Energy Transition in Canada and Ontario

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Who is IEEE

IEEE

Global Reach

420,000+ Members

160+ Countries

135,000+ Student Members

1,980+ Annual Conferences

Technical Breadth

4.5M+ Technical Documents

200+ Top-Cited Periodicals

1,300+ Active Standards

39 Technical Societies

Public Policy Engagement

Global Humanitarian Efforts

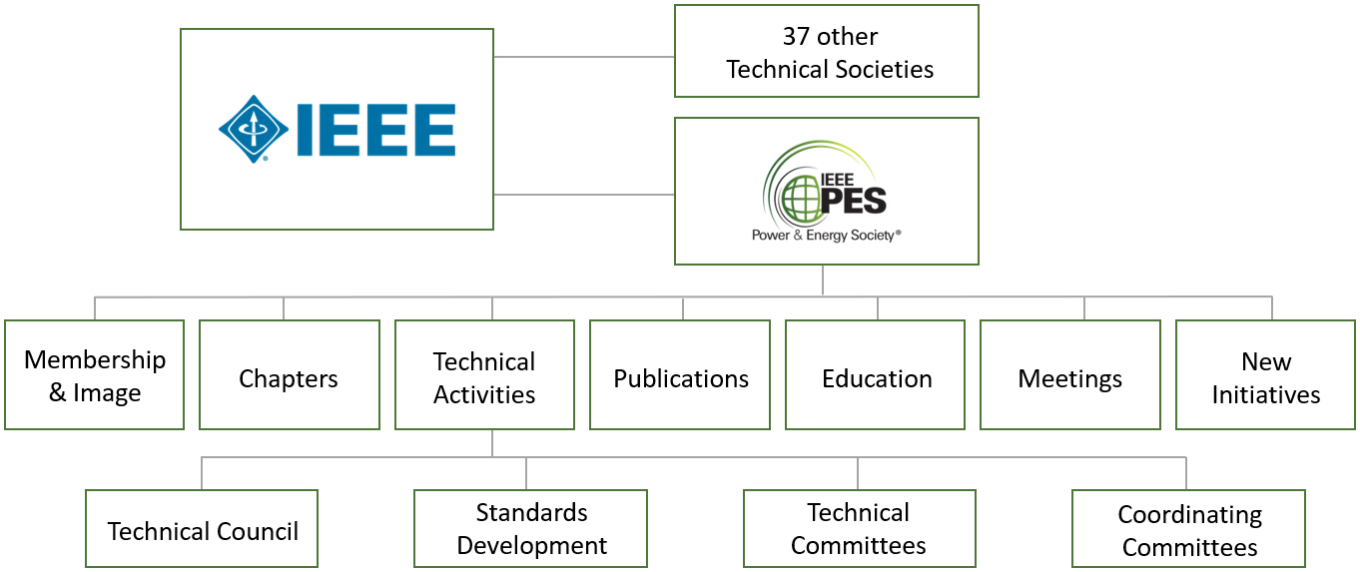
Education & Certification

Ethics in Technology

IEEE is the world's largest technical professional organization dedicated to advancing technology for the benefit of humanity.

Mission – IEEE's core purpose is to foster technological innovation and excellence for the benefit of humanity.

IEEE Power & Energy Society (PES)



PES is the 2nd largest IEEE technical society

Mission – To be the leading provider of scientific and engineering information on electric power and energy for the betterment of society, and the preferred professional development source for our members.

PES Global Engagement

Over 42,000 members and 780 chapters

REGION 1-7

136 chapters | **72** student chapters | **17,000** members

REGION 8

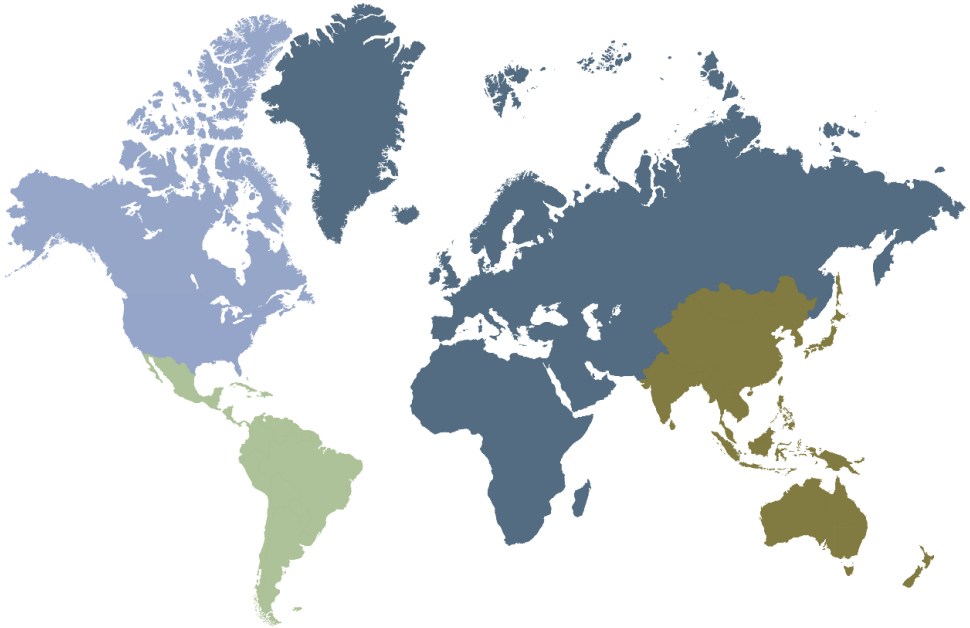
47 chapters | **92** student chapters | **6,000** members

REGION 9

36 chapters | **119** student chapters | **3,000** members

REGION 10

48 chapters | **231** student chapters | **16,000** members



>50% of members are outside USA

What We Do

- Technical Community
  - 21 technical committees
  - 50% of IEEE standards are created by PES committees
- Conferences and Meetings
  - Over 30 global conferences annually
  - PES T&D Conference & Exposition – largest IEEE event (13,000 attendees and 800 exhibitors)
  - PES Grid Edge Technologies Conference & Exposition – new event launching April 2023
- Publications
  - Two award-winning magazines, *Power & Energy* and *Electrification*
  - Spanish P&E Magazine, Transactions, and an open-access journal (OAJPE)
  - Updates shared in eNews, eBulletin, Trending Technical topics & email announcements
- Education
  - PES Resource Center - most extensive library in the world devoted to power and energy content
  - PES University - access to knowledge and learning platforms for professional growth and development
  - Offer industry-related education in the form of webinars, in-person and virtual tutorials, and other learning modalities

IEEE PES President-Elect Candidate

- IEEE PES member for 37 years.
- Held 52 PES and IEEE membership and leadership positions, particularly and most recently:
  - Member, TAB N&A Committee, 2023-2024.
  - Member, Fellow Committee Strategic Advisory Working Group, 2023.
  - Director and Director-Elect, Division VII, 2021-2023.
  - Member, Ad Hoc Committee to Coordinate ’s Response to Climate Change, 2022-2023.
  - Member, Ad Hoc Committee on Fellows Processes, 2022.
  - Editor in Chief, Transactions on Smart Grid, 2020-today.
  - Chair, Electrification Magazine Steering Committee, 2019-today.
  - Past-Chair, Chair, Vice-Chair, and Secretary, Power System Dynamic Performance Committee, 2013-2020.

IEEE PES President-Elect Candidate

- Support and enhance the diversity and transparency initiatives initiated over the past 2 years by the current PES President, Jessica Bian.
- Facilitate and support ongoing and new initiatives by PES members and volunteers.
- Support and enhance the impact and relevance of PES and its initiatives to IEEE decarbonization activities and programs, as the power grid will be the backbone of the world's Net-Zero future.
- Increase the growing PES relevance and leadership role in the IEEE, properly reflecting its size, for which I've been pushing as Division VII Director.

IEEE PES President-Elect Candidate

- Independent of who you vote for, **PLASE VOTE** before Oct. 1, 2023.

Vote Today! In The 2023 IEEE PES Elections

Dear Claudio,

You're invited to meet the 2023 IEEE Power & Energy Society Elections candidates for the following open leadership positions here. We encourage you to help choose the future direction of PES by exercising your vote by 2 October 2023.

- President-Elect
- Secretary
- Treasurer

Vote Here

The elected officers will serve two-year terms (1 January 2024 - 31 December 2025), with the President-Elect serving as PES President for the period of 2026 - 2027.

You will need your IEEE Account username/password to access the ballot. For quick reference, your username is your email address. If you do not remember your password, you may retrieve it on the voter login page.

Outline

- Motivation
- Overview of Canadian electrical grids:
  - Provincial grids
  - Remote communities
- Ontario overview:
  - Grid
  - Market
  - Future grid
- EVs in Canada
- Canada's Net-Zero 2050
- Canada's Hydrogen strategy
- Conclusions

Motivation

- Climate change is forcing a move away from fossil fuels and associated Green House Gas (GHG) emissions across the world economies.
- This will be accomplished by the “electrification of everything”, particularly transportation (EVs and FCVs) and thermal systems (Heat Pumps and Ground Source HPs).
- The backbone of electrification will be a clean electrical grid, which will require:
  - Replacement of fossil fuel-based generation with non-GHG emitting sources, particularly Renewable Energy Sources (RES) like wind and solar power, combined with Energy Storage Systems (ESS).
  - More generation and transmission systems to supply the increased load (e.g., a ~400km EV has a ~10kW max. demand, which doubles the max. load of a typical North American home).
  - Increase Demand Side Management (DSM) and Demand Response Programs (DRPs).
  - Further development of Distributed Energy Resources (DERs) and microgrids in Active Distribution Networks (ADNs).
- What is the status of the electrical grid in Canada and particularly in Ontario?

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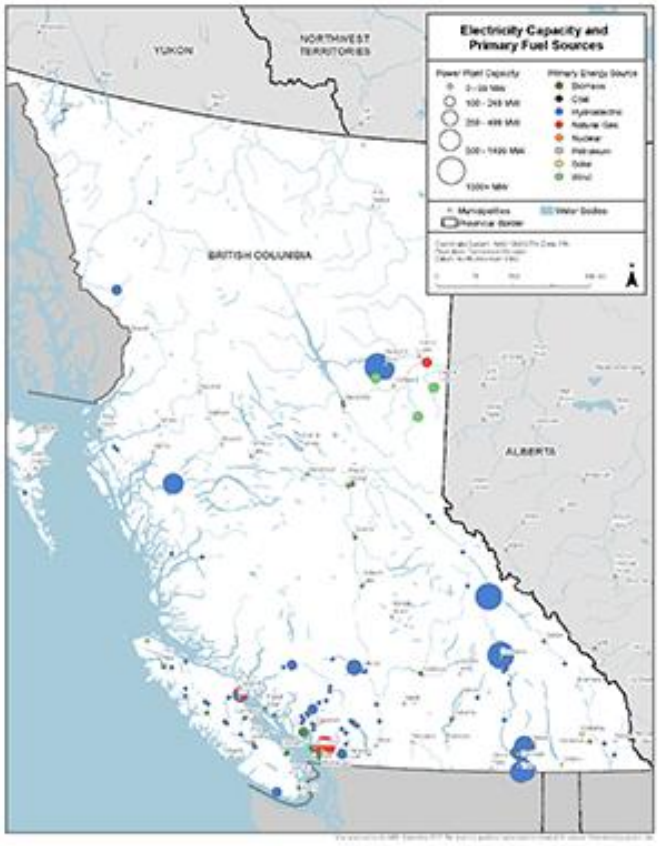
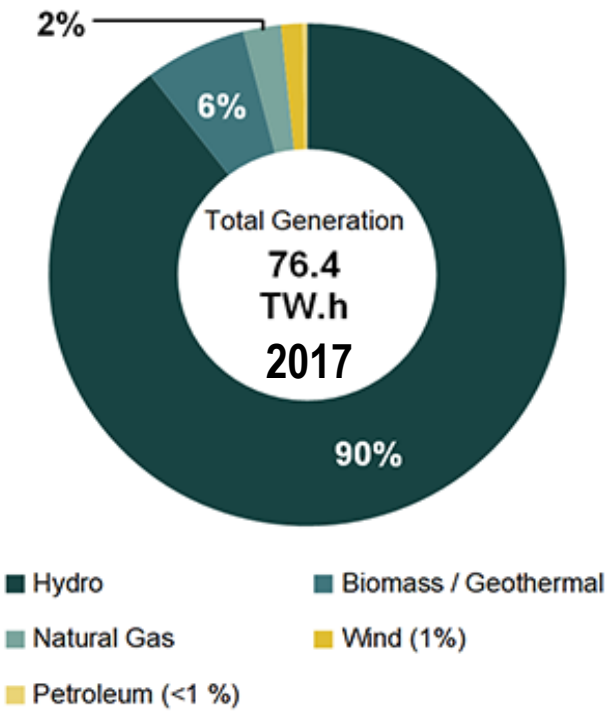
Canadian Grid

- British Columbia [www.neb-one.gc.ca]: No competitive market





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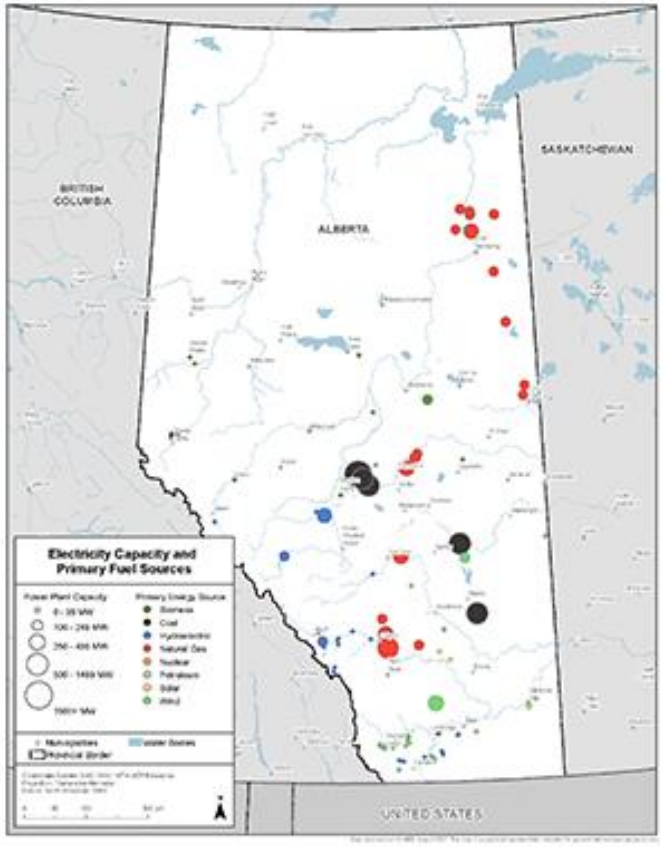
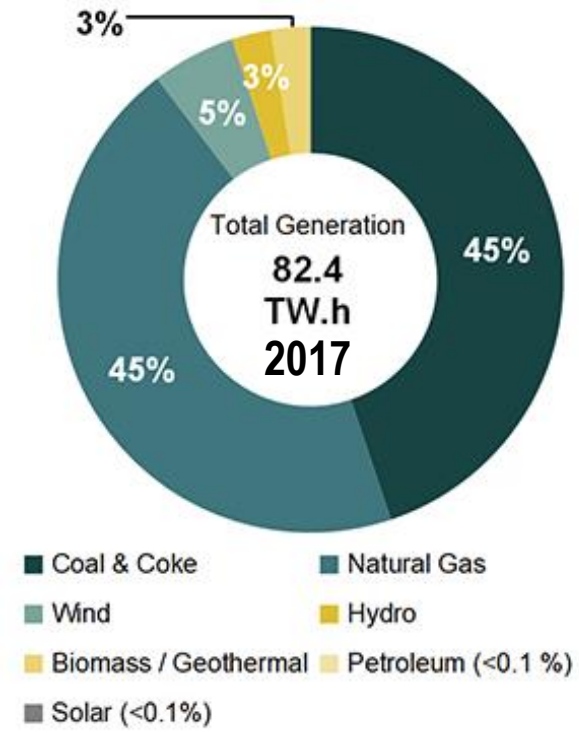
Canadian Grid

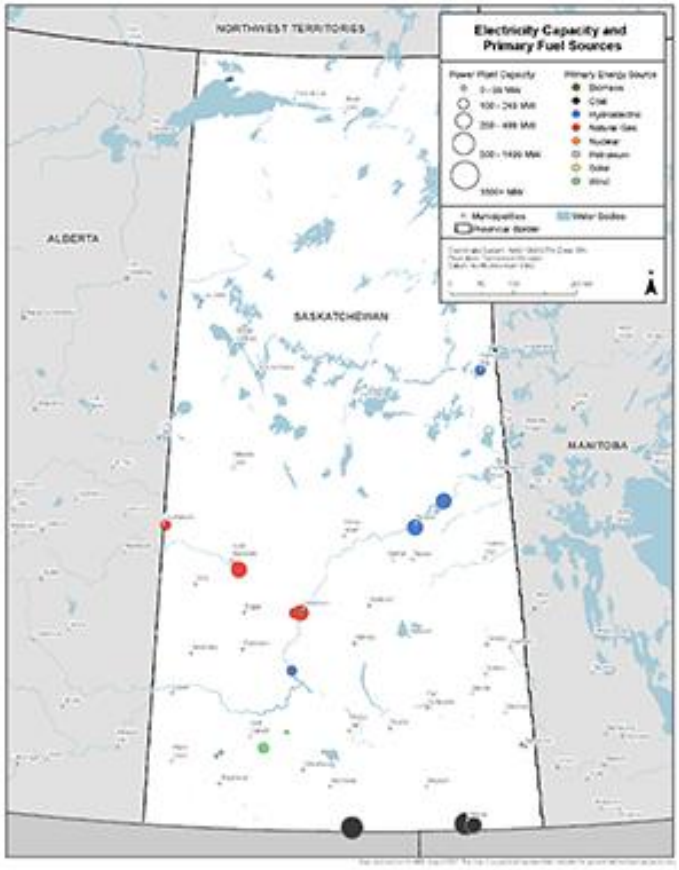
- Alberta [www.neb-one.gc.ca]: Competitive market

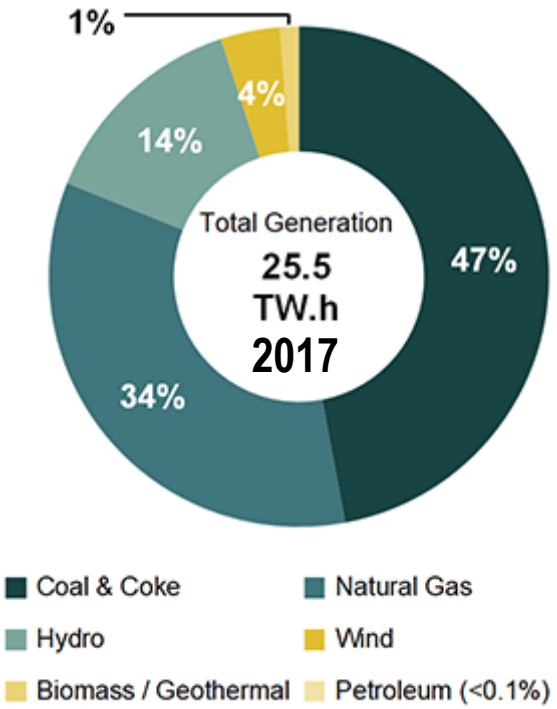




Canadian Grid

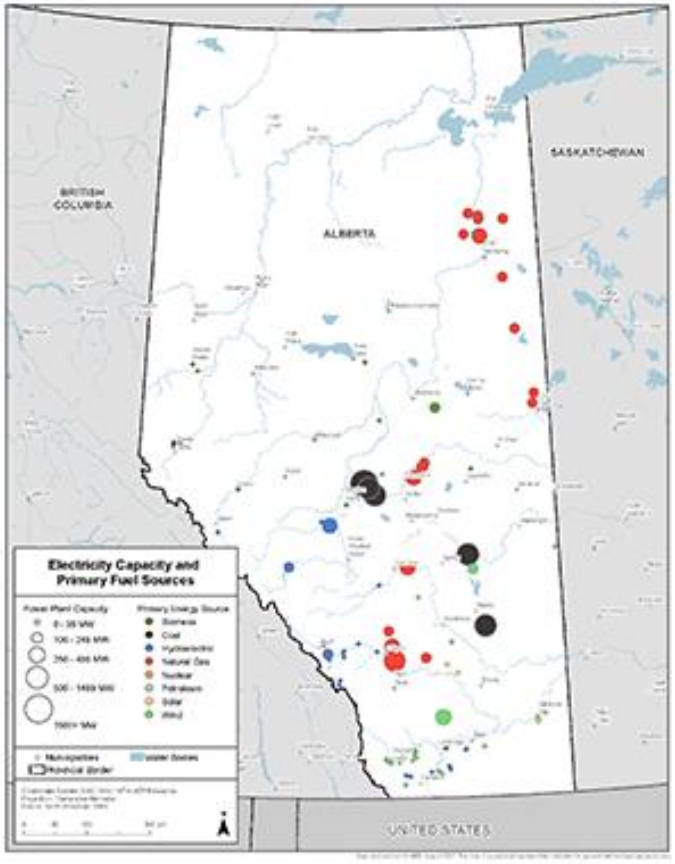
- Saskatchewan [www.neb-one.gc.ca]: No competitive market

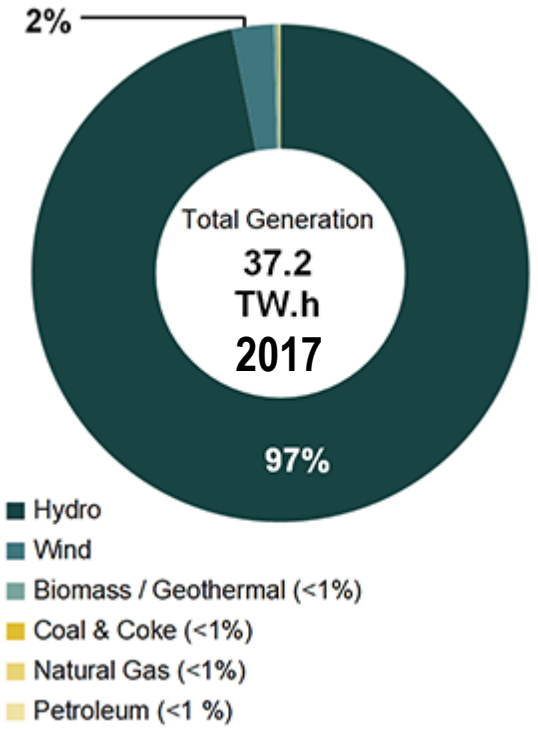




Canadian Grid

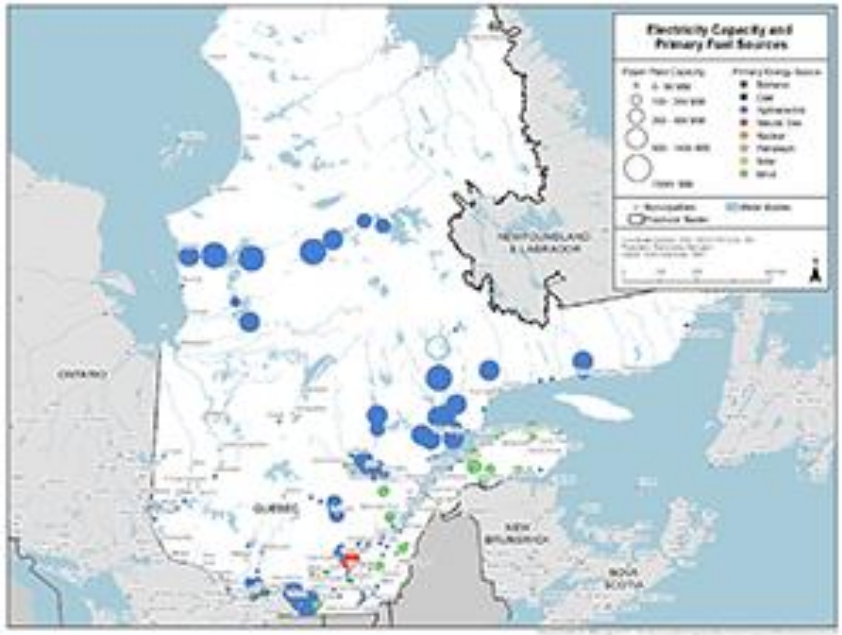
- Manitoba [www.neb-one.gc.ca]: No competitive market

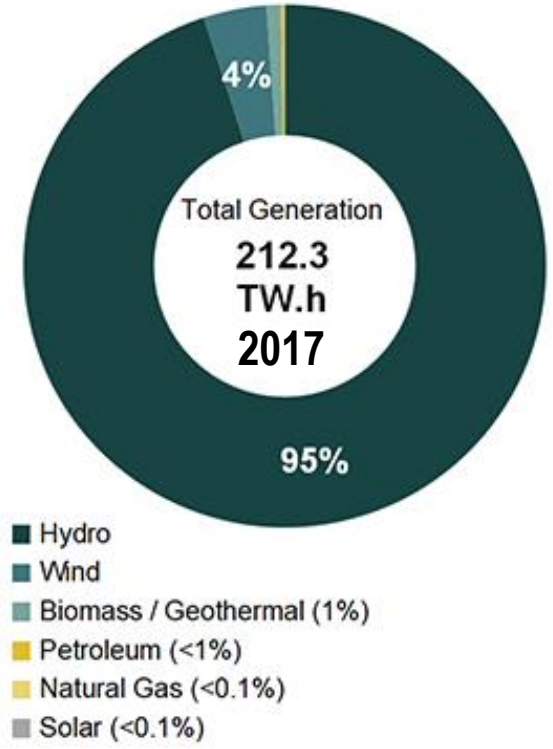




Canadian Grid

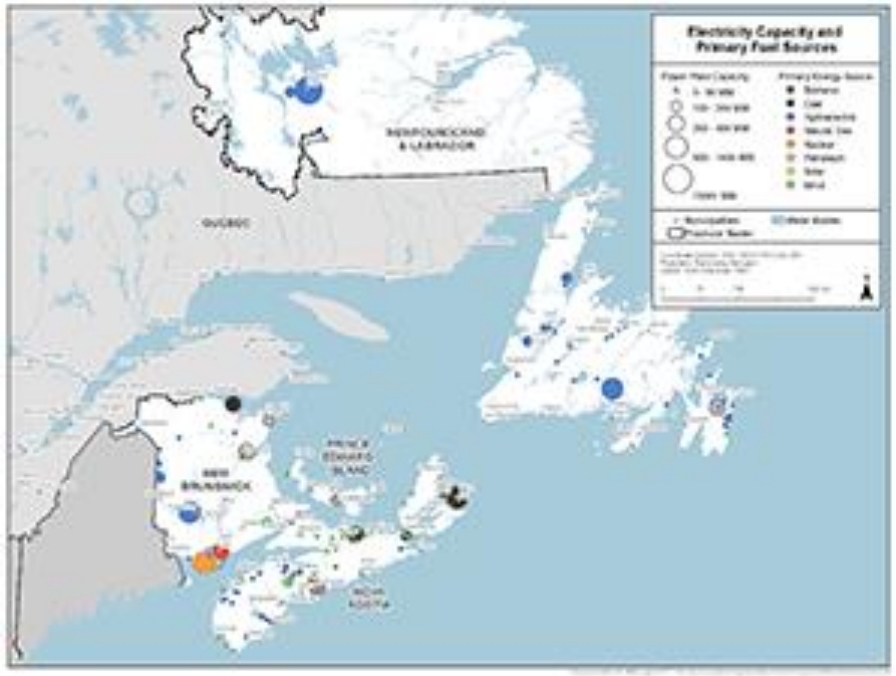
- Quebec [www.neb-one.gc.ca]: No competitive market

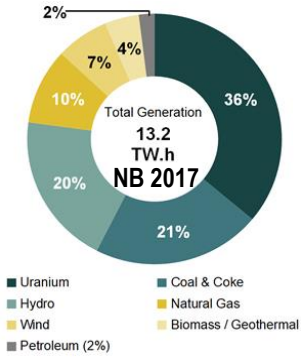


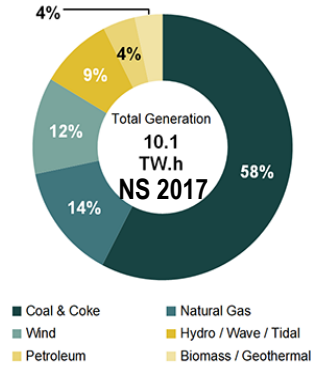


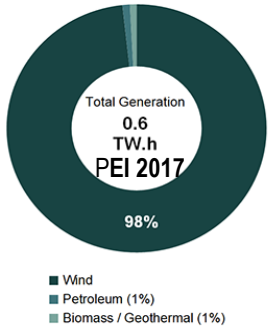
Canadian Grid

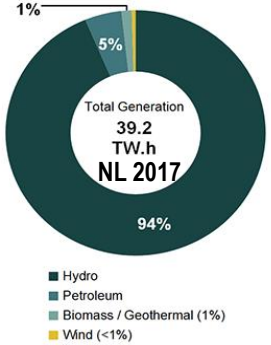
- Maritimes and Newfoundland & Labrador [www.neb-one.gc.ca]: No competitive market











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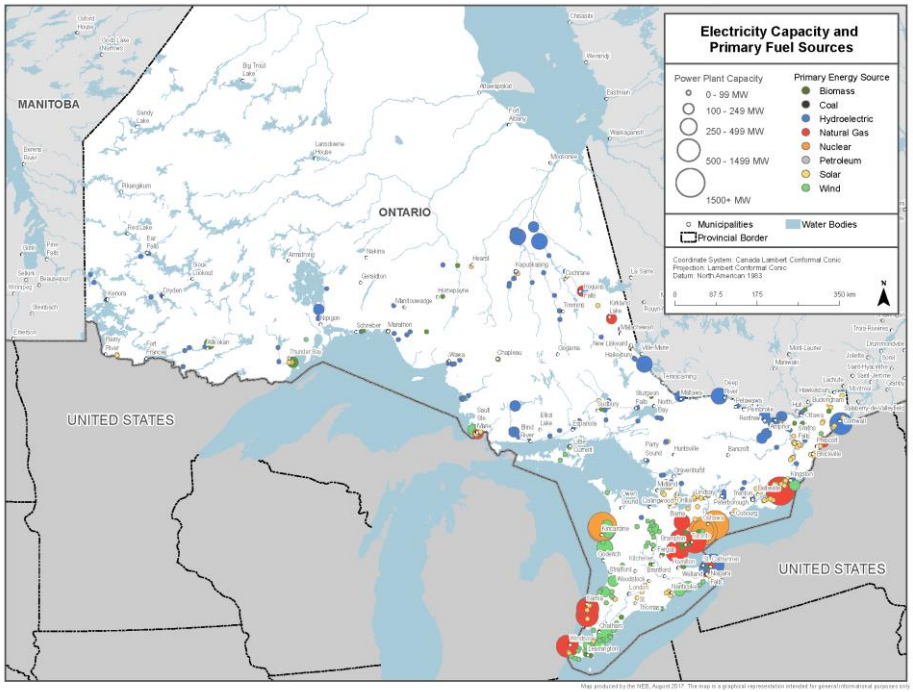
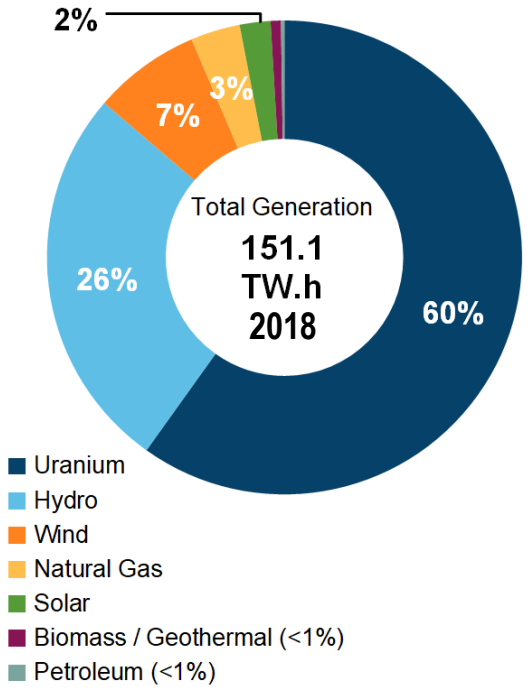
Canadian Grid

- Ontario [www.neb-one.gc.ca]: Competitive market





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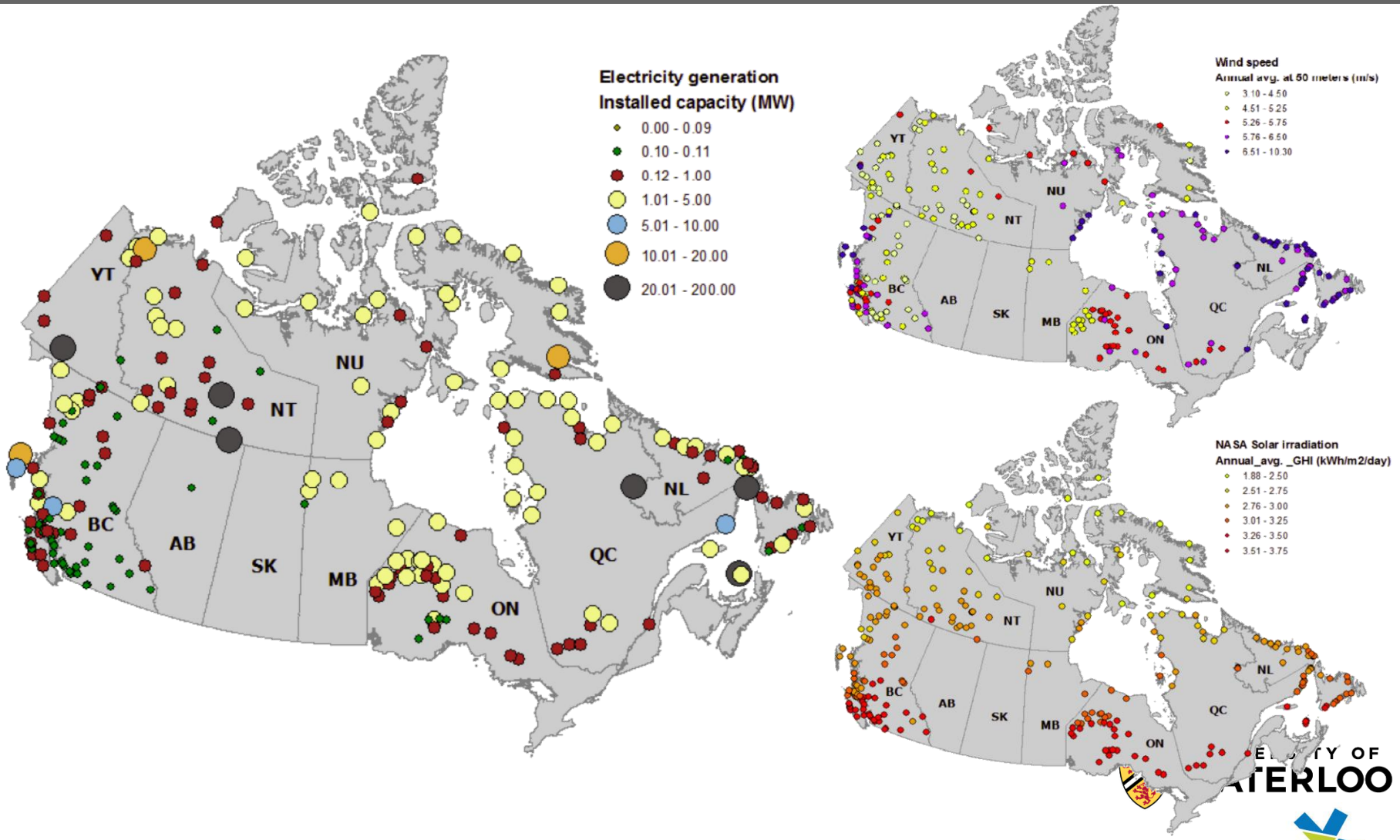
Canadian Remote Communities



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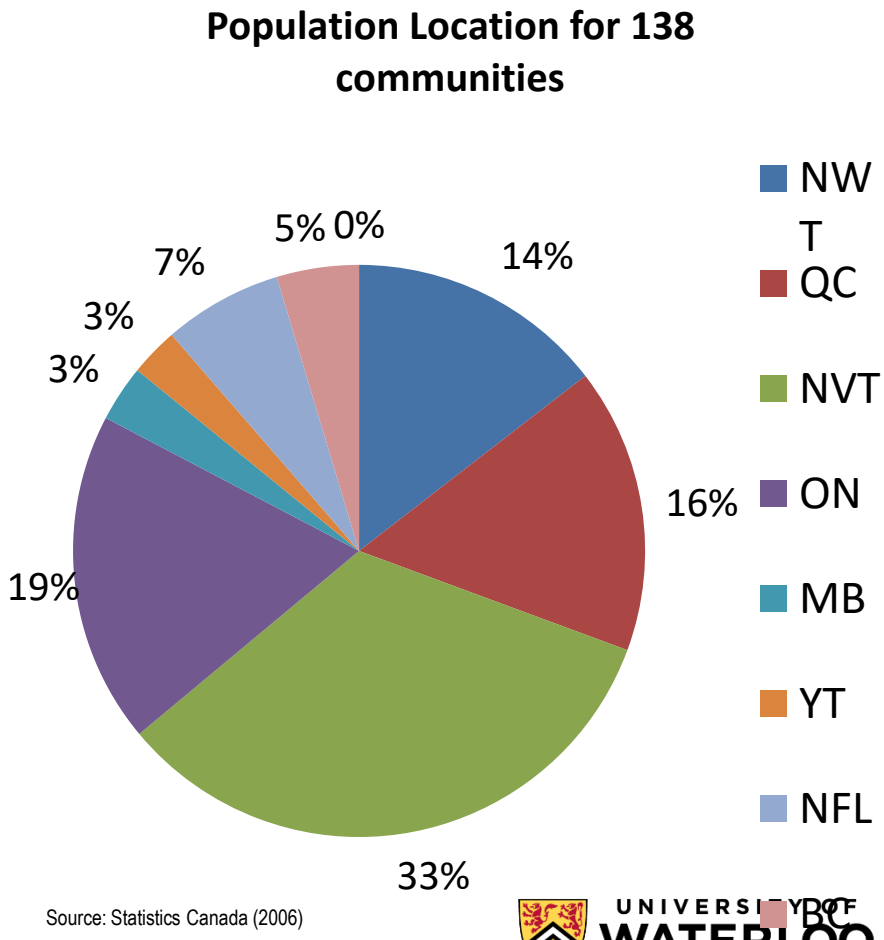
Canadian Remote Communities

- 175 locations using diesel for energy mix.
- Selected sample:
  - 138 communities running solely on diesel.
  - Accounts for 88,000 people.
  - 60+ communities with annual avg. wind speed above 6 m/s.



Source: Statistics Canada (2006)

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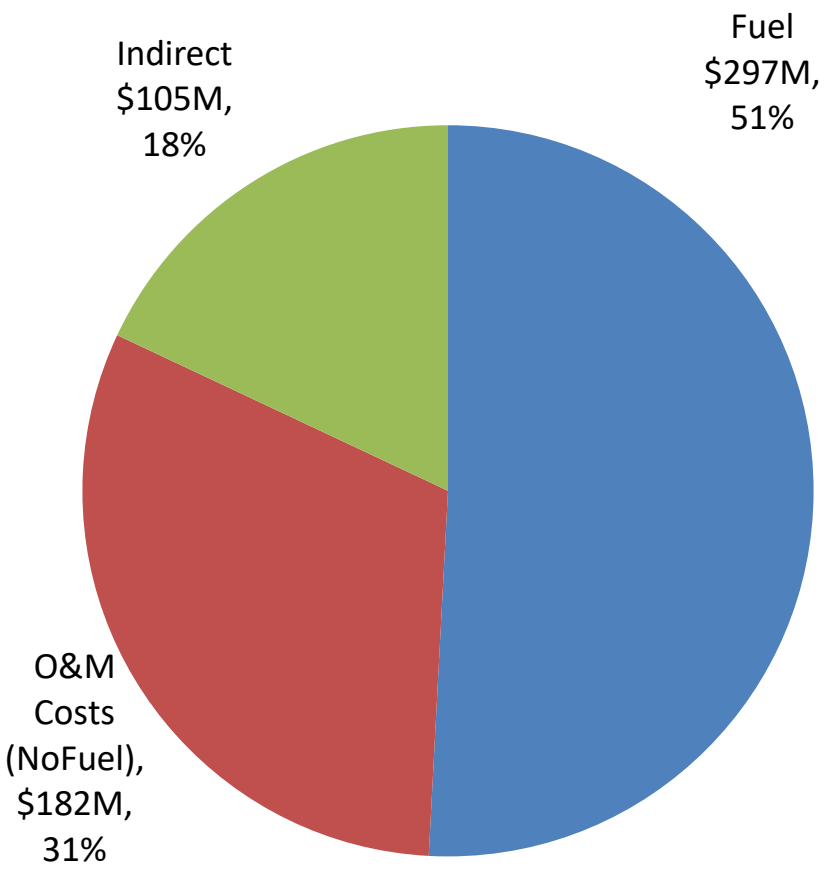
Canadian Remote Communities

- Fuel consumption: 129 million lt./year
- CO2 emissions: 368,000 ton/year
- Total cost: $583M/year
- Energy: 459 TWh/year
- Avg. LUEC: $1.2/kWh
- Subsidies: Provincial and federal.
- Operation/owner: Provincial utilities, community utilities.



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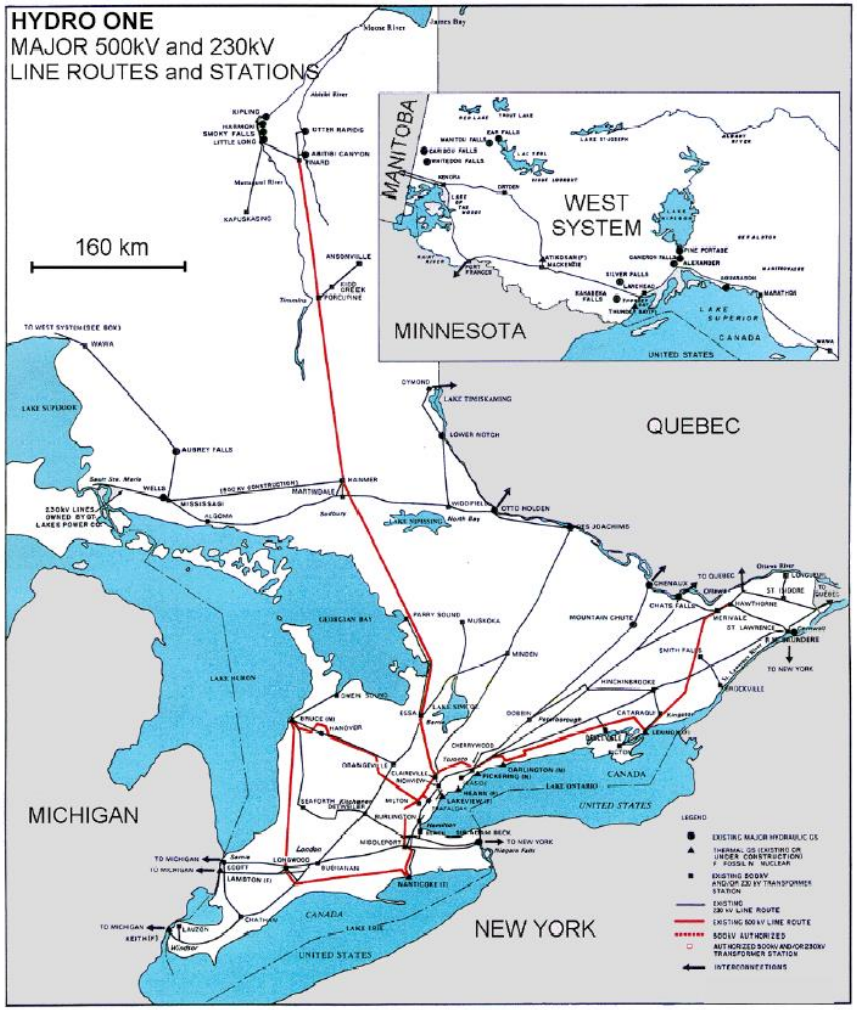
Ontario's Grid



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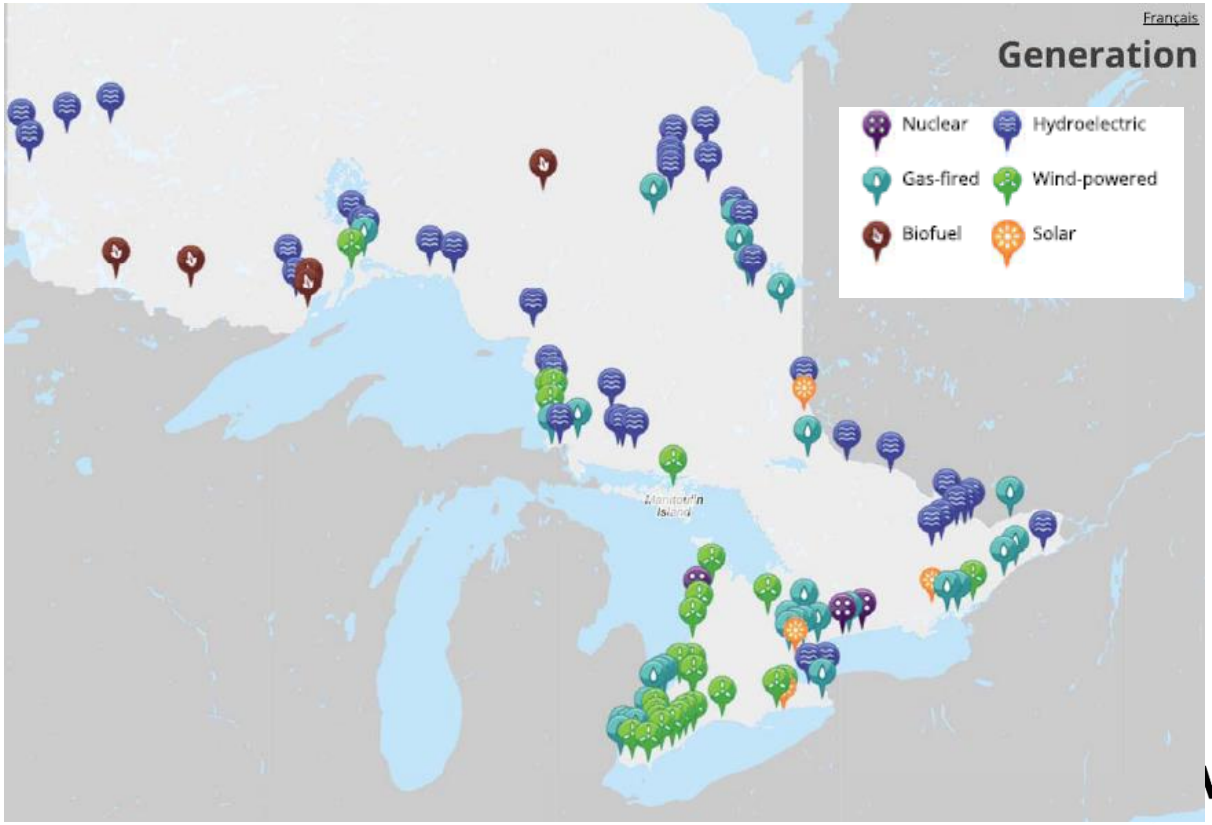
Ontario's Grid

- Ontario's generation location in 2015 [IESO]:



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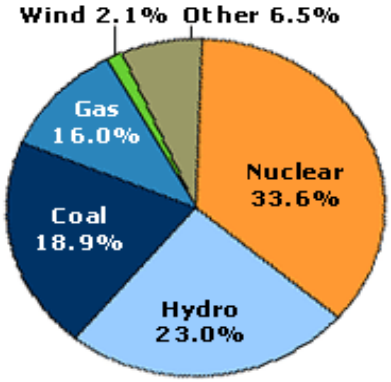
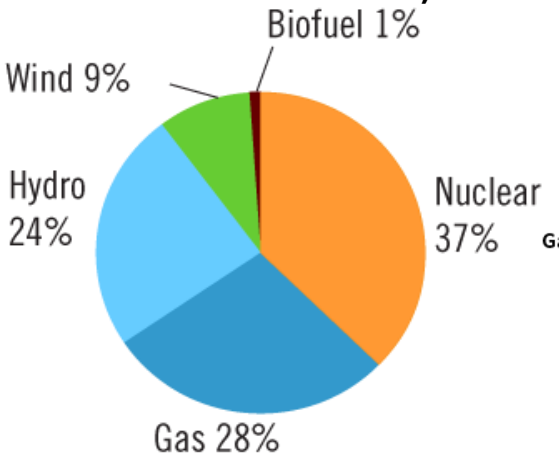
Ontario's Grid

- Supply capacity in Ontario [IESO]:

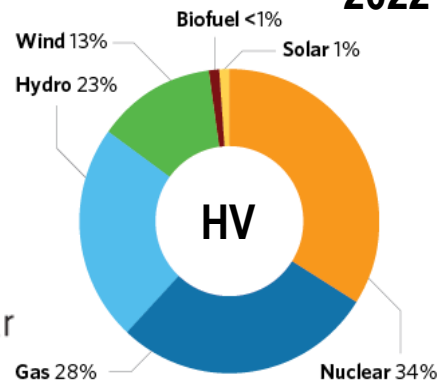
2009



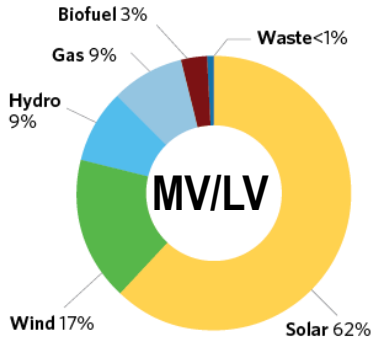
2015 (after Coal shutdown in 2014)



2022



Nuclear	13,089 MW or 34%
Gas/Oil	10,482 MW or 28%
Hydro	8,868 MW or 23%
Wind	4,783 MW or 13%
Solar	478 MW or 1%
Biofuel	296 MW or <1%



Solar	2,166 MW or 62%
Wind	590 MW or 17%
Gas	299 MW or 9%
Hydro	297 MW or 9%
Biofuel	110 MW or 3%
Waste	24 MW or <1%

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Ontario's Grid

- Ontario's imports and exports in GWh [IESO]:

Year	Total		Manitoba		Michigan		Minnesota		New York		Quebec	
	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports	Imports	Exports
Jan 2016	400	2,252	64	146	2	884	27	22	0	947	307	253
2015	5,764	22,618	477	789	198	10,248	42	157	280	8,571	4,767	2,852
2014	4,923	19,073	414	296	344	7,437	40	198	481	7,623	3,645	3,519
2013	4,880	18,309	319	123	21							
2012	4,722	14,626	326	90	25							
2011	3,913	12,847	661	89	45							
2010	6,373	15,164	626	213	28							
2009	4,844	15,104	221	193	1,							
2008	11,309	22,200	323	127	4,							
2007	7,198	12,286	585	181	4,							
2006	6,179	11,389	861	104	3,							
2005	10,941	10,181	1,477	43	7,157	565	227	137	960	8,429	1,120	1,007
2004	9,765	9,487	797	87	7,237	445	246	196	848	8,082	637	677
2003	10,432	6,261	1,384	322	6,731	326	434	154	1,522	4,982	271	477
2002	6,345	1,800	1,165	9	3,054	103	195	19	978	1,493	954	175

Year	Imports (TWh)	Exports (TWh)
2019	6.6	19.8
2018	8.4	18.6
2017	6.6	19.1
2016	8.0	21.9

Ontario's Market

- Process started in 1998 with the Energy Competition Act and the Ontario Energy Board (OEB) Act passed by the Conservative government.
- The Electricity Restructuring Act of 2004 passed by the Liberal government created the Ontario Power Authority (OPA) to mainly address the need for centralized planning to address lack of proper long-term resource adequacy. As of 2015, the OPA was absorbed by the IESO.
- OEB:
  - Market regulator.
  - Ensures marketplace fairness, network reliability and consumer protection.
  - Licenses market participants.
  - Sets transmission and distribution rates.

Ontario's Market

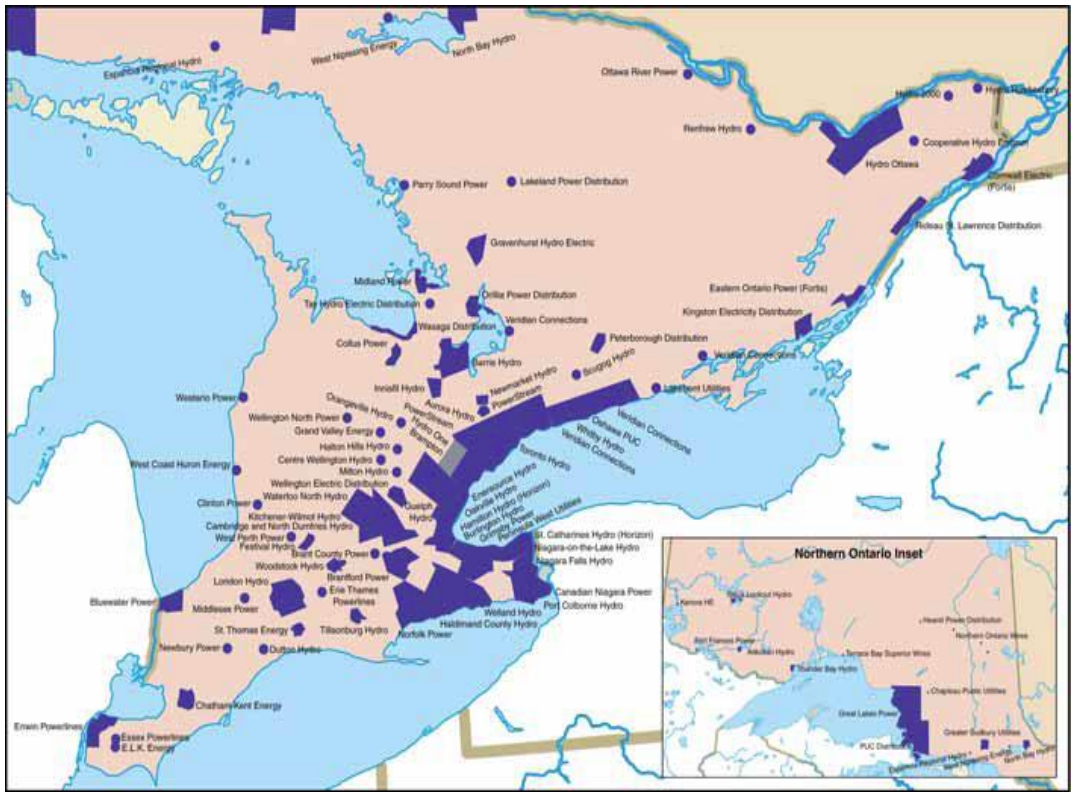
- OPA (part of the IESO as of 2015):
  - Assess long-term electricity resource adequacy.
  - Forecast future demand and the potential for conservation and renewable energy.
  - Centrally plan for conservation, generation, transmission.
  - Procure new supply, transmission and demand management by competition or by contract.
  - Plan to achieve the targets set by government for conservation and renewable energy.

Ontario's Market

- The Energy Competition Act resulted in the breakup of Ontario Hydro (OH) into:
  - Ontario Power Generation or OPG (GENCO):
    - Crown corporation.
    - Owns and operates about 70% of the power supply in the province.
    - Cannot bid in the market to avoid market power (price taker).
    - In 2011, there were are about 130 GENCOs.
  - Hydro One (TRANSCO):
    - Crown corporation being sold to private ownership (60%).
    - Owns and operates 97% of the transmission assets in Ontario and 75% of the distribution (rural) assets.
  - IESO (originally IMO):
    - Not-for-profit corporate entity
    - Operates and manages the power grid and associated market.

Ontario's Market

- Independent LDCs (DISCOs):
  - Private/municipal companies.
  - Own, operate and manage the distribution systems of most large cities in Ontario [EDA]:



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Ontario's Market

- The market opened in May 1, 2002, with about 2-year delay (initially scheduled to start in Nov. 2000):
  - Wholesale prices increased from 3.01 ¢/kWh in May to up to 6.2 ¢/kWh in July.
  - Under voter pressure, prices were fixed for "low power" customers (mostly residential) at a "fictitious" 4.3 ¢/kWh by the Electricity Pricing, Conservation and Supply Act in December 2002, subsidized by OPG's market profits.
  - Conservatives lost the election to the Liberals in Oct. 2003 in good part due to this debacle.

Ontario's Market

- With pioneering "smart" meters installed in 2010, the fixed tariff has been replaced by a time-of-use (TOU) tariff in 2011 [Hydro One & OEB]:

Summer Pricing
(May 1 - October 31)

Weekends/Holidays
(All Year)

Winter Pricing
(November 1 - April 30)

	2012	2016	2020
Off-peak Price:	6.2 ¢/kWh	8.3 ¢/kWh	10.1 ¢/kWh
Mid-peak Price:	9.2 ¢/kWh	12.8 ¢/kWh	14.4 ¢/kWh
On-peak Price:	10.8 ¢/kWh	17.5 ¢/kWh	20.8 ¢/kWh

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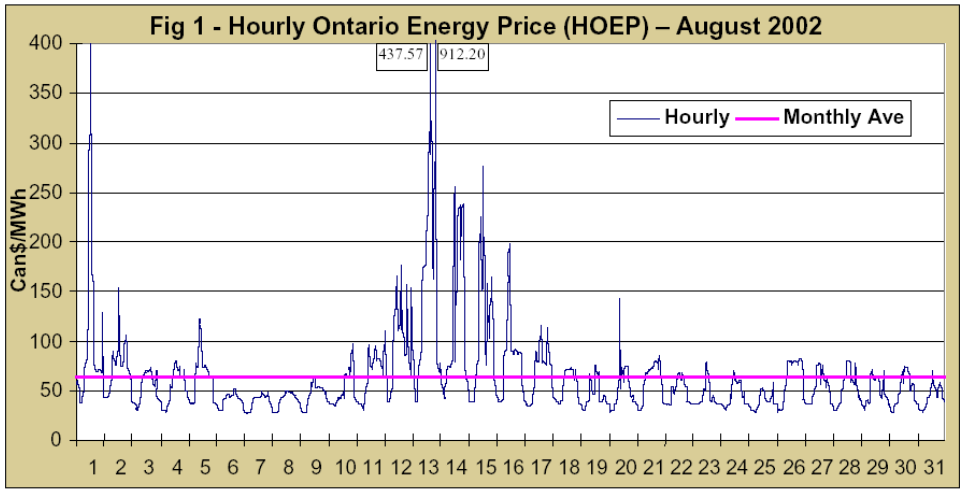
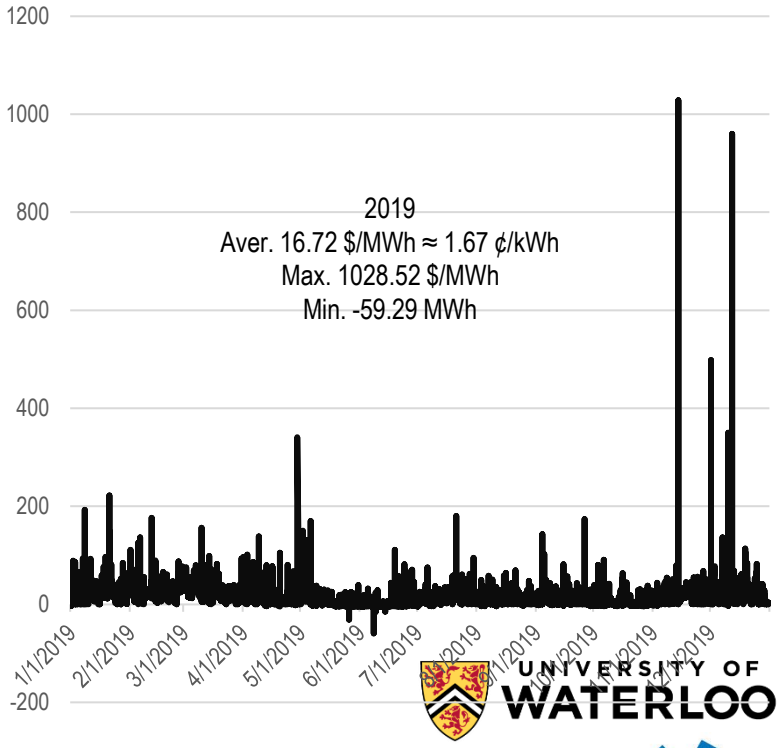
Ontario's Market

- HOEP prices are volatile, but much less now than a few years ago due to increased supply and reduced demand, with sometimes negative prices at night due to nuclear power and some wind generation [IESO]:

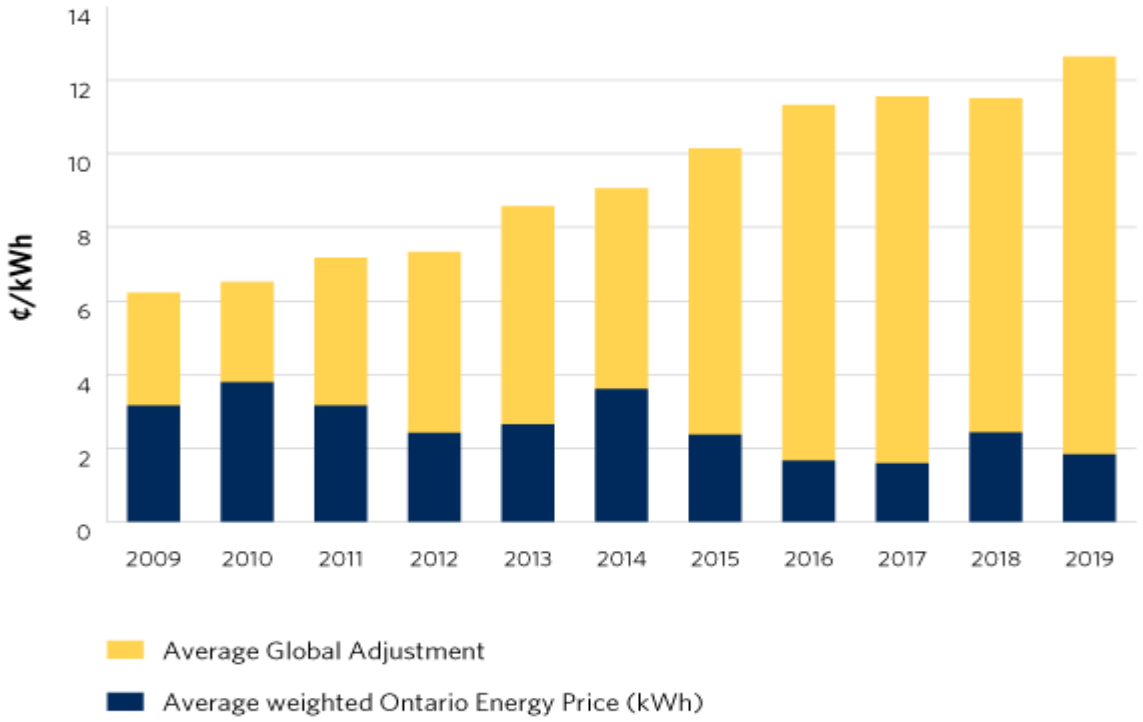


Hourly Ontario Energy Price $/MWh			
	August, 2002	On-Peak	Off-Peak
Average	64.18	83.44	48.32
Maximum	912.20	912.20	151.45
Minimum	26.90	34.99	26.90



Ontario's Market

- Demand charges [IESO]: Introduced in 2005 to support the provision of adequate generating capacity and demand response programs.



Capacity Markets

- Capacity (power) markets have been introduced to deal with peak power prices in (e.g. Alberta, Ontario in 2022).
- Designed to secure enough generating resources to supply the demand.
- Market operators run an auction ahead of time (e.g. 2-3 years) where generators and potentially loads may participate with capacity bids, and thus is a “forward market”.
- This market provides long-term incentives for generators to build capacity and loads to build demand response, as it secures payment for available power (MW).

Future Grid

- The IESO is in charge of power grid planning.
- In 2017, the IESO under Liberal Gov. directives presented an Ontario's Long-Term Energy Plan, updating the 2013 plan:
  - 20-year plan.
  - Focused on managing customer electricity costs that significantly increased under the previous plan, mainly due to gen. capacity additions (mainly nuclear, gas, coal phaseout).
  - Market renewal to increase competition and flexibility (e.g. capacity market, LMPs).
  - Integrate new technologies such as energy storage and DERs.
  - Improve LDC performance.
  - Increase energy conservation and efficiency such as improved DR programs.
  - Increase RES generation share to replace gas plants and thus decrease GHG emissions.

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Future Grid

- Planned/under-development RES plants were scrapped in 2018 by the newly elected Conservative government.
- IESO is now developing a new plan under Conservative Gov. directives focused on:
  - Renew the electricity market.
  - Provide expected supply increase due to electrification of transportation (EVs) and other energy systems (e.g. heating).
  - Consider stakeholder needs.
  - Maintain reliability.
  - Cybersecurity and situational awareness.
- No direct mention of increasing RES and eliminating gas plants, based on current low emission profile of power grid (7% of GHG emissions in Ontario).

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Future Grid

- The Energy Transformation Network of Ontario (ETNO):
  - WISE is a member.
  - Report: “Distribution System Structures For A High DER Future - A Blueprint to Guide the Local Energy Transition in Ontario”
    - Identify challenges and opportunities posed by the onset of DERs
    - Encourage coordination between the IESO and OEB on DER integration and other aspects of grid modernization.
    - Encourage organizations to participate in industry dialogue on issues related to DER integration and grid modernization.
    - Recommendations:
      1. Implementation of the DSO structure to enable integration of an DERs to maximize their value to ratepayers.
      2. Local Distribution Utilities (LDCs) should take on the role of DSOs.
      3. Further investigation of the LSE structure, noting that the DSO and LSEs are not mutually exclusive options.

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EVs

- More electric vehicles bought in the last two years than in the previous eight combined (https://www.thestar.com/business/2021/12/10/by-the-numbers-a-look-at-electric-vehicle-sales-in-canada.html):
  - 110,518: Total number of new battery-electric and plug-in hybrid passenger vehicles sold in Canada in 2019 and 2020.
  - 93,905: Total number of new battery-electric and plug-in hybrid passenger vehicles sold in Canada between 2011 and 2018.
  - 3.5%: Percentage of total vehicle registrations for battery-electric and plug-in hybrid cars in Canada in 2020.
  - 8.4%: Share of total vehicle registrations for electric vehicles in British Columbia in 2020.
  - 6.8%: Share of total vehicle registrations for electric vehicles in Quebec in 2020.
  - 1.3%: Share of total vehicle registrations for electric vehicles in all provinces and territories except Quebec and B.C. in 2020.
  - 76%: Share of total electric vehicle registrations in 2020 that occurred in Quebec or British Columbia.
  - 200,000: Estimated number of battery-electric and plug-in hybrid vehicles currently on the road in Canada.

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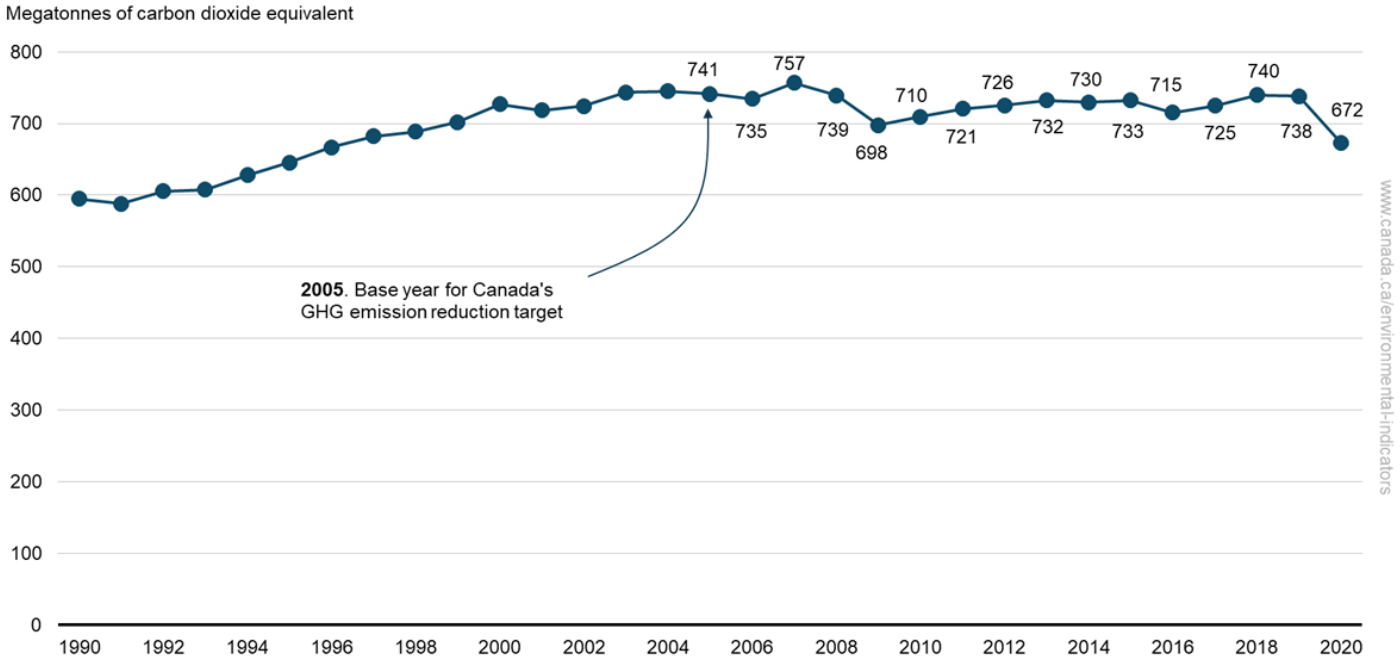
EVs

- Charging impact:
  - Aver. household peak/max power: 6/10 kW
  - Typical EV charge power (e.g. Hyundai Kona EV, Tesla Model S 400+km range): 7kW
  - Aver. commuting 1-way (total) distance: ~50 (100) km
  - Level 1 or 2 overnight charging enough, with min. impact on power grid, il Level 2 is coordinated with existing loads like dryer and range.
  - Charging at peak hours will double demand, with major impact on power grids, especially distribution transformers (overloading).
  - Smart (controlled) charging needed and is a significant concern for LDCs.
- PHEV and EV Incentives:
  - Federal: $5k rebate currently for PHEV/EV valued under $55k.
  - Ontario: $5k-$8.5k depending on battery size until 2018, when it was cancelled by Conservative gov.

Net-Zero

- GHG emissions regulated by Federal Gov. (e.g. Carbon tax and coal gen. phaseout);
- Canada GHG emissions:



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Net-Zero

- Canada GHG emission reduction commitments:
  - 40-45% by 2030 w.r.t. 2005.
  - No emission by 2050.
- Canadian 2030 emission reduction plan (https://pm.gc.ca/en/news/news-releases/2022/03/29/delivering-clean-air-and-strong-economy-Canadians) :
  - EVs: $2.9+ billion for charging infrastructure, purchasing rebates, and at least 20% EV sales by 2026, 60% by 2030, 100% by 2035.
  - Greener buildings: ~$1 billion for efficiency upgrades.
  - Help industry adopt new techs.
  - Even greener power grid: $ 850 mil for clean energy projects; zero emissions by 2035.
  - Oil and gas emission reductions: 75% reduction by 2030.
  - Farming: ~$ 1 billion to support sustainable practices.
  - Community climate action: $2.2 billion to expand Low Carbon Economy Fund to support clean energy community projects.
  - Nature carbon capture and storage (CCS): $780 million for oceans, wetlands, peatlands, grasslands, and agricultural lands, and forest negative emission technologies.

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Net-Zero

- Net-zero Accelerator Fund: $8 billion to help large emitters such steel and cement factories reduce emissions.
- Net-zero Challenge:
  - Normalize net-zero planning for businesses.
  - Provide guidance and leadership.
  - Reduce GHG from industrial and other sectors.
  - Position industries to be green and competitive in the global net-zero economy.

Hydrogen

- NRCAN's Hydrogen strategy (https://www.nrcan.gc.ca/climate-change-adapting-impacts-and-reducing-emissions/canadas-green-future/the-hydrogen-strategy/23080):
  - Position Canada as a world-leading producer, user and exporter of clean H2 and associated technologies.
  - Enabler of Net-Zero 2050 target.
  - Advantages:
    - Production: Canada well position to produce green H2 (water resources, clean electric grid, expertise).
    - Distribution and storage: existing gas pipelines and storage areas (e.g. Ontario, Alberta) across Canada.
    - Transportation: Suitable for long-haul heavy transportation trucks which is significant in Canada.
    - Heat and power: Replace natural gas with H2.
    - Industry: Replace brown/black H2 (gas reforming with high GHG emissions) with green H2.
    - Expertise: Canada is a pioneer on H2 innovation and training (e.g. Ballard, Hydrogenics).
    - Opportunity: Growing international interest on and demand for green H2 (e.g. Germany).

Hydrogen

- Challenges:
  - Economics: current high costs of H2 systems.
  - Innovation: lack of sustained investment.
  - Policies: nonexistent.
  - Codes and Standards: gaps.
  - Availability: limited H2 supply.
  - Awareness: lacking.
- Recommendations:
  - Establish strategic partnerships.
  - De-risk investments.
  - Sustained support for R&D.
  - Modernize codes and standards
  - Develop policies and regulations.
  - Increase community and public awareness.
  - Establish regional blueprints for H2 production and applications.
  - Establish international markets with interested partners (e.g. Germany).

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Conclusions

- Could GHG emissions be eliminated in Canadian grids by 2035?
  - For the most part, but doubtful in AB, NB, and NS.
- Would the grid be ready for the Net Zero 2050 expected demand?
  - This will require huge gov. investments, like the US $300b+ of the Inflation Reduction Act US, as energy markets only will not do.
  - Further DER and microgrid development will be necessary.
- How fast would the transition to EVs will take place?
  - For sure by 2050 in personal vehicles and local fleets, with the 2035 EV production commitments by vehicle manufactures and current EV state-of-the-art.
  - Heavy and long-haul transportation is a more challenging issue that will require significant battery improvements (e.g., solid state batteries) and hydrogen-fuel vehicles.
- How fast would thermal systems be electrified?
  - For sure by 2050, given the current state of deployment of heat pumps.
- What would be the role of Hydrogen in a Net zero future?
  - Needed for decarbonizing some industrial sectors that depend on it like the steel and cement industry.
  - Likely to play a role in decarbonizing heavy and log-haul transportation.

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Conclusions

- Cannot wait any longer to start decarbonizing our economy, we must start NOW!
  - Get and EV.
  - Install a Solar PV.
  - Replace the gas furnace with a heat pump.
  - Not cheap even with gov. incentives.
  - A COMMITMENT to INVEST in the future of the planet is needed!
  - We MUST stop dillydallying and start walking the walk and talking the talk!

- My contributions to climate change mitigation:
  - EV:
    - Hyundai Kona: 150 kW (200HP), 64kWhj Li^+, 430kM range, 7kW_{ac} Level 2, 75kW_{dc} Level 3.
    - ~$50k - $5k incentive = ~$45k.
  - Solar PV:
    - 4kWp.
    - ~$20k - $5k incentive = ~$15k.
  - Heat pump:
    - Mitsubishi Zuba 36k BTU + 10kW heater.
    - ~$27.5k - $5k incentive = ~$22.5k.
  - Plus:
    - LED lighting @ ~$6/60Weq LED = ~$0.5k Tot.
    - Induction stove @ ~$4k.
  - Tot costs **~$86k** => not done for economic but env. reasons.
  - No more natural gas at home!

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