

Electricity Markets

Andrew Leach

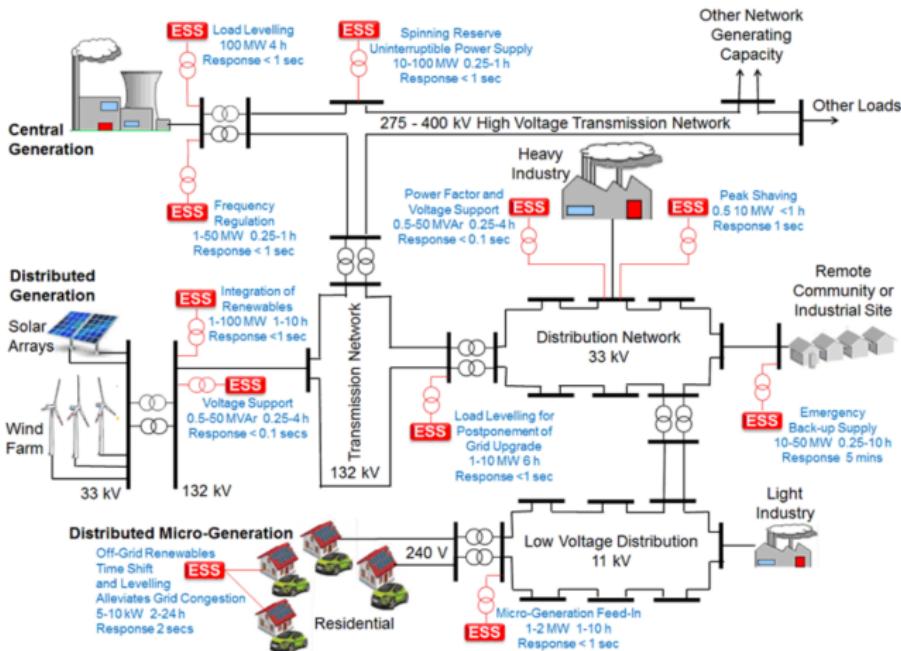
University of Alberta

October 3, 2021

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

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

Market Regulation in Alberta

- Generation is a competitive market competitive
- Transmission is regulated on a cost-of-service basis
- Distribution (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)
- Microgeneration (free market for self-supply)

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)
 - GHG or other emissions permits or credits (\$/tonne)

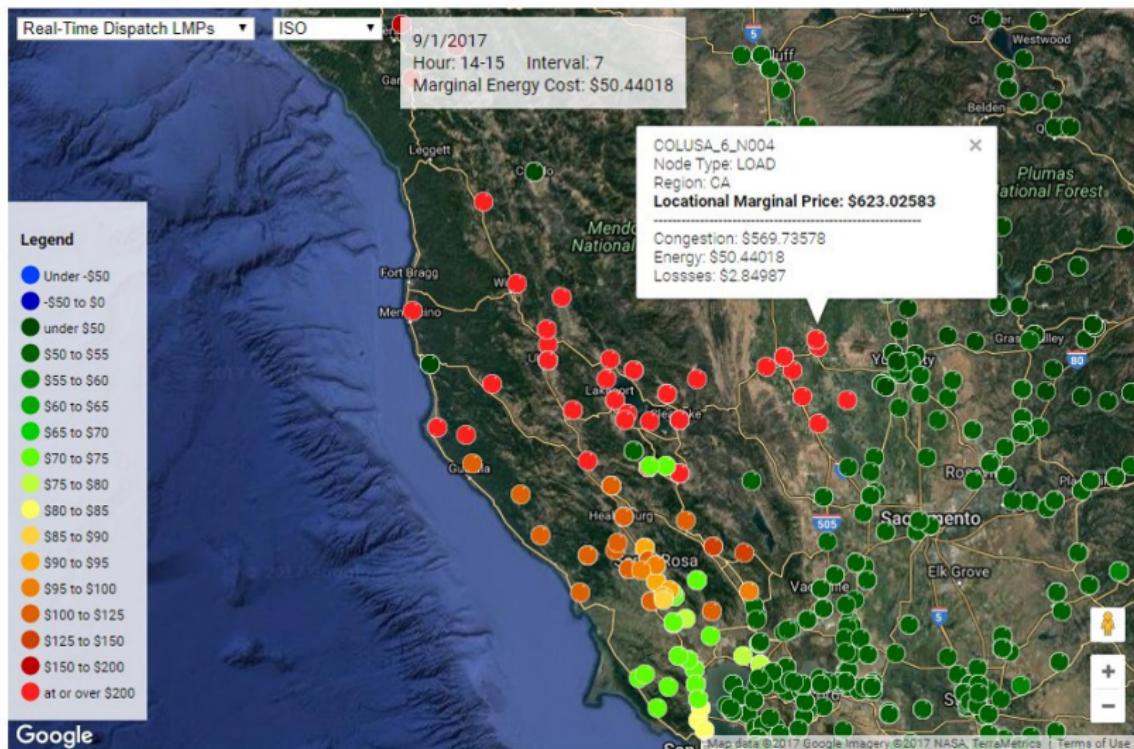
Regulatory characteristics

- Rate-regulated or state-owned utilities
- Competitive markets
 - Energy only markets: ERCOT and Alberta
 - Energy and capacity markets: MISO, PJM
 - 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

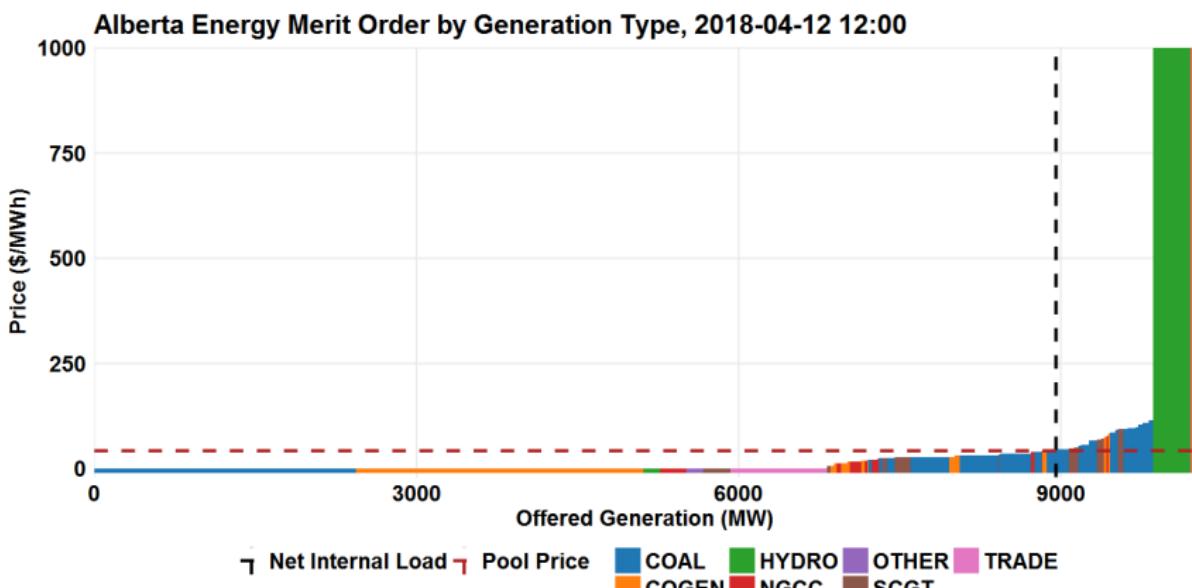


Source: CAISO

The Alberta Wholesale Market

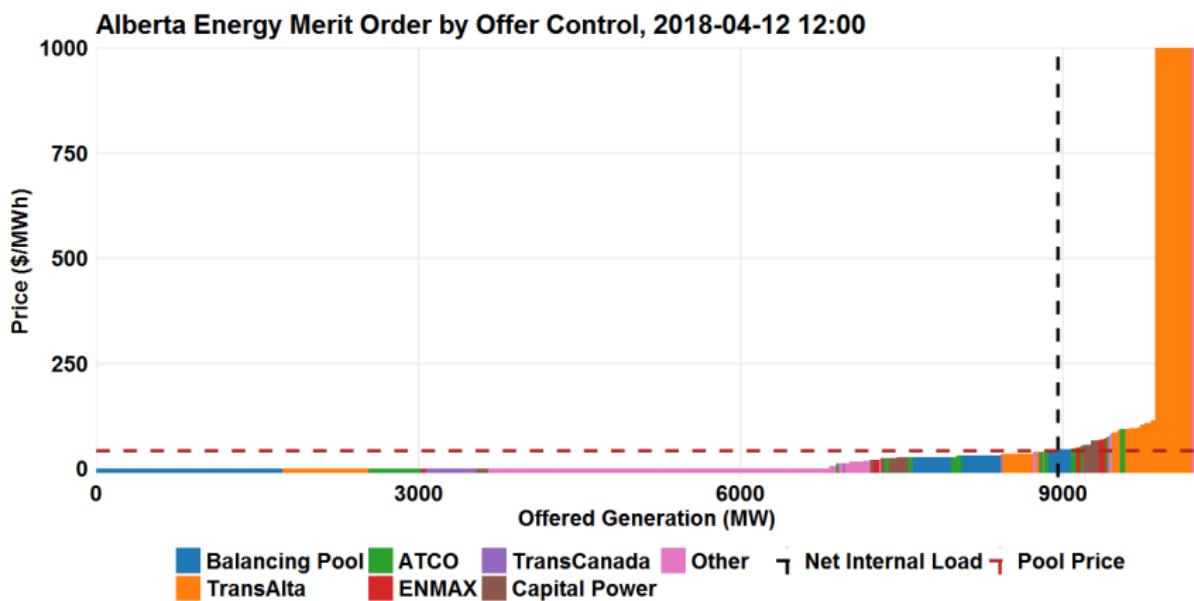
- Suppliers place offers of power at particular price[-5em]
- Demand-side bids placed for power with a maximum price
- Supply offers are sorted from low to high
- Demand offers are sorted from high to low
- Marginal price is set at the price which equates supply and demand - economics 101 at work!
- 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



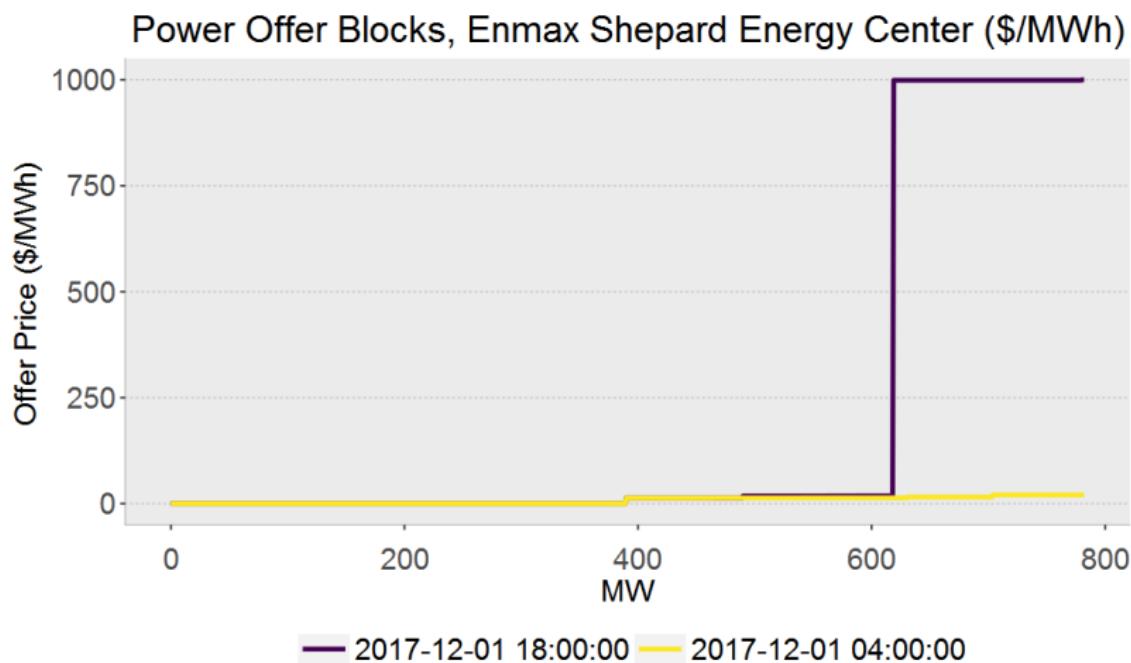
Source: AESO Data, graph by Andrew Leach.

The Merit Order



Source: AESO Data, graph by Andrew Leach.

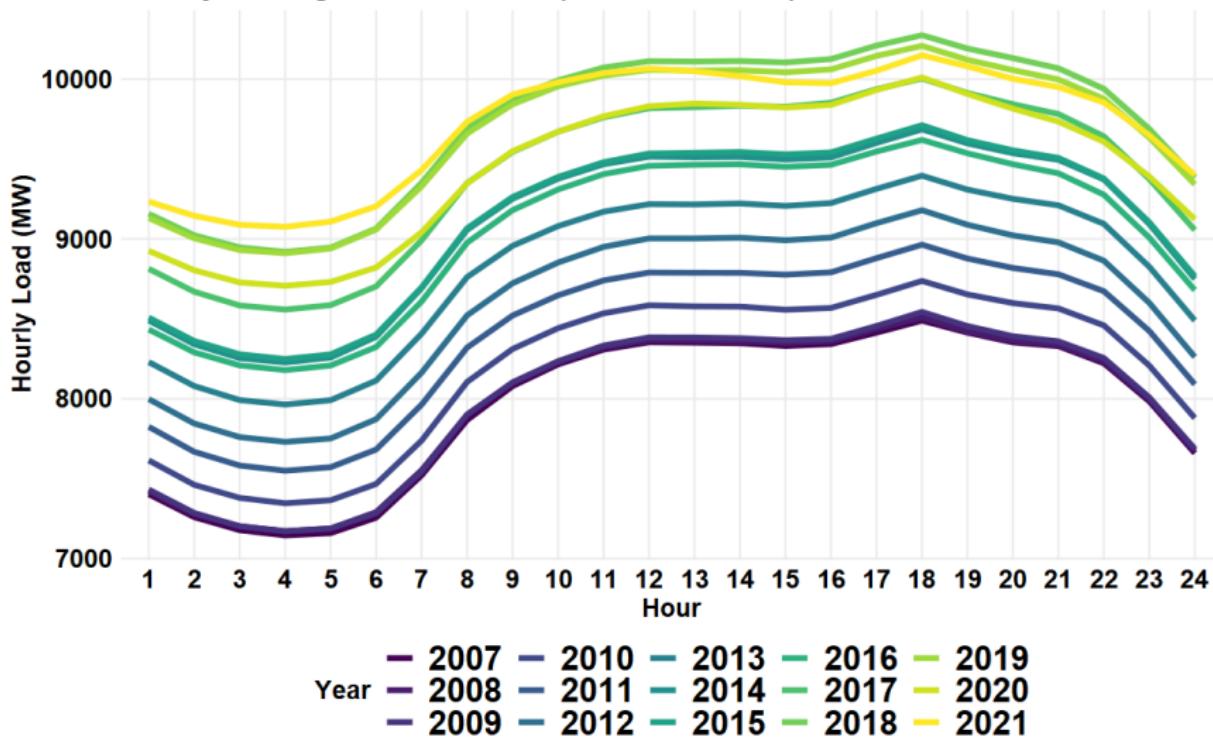
Offers



Source: AESO Data, Graph by Andrew Leach

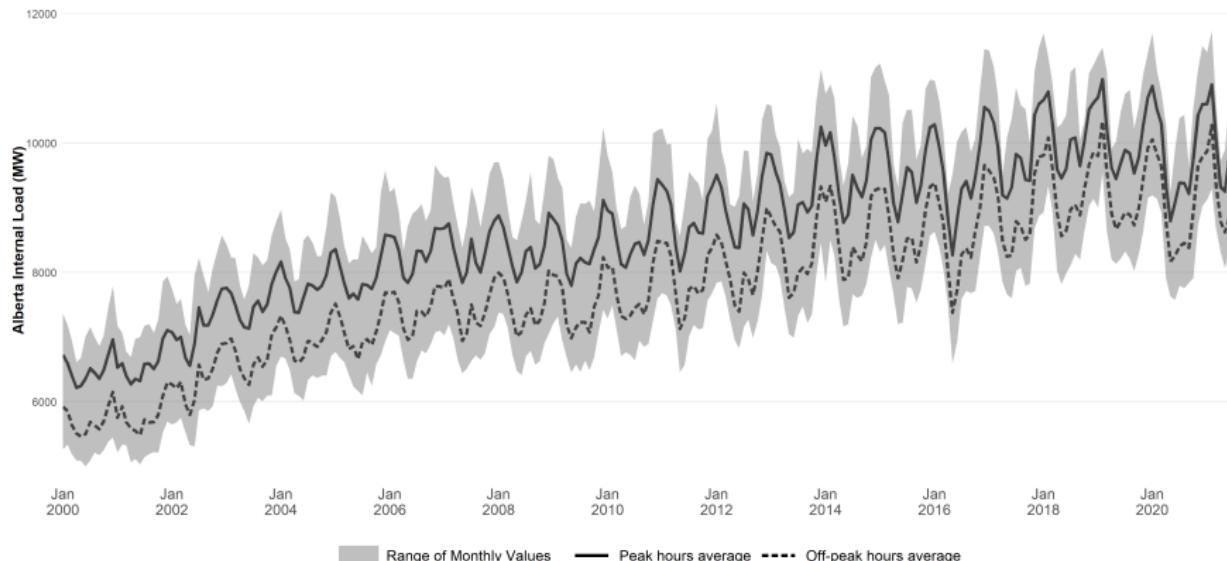
Hourly Loads

Hourly Average Internal Load (MW, 2007-2019)

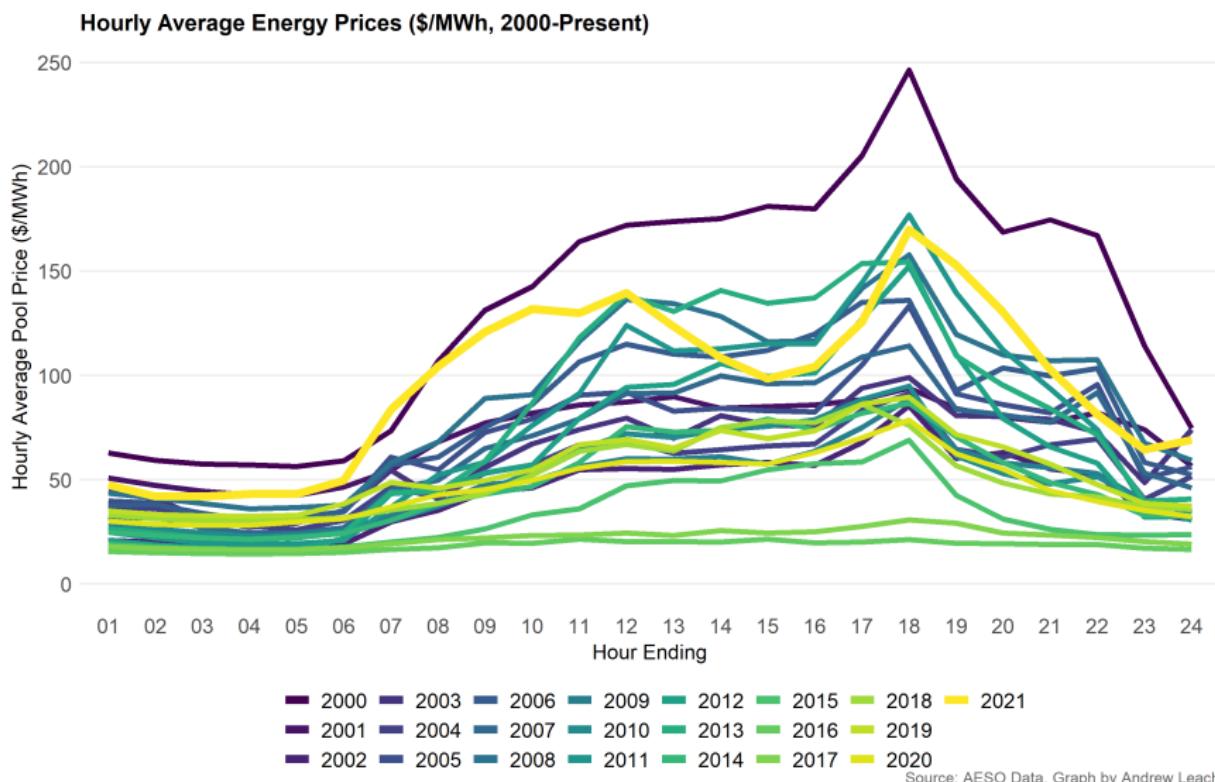


Source: AESO Data, Accessed via NRGStream, Graph by Andrew Leach

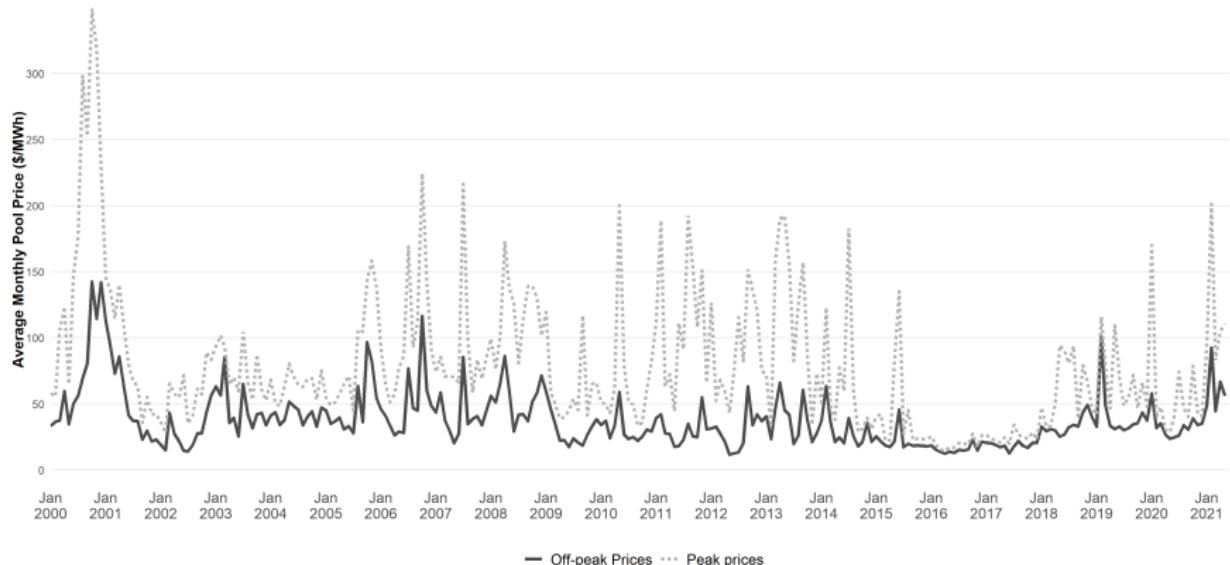
Peak and Average Loads



Hourly Prices



Prices over time



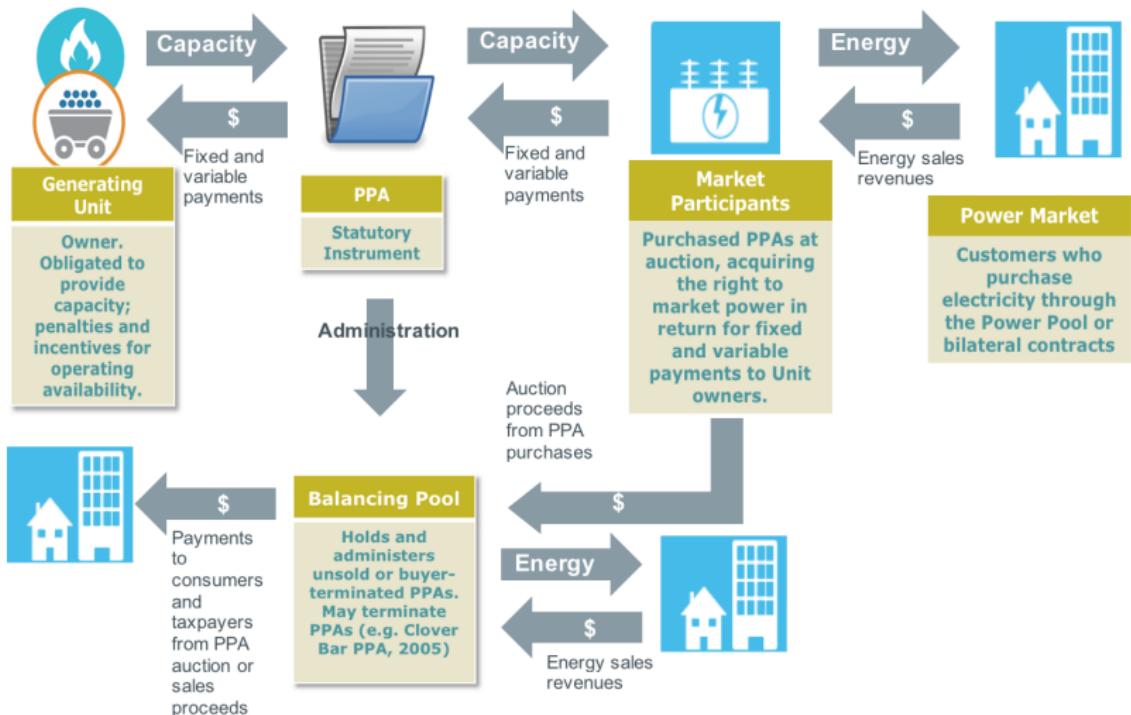
Forward Markets

Alberta Power Forward Curves (Calendar Strip)



Source: Data via NRGStream
Graph by Andrew Leach

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



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)

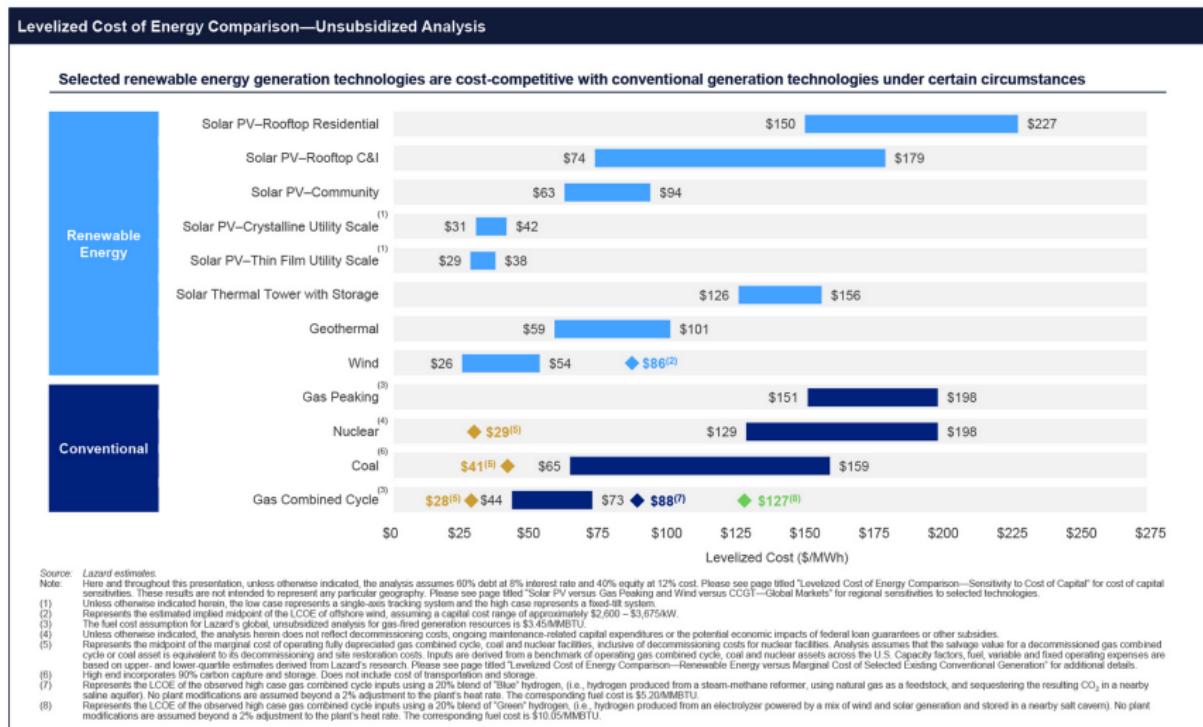
Costs of New Capacity Additions

Table 1b. Estimated unweighted leveledized cost of electricity (LCOE) and leveledized cost of storage (LCOS) for new resources entering service in 2026 (2020 dollars per megawatthour)

| Plant type | Capacity factor (percent) | Levelized capital cost | Levelized fixed O&M ¹ | Levelized variable cost | Levelized transmission cost | Total system LCOE or LCOS | Leveledized tax credit ² | Total LCOE or LCOS including tax credit |
|--------------------------------------|---------------------------|------------------------|----------------------------------|-------------------------|-----------------------------|---------------------------|-------------------------------------|---|
| Dispatchable technologies | | | | | | | | |
| Ultra-supercritical coal | 85% | \$43.80 | \$5.48 | \$22.48 | \$1.03 | \$72.78 | NA | \$72.78 |
| Combined cycle | 87% | \$7.78 | \$1.61 | \$26.68 | \$1.04 | \$37.11 | NA | \$37.11 |
| Combustion turbine | 10% | \$45.41 | \$8.03 | \$44.13 | \$9.05 | \$106.62 | NA | \$106.62 |
| Advanced nuclear | 90% | \$50.51 | \$15.51 | \$2.38 | \$0.99 | \$69.39 | -\$6.29 | \$63.10 |
| Geothermal | 90% | \$19.03 | \$14.92 | \$1.17 | \$1.28 | \$36.40 | -\$1.90 | \$34.49 |
| Biomass | 83% | \$34.96 | \$17.38 | \$35.78 | \$1.09 | \$89.21 | NA | \$89.21 |
| Battery storage | 10% | \$57.98 | \$28.48 | \$23.85 | \$9.53 | \$119.84 | NA | \$119.84 |
| Non-dispatchable technologies | | | | | | | | |
| Wind, onshore | 41% | \$27.01 | \$7.47 | \$0.00 | \$2.44 | \$36.93 | NA | \$36.93 |
| Wind, offshore | 44% | \$89.20 | \$28.96 | \$0.00 | \$2.35 | \$120.52 | NA | \$120.52 |
| Solar, standalone ³ | 29% | \$23.52 | \$6.07 | \$0.00 | \$3.19 | \$32.78 | -\$2.35 | \$30.43 |
| Solar, hybrid ^{3, 4} | 28% | \$31.13 | \$13.25 | \$0.00 | \$3.29 | \$47.67 | -\$3.11 | \$44.56 |
| Hydroelectric ⁴ | 55% | \$38.62 | \$11.23 | \$3.58 | \$1.84 | \$55.26 | NA | \$55.26 |

Source: U.S. Energy Information Administration, *Annual Energy Outlook 2021*

Costs of New Capacity Additions

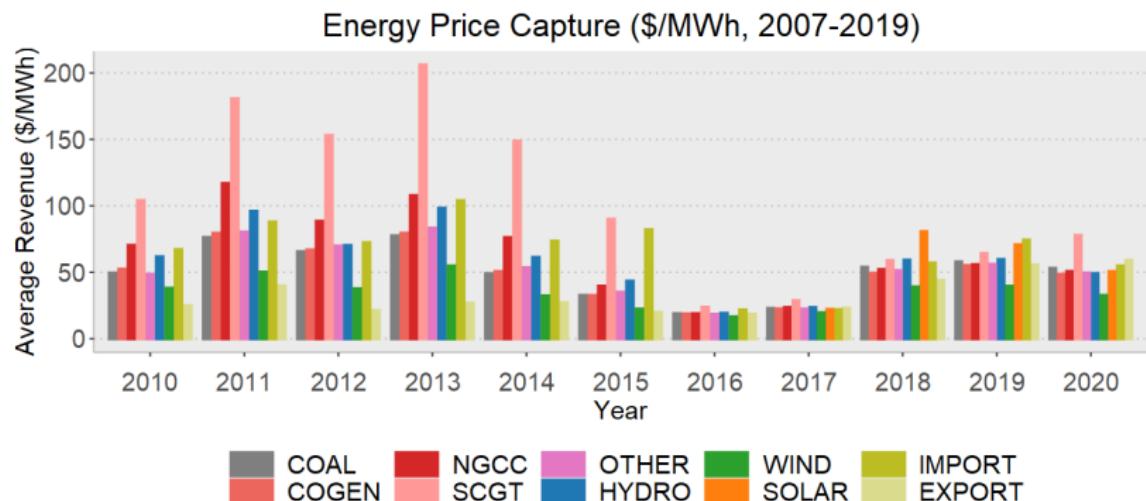


New Technology

SOLAR

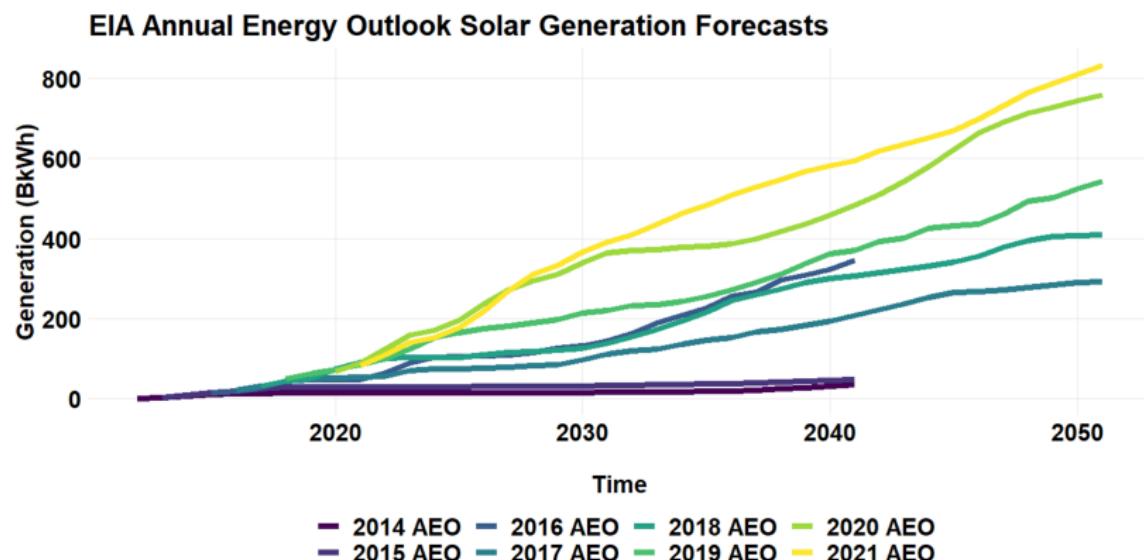
| ASSET | MC | TNG | DCR |
|------------------------------|----|-----|-----|
| BRD1 Burdett (BRD1) | 11 | 2 | 0 |
| BUR1 Burdett (BUR1) | 20 | 3 | 0 |
| Brooks Solar (BSC1) | 15 | 3 | 0 |
| Claresholm 1 (CLR1) | 58 | 19 | 0 |
| Claresholm 2 (CLR2) | 75 | 9 | 0 |
| Hays (HYS1) | 23 | 21 | 0 |
| Hull (HUL1) | 25 | 7 | 0 |
| Innisfail (INF1) | 22 | 10 | 0 |
| Jenner (JER1) | 23 | 21 | 0 |
| Suffield (SUF1) | 23 | 16 | 0 |
| Vauxhall (VXH1) | 22 | 7 | 0 |
| Westfield Yellow Lake (WEF1) | 19 | 4 | 0 |

Price Capture by Technology



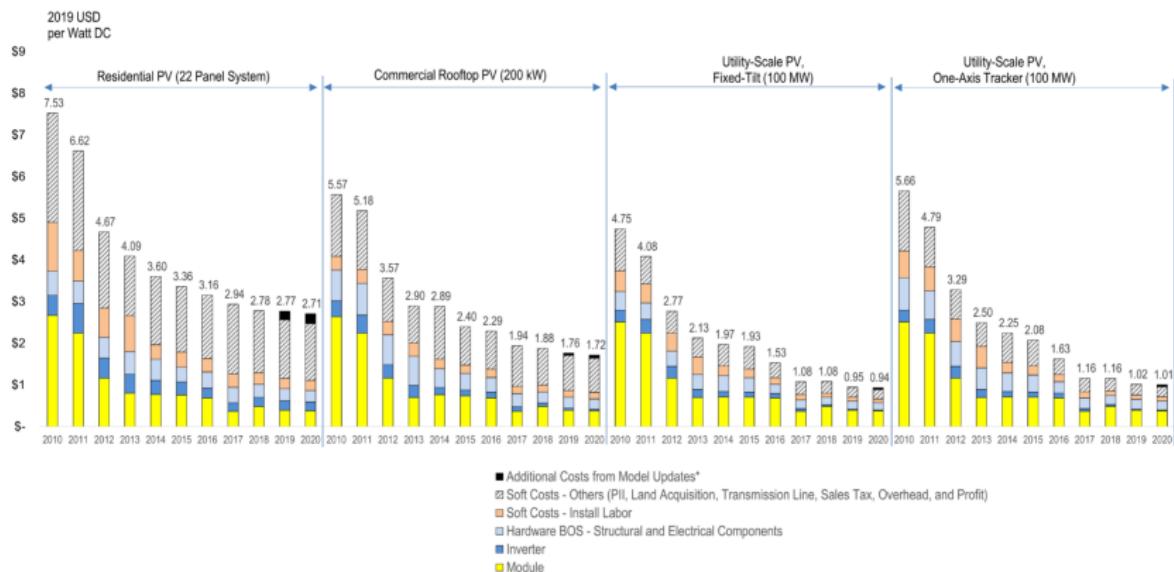
Source: AESO Data, accessed via NRGStream
Graph by @andrew_leach

Evolution of Technology



Source: EIA API
Graph by Andrew Leach

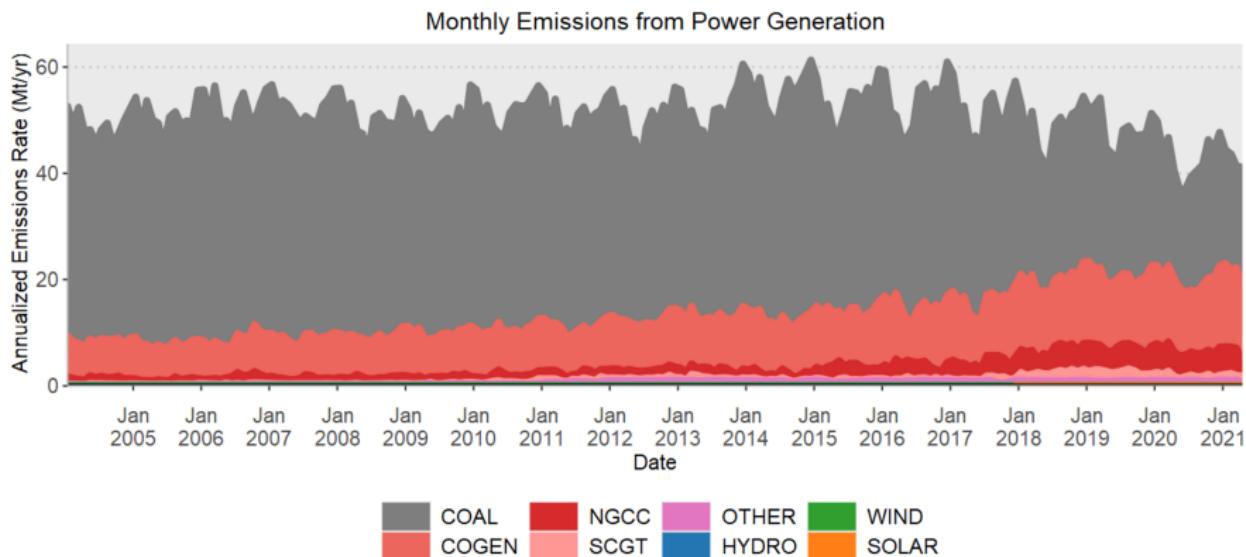
Evolution of Technology



Source: NREL

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

GHG Policy and Electricity Supply



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.