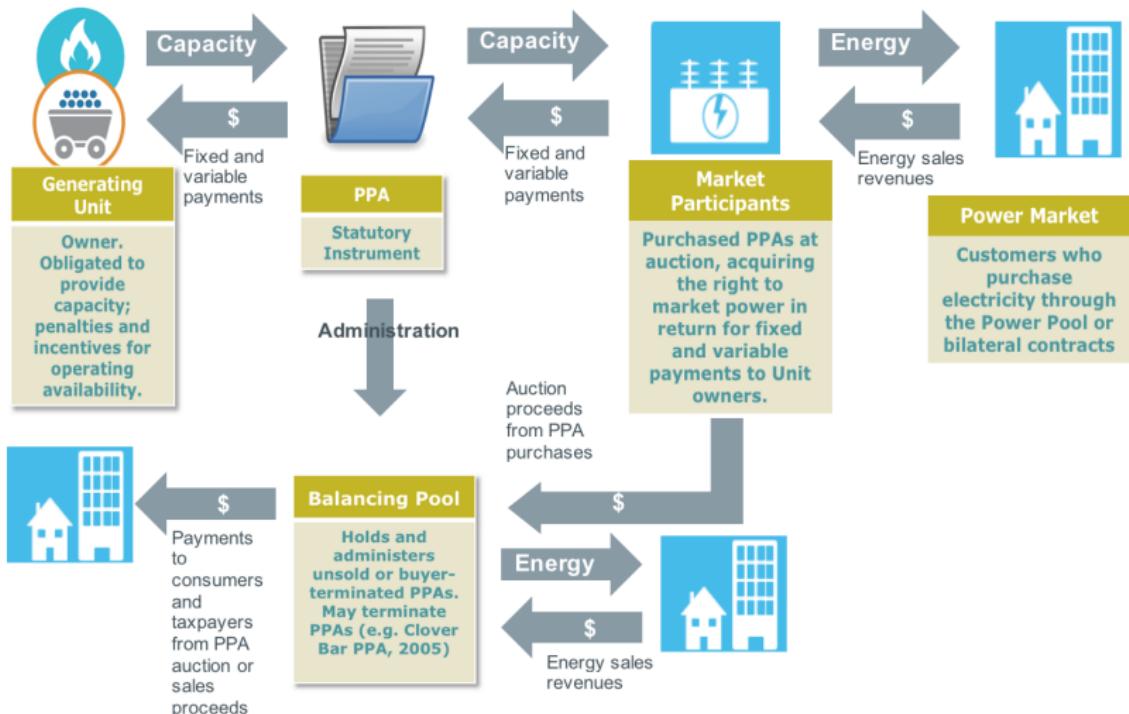
Forward Markets

Alberta Power Forward Contract Values (Calendar Strip)



Source: Data via NRGStream
Graph by Andrew Leach

The Balancing Pool: What on earth does it do?



Alberta's Evolving Electricity Market

- Capacity Market
- Coal Phase Out
- Renewables (the REP Program)
- Carbon Pricing

Costs of New Capacity Additions

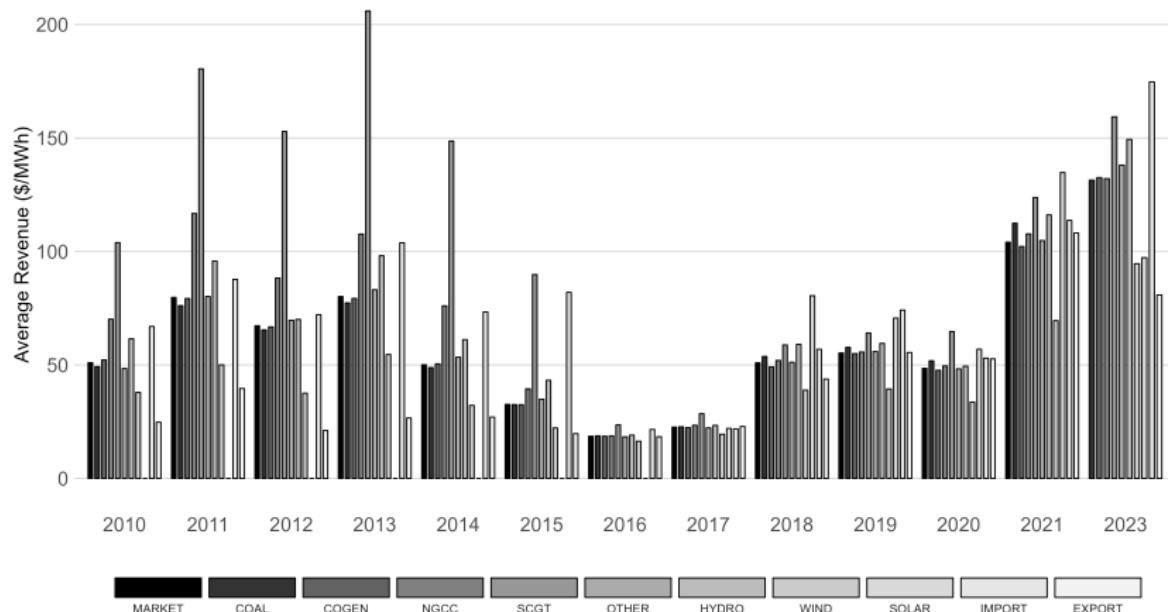
Table 1b. Estimated levelized cost of electricity (unweighted average) for new generation resources entering service in 2023 (2018 \$/MWh)

Plant type	Capacity factor (%)	Levelized capital cost	Levelized fixed O&M	Levelized variable O&M	Levelized transmission cost	Total system LCOE	Levelized tax credit ¹	Total LCOE including tax credit
Dispatchable technologies								
Coal with 30% CCS ²	85	61.3	9.7	32.2	1.1	104.3	NA	104.3
Coal with 90% CCS ²	85	50.2	11.2	36.0	1.1	98.6	NA	98.6
Conventional CC	87	9.3	1.5	34.4	1.1	46.3	NA	46.3
Advanced CC	87	7.3	1.4	31.5	1.1	41.2	NA	41.2
Advanced CC with CCS	87	19.4	4.5	42.5	1.1	67.5	NA	67.5
Conventional CT	30	28.7	6.9	50.5	3.2	89.3	NA	89.3
Advanced CT	30	17.6	2.7	54.2	3.2	77.7	NA	77.7
Advanced nuclear	90	53.8	13.1	9.5	1.0	77.5	NA	77.5
Geothermal	90	26.7	12.9	0.0	1.4	41.0	-2.7	38.3
Biomass	83	36.3	15.7	39.0	1.2	92.2	NA	92.2
Non-dispatchable technologies								
Wind, onshore	41	39.8	13.7	0.0	2.5	55.9	-6.1	49.8
Wind, offshore	45	107.7	20.3	0.0	2.3	130.4	-12.9	117.5
Solar PV ³	29	47.8	8.9	0.0	3.4	60.0	-14.3	45.7
Solar thermal	25	119.6	33.3	0.0	4.2	157.1	-35.9	121.2
Hydroelectric ⁴	75	29.9	6.2	1.4	1.6	39.1	NA	39.1

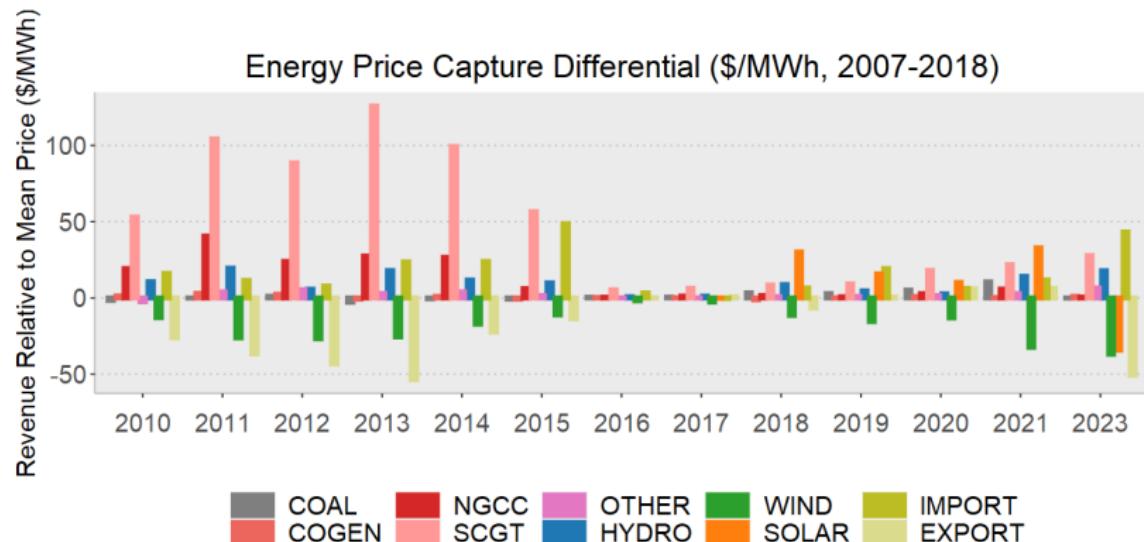
See for more information:

<https://www.lazard.com/media/451086/lazards-levelized-cost-of-energy-version-130-vf.pdf>

Price Capture by Technology



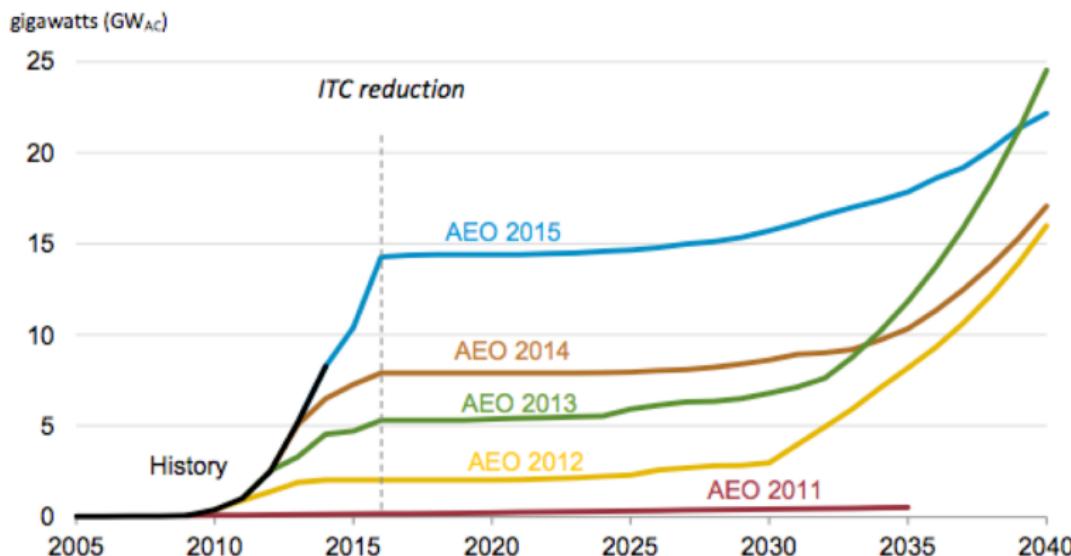
Price Capture by Technology



Source: AESO Data, accessed via NRGStream
Graph by @andrew_leach

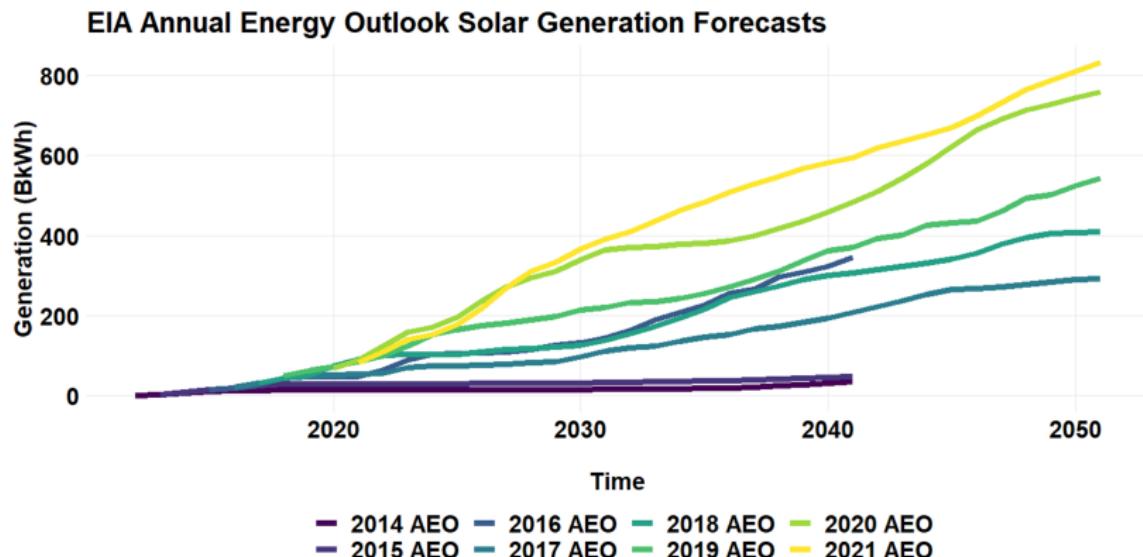
Evolution of Technology

Figure A-10. Utility-Scale solar PV capacity projections in AEO 2011 to 2015 Reference cases, 2005-2040



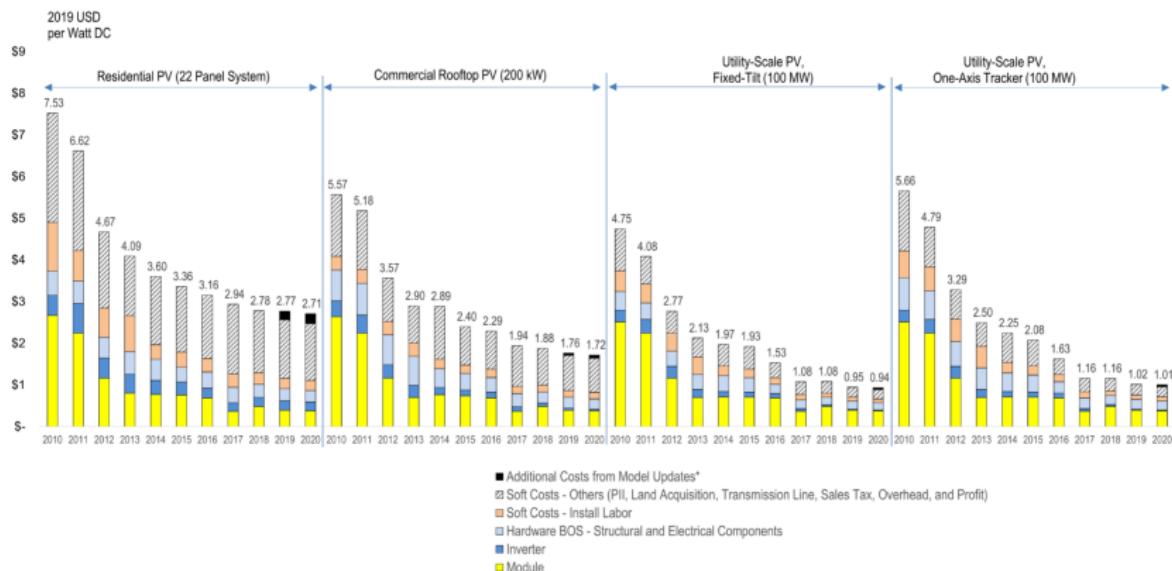
Sources: EIA, Annual Energy Outlook 2011–2015 editions.

Evolution of Technology



Source: EIA API
Graph by Andrew Leach

Evolution of Technology

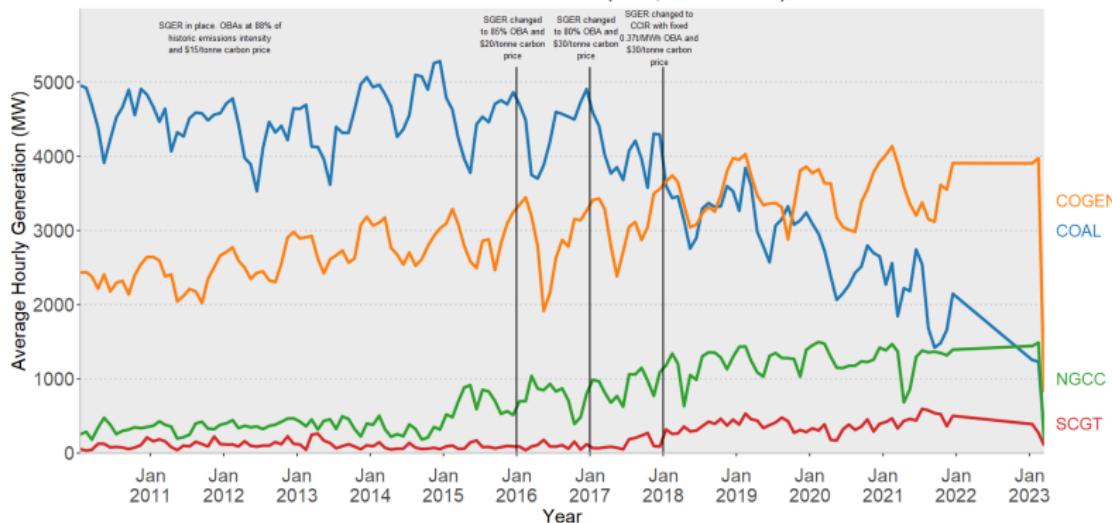


Source: NREL

Figure ES-1. NREL PV system cost benchmark summary (inflation-adjusted), 2010–2020

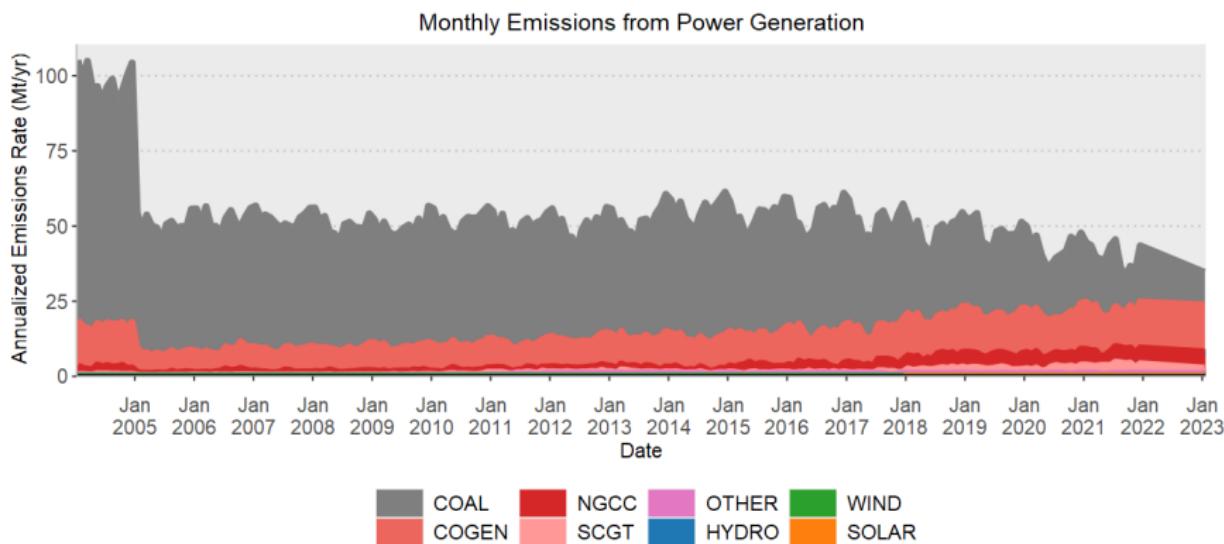
GHG Policy and Electricity Supply

Coal and Gas Generation (MW, 2010-2020)



Source: AESO Data, accessed via NRGStream

GHG Policy and Electricity Supply



GHG Policy and Electricity Supply

